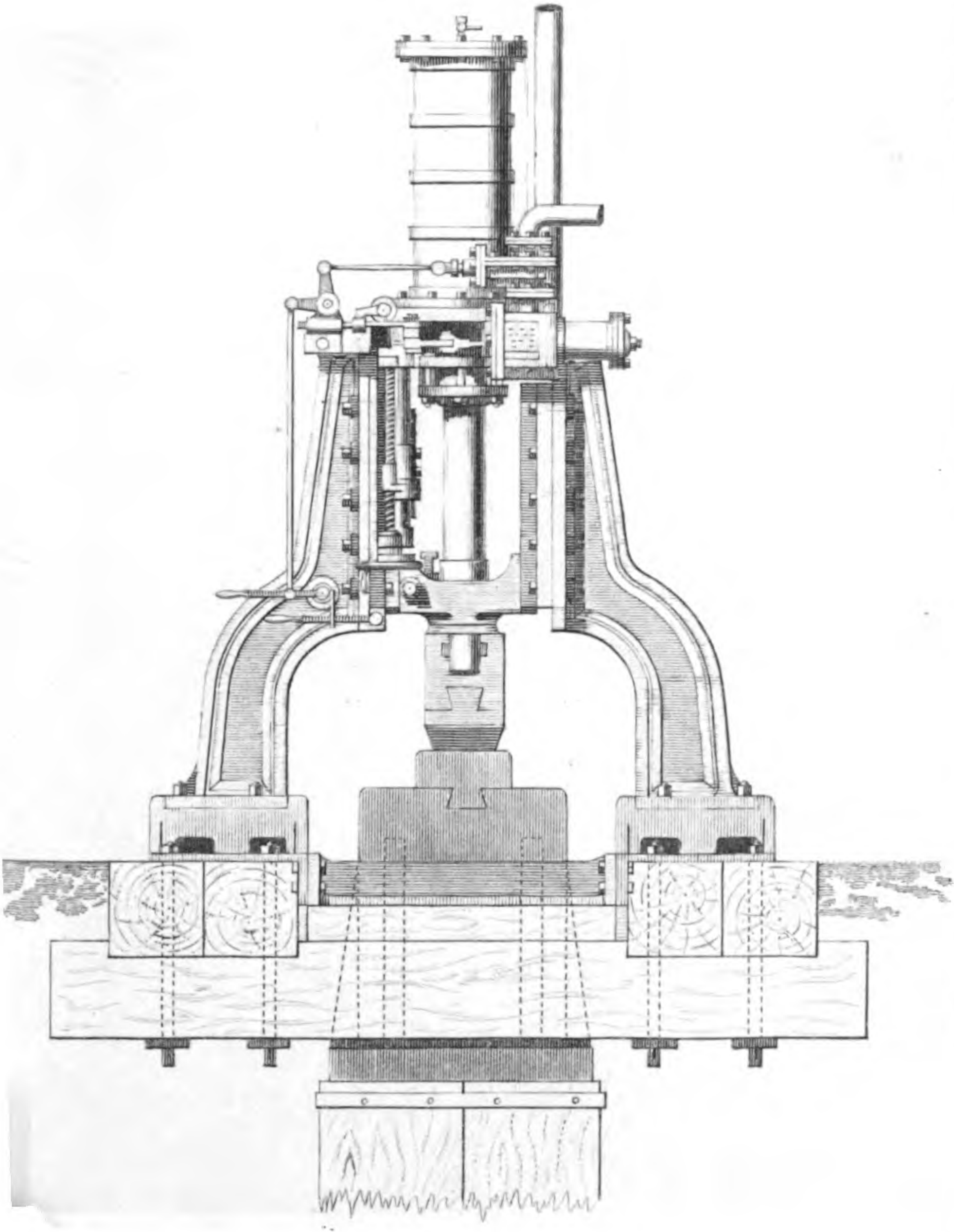
IMPROVED STEAM HAMMER.

Manufactured at Paragon Works, South Queensferry, Scotland.



THE

OPERATIVE MECHANIC'S WORKSHOP COMPANION,

AND

THE SCIENTIFIC GENTLEMAN'S Practical Assistant;

COMPRISING

A GREAT VARIETY OF THE MOST USEFUL RULES IN MECHANICAL SCIENCE,

WITH

NUMEROUS TABLES OF PRACTICAL DATA AND CALCULATED RESULTS FOR FACILITATING MECHANICAL AND COMMERCIAL TRANSACTIONS.

BY WILLIAM TEMPLETON.

EIGHTH EDITION, REVISED AND ENLARGED,

WITH THE ADDITION OF

MECHANICAL TABLES FOR THE USE OF OPERATIVE SMITHS, MILLWRIGHTS, ENGINEERS, ETC.

TO WHICH ALSO HAVE BEEN NOW ADDED

SEVERAL USEFUL AND PRACTICAL RULES IN

HYDRAULICS AND HYDRODYNAMICS,

A VARIETY OF EXPERIMENTAL RESULTS,

AND

AN EXTENSIVE TABLE OF POWERS AND ROOTS.

LONDON:
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1864.

HARRILD, PRINTER, LONDON.

TO THE PUBLIC.

The subjects of the following pages are chiefly compiled at the instigation of pressing solicitations by numerous individuals, no few of whom complain of the want of a convenient Text Book of Reference in which Mechanical and Commercial demands are judiciously combined. Others, with apparently equal reasons, for the sake of instruction, complain of the want of a compendium in which tuition and practical reference are discriminately arranged; and generally, that for purposes of Estimation, no properly portable work is yet in existence; hence it is with a wish to diminish those wants in some degree that the present attempt has been made to supply the necessary information.

In regard to the selection, great care has been taken that the subjects be not only intimately interwoven, but also of such a nature as business transactions call most frequently into requisition.

The elementary or educational portion will be found exceedingly plain and simple, though compendious. The practical rules, too, are much abbreviated by the application of decimal approximates, by which results are obtained sufficiently exact, and the means of calculation considerably facilitated.

That the production might be rendered still more worthy of public patronage, numerous diagrams and engravings are interspersed, which add much to its value in regard to practical utility; and it only remains to add the hope, that the Operative, the Man of Science, and the intelligent Public, may give due appreciation to the work, in proportion to its merits.

W. T.

The preceding, or seventh edition was much extended by the insertion of numerous Tables for the use of Operative Smiths, Millwrights, and Engineers, and the present, which has undergone a searching revision, is, it is hoped, rendered still further acceptable, by the introduction of a copious table of Squares and Cubes, with the corresponding Roots; and also by additional information of a miscellaneous kind, on matters of philosophical and practical utility.

March, 1864.

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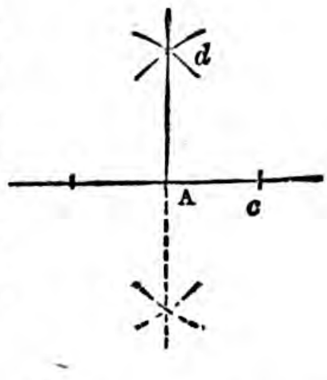
PRACTICAL GEOMETRY.

Geometry is the science which investigates and demonstrates the properties of lines, surfaces, and solids: hence, **Practical Geometry** is the method of applying the rules of the science to practical purposes.

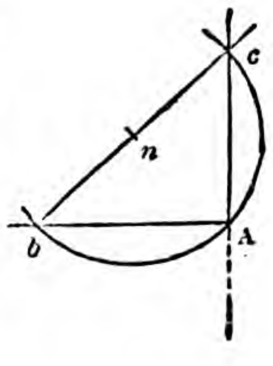
1. *From any given point, in a straight line, to erect a perpendicular; or, to make a line at right angles with a given line.*

On each side of the point A from which the line is to be drawn, take equal distances, as A *b*, A *c*; and from *b* and *c* as centres, with any distance greater than *b* A, or *c* A, describe arcs cutting each other at *d*; join A *d*, which will be the perpendicular, and it will bisect *b c*.



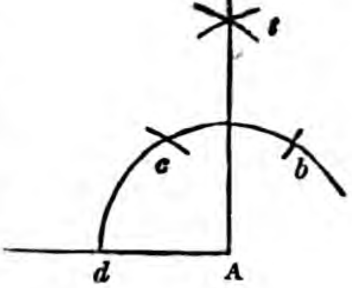
2. *When a perpendicular is to be drawn at or near the end of a given line.*

Take any point *n* above A *b*, and with centre *n* and distance *n* A, describe a circle, cutting the given line at *b*; through *b* and the centre *n*, draw the diameter *b n c*, and join *c* A, which will be the perpendicular required.



3. *To do the same otherwise.*

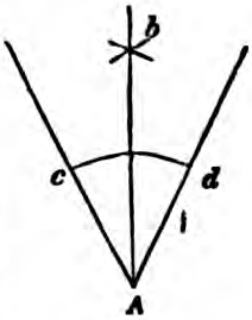
From the given point A, with any convenient radius, describe the arc *d c b*; with the same radius from *d*, cut the arc in *c*, and from *c*, cut the arc in *b*; also from *c* and *b* as centres, with the same or any other radius, describe arcs cutting each other in *t*; then will the line A *t* be the perpendicular required.



Note.—When the three sides of a triangle are in the proportion of 3, 4, and 5 equal parts respectively, two of the sides form a right angle; and observe that in each of the preceding problems, the perpendiculars may be continued below the given lines, if necessarily required.

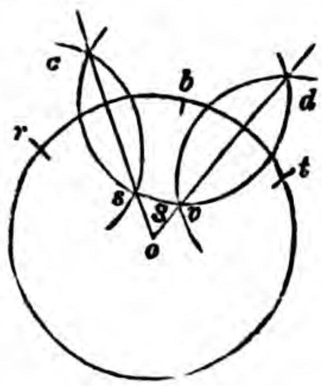
4. *To bisect any given angle.*

From the point A as a centre, with any radius less than the extent of the sides, describe an arc, as *c d*; and from *c* and *d* as centres, describe arcs cutting each other at *b*; then will the line A *b* bisect the angle as required.

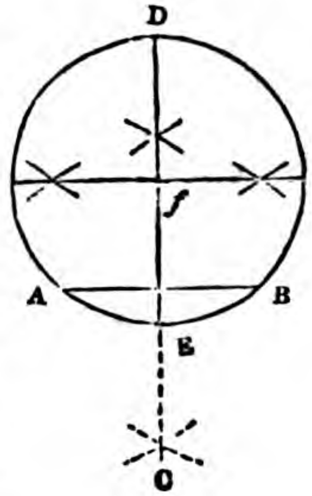


5. *To find the centre of a circle that shall cut any three given points, not in a direct line.*

From the middle point *b* as a centre, with any radius, as *b c*, *b d*, describe a portion of a circle, as *c s d*; and from *r* and *t* as centres, with an equal radius, cut the portion of the circle in *c*, *s* and *d*, *v*; draw lines through where the arcs cut each other, and the



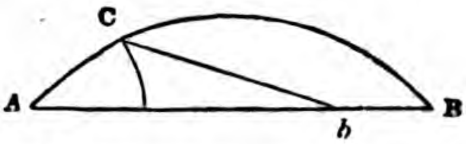
intersection of the lines at *o* is the centre of the circle passing through *r*, *b*, *t*.



6. *To find the centre of a given circle.*

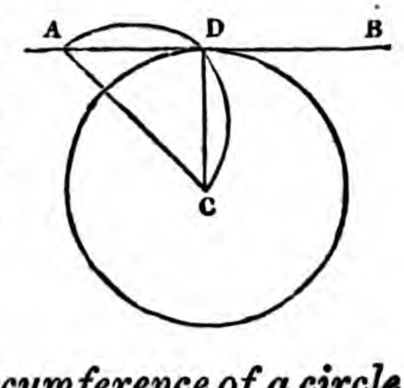
Bisect any chord in the circle, as A B, by a perpendicular C D; bisect also the diameter E D in *f*, and the intersection of the lines at *f* is the centre of the circle required.

7. *To find the length of any given arc of a circle.*



With the radius A C, equal to $\frac{1}{4}$th the length of the chord of the arc A B, and from A as a centre, cut the arc in C; also from B as a centre, with equal radius, cut the chord in *b*; draw the line C *b*, and twice the length of the line is the length of the arc nearly.

8. *Through any given point, to draw a tangent to a circle.*

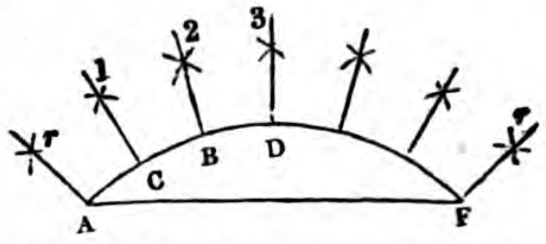


Let the given point be at A: draw the line A C, on which describe the semicircle A D C; join A D, which, produced if necessary, is the tangent required.

9. *To draw from, or to the circumference of a circle*

lines tending towards the centre, when the centre is inaccessible.

Divide the whole or any given portion of the circumference into the desired number of equal parts; then with any radius less than the distance of two divisions, describe arcs cutting each other, as A 1, B 1; C 2, D 2; &c.; draw the lines C 1, B 2, D 3, &c., which lead to the centre as required.

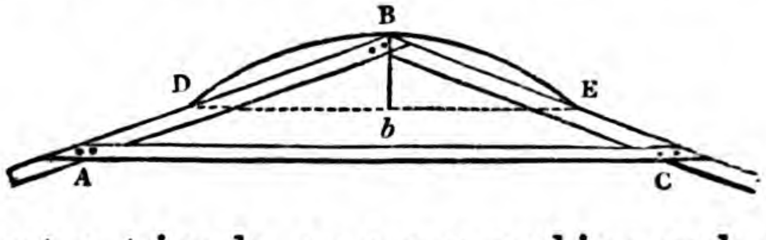


To draw the end lines, as A *r*, F *r*.

With the radius C 2, describe the arc *r*, and with the radius C 1, from A or F as centres, cut the former arcs at *r*, or *r*, and the lines A *r*, F *r*, will tend to the centre as required.

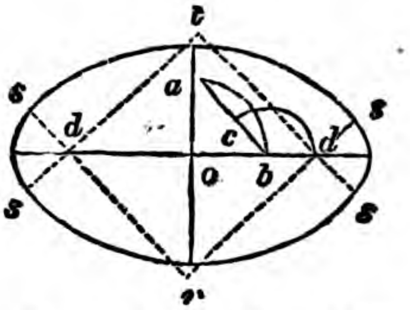
10. *On a given straight line, to describe an arc of a circle, the altitude being given.*

Let D E be the given straight line, B *b* the given altitude: join D B, B E, and of any suitable material



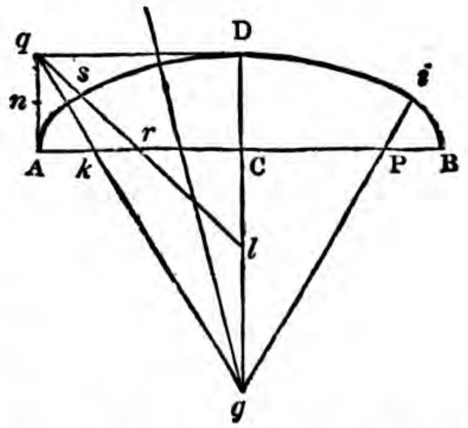
construct a triangle, as A B C, making each of the sides A B, B C, equal at least to the chord D E, and the angle contained by them equal to D B E; at each end of the chord D E, fix a pin, and at B a tracer, as a pencil; move the triangle along the pins as guides, and the tracer will describe the arc required.

11. *To describe an ellipse, having the two diameters given.*



On the intersection of the two diameters as a centre, with a radius equal to the difference of the semi-diameters, describe the arc *a b*, and from *b* as a centre, with half the chord *b c a*, describe the arc *c d*; from *o*, as a centre, with the distance *o d*, cut the diameters in *d*, *r*, *d*, *t*; draw the lines *r s*, *r s*, *t s*, *t s*, then from *r* and *t* describe the arcs *s s*, *s s*; also from *d* and *d* describe the smaller arcs *s s*, *s s*, which will complete the ellipse as required.

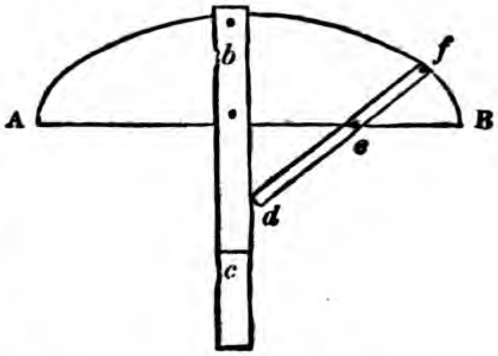
12. *To describe an elliptic arch, the width and rise of span being given.*



Bisect with a line at right angles the chord or span A B, erect the perpendicular A *q*, and draw the line *q* D equal and parallel to A C; bisect A C and A *q* in *r* and *n*, and draw the line *q r l*: and though not in the cut, draw also the line *n s* D; bisect *s* D with a line at right angles, and meeting the line C D produced in *g*; draw the line *g q*, make C P equal to C *k*, and draw the line *g* P *i*; then from *g* as a centre, with the radius *g* D, describe the arc *s* D *i*, and from *k* and P as centres, with the radius A *k*, describe the arcs A *s* and B *i*, which completes the arch as required. *Or,*

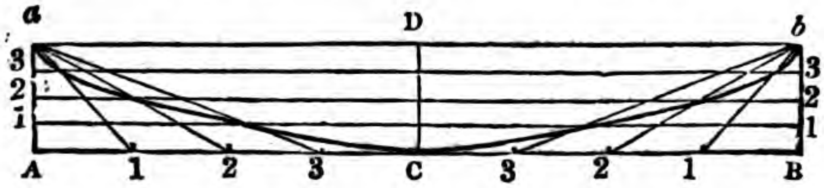
13. Bisect the chord A B, and fix at right angles any straight guide, as *b c*; prepare of any suitable

material a rod or staff, equal to half the chord's length, as *d e f*; from the end of the staff, equal to the height of the arch, fix a pin *e*, and at the extremity a tracer *f*; move the staff, keeping its end to the guide and the fixed pin to the chord, and the tracer will describe one-half the arch required.



14. *To describe a parabola, the dimensions being given.*

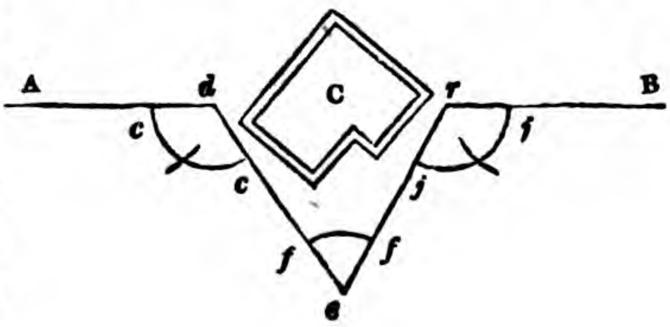
Let A B equal the length, and C D the breadth of



the required parabola: divide C A, C B into any number of equal parts, also divide the perpendiculars A *a* and B *b* into the same number of equal parts; then from *a* and *b* draw lines meeting each division on the line A C B, and a curve line drawn through each intersection will form the parabola required.

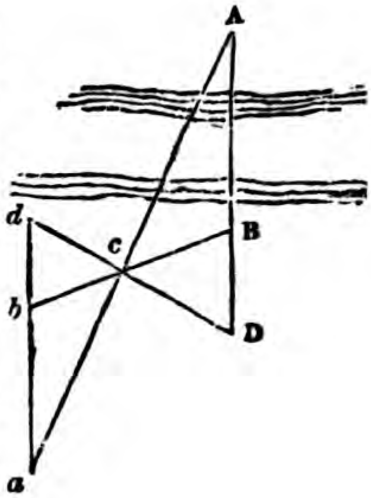
15. *To obtain by measurement the length of any direct line, though intercepted by some material object.*

Suppose the distance between A and B is required, but the right line is intercepted by the object C. On the point *d*, with any



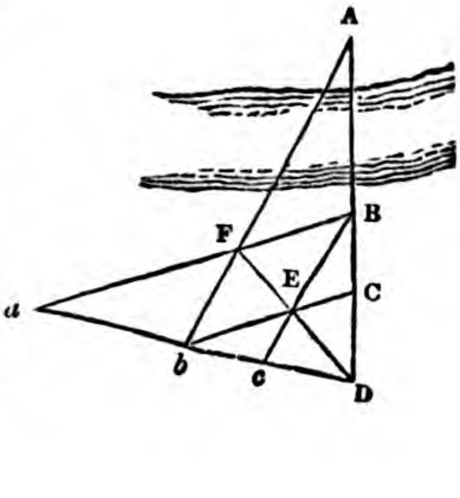
convenient radius, describe the arc *c c*, make the arc twice the radius in length, through which draw the line *d c e*, and on *e* describe another arc equal in length to once that radius, as *f f*; draw the line *e f r* equal to *e f d*; on *r* describe the arc *j j*, in length twice the radius; continue the line through *r*, *j*, which will be a right line, and *d e* or *e r*, will equal the distance between *d*, *r*, by which the distance between A and B is obtained as required.

16. *To ascertain the distance geometrically, of any inaccessible object on an equal plane.*



Let it be required to find the distance between A and B, A being inaccessible: produce the line in the direction of A B to any point, as D; draw the line D *d* at any angle to the line A B; bisect the line D *d* in *c*, through which draw the line B *b*, making *c b* equal to B *c*; join A *c*, and draw *d b a* meeting A *c*, produced in *a*. Then *b a*, equal to A B, is the distance required.

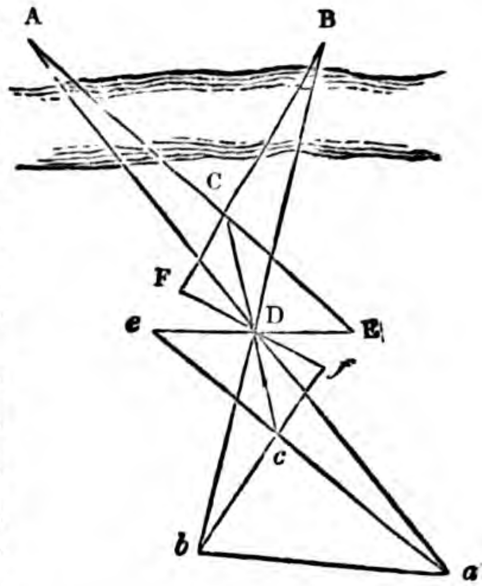
17. *Or otherwise,*



Produce A B to any point D, and bisect B D in C; through D draw D *a*, making any angle with D A, and take D *c*, D *b*, equal to D C and D B respectively; join B *c*, C *b*, and A *b*. Through E, the intersection of B *c*, C *b*, draw D E F meeting A *b* in

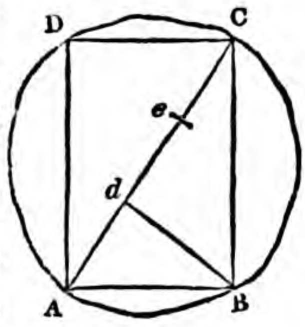
F; join B F, which being produced will meet D *a* in *a*. Then *a b* is equal to A B, the distance required.

18. *To measure the distance between two objects, both being inaccessible.*



From any point C draw any line C *c*, and bisect it in D; take any point E in the prolongation of A C, and draw the line E *e*, making D *e* equal to D E; in like manner take any point F in the prolongation of B C, and make D *f* equal to F D. Produce A D and *e c* till they meet in *a*, and also B D and *f c* till they meet in *b*; then *a b* is equal to A B, or the distance between the objects as required.

19. *A round piece of timber being given, out of which to cut a beam of strongest section.*

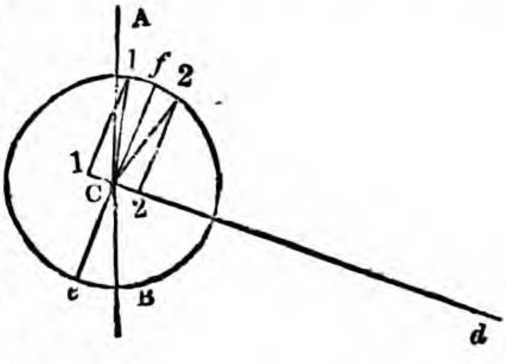


Divide into three equal parts any diameter in the circle, as A *d*, *d e*, *e* C; from *d* or *e*, erect a perpendicular meeting the circumference of the circle, as *d* B; draw A B and B C, also A D equal to B C, and D C equal to A B, and the rectangle will be a section of the beam as required.

20. *To find the proper position for an eccentric, in relation to the crank in a steam engine, the angle*

of eccentric rod and travel of the valve being given.

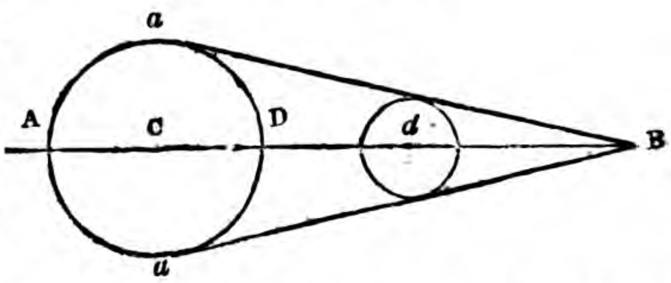
Draw the right line A B, as the situation of the crank at commencement of the stroke; draw also the line C *d*, at the proper given angle of eccentric rod with the crank; then from C as centre, describe a circle



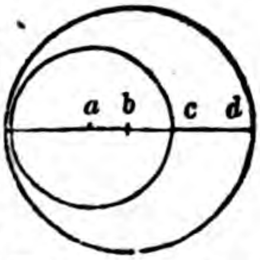
equal to the travel of the valve; draw the line *e f* at right angles to the line C *d*; draw also the lines 1 1, and 2 2, parallel to the line *e f*; and at a distance from *e f* on each side, equal to the lap and lead of the valve, draw the angular lines C 1, C 2, which are the angles of eccentric with the crank, for forward or backward motion, as may be required.

21. *The throw of an eccentric, and the travel of the valve in a steam engine, also the length of one lever for communicating motion to the valve, being given, to determine the proper length for the other.*

On any right line, as A B, describe a circle A D, equal to the throw of eccentric and travel of valve; then from



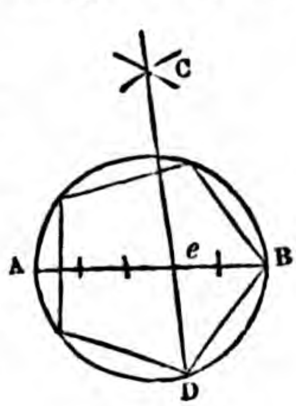
C as a centre, with a radius equal to the length of lever given, cut the line A B, as at *d*, on which describe a circle, equal to the throw of eccentric or travel of valve, as may be required; draw the tangents B *a*, B *a*, cutting each other in the line A B, and *d* B is the length of the lever as required.



Note.—The throw of an eccentric is equal to the sum of twice the distance between the centres of formation and revolution, as *a b*, or to the degree of eccentricity it is made to describe, as *c d*. And

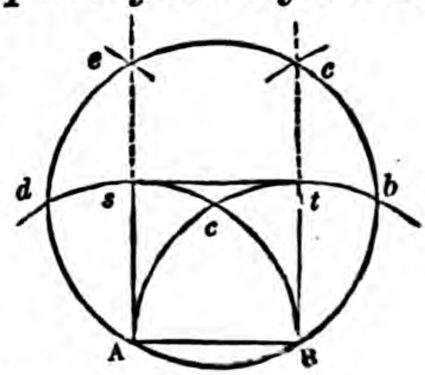
The travel of a valve is equal to the sum of the widths of the two steam openings, and the valve's excess of length more than just sufficient to cover the openings.

22. *To inscribe any regular polygon in a given circle.*



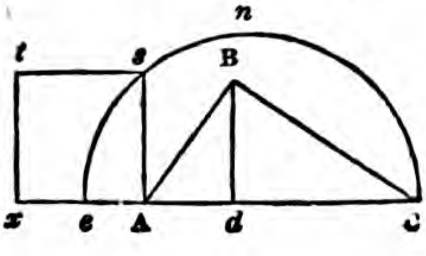
Divide any diameter, as A B, into so many equal parts as the polygon is required to have sides; from A and B as centres, with a radius equal to the diameter, describe arcs cutting each other in C; draw the line C D through *e*, the second point of division on the diameter, and the line D B is one side of the polygon required.

23. *To construct a square upon a given right line.*



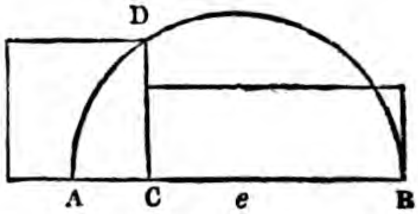
From A and B as centres, with the radius A B, describe the arcs A *c b*, B *c d*, and from *c* with an equal radius describe the circle or portion of a circle *e d* A B *b c*; from *b*, *d*, cut the circle at *e* and *c*; draw the lines A *e*, B *c*, also the line *s t*, which completes the square as required.

24. *To form a square equal in area to a given triangle.*



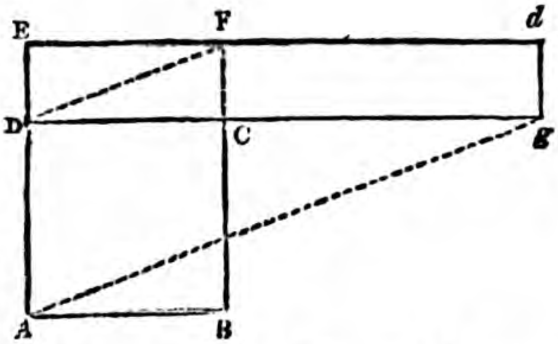
Let A B C be the given triangle: let fall the perpendicular B *d*, and make A *e* half the height *d* B; bisect *e* C, and describe the semicircle *e n* C; erect the perpendicular A *s*, or side of the square, then A *s t x* is the square of equal area as required.

25. *To form a square equal in area to a given rectangle.*



Let the line A B equal the length and breadth of the given rectangle: bisect the line in *e*, and describe the semicircle A D B; then from A with the breadth, or from B with the length of the rectangle, cut the line A B at C, and erect the perpendicular C D, meeting the curve at D, and C D is equal to a side of the square required.

26. *To find the length for a rectangle whose area shall be equal to that of a given square, the breadth of the rectangle being also given.*



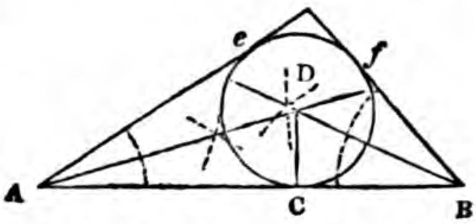
Let A B C D be the given square, and D E the given breadth of rectangle. Through E draw E F parallel to A B or D C; produce B C to F, and join D F. Through A draw A *g* parallel to D F, cutting D C produced in *g*, through which draw *g d* parallel to D E, meeting E F produced in *d*. E D *g d* is the rectangle required.

27. *To bisect any given triangle.*

Suppose A B C the given triangle: bisect one of its sides, as A B in *e*, from which describe the semicircle A *r* B; bisect the same in *r*, and from B with the distance B *r*, cut the diameter A B in *v*; draw the line *v y* parallel to A C, which will bisect the triangle as required.

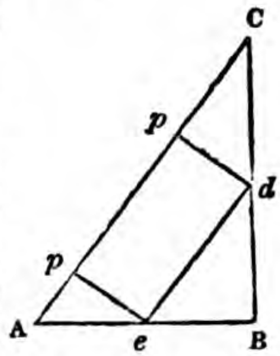
28. *To describe a circle of greatest diameter in a given triangle.*

Bisect the angles A and B, and draw the intersecting lines A D, B D, cutting each other in D; then from D as centre, with the distance D C, which is drawn perpendicular to A B, describe the circle, C *e f*, as required.



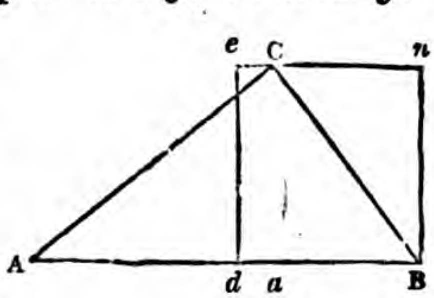
29. *To form a rectangle of greatest surface, in a given triangle.*

Let A B C be the given triangle: bisect any two of its sides, as A B, B C, in *e* and *d*; draw the line *e d*; also at right angles with the line *e d*, draw the lines *e p*, *d p*, and *e p p d* is the rectangle required.

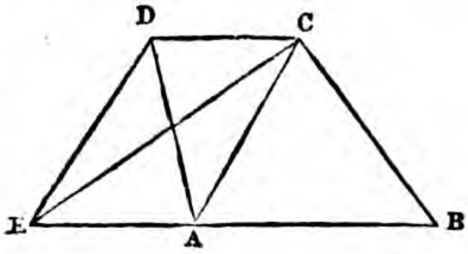


30. *To make a rectangle equal to a given triangle.*

Suppose A B C the given triangle: bisect A B in *d*, and erect the perpendicular *d e*; erect also the perpendicular B *n*; through C draw the line *e* C *n* parallel to A B, meeting the above in *e* and *n* respectively; then *e d* B *n* is the rectangle as required.

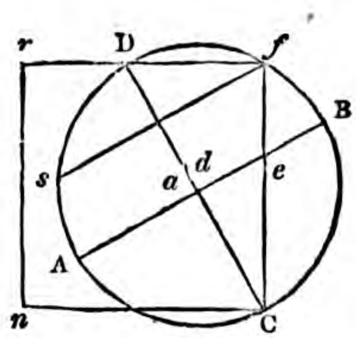


31. *To make a triangle equal to a given quadrilateral, as* A B C D.



Prolong the line B A, and draw the line A C; draw also the line D E parallel to A C, and cutting the line B A in E; then draw the line E C, and C E B is the triangle required.

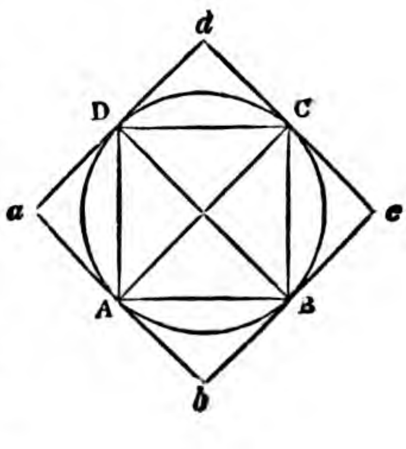
32. *To form a square nearly equal in area to a given circle.*



Let A C B D be the given circle: draw the diameters A B and C D at right angles to each other, bisect the radius *d* B in *e*, and draw the line C *e f*; draw also at right angles the lines C *n* and *f r*, making each equal to C *f*; join *n r*, and *n* C *f r* is the square as required.

Note.—The line *s f* is equal to one-fourth the circumference of the circle nearly.

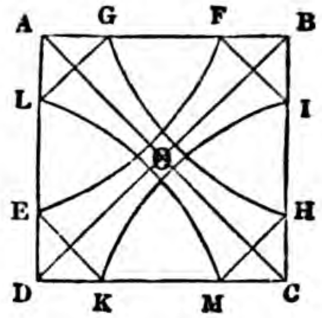
33. *To inscribe or describe a square within or without a given circle: also to form an octagon from a given square.*



1. Let A B C D be the given circle: draw the diameters A C, B D, at right angles to each other, and join A B, B C, C D, D A, which will complete the inscribed square: through the extremities of the same diameters draw *a b*, *c d*, parallel

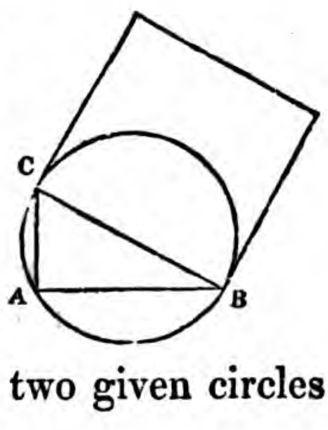
to B D, and *a d*, *b c*, parallel to A C, which will complete the square equal in breadth to the diameter of the circle.

2. Let A B C D be the given square. Draw the two diagonal lines A C and B D intersecting in O; then with a radius equal to A O, or half the diagonal, and with A as a centre, describe the arc E F, cutting the sides of the square in E and F; then from B as a centre, describe the arc G H, and in the same manner from C and D describe the arcs I K and L M. Draw the lines L G, F I, H M, and K E, which, with the parts G F, I H, M K, and E L, form the octagon required.



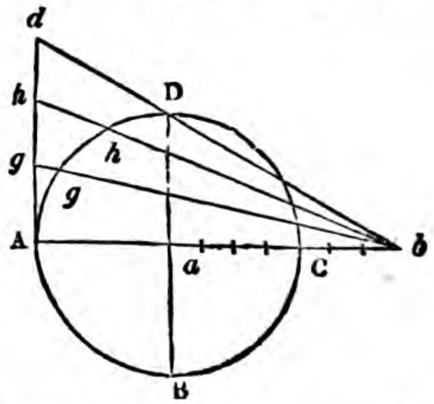
34. *To form a square equal to two given squares, or, a circle equal to two given circles.*

Let A B, A C, equal the sides of the given squares, or diameters of the given circles: make the angle at A a right angle, and draw the line C B, which is the side of a square equal to both the given squares; or bisect the line C B as a diameter, on which describe the circle C B A, which is equal to the two given circles as required.



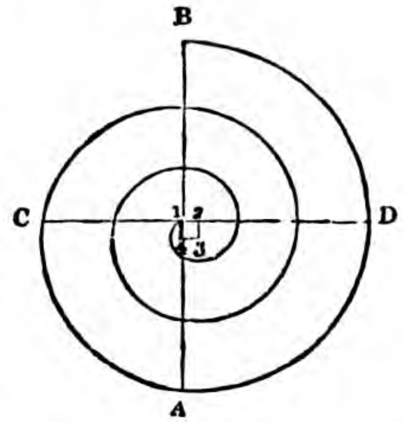
35. *To draw a right line equal to any given portion of the circumference of a circle nearly.*

Let A B C D be a given circle, the whole circumference of which is required: draw at right angles the diameters A C, B D, divide the radius *a* C into four equal parts, and make C *b* equal to three of them; draw the tangent A *d* parallel to B D, draw the line *b* D *d*, then will A *d* be nearly a fourth of the whole circumference; and if lines be drawn from *b*, through points in the circumference, meeting the line A *d*, as *g g*, *h h*, &c., the corresponding parts will be equal to each other nearly.

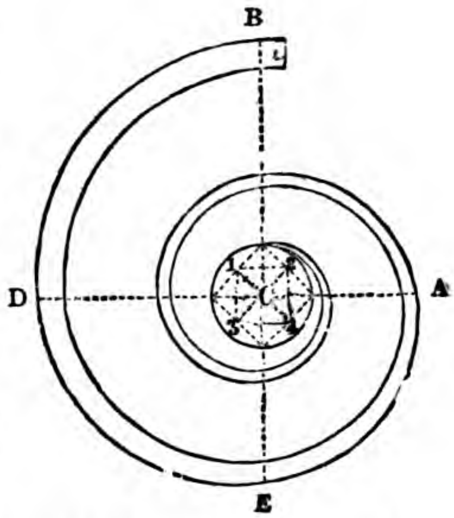


36. *To draw a spiral with spaces of uniform distance.*

Bisect the height of the spiral, as A B, and divide either half into the number of spaces or revolutions required; then again subdivide any one space into four equal parts, one of which add to half the height of the spiral, and through the termination draw C D at right angles to A B, thus forming the centre of the spiral, around which and equal to one of the subdivisions form a square, its sides being parallel with the lines A B and C D, the angles of which are the centres from whence to describe the various curves; as from 1, with the distance 1 B, describe the curve B D; from 2, with the distance 2 D, describe D A; from 3, with the distance 3 A, describe A C, &c., &c., and from the same centres the spiral may be continued to any extent required.

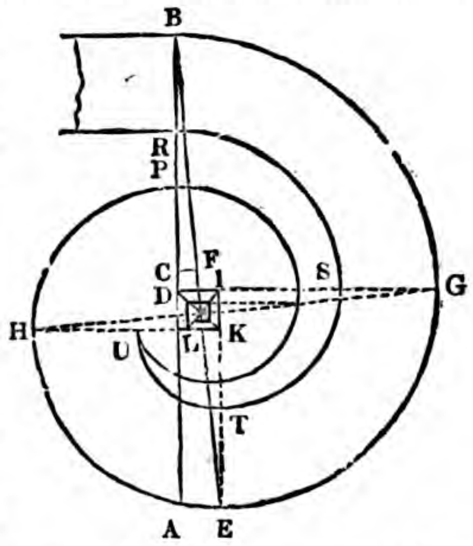


37. *To draw a volute for the capital of the Ionic column.*



Draw at right angles C A, C B, and on the centre C describe a circle equal to one-fourth of the height C B; form a square in the circle, the diagonals of which correspond with or cut the diameters A D, E B; bisect the square with lines crossing each other in the centre C, and parallel with the sides of the square; divide each into six equal parts, which are the centres from which the volute is to be described: thus, from 1, with the distance 1 B, describe the curve B D; from 2, with 2 D, describe D E; from 3, with 3 E, describe E A, &c., approaching the centre by degrees until the volute is completed as required.

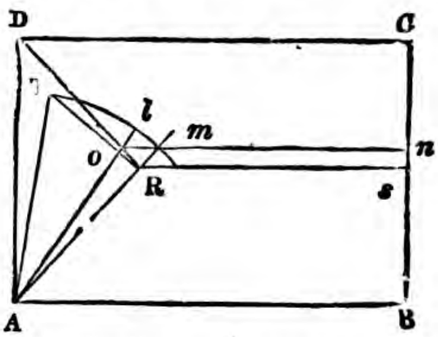
38. *To draw a scroll for the termination of a hand-rail, &c.*



Let A B equal the given breadth: draw A E perpendicular to A B, which divide into eleven equal parts, and A E equal to one of them; join B E, bisect A B in C and B E in F, make C D equal to C F, and draw D G perpendicular to A B; from F, with the radius F E, or F B, describe an arc cutting D G at G; draw G H perpendicular to B E, cutting B E at O (or centre of the scroll); draw the diagonals

D O K, I O L, perpendicular to D O K; draw I K parallel to B A, K L parallel to I D, &c., meeting the diagonals; from D as a centre, with the distance D B, describe the arc B G; from I as a centre, with the distance I G, describe G E; from K, with the distance K E, describe K H, &c., proceeding in the same manner until the outside of the scroll is completed; make B R equal to the breadth of the rail; then from D, with the distance D R, describe the arc R S; from I, and distance I S, describe S T; and from T, with K T, describe T U, which completes the scroll as required.

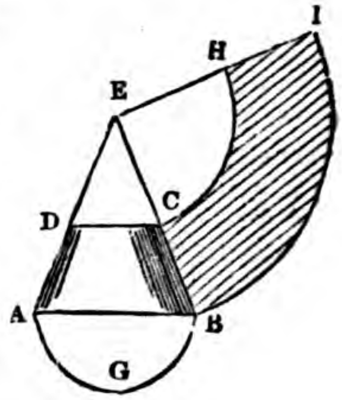
39. *To find the various angles and proper dimensions of materials whereby to construct any figure whose form is the frustum of a proper or inverted pyramid, as hipped roofs, mill hoppers, &c., &c.*

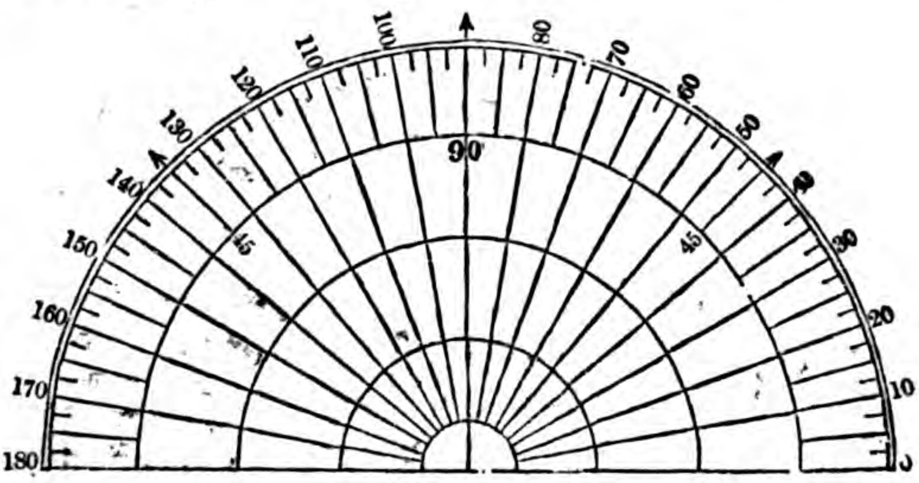


Let A B C D be the given dimensions of plan for a roof, the height R T also being given; draw the diagonal A R, meeting the top or ridge R *s* on plan; from R, at right angles with A R and equal to the required height, draw the line R T, then T A, equals the length of the struts or corners of the roof; from A, with the distance A T, describe an arc T *l*, continue the diagonal A R until it cuts the arc T *l*, through which, and parallel with the ridge R *s*, draw the line *m n*, which determines the required breadth for each side of the roof: from A, meeting the line *m n*, draw the line A *o*, or proper angle for the end of each board by which the roof might require to be covered; and the angle at T is what the boards require to be made in the direction of their thickness, when the corners or angles require to be mitred.

40. *To describe the proper form of flat plate by which to construct any given frustum of a cone.*

Let A B C D represent the required frustum: continue the lines A D and B C until they meet at E; then from E as centre, with the radius E C, describe the arc C H; also from E, with the radius E B, describe the arc B I; make B I equal in length to twice A G B, draw the line E I, and B C I H is the form of plate as required.





Sector from which angles may be obtained.

GEOMETRY APPLIED TO MECHANICS.

41. *To delineate a vee-threaded screw, the pitch and diameter of the screw being given.* (See Plate A, fig. 1.)

Upon the end of the line, or vertical centre of the screw A B, describe the semicircles C D, *c d*, the one being equal to the greatest diameter of the screw, and the other to the lesser diameter, or diameter at the bottom of the threads; divide each semi-circumference

Fig. 2.

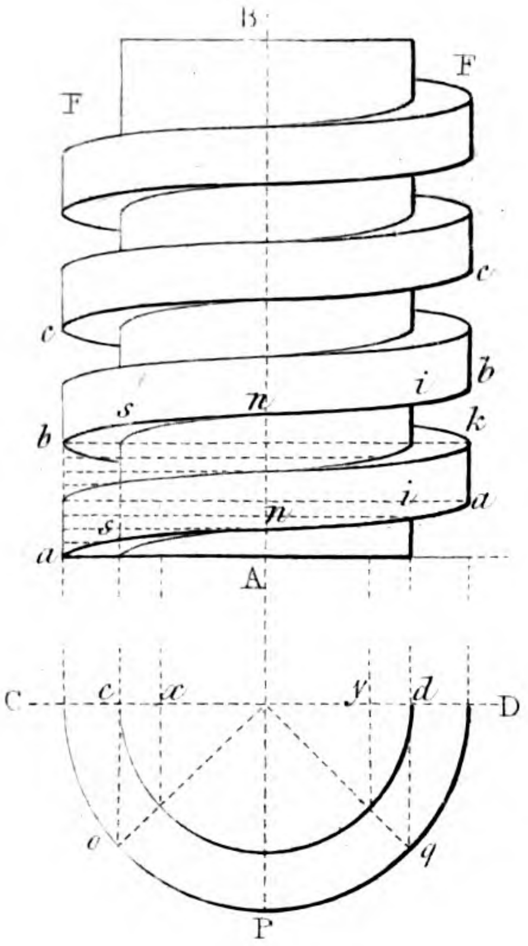


Fig. 3.

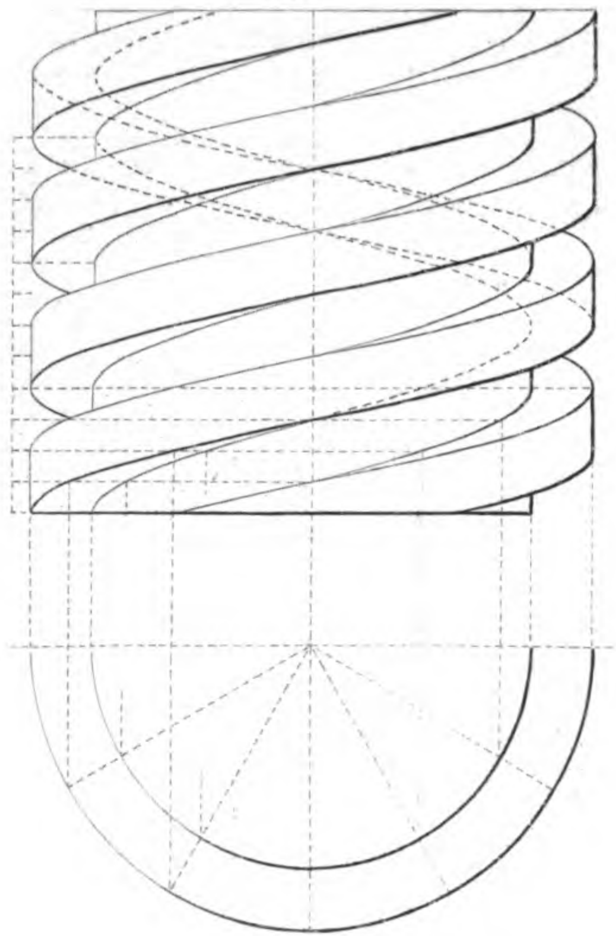
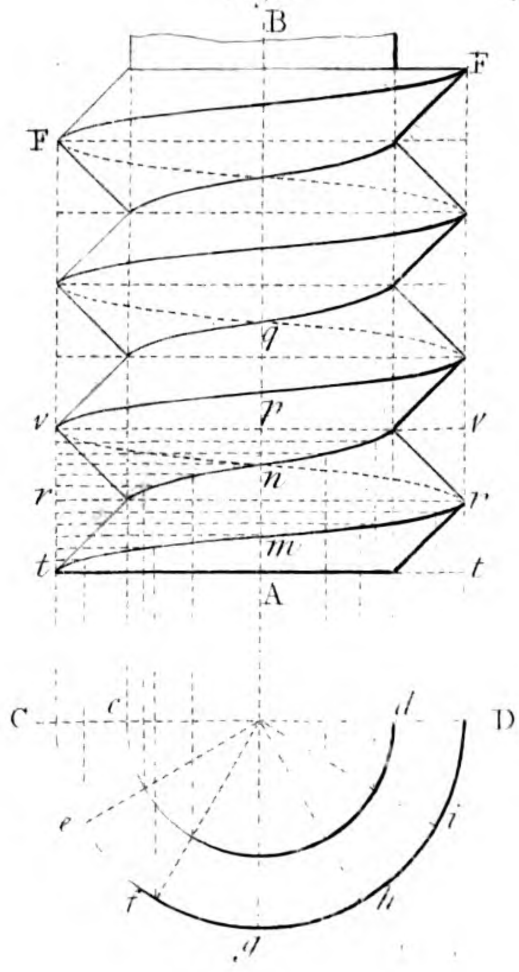


Fig. 1.



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into any number of equal parts, as C, *e*, *f*, *g*, *h*, *i*, D, from which draw lines parallel to the line A B; divide the lines C F, D F, into equal divisions of half the required pitch or consecutive threads, as *t*, *r*, *v*, &c.; draw the lines *t t*, *r r*, *v v*, &c., parallel with the diameter C D, and subdivide any two connected divisions into the same number of equal parts contained in both semicircles, from which draw lines meeting the vertical lines; then by hand, or otherwise, and through the intersections, draw the waved lines, *m*, *n*, *p*, *q*, &c., and a thread of the screw is delineated as required.

Note.—The same process might be continued throughout the whole length of the screw, but it is much more convenient, when the proper curves are obtained, to form a suitable ruler: lay it in its proper situation upon each division, and draw the lines as required.

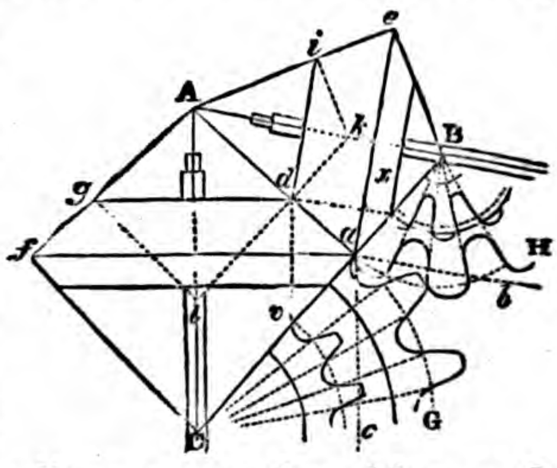
42. *To delineate a square-threaded screw, the pitch and diameter of screw being given.* (See Plate A, fig. 2.)

On the line A B representing the centre of the screw, describe the semicircles C D, *c d*, equal to the diameters at the tops and bottoms of the threads; divide each semi-circumference into four equal parts, draw lines from each and parallel to the line A B; draw also the lines C F, D F, which divide into the proper required pitch, as *a a*, *b b*, *c c*, &c.; divide any two connected pitches or divisions, as *a*, *b*, into four equal parts, from which draw lines parallel to the diameter C D, meeting the vertical lines *o*, P, *q*, and forming intersections through which the waved lines *s*, *n*, *i*, *s*, *n*, *i*, or tops of the threads, must be traced by hand or otherwise; draw also the lines *x*, *y*, forming intersections through which to trace the curve surface exhibited between and caused by the angular return of the thread; describe also the curves *k* and *b*, which terminates the returning thread, and completes the delineation as required.

Fig. 3, as to mode of construction, is exactly similar to that of fig. 2, but intended, by displacement of the cylinder, to delineate a continuous vein of the spiral in its proper form around the whole circumference: hence, being deemed by the preceding figure already sufficiently described, further elucidation must be considered unnecessary.

43. *To determine the proper forms for a pair of bevel wheels, the required angle of the shafts and diameters of the wheels being given.*

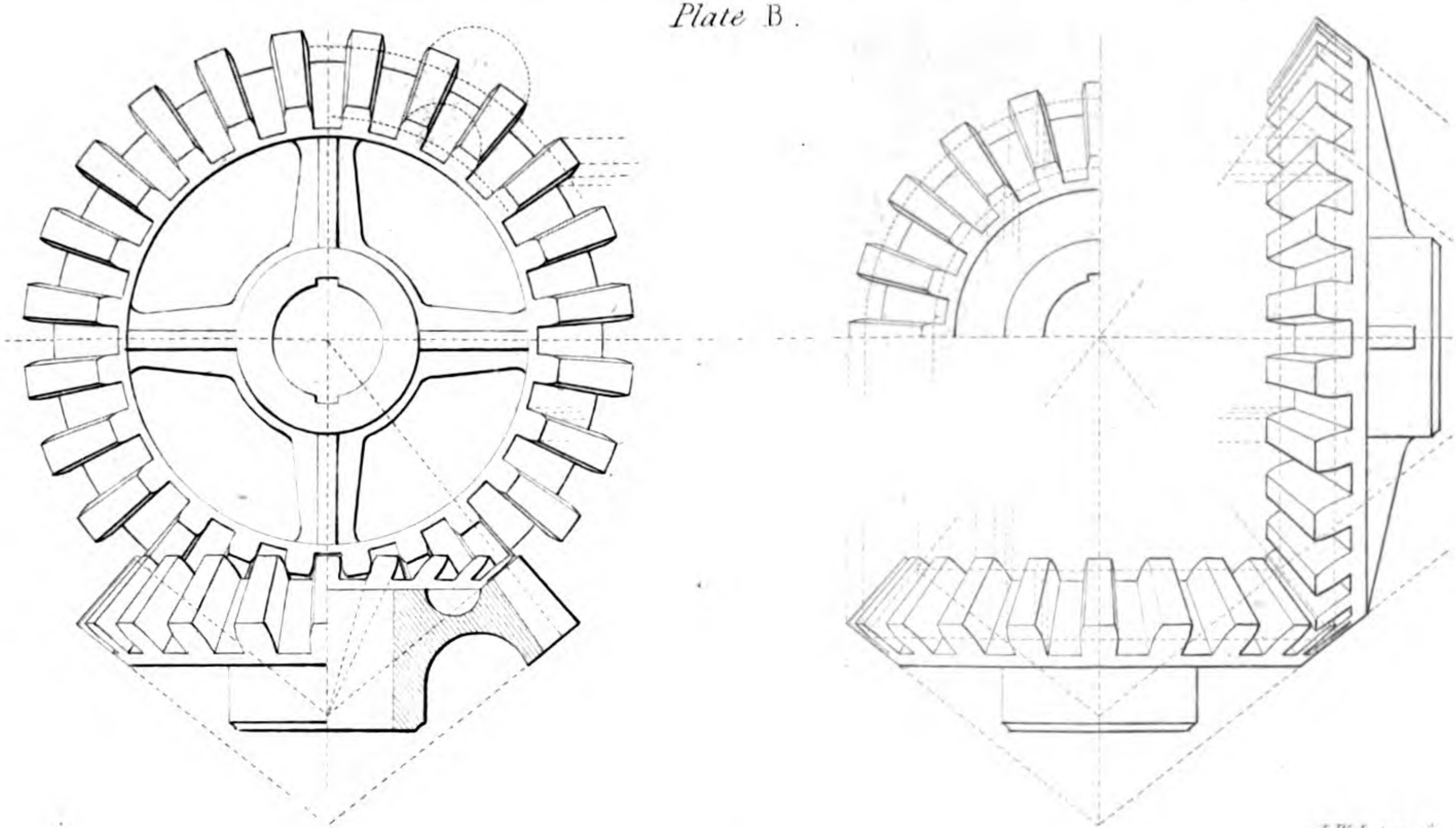
Draw at the given angles lines representing the shafts on which the wheels are to be fixed, as A B, A C; make the lines *a b*, *a c*, parallel with and at a distance from A B, A C, equal to the radius of each respective wheel at the greatest pitch circle; draw the line A *a* through the intersection at *d*; then from *a* at right angles



with A B, A C, draw the lines *a e*, *a f*, making each in length equal to the wheel's diameter; draw the lines A *e*, A *f*, and from *a*, with the intended breadth of the wheels on the face, cut the line A *a* in *d*; draw the lines *d i*, *d g*, parallel to *a e*, *a f*, (hence the proper conical forms of the wheels and the pitch circles;) draw at right angles with A *a*, and through the intersection of the lines *a e*, *a f*, the line C B, also the lines B *e*, *c f*, *d k i*, *d l g*; from B and C, with

ILLUSTRATIONS TO THE DRAWING OF BEVEL WHEELS.

Plate B.



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the radius B a, C a, describe portions of circles, as a G, a H, on which describe the greatest dimensions of, and proper form of the teeth; then from d, and parallel with A B, A C, draw the lines $a\ v$, $a\ x$, cutting the line C B in v and x; from B and C, with the distances C v, B x, describe the portions of circles, which determines the dimensions of the teeth on the interior pitch circle, and completes the proper forms of the wheels as required.

Proportions for the construction of toothed wheels.

Length of the teeth $= \frac{5}{7}$ of the pitch.
Thickness " $= \frac{4}{9}$ do.
Breadth on face $= 2\frac{1}{2}$ times the pitch.
Edge of the rim
Projecting rib inside do. } each $\frac{4}{9}$ of the pitch.
Thickness of flat arms

Breadth of arms at rim $= 2$ teeth and $\frac{1}{4}$ the pitch, increasing in breadth towards the centre of the wheel, in the proportion of $\frac{1}{2}$ an inch for every foot in length.

Thickness of the ribs or feathers on the arms $= \frac{1}{4}$ of the pitch.

Thickness of metal around the eye, or centre, $= \frac{7}{9}$ of the pitch.

Wheels and other circular bodies are very conveniently transferred from plan to that of a projected perspective by means of a peculiar appropriation of straight lines, commonly called orthographic projection, the principle of which will be readily understood by reference to the diagrams and illustrations given for the purpose in Plate C.

Fig. 1 is a circle divided into equal parts, and its form in projection is required, $v\ n$ being supposed the line of intersection: parallel with the diameter of the circle *b f*, draw at right angles, and through the centre, the line *c e*; draw also the line or chord *f g*, cutting the line *v n* in *g*; then, with the distance *v g*, describe the quadrant *i r s*; bisect the arc in *r*, from which and parallel with *v n*, draw the line *r t*; draw also the lines *f t*, *g t*, which determines the breadth of the ellipsis or projected form of the circle, and which may be drawn as described (page 5, fig. 12): hence all the other lines being so distinctly described, by mere inspection of the diagrams, further explanation is unnecessary.

Fig. 2 is a projected representation of an undershot water-wheel, of which A is the plan, *v n* the line of intersection, and B the diameter and breadth, laid at a proper angle or inclination, as determined by the principles of the diagrams: the breadth of the ellipsis is found and formed as there described, and the lines in the illustration, or fig. 2, whereby to obtain the proper angles for projection, render sufficiently explicit the proper mode by which the representation is effected.

ORTHOGRAPHIC PROJECTION.

Plate C.

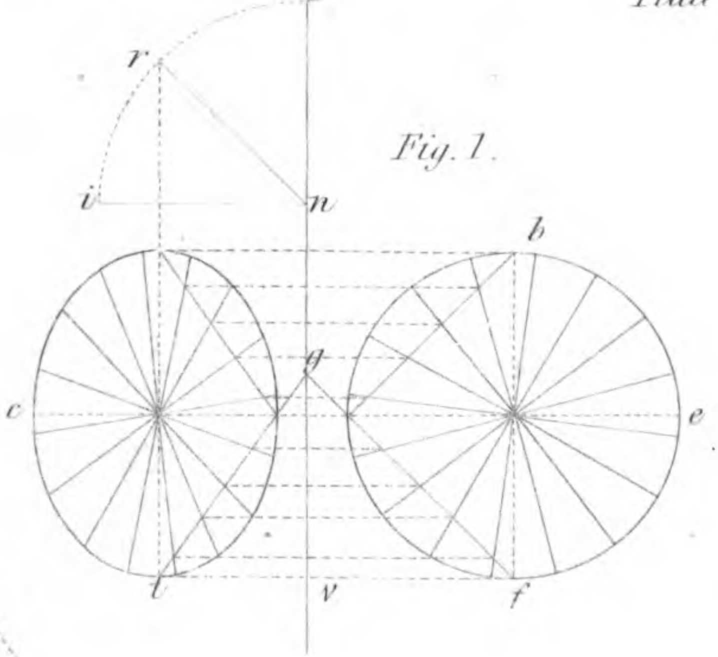

Fig. 1.

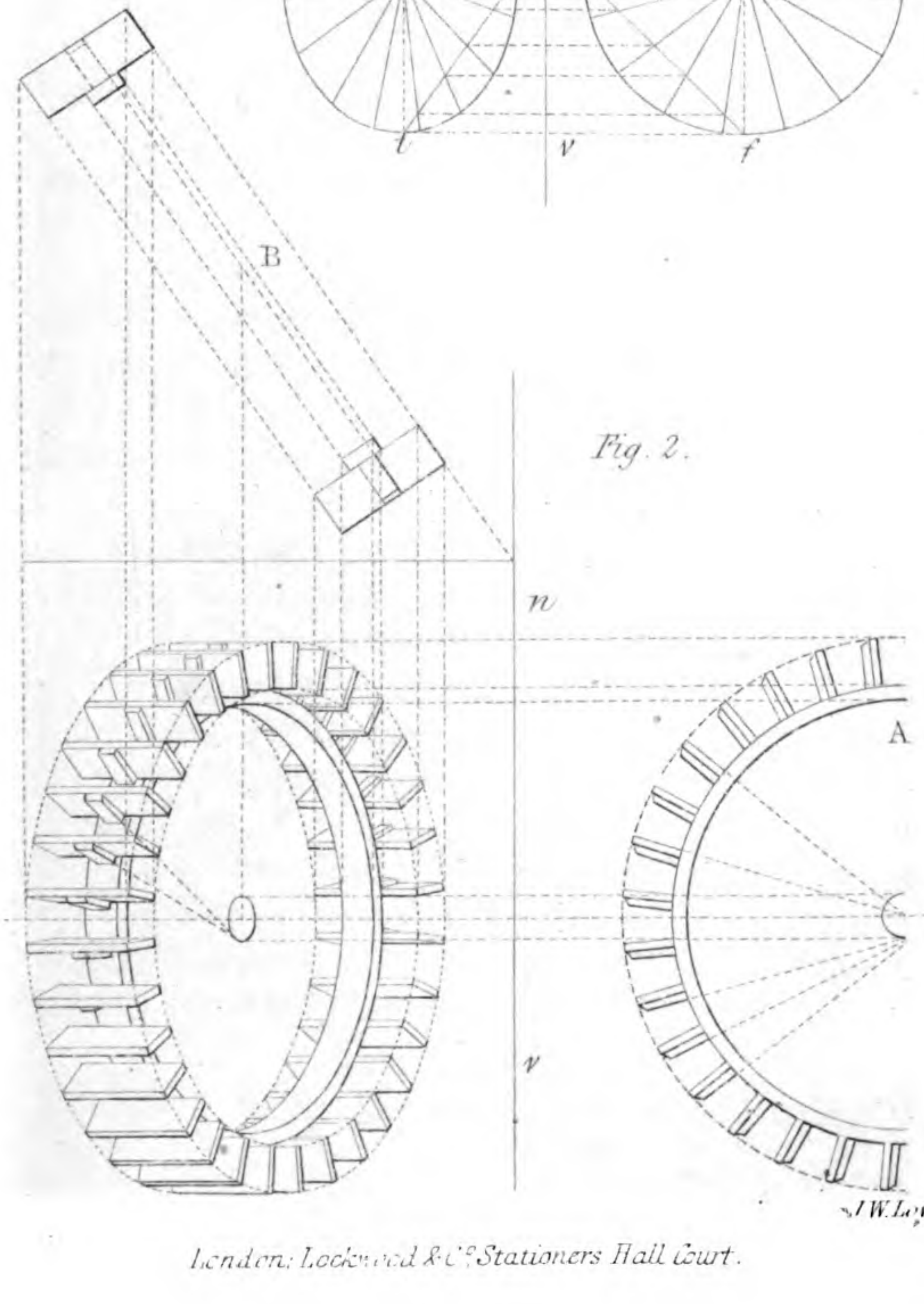

Fig. 2.

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DECIMAL ARITHMETIC.

Decimal Arithmetic is the most simple and explicit mode of performing practical calculations; on account of its doing away with the necessity of fractional parts in the fractional form, thereby reducing long and tedious operations to a few figures, arranged and worked in all respects according to the usual rules of common arithmetic.

Decimals simply signify tenths: thus, the decimal of a foot is the tenth part of a foot, the decimal of that tenth is the hundredth of a foot, the decimal of that hundredth is the thousandth of a foot, and so might the divisions be carried on and lessened to infinity; but in practice it is seldom necessary to take into account any degree of less measure than a one-hundredth part of the integer or whole number. And, as the entire system consists in supposing the whole number divided into tenths, hundredths, thousandths, &c., no peculiarity of notation is required, otherwise than placing a mark or dot, to distinguish between the whole and any part of the whole: thus 34·25 gallons signify 34 gallons 2 tenths and 5 hundredths of a gallon; 11·04 yards signify 11 yards and 4 hundredths of a yard; 16·008 shillings signify 16 shillings and 8 thousandth parts of a shilling: from which it must appear plain, that ciphers on the right hand of decimals are of no value whatever; but placed on the left hand, they diminish the decimal value in a tenfold proportion,—for ·6 signifies 6 tenths; ·06 signifies 6 hundredths; and ·006 signifies 6 thousandths, of the integer or whole number.

REDUCTION.

Reduction means the construing or changing of vulgar fractions to decimals of equal value; also finding the fractional value of any decimal given.

Rule 1. Add to the numerator of the fraction any number of decimal ciphers at pleasure, divide by the denominator, and the quotient is the decimal of equivalent value.

Rule 2. Multiply the decimal by successive small numbers, such as to cause the decimals in the last product to be all 0. The integer prefixed to these will be the numerator, and the product of the multipliers the denominator of the equal fraction; or, under the figures of the decimal write 1, followed by as many 0's.

Ex. 1. Required the decimal equivalent, or decimal of equal value, to $\frac{3}{12}$ of a foot.

$$\frac{3{\cdot}00}{12} = {\cdot}25, \text{ the decimal required.}$$

Ex. 2. Reduce the fraction $\frac{1}{8}$ of an inch to a decimal of equal value.

$$\frac{1{\cdot}000}{8} = {\cdot}125, \text{ the decimal required.}$$

Ex. 3. What is the decimal equivalent to $\frac{7}{8}$ of a gallon?

$$\frac{7{\cdot}000}{8} = {\cdot}875, \text{ the decimal equivalent.}$$

Ex. 4. Required the value of the decimal ·40625 of an inch.

$$\begin{array}{r} {\cdot}40625 \\ 8 \\ \hline 3{\cdot}25000 \\ 2 \\ \hline 6{\cdot}50000 \\ 2 \\ \hline 13{\cdot}00000 \end{array}$$

13·00000, hence $\frac{13}{32}$ of an inch, the value required.

Ex. 5. What is the value of ·625 of a cwt.?

```
                      ·625
Multiply by 4 qrs.       4
                    ------
                     2·500
      × 28 lbs.         28
                    ------
                    14·000 = 2 quarters and 14 lbs., the value
                    ======           required.
```

Ex. 6. Ascertain the value of ·875 of an imperial gallon.

```
                          ·875
Multiply by 4 quarts         4
                         -----
                         3·500
        × 2 pints            2
                         -----
                         1·000 = 3 quarts and 1 pint, the value
                         =====          required.
```

Ex. 7. What is the value of ·525 of a £. sterling?

```
                        ·525
Multiply by 20 sh.        20
                      ------
                      10·500
     × 12 pence           12
                      ------
                       6·000 = 10 shillings and 6 pence, the
                      ======          value required.
```

Independent of the mark or dot which distinguishes between integers and decimals, the fundamental rules, viz., Addition, Subtraction, Multiplication, and Division, are in all respects the same as in Simple Arithmetic; and an example in each, illustrative of placing the separating point, will no doubt render the whole system sufficiently intelligible, even to the dullest capacity.

Ex. 1. Add into one sum the following integers. and decimals.

16·625; 11·4; 20·7831; 12·125; 8·04; and 7·002.

```
 16·625
 11·4
 20·7831
 12·125
  8·04
  7·002
 -------
 75·9751 = the sum required.
```

Ex. 2. Subtract 119·80764 from 234·98276.

```
 234·98276
 119·80764
 ---------
 115·17512 = the remainder required.
```

Ex. 3. Multiply 62·10372 by 16·732.

```
      62·10372
        16·732
   -----------
      12420744
     18631116
    43472604
   37262232
   6210372
   -----------
   1039·11944304 = the product required.
```

Observe that the number of figures in the product from the right hand, accounted as decimals, are equal to the number of decimals in the multiplier and multiplicand taken together.

Ex. 4. Divide 39·375 by 9·25.

9·25) 39·375 (4·256 = the quotient required.

```
9·25) 39·375 (4·256
      3700
      ----
       2375
       1850
       ----
        5250
        4625
        ----
         6250
         5550
         ----
          700
```

Observe that the number of decimals in the divisor and quotient together, must be equal to the number in the dividend.

Note.—The operation might be still continued, so as to reduce the quotient to a degree of greater exactitude, but in practice it is quite unnecessary, being even now reduced to a measure of greater nicety than is commonly required.

Definitions of Arithmetical signs employed in the following calculations, which ought to be particularly attended to.

$=$	sign of	equality, and	signifies	equal to, as 3 added 4 $= 7$.
$+$	,,	addition	,,	plus or more, as $5 + 3 = 8$.
$-$	,,	subtraction	,,	minus or less, as $8 - 3 = 5$.
$\times$	,,	multiplication	,,	multiplied by, as $8 \times 3 = 24$.
$\div$	,,	division	,,	divided by, $24 \div 4 = 6$ or $\frac{24}{4} = 6$.
: :: :		proportion	,,	that 2 is to 3 as 4 is to 6, &c.
$\sqrt{}$	,,	square root	,,	evolution, or the extr^n. of roots;
$\sqrt[3]{}$	,,	cube root	,,	thus, $\sqrt{64} = 8$ and $\sqrt[3]{64} = 4$.
4^2	,,	to be squared	,,	involution, or the raising of powers;
4^3	,,	to be cubed	,,	thus, $4^2 = 16$, and $4^3 = 64$.

$\overline{3+5} \times 4 = 32$ — that, 3 plus 5, or 8 multiplied by $4 = 32$.

$\sqrt{5^2 - 3^2} = 4$ — 5 squared, minus 3 squared, the square root of the remainder $= 4$.

$\sqrt[3]{\frac{20 \times 12}{30}} = 2$, 20 multiplied by 12, and divided by 30, the cube root of the quotient $= 2$.

BRITISH STANDARD MEASURES.

1. *Measures of length.*

12 inches	= 1 foot.
3 feet	= 1 yard.
$5\frac{1}{2}$ yards	= 1 pole or rod.
40 poles	= 1 furlong.
8 furlongs, 1760 yards, or 5280 feet	= 1 mile.

2. *Measures of surface, or square measure.*

144 square inches	= 1 square foot
9 square feet	= 1 square yard.
$30\frac{1}{4}$ square yards	= 1 square pole.
40 square poles	= 1 rood.
4 roods, or 4840 square yards	= 1 acre.

3. *Measures of solidity, or cubic measure.*

1728 cubic inches	= 1 cubic foot.
27 cubic feet	= 1 cubic yard.

4. *Measures of capacity.*

LIQUIDS.

8·665 cubic inches	= 1 gill.
4 gills	= 1 pint
2 pints	= 1 quart.
4 quarts, or $277\frac{1}{4}$ cubic inches	= 1 gallon.

GRAIN, FRUITS, &c.

2 gallons	= 1 peck.
4 pecks, or 2218·192 cubic inches	= 1 bushel.
8 bushels	= 1 quarter.
5 quarters	= 1 load.

5. *Measures of weight.*

TROY.

24 grains	= 1 pennyweight.
20 pennyweights	= 1 ounce
12 ounces	= 1 pound.

AVOIRDUPOIS.

27·34375 troy grains	= 1 dram.
16 drams	= 1 ounce.
16 ounces	= 1 pound.
14 pounds	= 1 stone.
2 stones	= 1 quarter.
4 quarters, or 112 lbs	= 1 cwt.
20 cwt.	= 1 ton.

BRITISH SPECIAL MEASURES.

1. *Lineal measures for land.*

7·92 inches	= 1 link.
100 links, or 22 yards	= 1 chain.
80 chains	= 1 mile.
69·121 miles	= 1 geog. degree.

2. *Square measures for land.*

62·7264 square inches	= 1 square link.
10,000 square links	= 1 square chain.
10 square chains	= 1 acre.

3. *Nautical measures.*

6082·66 feet	= 1 nautical mile.
3 miles	= 1 league.
20 leagues	= 1 degree.
360 degrees	= the earth's circumference.

Miscellaneous special measures.

6 lineal feet	= 1 fathom.	
100 square feet	= 1 square of flooring.	
272 sq. feet, at 14 in. in thickness	= 1 rod of brick-work.	
600 square feet of inch boards	= 1 load.	
40 cubic feet of round timber 50 cubic feet of hewn timber	= 1 ton or load.	
40 cubic feet	= 1 ton of shipping.	
120 deals	= 1 hundred.	
120 nails	= 1 hundred.	
1200 do.	= 1 thousand.	
500 bricks	= 1 load.	
32 bushels of lime	= 1 do.	
36 do. sand	= 1 do.	
19½ cwt.	= 1 fother of lead.	
108 cubic feet	= 1 stack of wood.	
42 gallons	= 1 tierce	old wine measure.
63 do.	= 1 hogshead	
84 do.	= 1 puncheon	
126 do.	= 1 pipe	
252 do.	= 1 tun	
36 do.	= 1 barrel	old ale measure.
54 do.	= 1 hogshead	
72 do.	= 1 puncheon	
108 do.	= 1 butt	

DECIMAL APPROXIMATIONS FOR FACILITATING CALCULATIONS IN MENSURATION.

Lineal feet	multiplied by	·00019	= miles.
,, yards	,,	·000568	= ,,
Square inches	,,	·007	= square feet.
,, yards	,,	·0002067	= acres.
Circular inches	,,	·00546	= square feet.
Cylindrical inches	,,	·0004546	= cubic feet.
,, feet	,,	·02909	= cubic yards.
Cubic inches	,,	·00058	= cubic feet.
,, feet	,,	·03704	= cubic yards.
,, ,,	,,	6·232	= imperial gallons.
,, inches	,,	·003607	= ,, ,,
Cylindrical feet *	,,	4·895	= ,, ,,
,, inches	,,	·002832	= ,, ,,
Cubic inches	,,	·263	= lbs. av^{s}. of cast iron.
,, ,,	,,	·281	= ,, wrought do.
,, ,,	,,	·283	= ,, steel.
,, ,,	,,	·3225	= ,, copper
,, ,,	,,	·3037	= ,, brass.
,, ,,	,,	·26	= ,, zinc.
,, ,,	,,	·4103	= ,, lead.
,, ,,	,,	·2636	= ,, tin.
,, ,,	,,	·4908	= ,, mercury.
Cylindrical inches	,,	·2065	= ,, cast iron.
,,	,,	·2168	= ,, wrought iron.
,,	,,	·2223	= ,, steel.
	,,	·2533	= ,, copper.
,,	,,	·2385	= ,, brass.
,,	,,	·2042	= ,, zinc.
,,	,,	·3223	= ,, lead.
,,	,,	·207	= ,, tin.
,,	,,	·3854	= ,, mercury.
Avoirdupois lbs.	,,	·009	= cwts.
,,	,,	·00045	= tons.

* This means cubic feet multiplied by ·7854. The number in the table, multiplied by the height of a cylinder and the square of its diameter, gives its capacity in gallons (*See Ex.* 3, *p.* 44).

DECIMAL EQUIVALENTS TO FRACTIONAL PARTS OF LINEAL MEASURES.

One inch, the integer or whole number.

	are equal to		are equal to		are equal to
·96875	$\frac{7}{8}$ & $\frac{3}{32}$	·625	$\frac{5}{8}$	·28125	$\frac{1}{4}$ & $\frac{1}{32}$
·9375	$\frac{7}{8}$ & $\frac{1}{16}$	·59375	$\frac{1}{2}$ & $\frac{3}{32}$	·25	$\frac{1}{4}$
·90625	$\frac{7}{8}$ & $\frac{1}{32}$	·5625	$\frac{1}{2}$ & $\frac{1}{16}$	·21875	$\frac{1}{8}$ & $\frac{3}{32}$
·875	$\frac{7}{8}$	·53125	$\frac{1}{2}$ & $\frac{1}{32}$	·1875	$\frac{1}{8}$ & $\frac{1}{16}$
·84375	$\frac{3}{4}$ & $\frac{3}{32}$	·5	$\frac{1}{2}$	·15625	$\frac{1}{8}$ & $\frac{1}{32}$
·8125	$\frac{3}{4}$ & $\frac{1}{16}$	·46875	$\frac{3}{8}$ & $\frac{3}{32}$	·125	$\frac{1}{8}$
·78125	$\frac{3}{4}$ & $\frac{1}{32}$	·4375	$\frac{3}{8}$ & $\frac{1}{16}$	·09375	$\frac{3}{32}$
·75	$\frac{3}{4}$	·40625	$\frac{3}{8}$ & $\frac{1}{32}$	·0625	$\frac{1}{16}$
·71875	$\frac{5}{8}$ & $\frac{3}{32}$	·375	$\frac{3}{8}$	·03125	$\frac{1}{32}$
·6875	$\frac{5}{8}$ & $\frac{1}{16}$	·34375	$\frac{1}{4}$ & $\frac{3}{32}$		
·65625	$\frac{5}{8}$ & $\frac{1}{32}$	·3125	$\frac{1}{4}$ & $\frac{1}{16}$		

One foot, or 12 inches, the integer.

	are equal to		are equal to		are equal to
·9166	11 inches.	·4166	5 in.	·0625	$\frac{3}{4}$ of in.
·6338	10 "	·3333	4 "	·05208	$\frac{5}{8}$ "
·75	9 "	·25	3 "	·04166	$\frac{1}{2}$ "
·6666	8 "	·1666	2 "	·03125	$\frac{3}{8}$ "
·5833	7 "	·0833	1 "	·02083	$\frac{1}{4}$ "
·5	6 "	·07291	$\frac{7}{8}$ "	·01041	$\frac{1}{8}$ "

One yard, or 36 inches, the integer.

	are equal to		are equal to		are equal to
·9722	35 inches.	·6389	23 inches.	·3055	11 inches.
·9444	34 "	·6111	22 "	·2778	10 "
·9167	33 "	·5833	21 "	·25	9 "
·8889	32 "	·5556	20 "	·2222	8 "
·8611	31 "	·5278	19 "	·1944	7 "
·8333	30 "	·5	18 "	·1667	6 "
·8056	29 "	·4722	17 "	·1389	5 "
·7778	28 "	·4444	16 "	·1111	4 "
·75	27 "	·4167	15 "	·0833	3 "
·7222	26 "	·3889	14 "	·0555	2 "
·6944	25 "	·3611	13 "	·0278	1 "
·6667	24 "	·3333	12 "		

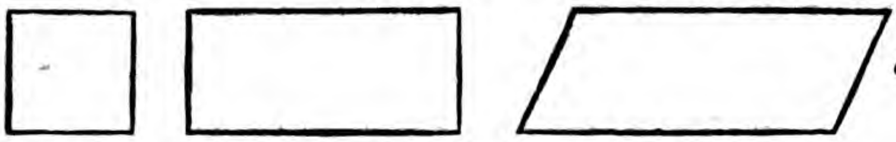
MENSURATION.

MENSURATION is that branch of Mathematics which is employed in ascertaining the extension, solidities, and capacities of bodies, capable of being measured.

1. MENSURATION OF SURFACE.

To measure or ascertain the quantity of surface in any right-lined figure whose opposite sides are parallel to each other, as a

Square, Rectangle, Rhomboid,



&c.

Rule.—Multiply the length by the breadth; the product is the area or superficial contents.

Application of the rule to practical purposes.

1. The side of a square piece of board is $8\frac{3}{16}$ inches in length; required the area or superficies.

Decimal equivalent to the fraction $\frac{3}{16}$=·1875 (see page 31); and 8·1875 × 8·1875=67·03515625 square inches, the area.

2. The length of the fire-grate under the boiler of a steam engine is 4 feet 7 inches, and its width 3 feet 6 inches: required the area of the fire-grate.

7 in.=·5833 and 6 in.=·5 (see Table of Equivalents, p. 31): hence 4·5833 × 3·5=16·04155 square feet, the area.

3. Required the number of square yards in a floor whose length is $13\frac{1}{2}$, and breadth $9\frac{3}{4}$ feet.

$13{\cdot}5 \times 9{\cdot}75 = 131{\cdot}625 \div 9 = 14{\cdot}625$ square yards.

Note 1.—The above rule is rendered equally applicable to figures whose sides are not parallel to each other, by taking the mean breadth as that by which the contents are to be estimated.

2. The square root of any given sum equals the side of a square of equal area.

3. Any square whose side is equal to the diagonal of another square, contains double the area of that square.

4. Any sum or area (of which to form a rectangle) divided by the breadth, the quotient equals the length; or divided by the length, the quotient equals the breadth of the rectangle required.

TRIANGLES.

Any two sides of a right-angled triangle being given, to find the third side.

Rule 1.—Add together the squares of the base and perpendicular, and the square root of the sum is the hypotenuse or longest side.

Rule 2.—Add together the hypotenuse and any one side, multiply the sum by their difference, and the square root of the product equals the other side.

Application to practical purposes.

1. Wanting to prop a building with raking shores, the top ends of which to be 25 feet from the ground, and the bottom ends, 16 feet from the base of the building; what must be their length, independent of any extra length allowed below the surface of the ground?

$\overline{25^2 + 16^2} = \sqrt{881} = 29{\cdot}6816$ feet, or $\cdot 6816 \times 12 = 8$ inches; consequently, 29 feet 8 inches nearly.

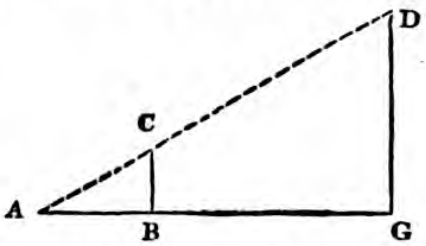
2. From the top of a wall 18 feet in height, a line was stretched across a canal for the purpose of ascer-

taining its breadth; the length of the line, when measured, was found to be 40 feet; required the breadth from the opposite embankment to the base of the wall.

$40-18=22$, and $\sqrt{\overline{40+18}\times 22}=\sqrt{1276}=35\cdot72$, or 35 feet 9 inches nearly, the width of the canal.

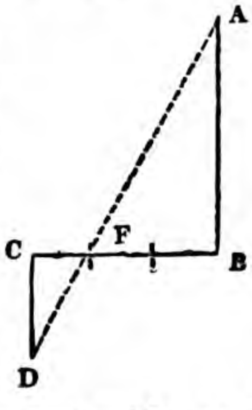
Triangles similar to each other are proportional to each other; hence their utility in ascertaining the heights and distances of inaccessible objects.

Thus, suppose the height of an inaccessible object D is required, I find by means of two staffs or otherwise, the height of the perpendicular B C and the length of the base line A B; also the distance from A to the base of the object G D;



then A B : B C : : A G : G D. And suppose A B=6 feet, B C=2 feet, and A G=150;
6 : 2 : : 150 : 50 feet, the height of D from G.

Again, suppose the inaccessible distance B A be required, make the line B A, B C, at right angles, and B C of three or four equal parts of any convenient distance, through one of which and in a line with the object A, determine the triangle C D F, then the proportion will be as

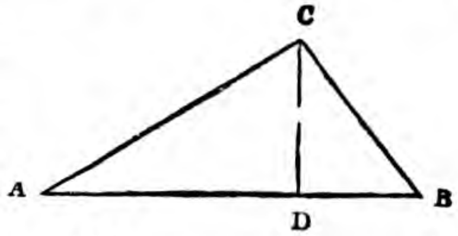


C F : C D : : B F : B A. Let C F=10 yards, C D=53, and B F=30, 10 : 53 : : 30 : 159 yards, the distance from B.

To find the area of a triangle when the base and perpendicular are given.

Rule.—Multiply the base by the perpendicular height, and half the product is the area.

1. The base of the triangle A D B is $11\frac{3}{32}$ inches in length, and the height D C, $3\frac{3}{8}$ inches; required the area.



$\frac{3}{32}$=·09375 and $\frac{3}{8}$=·375 (see page 31):

hence $\frac{11·09375 \times 3·375}{2}$=18·72075 square inches, the area.

2. The base of a triangle is 53 feet 3 inches, and the perpendicular 7 feet 9 inches; required the area or superficies.

$$\frac{53·25 \times 7·75}{2} = 206·34375$$ square feet, the area.

When only the three sides of a triangle can be given, to find the area.

Rule.—From half the sum of the three sides, subtract each side severally; multiply the half sum and the three remainders together, and the square root of the product is equal to the area required.

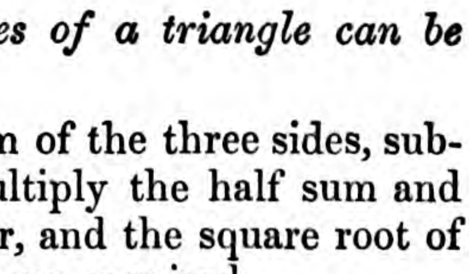
Required the area of a triangle whose three sides are respectively 50, 40, and 30 feet.

$\frac{50+40+30}{2}$=60, or half the sum of the three sides.

60−30=30, first difference,
60−40=20, second difference,
60−50=10, third difference;

then $30 \times 20 \times 10 \times 60 = \sqrt{360000} = 600$, the area required.

Triangles are employed to great advantage in determining the area of any rectilineal figure, as the annexed, and by which the measurement is rendered comparatively simple.



POLYGONS.

Polygons being composed of triangles, may of course be similarly measured: hence in regular polygons, multiply the length of a side by the perpendicular height to the centre, and by the number of sides, and half the product is the area.

Table relative to the Construction and Estimation of Polygons.

Name.	No. of sides.	Angle at centre.	Angle at circum.	Perpen. side being 1.	Length of side, radius being 1.	Radius of circle, side being 1.	Radius of circle, per. being 1.	Area, side being 1.
Triangle .	3	120°	60°	0·2886	1·73	·579	2	0·4330
Square . . .	4	90	90	0·5	1·412	·705	1·41	1
Pentagon .	5	72	108	0·6882	1·174	·852	1·238	1·7204
Hexagon .	6	60	120	0·8660	1	1	1·156	2·5980
Heptagon.	7	$51\frac{3}{7}$	$128\frac{4}{7}$	1·0382	·867	1·16	1·11	3·6339
Octagon .	8	45	135	1·2071	·765	1·307	1·08	4·8284
Nonagon .	9	40	140	1·3737	·681	1·47	1·062	6·1818
Decagon .	10	36	144	1·5388	·616	1·625	1·05	7·6942
Undecagon	11	$32\frac{8}{11}$	$147\frac{3}{11}$	1·7028	·561	1·777	1·04	9·3656
Dodecagon	12	30	150	1·8660	·516	1·94	1·037	11·1961

Application of the Table.

1. The radius of a circle being $6\frac{1}{2}$ feet, required the side of the greatest heptagon that may be inscribed therein.

$\cdot 867 \times 6\cdot 5 = 5\cdot 6355$, or 5 feet $7\frac{1}{2}$ inches nearly.

2. Each side of a pentagon is required to be 9 feet; required the radius of circumscribing circle.

$\cdot 852 \times 9 = 7\cdot 668$, or 7 feet 8 inches.

3. A perpendicular from the centre to either side of an octagon is required to be 12 feet; what must be the radius of circumscribing circle?

$1\cdot 08 \times 12 = 12\cdot 96$, or 12 feet $11\frac{1}{2}$ inches.

4. Each side of a hexagon is $4\frac{1}{2}$ yards; required its superficial contents.

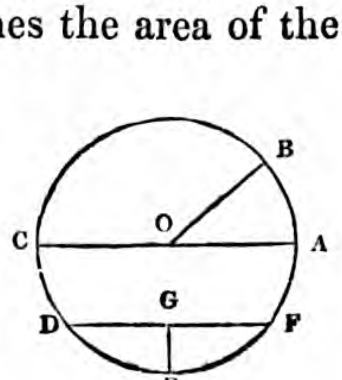
$4\frac{1}{2}^2 \times 2\cdot 598 = 52\cdot 6095$ square yards.

THE CIRCLE AND ITS SECTIONS.

Observations and Definitions.

1. The circle contains a greater area than any other plane figure bounded by the same perimeter or outline.

2. The areas of circles are to each other as the squares of their diameters; any circle twice the diameter of another contains four times the area of the other.



3. The radius of a circle is a straight line drawn from the centre to the circumference, as O B.

4. The diameter of a circle is a straight line drawn through the centre, and terminated both ways at the circumference, as C O A.

5. A chord is a straight line joining any two points of the circumference, as D F.

6. The versed sine is a perpendicular joining the middle of the chord and circumference, as E G.

7. An arc is any part of the circumference, as C D E.

8. A semicircle is half the circumference cut off by a diameter, as C E A.

9. A segment is any portion of a circle cut off by a chord, as D E F.

10. A sector is a part of a circle cut off by two radii, as A O B.

General rules in relation to the circle.

1. Multiply the diameter by 3·1416, the product is the circumference.

2. Multiply the circumference by ·31831, the product is the diameter.

3. Multiply the square of the diameter by ·7854, the product is the area.

4. Multiply the square root of the area by 1·12837, the product is the diameter.

5. Multiply the diameter by ·8862, the product is the side of a square of equal area.

6. Multiply the side of a square by 1·128, the product is the diameter of a circle of equal area.

Application of the rules as to purposes of practice.

1. The diameter of a circle being $7\frac{3}{16}$ inches, required its circumference.

$7·1875 \times 3·1416 = 22·58025$ inches, the circumference.

Or, the diameter being $30\frac{1}{2}$ feet, required the circumference.

$3·1416 \times 30·5 = 95·8188$ feet, the circumference.

2. A straight line, or the circumference of a circle,

being 274·89 inches, required the circle's diameter corresponding thereto.

$\cdot 274 \cdot 89 \times \cdot 31831 = 87 \cdot 5$ inches diameter.

Or, what is the diameter of a circle when the circumference is 39 feet?

$\cdot 31831 \times 39 = 12 \cdot 41409$ feet, and $\cdot 41409 \times 12 = 4 \cdot 96908$ inches, or 12 feet 5 inches, very nearly the diameter.

3. The diameter of a circle is $3\frac{3}{4}$ inches; what is its area in square inches?

$3 \cdot 75^2 = 14 \cdot 0625 \times \cdot 7854 = 11 \cdot 044$, &c. inches area.

Or, suppose the diameter of a circle 25 feet 6 inches, required the area.

$25 \cdot 5^2 = 650 \cdot 25 \times \cdot 7854 = 510 \cdot 706$, &c. feet, the area.

4. What must the diameter of a circle be, to contain an area equal to 706·86 square inches?

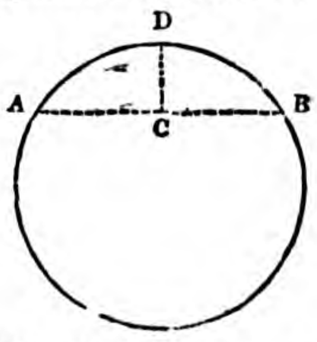
$\sqrt{706 \cdot 86} = 26 \cdot 586 \times 1 \cdot 12837 = 29 \cdot 998$ or 30 inches, the diameter required.

5. The diameter of a circle is $14\frac{1}{4}$ inches; what must I make each side of a square, to be equal in area to the given circle?

$14 \cdot 25 \times \cdot 8862 = 12 \cdot 62835$ inches, length of side required.

A chord and versed sine given to find the diameter.

Rule.—Divide the sum of the squares of half the chord and versed sine, by the versed sine; the quotient is the diameter.



1. The chord of a circle A B equal $6\frac{1}{2}$ feet, and the versed sine C D equal 2 feet; required the circle's diameter.

$\frac{1}{2}(6 \cdot 5) = 3 \cdot 25$, and $3 \cdot 25^2 + 2^2 = 7 \cdot 28125$ feet diameter.

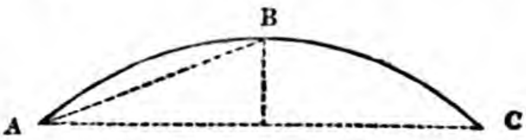
2. In a curve of a railway, I stretched a line 72 feet in length, and the distance from the line to the curve I found to be $1\frac{1}{4}$ ft.; required the radius of the curve.

$\frac{72}{2}=36$, and $36^2+1{\cdot}25^2=\frac{1297{\cdot}5625}{1{\cdot}25\times 2}=519$ ft. the radius.

To find the length of any given arc of a circle.

Rule.—From eight times the chord of half the arc, subtract the chord of the whole arc, and one-third of the remainder is equal the length of the arc.

Required the length of the arc A B C, the chord A B of half the arc being 4 feet 3 inches, and chord A C of the whole arc 8 feet 4 inches.

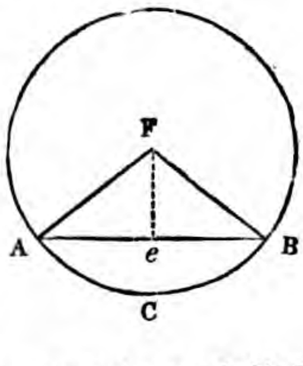


$4{\cdot}25\times 8=34$, and $34-8{\cdot}333=\frac{25{\cdot}667}{3}=8{\cdot}555$ feet, the length of the arc.

To find the area of the sector of a circle.

Rule.—Multiply the length of the arc by its radius, and half the product is the area.

The length of the arc A C B equal $9\frac{1}{2}$ feet, and the radii F A, F B, equal each 7 feet; required the area.



$9{\cdot}5\times 7=65{\cdot}5\div 2=32{\cdot}75$, the area.

Note.—The most simple means whereby to find the area of the segment of a circle, is, to first find the area of a sector whose arc is equal to that of the given segment; and if it be less than a semicircle, subtract the area of the triangle formed by the chord of the segment and radii of its extremities; but if more than a semicircle, add the area of the triangle to the area of the sector, and the remainder or sum is the area of the segment.

Thus, suppose the area of the segment A C B A is required, and that the length of the arc A C B equal $9\frac{3}{4}$ feet, F A and F B each equal 7 feet, and the chord A B equal 8 feet 4 inches, also the perpendicular e F equal $3\frac{3}{4}$ feet.

$$\frac{9{\cdot}75 \times 7}{2} = 34{\cdot}125 \text{ feet, the area of the sector.}$$

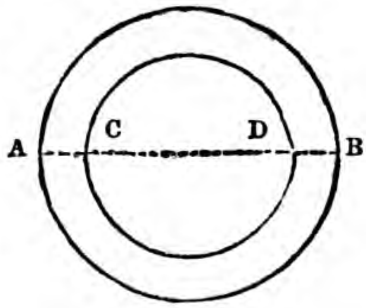
$$\frac{8{\cdot}333 \times 3{\cdot}75}{2} = 15{\cdot}624 \text{ feet, area of the triangle.}$$

And $34{\cdot}125 - 15{\cdot}624 = 18{\cdot}501$ feet, the area of the segment.

To find the area of the space contained between two concentric circles.

Rule.—Multiply the sum of the inside and outside diameters by their difference, and by ·7854; the product is the area.

1. Suppose the external circle A B equal 32 inches, and internal circle C D equal 28 inches; required the area of the space contained between them.



$\overline{32+28} = 60$, and $32-28=4$; hence $60 \times 4 \times {\cdot}7854 = 188{\cdot}496$ in. the area.

2. The exterior diameter of the fly-wheel of a steam engine is 20 feet, and the interior diameter $18\frac{1}{2}$ feet; required the area of the surface or rim of the wheel.

$\overline{20+18{\cdot}5} = 38{\cdot}5$, and $20-18{\cdot}5 = 1{\cdot}5$; hence $38{\cdot}5 \times 1{\cdot}5 \times {\cdot}7854 = 45{\cdot}35$, &c. feet, the area.

To find the area of an ellipse or oval.

Rule.—Multiply the longest diameter by the shortest, and the product by ·7854; the result is the area.

An oval is 25 inches by 16·5; what are its superficial contents?

$25 \times 16{\cdot}5 = 412{\cdot}5 \times {\cdot}7854 = 323{\cdot}9775$ inches, the area.

Note.—Multiply half the sum of the two diameters by 3·1416, and the product is the circumference of the oval or ellipse.

To find the area of a parabola, or its segment.

Rule.—Multiply the base by the perpendicular height, and two-thirds of the product is the area.

What is the area of a parabola whose base is 20 feet and height 12?

$$20 \times 12 = \frac{240 \times 2}{3} = 160 \text{ feet, the area.}$$

Note.—Although the whole of the preceding practical applications or examples are given in measures of feet or inches, these being considered as the most generally familiar, yet the rules are equally applicable to any other unit of measurement whatever, as yards, chains, acres, &c. &c. &c.

2. MENSURATION OF THE SUPERFICIES, SOLIDITIES, AND CAPACITIES OF BODIES.

To find the solidity or capacity of any figure in the cubical form.

Rule.—Multiply the length of any one side by its breadth and by the depth or distance to its opposite side; the product is the solidity or capacity, in equal terms of measurement.

Application of the rule to practical purposes.

1. Required the number of cubic inches in a piece of timber $23\frac{1}{2}$ inches long, $7\frac{3}{4}$ inches broad, and $3\frac{5}{8}$ inches in thickness.

$$23{\cdot}5 \times 7{\cdot}75 \times 3{\cdot}625 = 660{\cdot}203 \text{ cubic inches.}$$

2. A rectangular cistern is in length $8\frac{1}{2}$ feet, in breadth $5\frac{1}{4}$ feet, and in depth 4 feet; required its

capacity in cubic feet, also its capacity in British imperial gallons.

$8{\cdot}5 \times 5{\cdot}25 \times 4 = 178{\cdot}5$ cubic feet, and $178{\cdot}5 \times 6{\cdot}232$ (see Table of Decimal Approximations, p. 30) $= 1112{\cdot}412$ gallons.

3. A rectangular cistern capable of containing 520 imperial gallons is to be $7\frac{1}{4}$ feet in length, and $4\frac{1}{2}$ feet in width; it is required to ascertain the necessary depth.

$7{\cdot}25 \times 4{\cdot}5 \times 6{\cdot}232 = 203{\cdot}318$, and $\frac{520{\cdot}000}{203{\cdot}318} = 2{\cdot}557$ feet, or 2 feet $6\frac{3}{4}$ inches nearly.

4. A rectangular piece of cast iron, 20 inches long and 6 inches broad, is to be formed of sufficient dimensions to weigh 150 lbs.; what will be the depth required?

$20 \times 6 \times {\cdot}263$ (see Table of Decimal Approximations, Cast Iron, p. 30) $= 31{\cdot}96$, and $\frac{150}{31{\cdot}96} = 4{\cdot}69$ in., or 4 and $\frac{11}{16}$ in., the thickness required.

To find the convex surface, and solidity or capacity of a cylinder.

Rule. 1.—Multiply the circumference of the cylinder by its length or height; the product is the convex surface.

Rule 2.—Multiply the area of the base into the length or height; and the product is the cylinder's solidity or capacity, as may be required.

Application of the rules.

1. The circumference of a cylinder is $37\frac{1}{2}$ inches, and its length $54\frac{3}{4}$ inches; required the convex surface in square feet.

$54{\cdot}75 \times 37{\cdot}5 \times {\cdot}007$ (see Table of Approximations) $= 14{\cdot}371$ square feet.

2. A cylindrical piece of timber is 9 inches dia-

meter, and 3 feet 4 inches in length; required its solidity in cubic inches, and also in cubic feet.

3 feet 4 inches=40 inches, and $9^2 \times \cdot7854 \times 40 = 2544\cdot696$ cubic inches; then $2544\cdot696 \times \cdot00058 = 1\cdot4759$ cubic feet.

3. Suppose a well to be 4 feet 9 inches diameter, and $16\frac{1}{2}$ feet from the bottom to the surface of the water; how many imperial gallons are therein contained?

$$4\cdot75^2 \times 16\cdot5 \times 4\cdot895 = 1822\cdot162 \text{ gallons.}$$

4. Again, suppose the well's diameter the same, and its entire depth 35 feet; required the quantity in cubic yards of material excavated in its formation.

$$4\cdot75^2 \times 35 \times \cdot02909 = 22\cdot973 \text{ cubic yards.}$$

5. I have a cylindrical cistern capable of holding 7068 gallons, and its depth is 10 feet; now I want to replace it with one of an equal depth, but capable of holding 12,500 gallons; what must be its diameter?

$4\cdot895 \times 10 = 48\cdot95$, and $\frac{12500}{48\cdot95} = \sqrt{255\cdot3} = 15\cdot9687$ feet, or 15 feet $11\frac{5}{8}$ inches.

6. A cylindrical piece of lead is required $7\frac{1}{2}$ inches diameter, and 168lbs. in weight; what must be its length in inches?

$$7\cdot5^2 \times \cdot3223 = 18, \text{ and } \frac{168}{18} = 9\cdot3 \text{ inches.}$$

To find the length of a cylindrical helix, or spiral, wound round a cylinder.

Rule.—Multiply the circumference of the base by the number of revolutions of the spiral, and to the square of the product add the square of the height; the square root of the sum is the length of the spiral.

Application of the rule.

1. Required the length of the thread or screw twisting round a cylinder 22 inches in circumference $3\frac{1}{2}$ times, and extending along the axis 16 inches.

$22 \times 3{\cdot}5 = 77^2 = 5929$, and $16^2 = 256$; then $\sqrt{5929 + 256} = 78{\cdot}64$ inches.

2. The well of a winding staircase is 5 feet diameter, and height to the top landing 25 feet, the hand-rail is to make $2\frac{1}{2}$ revolutions; required its length.

5 feet diameter $= 15{\cdot}7$ feet circumference.
$15{\cdot}7 \times 2{\cdot}5 = 39{\cdot}25^2 = 1540{\cdot}5625$, and $25^2 = 625$; then
$\sqrt{1540 + 625} = 46{\cdot}5$ feet, the length required.

To find the convex surface, solidity, or capacity of a cone or pyramid.

Rule 1.—Multiply the circumference of the base by the slant height, and half the product is the slant surface.

Rule 2.—Multiply the area of the base by the perpendicular height, and one-third of the product is the solidity or capacity, as may be required.

Application of the rules.

1. Required the area in square inches of the slant surface of a cone whose slant height equals $18\frac{3}{4}$ inches, and diameter at the base $6\frac{1}{4}$ inches.

$6{\cdot}25 \times \dot{3}{\cdot}1416 = 19{\cdot}635$, circumference of the base; and
$$\frac{19{\cdot}635 \times 18{\cdot}75}{2} = 184{\cdot}078125 \text{ square inches.}$$

2. Required the quantity of lead, in square feet, sufficient to cover the slant surface of a hexagonal pyramid whose slant height is 42 feet, and the breadth of each side at the base 4 feet 9 inches.

$$\frac{4{\cdot}75 \times 42 \times 6 \text{ sides}}{2} = 598{\cdot}5 \text{ square feet.}$$

3. What is the solidity of a cone in cubic inches, the diameter at the base being 15 inches, and perpendicular height $32\frac{1}{2}$ inches?

$$\frac{15^2 \times \cdot 7854 \times 32\cdot 5}{3} = 1914\cdot 4125 \text{ cubic inches.}$$

4. In a square solid pyramid of stone 67 feet in height, and $16\frac{1}{2}$ feet at the base, how many cubic feet?

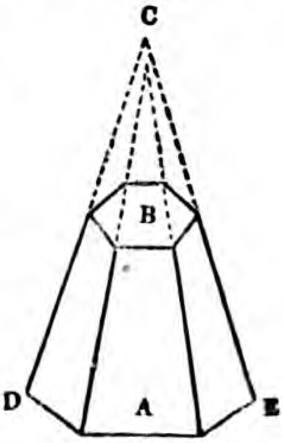
$$\frac{16\cdot 5 \times 16\cdot 5 \times 67}{3} = 6080\cdot 25 \text{ cubic feet.}$$

To find the solidity or capacity of any frustum of a cone or pyramid.

Rule.—If the base be a circle, add into one sum the two diameters, or, if a regular polygon, the breadth of one side at the top and at the base; then from the square of the sum subtract the product of these diameters or breadths; multiply the remainder by ·7854, if a circle, or by the tabular area (see Table of Polygons, p. 36) and by one-third of the height, and the product is the content in equal terms of unity.

Note.—Where the whole height of the cone or pyramid can be obtained, of which the given frustum forms a part, the most simple method is first to find the whole contents, then the contents extending beyond the frustum, and subtracting the less from the greater, leaves the contents of the frustum required.

Application of the rules.



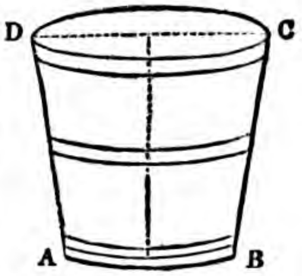
1. The perpendicular height A B of the frustum of a hexagonal pyramid C D E is $7\frac{1}{2}$ feet, and the breadth of each side at top and base equal $3\frac{3}{4}$ and $2\frac{1}{2}$ feet; required the solid contents of the frustum in cubic feet

$3{\cdot}75+2{\cdot}5=6{\cdot}25$, and $6{\cdot}25\times6{\cdot}25=39{\cdot}0625$; then $3{\cdot}75\times2{\cdot}5$ $=9{\cdot}375$, and $39{\cdot}0625-9{\cdot}375=29{\cdot}6875\times2{\cdot}598$ (tabular area, p. 36) $=77{\cdot}138\times2{\cdot}5$ or $\frac{1}{3}$ of the height $=192{\cdot}845$ cubic feet.

2. Required the solidity of the frustum of a cone, the top diameter of which is 7 inches, the base diameter $9\frac{1}{2}$, and the perpendicular height 12.

$(7+9{\cdot}5)^2=272{\cdot}25$, and $7\times9{\cdot}5=66{\cdot}5$; then $272{\cdot}25-66{\cdot}5$ $=205{\cdot}75\times{\cdot}7854=161{\cdot}576\times4$ or $\frac{1}{3}$ of the height $=646{\cdot}3$ cubic inches.

3. A vessel in the form of an inverted cone, as A B C D, is 5 feet in diameter at the top, 4 feet at the bottom, and 6 feet in depth; required its capacity in imperial gallons.



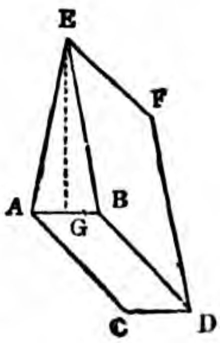
$\overline{5+4}=9^2=81$, and $5\times4=20$; hence $81-20=61\times{\cdot}7854$, and by 2 or $\frac{1}{3}$ of the depth $=95{\cdot}8188$ cubic feet, and $\times\ 6{\cdot}232$ $=597{\cdot}1427$ gallons.

To find the solid contents of a wedge.

Rule.—To twice the length of the base add the length of the edge; multiply the sum by the breadth of the base, and by the perpendicular height from the base, and one-sixth of the product is the solid contents.

Application of the rule.

Required the solidity of a wedge in cubic inches, the base A B C D being 9 inches by $3\frac{1}{2}$, the edge E F, 7 inches, and the perpendicular height G E, 15.



$$\frac{\overline{18+7}\times3{\cdot}5\times15}{6}=218{\cdot}75 \text{ cubic inches.}$$

To find the convex surface, the solidity, or the capacity of a sphere or globe.

Rule 1.—Multiply the square of the diameter by 3·1416, the product is the convex surface.

Rule 2.—Multiply the cube of the diameter by ·5236, the product is the solid contents.

Rule 3.—Multiply the cube of the diameter in feet by ·263, or in inches by ·001888, the product is the capacity in imperial gallons.

Application of the rules.

1. Required the convex surface, the solidity, and the weight in cast iron, of a sphere or ball $10\frac{1}{2}$ inches in diameter.

$10·5^2 \times 3·1416 = 346·3614$ square inches.
$10·5^3 \times ·5236 = 606·132$, &c. cubic inches, and
$606·132 \times ·263$ (see Table of Approximations, p. 30) $= 159·4$ lbs.

2. A hollow or concave copper ball is required 8 inches diameter, and in weight just sufficient to sink to its centre in common water; what is the proper thickness of copper of which it must be made?

Weight of a cubic inch of water $= ·03617$ lbs. } see p. 113.
" " copper $= ·3225$ " }

$\frac{8^3 \times ·5236 \times ·03617}{2} = 4·84828$ cub. in. of water to be displaced.

And $\frac{4·84828}{·3225} = 15·0334$ cubic inches of copper in the ball.

Then $8^2 \times 3·1416 = 201·0624$, and $\frac{15·0334}{201·0624} = ·0747$ inch, the thickness of copper required.

$·0747 \times 16 = \frac{1}{16}$ of an inch full, or 3 lbs. copper to a square foot.

3. What diameter must I make a leaden ball, so as to weigh 72lbs.?

$·5236 \times ·4103 = ·21483308$, and $\frac{72}{·21483308} = \sqrt[3]{340} = 6·97$ inches diameter.

To ascertain the amount of convex surface, also the solid contents, of the segment of a globe.

Rule 1.—Multiply the circumference of the globe or sphere by the height of the segment, and the product is the convex surface.

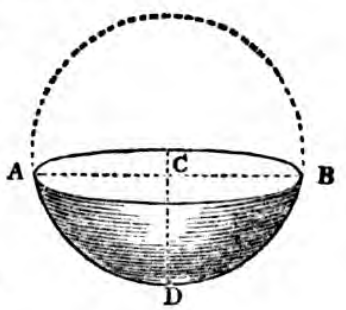
Rule 2.—To three times the square of the segment's radius add the square of its height, multiply the sum by the height, and by ·5236; the product is the solid contents.

Application of the Rules.

1. Required the number of square feet in the convex surface of a sphere, the height of which is $9\frac{1}{2}$ feet, and the circumference of the sphere of which it is a part equal $70\frac{1}{2}$ feet.

$$70{\cdot}5 \times 9{\cdot}5 = 669{\cdot}75 \text{ square feet.}$$

2. The radius A C or B C of the spherical segment A D B equal 48 inches, and the height D C equal 12 inches; required its solidity in cubic inches.



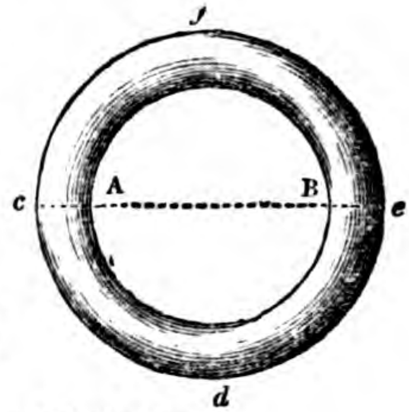
$48^2 \times 3 = 6912$, and $12^2 = 144$; then $\overline{6912 + 144} \times 12 \times {\cdot}5236 = 44334{\cdot}75$ cubic inches.

To find the convex surface and solidity of a cylindrical ring.

Rule 1.—To the sectional diameter of the ring add the inner diameter of the circle, multiply the sum by the sectional diameter, and by 9·8696; the product is the convex surface.

Rule 2.—To the sectional diameter of the ring add the inner diameter of the circle, multiply the sum by the square of the sectional diameter, and by 2·4674; the product is the solid contents.

Application of the Rules.



The inner diameter A B of the cylindric ring *c d e f* equal 18 feet, and the sectional diameter *c* A or B *e* equal 9 inches; required the convex surface and solidity of the ring.

18 feet × 12 = 216 inches, and $\overline{216+9} \times 9 \times 9{\cdot}8696 = 19985{\cdot}94$ square inches.

$\overline{216+9} \times 9^2 \times 2{\cdot}4674 = 44968{\cdot}365$ cubic inches.

In the formation of a hoop or ring of wrought iron it is found in practice, that in bending the iron the side or edge which forms the interior diameter of the hoop is upset or shortened, while at the same time the exterior diameter is drawn or lengthened; therefore, the proper diameter by which to determine the length of the iron in an unbent state, is the distance from centre to centre of the iron of which the hoop is composed: *hence the rule to determine the length of the iron.* If it is the interior diameter of the hoop that is given, add the thickness of the iron; but if the exterior diameter, subtract from the given diameter the thickness of the iron, multiply the sum or remainder by 3·1416, and the product is the length of the iron.

Supposing the interior diameter of a hoop to be 32 inches, and the thickness of the iron $1\frac{1}{4}$, what must be the proper length of the iron, independent of any allowance for shutting?

$$\overline{32+1{\cdot}25} = 33{\cdot}25 \times 3{\cdot}1416 = 104{\cdot}458 \text{ inches.}$$

But the same is obtained simply by inspection in the Table of Circumferences.

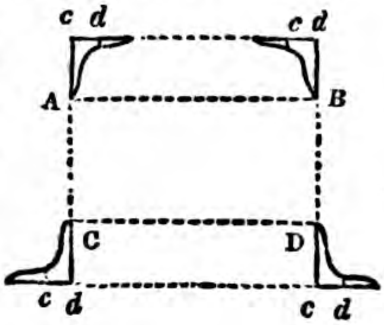
Thus, 33·25 = 2 ft. $9\frac{1}{4}$ in., opposite to which is 8 ft. $8\frac{3}{8}$ inches.

Again, let it be required to form a hoop of iron $\frac{7}{8}$ inch in thickness, and $16\frac{1}{2}$ inches outside diameter.

$$16{\cdot}5-{\cdot}875=15{\cdot}625, \text{ or 1 foot } 3\tfrac{5}{8} \text{ inches;}$$

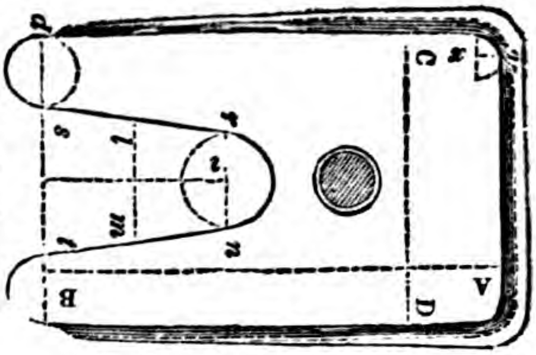
opposite to which, in the Table of Circumferences, is 4 feet 1 inch, independent of any allowance for shutting.

The length for angle iron, of which to form a ring of a given diameter, varies according to the strength of the iron at the root; and the rule is, for a ring with the flange outside, *add* to its required interior diameter, twice the extreme strength of the iron at the root; or, for a ring with the flange inside, *subtract* twice the extreme strength; and the sum or remainder is the diameter by which to determine the length of the angle iron. Thus, suppose two angle iron rings similar to the following be required, the exterior diameter A B, and interior diameter C D, each to be 1 foot $10\frac{1}{2}$ inches, and the extreme length of the iron at the root *c d*, *c d*, &c. $\frac{7}{8}$ of an inch.



twice $\frac{7}{8}=1\frac{3}{4}$, and 1 ft. $10\frac{1}{2}$ in. + $1\frac{3}{4}$ = 2 ft. $\frac{1}{4}$ in., opposite to which, in the Table of Circumferences, is 6 ft. $4\frac{1}{4}$ in., the length of the iron for C D; and 1 ft. $10\frac{1}{2}$ in. $-1\frac{3}{4}$ = 1 ft. $8\frac{3}{4}$ in., opposite to which is 5 ft. $5\frac{1}{4}$ in., the length of the iron for A B.

But observe as before, that the necessary allowance for shutting must be added to the length of the iron, in addition to the length as expressed by the Table.



Required the capacity in imperial gallons of a Locomotive Engine Tender tank, 2 feet 8 inches in depth, and its superficial dimensions the following, with reference to the annexed plan.

Length, or dist. between	A and B	=10 ft.	$2\frac{3}{4}$ in.	or,	122·75	in.
Breadth ,,	C ,, D	= 6 ,,	$7\frac{1}{2}$	,,	79·5	,,
Length ,,	*i* ,, *g*	= 3 ,,	$10\frac{3}{4}$	,,	46·75	,,
Mean breadth of coke space or	*lm* ,,	= 3 ,,	$1\frac{1}{4}$	,,	37·25	,,
Diameter of circle	*rn* ,,	= 2 ,,	$8\frac{1}{4}$	,,	32·25	,,
,, ,,	*ps* ,,	= 1 ,,	$6\frac{1}{2}$	,,	18·5	,,
Radius of back corners	*v x* ,,	=	4	,,	4	,,

Then, $122{\cdot}75 \times 79{\cdot}5 = 9758{\cdot}525$ square inches, as a rectangle.
And $18{\cdot}5^2 \times {\cdot}7854 = 268{\cdot}8$,, ,, area of circle formed by the two ends.

Total $\overline{10027{\cdot}325}$,, ,, from which deduct the area of the coke space, and the difference of area between the semicircle formed by the two back corners, and that of a rectangle of equal length and breadth;

Then $46{\cdot}75 \times 37{\cdot}25 = 1731{\cdot}4375$ area of *r*, *n*, *s*, *t*, in sq. ins.

$\dfrac{32{\cdot}25^2 \times {\cdot}7854}{2} = 408{\cdot}4$ area of half the circle *r n*.

Radius of back corners=4 inches;
consequently $8^2 \times {\cdot}7854 = 25{\cdot}13$, the semicircle's area;
and $8 \times 4 = 32 - 25{\cdot}13 = 6{\cdot}87$ inches taken off by rounding the corners.

Hence, $1731{\cdot}4375 + 408{\cdot}4 + 6{\cdot}87 = 2146{\cdot}707$, and
$10027{\cdot}325 - 2146{\cdot}707 = 7880{\cdot}618$ square inches, or whole area in plan,
$7880{\cdot}618 \times 32$ the depth$=252179{\cdot}776$ cubic inches, and $252179{\cdot}776 \times {\cdot}003607$ (see Table of Approximations, page 30)$=909{\cdot}61245$ gallons.

PROPERTIES OF BODIES.

Tables combining the Specific Gravities and other Properties of Bodies. Water the standard of comparison, or 1000.

METALS.

Names.	Specific gravity.	Melting points in degrees of Fahrenheit.	Contraction in parts of an in. per lineal ft. from the fluid to the average temperature in solid state.	Ultimate cohesive strength of an inch sq. prism in tons.	Scale of wire-drawing ductility.	Scale of laminable ductility.	Ratio of hardness.	Scale as conductors of electricity.	Ratio of power in the conduction of heat.
Platinum	19500	3280	—	—	3	5	—	—	3·8
Pure Gold . . .	19258	2016	—	—	1	1	1·8	3	10·0
Mercury	13500	—	—	—	—	—	—	—	—
Lead	11352	612	·319	·81	8	7	1·0	6	1·8
Pure Silver . . .	10474	1873	—	—	2	2	2·4	2	9·7
Bismuth	9823	476	·156	1·45	—	—	2·0	—	—
Copper, cast . .	8788	1996	·193	8·51	—	—	—	—	—
„ wrought	8910	—	—	15·08	5	3	2·8	1	8·9
Brass, cast . . .	7824	1900	·210	8·01	—	—	to any degree	—	—
„ sheet . .	8396	—	—	12·23	6	6	—	—	8·6
Iron, cast	7264	2786	·125	7·87	—	—	to any degree	—	—
„ bar	7700	—	·137	25·00	4	8	4·7	4	3·7
Steel, soft . . .	7833	—	·133	58·91	—	—	—	—	—
„ hard . . .	7816	—	—	—	—	—	to any degree	—	—
Tin, cast	7291	442	·278	2·11	8	4	1·2	5	3·0
Zinc, cast . . .	7190	773	·329	5·06	7	8	1·6	7	3·6

STONES, EARTHS, &c.

Names.	Specific gravity.	Weight of a cubic foot in lbs.	Cubic feet in a ton.	Tons required to crush 1½-inch cubes.
Marble, average	2720	170·00	13	9·25
Granite, do. . .	2651	165·68	13½	6·2
Purbeck stone .	2601	162·56	13¾	9·0
Portland do. . .	2570	160·62	14	4·5
Bristol do. . . .	2554	159·62	14	—
Millstone	2484	155·25	14½	—
Paving stone . .	2415	150·93	14¾	5·7
Craigleith do. .	2362	147·62	15	5·0
Grindstone . . .	2143	133·93	16¾	6·6
Chalk, Brit. . .	2781	173·81	12¾	0·5
Brick	2000	125·00	17	0·8
Coal, Scotch . .	1300	81·15	27½	—
„ Newcastle	1270	79·37	27¼	—
„ Staffordsh.	1240	77·50	29	—
„ Cannel . .	1238	77·37	29	—

WOODS.							
Names.	Specific gravity, water, 1000.	Average wt. of a cubic foot in lbs.	Cubic feet in a ton.	Ultimate cohesive strength of an inch square prism in lbs.	Comparative		
					Stiffness.	Strength.	Resilience.
English oak	934	58	38½	11880	100	100	100
Riga do.	872	54	41½	12888	93	108	125
Dantzic do........	756	47	48	12780	117	107	99
American do.	672	42	53	10253	114	86	64
Beech...........	852	48	45	12225	77	103	138
Alder	800	46	48½	9540	63	80	101
Plane	640	40	55	10935	78	92	108
Sycamore	604	38	59	9630	59	81	111
Chestnut.........	610	38	59	10656	67	89	118
Ash.............	845	52	43	14130	89	119	160
Elm.............	673	42	53	9720	78	82	86
Mahog. Spanish ..	800	50	45	7560	73	67	61
" Honduras	637	40	55	11475	93	96	99
Walnut..........	671	42	53	8800	49	74	111
Teak............	750	46	48½	12915	126	109	94
Poona...........	640	40	55	12350	99	104	82
African oak......	944	59	38	17200	101	144	138
Poplar..........	383	34	66	5928	44	50	57
Cedar	561	33	68	7420	28	62	106
Riga fir.........	753	47	48	9540	98	80	64
Memel do.	546	34	66	9540	114	80	56
Scotch do.	528	33	68	7110	55	60	65
Christ. wh[te]. deal .	590	37	60	12346	104	104	104
Am[n]. white spruce	551	34	66	10296	72	86	102
Yellow pine	461	28	80	11853	95	99	103
Pitch pine	660	41	54½	9796	73	82	92
Larch	530	31	72	12240	79	103	134
Cork...........	240	15	149	—	—	—	—

LIQUIDS.

Names.	Specific grav., water, 1000.	Weight of an imperial gall. in lbs.
Acid, sulphuric ..	1850	18·5
„ nitric	1271	12·7
„ muriatic ...	1200	12·0
„ fluoric.....	1060	10·6
„ citric......	1034	10·3
„ acetic	1062	10·6
Water from the Baltic	1015	10·2
Water from the Dead Sea	1240	12·4
Water from the Mediterranean .	1029	10·3
Water, distilled ..	1000	10·0
Oils, expressed:		
„ linseed.....	940	9·4
„ sweet almond	932	9·3
„ whale......	923	9·2
„ hempseed...	926	9·3
„ olive.......	915	9·2
Oils, essential:		
„ cinnamon...	1043	10·4
„ lavender....	894	8·9
„ turpentine ..	870	8·7
„ amber......	868	8·7
Alcohol	825	8·2
Ether, nitric	908	9·1
Proof spirit......	922	9·2
Vinegar	1009	10·1

GASES.

Atmospheric air being the standard of comparison, or 1000.

Names.	Specific gravity.
Hydriodic acid gas	4340
Chlorine acid „	2500
Carbonic acid „	1527
Nitrous oxide „	1527
Cyanogen „	1805
Oxygen „	1111
Carbonic oxide „	972
Carburetted hydrogen gas	972
Prussic acid „	937
Ammoniacal do. „	590
Steam of water „	623
Hydrogen „	69

Weight of water at the common temperature:

1 cubic inch = ·03617 lb.
1 „ foot = 62·5 „
1 „ „ = 6·25 imp. galls.
1·8 „ „ = 1 cwt.
1 cylindrical inch = ·02842 lb.
1 „ foot = 49·1 „
1 „ „ = 5 imp. galls.
2·282 feet = 1 cwt.
11·2 imp. gallons = 1 cwt.
224 „ „ = 1 ton.

WEIGHT OF A LINEAL FOOT OF SQUARE AND ROUND BAR IRON IN POUNDS.

Square iron.				Round iron.			
Inches square.	lbs.	Inches square.	lbs.	Inches diam.	lbs.	Inches diam.	lbs.
1/4	·208	2	13·33	1/4	·163	2	10·47
5/16	·325	2 1/8	15·05	5/16	·255	2 1/8	11·82
3/8	·468	2 1/4	16·87	3/8	·368	2 1/4	13·25
7/16	·638	2 3/8	18·80	7/16	·501	2 3/8	14·76
1/2	·833	2 1/2	20·81	1/2	·654	2 1/2	16·36
9/16	1·05	2 5/8	22·96	9/16	·828	2 5/8	18·03
5/8	1·30	2 3/4	25·20	5/8	1·02	2 3/4	19·79
11/16	1·57	2 7/8	27·55	11/16	1·23	2 7/8	21·63
3/4	1·87	3	30·00	3/4	1·47	3	23·56
13/16	2·20	3 1/8	32·55	13/16	1·72	3 1/8	25·56
7/8	2·55	3 1/4	35·20	7/8	2·00	3 1/4	27·65
15/16	2·92	3 3/8	37·96	15/16	2·30	3 3/8	29·82
1	3·33	3 1/2	40·80	1	2·61	3 1/2	32·07
1 1/16	3·76	3 5/8	43·81	1 1/16	2·95	3 5/8	34·40
1 1/8	4·21	3 3/4	46·87	1 1/8	3·31	3 3/4	36·81
1 3/16	4·70	3 7/8	50·05	1 3/16	3·69	3 7/8	39·31
1 1/4	5·20	4	53·33	1 1/4	4·09	4	41·88
1 5/16	5·74	4 1/4	60·20	1 5/16	4·51	4 1/4	47·28
1 3/8	6·30	4 1/2	67·50	1 3/8	4·95	4 1/2	53·01
1 7/16	6·88	4 3/4	75·20	1 7/16	5·40	4 3/4	59·06
1 1/2	7·50	5	83·33	1 1/2	5·89	5	65·45
1 9/16	8·15	5 1/4	92·43	1 9/16	6·40	5 1/4	72·61
1 5/8	8·80	5 1/2	101·03	1 5/8	6·91	5 1/2	79·36
1 11/16	9·50	5 3/4	110·40	1 11/16	7·46	5 3/4	86·73
1 3/4	10·20	6	120·21	1 3/4	8·01	6	94·60
1 13/16	10·69	6 1/2	130·20	1 13/16	8·60	6 1/2	110·60
1 7/8	11·71	7	151·81	1 7/8	9·20	7	128·28
1 15/16	12·52	8	213·29	1 15/16	9·33	8	167·51

Note.—The elastic power or direct tension of bar iron medium quality per square inch of cross section equals 10 tons; and a bar is extended ·000096, or nearly one ten-thousandth part of its length for every ton of direct strain per square inch of its sectional area: note, also, that either of the metals,—iron, tin, or zinc,—at a red heat, possesses the property of decomposing water when in an aëriform state.

WEIGHT OF A LINEAL FOOT OF FLAT BAR IRON IN POUNDS.

Breadth in inches.	Thickness in parts of an inch.						
	1/4	5/16	3/8	7/16	1/2	9/16	5/8
1/2	·417	·52	—	—	—	—	—
5/8	·52	·65	·78	·91	—	—	—
3/4	·625	·785	·93	1·09	1·25	1·40	—
7/8	·725	·91	1·09	1·27	1·46	1·64	1·82
1	·834	1·04	1·25	1·45	1·67	1·87	2·08
1 1/8	·937	1·17	1·40	1·64	1·87	2·10	2·34
1 1/4	1·04	1·30	1·56	1·82	2·08	2·34	2·60
1 3/8	1·14	1·43	1·71	2·00	2·29	2·57	2·86
1 1/2	1·25	1·56	1·87	2·18	2·50	2·81	3·12
1 5/8	1·35	1·69	2·03	2·36	2·70	3·04	3·38
1 3/4	1·45	1·82	2·18	2·55	2·91	3·28	3·64
1 7/8	1·56	1·95	2·34	2·73	3·12	3·51	3·90
2	1·66	2·08	2·50	2·91	3·33	3·75	4·16
2 1/8	1·77	2·21	2·65	3·09	3·54	3·98	4·42
2 1/4	1·87	2·34	2·81	3·28	3·75	4·21	4·68
2 3/8	1·97	2·47	2·96	3·46	3·95	4·45	4·94
2 1/2	2·08	2·60	3·12	3·64	4·16	4·68	5·20
2 5/8	2·18	2·73	3·28	3·82	4·37	4·92	5·46
2 3/4	2·29	2·86	3·43	4·01	4·58	5·15	5·72
2 7/8	2·39	2·99	3·59	4·19	4·79	5·39	5·98
3	2·50	3·12	3·75	4·37	5·00	5·62	6·25
3 1/4	2·70	3·38	4·06	4·73	5·41	6·09	6·77
3 1/2	2·91	3·64	4·37	5·10	5·83	6·56	7·29
3 3/4	3·12	3·90	4·68	5·46	6·25	7·03	7·81
4	3·33	4·16	5·00	5·83	6·66	7·50	8·33
4 1/4	3·54	4·42	5·31	6·19	7·08	7·96	8·85
4 1/2	3·75	4·68	5·62	6·56	7·50	8·43	9·37
4 3/4	3·95	4·94	5·93	6·92	7·91	8·90	9·89
5	4·17	5·20	6·25	7·29	8·33	9·37	10·41
5 1/4	4·37	5·46	6·56	7·65	8·75	9·84	10·93
5 1/2	4·58	5·72	6·87	8·02	9·16	10·31	11·45
5 3/4	4·79	5·98	7·18	8·38	9·58	10·78	11·97
6	5·	6·26	7·50	8·75	10·00	11·25	12·50

WEIGHT OF FLAT BAR IRON—*continued.*

Breadth in inches.	Thickness in parts of an inch.						
	11/16	3/4	13/16	7/8	15/16	1	1 1/8
1	2·29	—	—	—	—	—	—
1 1/8	2·57	2·81	3·04	—	—	—	—
1 1/4	2·86	3·12	3·38	3·64	3·90	—	—
1 3/8	3·15	3·43	3·72	4·01	4·29	4·58	—
1 1/2	3·43	3·75	4·06	4·37	4·68	5·00	5·62
1 5/8	3·72	4·06	4·40	4·73	5·07	5·41	6·08
1 3/4	4·01	4·37	4·73	5·10	5·46	5·83	6·56
1 7/8	4·29	4·68	5·07	5·46	5·85	6·25	7·02
2	4·58	5·00	5·41	5·83	6·25	6·66	7·50
2 1/8	4·86	5·31	5·75	6·19	6·64	7·08	7·96
2 1/4	5·15	5·62	6·09	6·56	7·03	7·50	8·43
2 3/8	5·44	5·93	6·43	6·92	7·42	7·91	8·90
2 1/2	5·72	6·25	6·77	7·29	7·81	8·33	9·36
2 5/8	6·01	6·56	7·10	7·65	8·20	8·75	9·84
2 3/4	6·30	6·87	7·44	8·02	8·59	9·16	10·30
2 7/8	6·58	7·18	7·78	8·38	8·98	9·58	10·78
3	6·87	7·50	8·12	8·75	9·37	10·00	11·25
3 1/4	7·44	8·12	8·80	9·47	10·15	10·83	12·18
3 1/2	8·02	8·75	9·47	10·20	10·93	11·66	13·12
3 3/4	8·59	9·37	10·15	10·93	11·71	12·50	14·06
4	9·16	10·00	10·83	11·66	12·50	13·33	15·00
4 1/4	9·73	10·62	11·51	12·39	13·28	14·16	15·92
4 1/2	10·31	11·25	12·18	13·12	14·06	15·00	16·86
4 3/4	10·88	11·87	12·86	13·85	14·84	15·83	17·80
5	11·45	12·50	13·54	14·58	15·62	16·66	18·75
5 1/4	12·03	13·12	14·21	15·31	16·40	17·50	19·68
5 1/2	12·60	13·75	14·89	16·04	17·18	18·33	20·62
5 3/4	13·17	14·37	15·57	16·77	17·96	19·16	21·56
6	13·75	15·00	16·25	17·50	18·75	20·00	22·50
6 1/2	14·88	16·24	17·60	18·95	20·30	21·66	24·36
7	16·04	17·50	18·94	20·41	21·86	23·33	26·24
7 1/2	17·18	18·74	20·30	21·86	23·42	25·00	28·12
8	18·32	20·00	21·76	23·32	25·00	26·66	30·00

WEIGHT OF FLAT BAR IRON—*continued.*

Breadth in inches.	Thickness in inches.					
	1¼	1⅜	1½	1¾	2	2½
1½	6·24	6·86	—	—	—	—
1¾	7·28	8·02	8·74	—	—	—
2	8·32	9·16	10·00	11·66	—	—
2¼	9·36	10·30	11·24	13·12	15·00	—
2½	10·40	11·44	12·50	14·58	16·66	—
2¾	11·44	12·60	13·74	16·04	18·32	22·88
3	12·50	13·74	15·00	17·50	20·00	25·00
3¼	13·54	14·88	16·24	18·94	21·66	27·08
3½	14·58	16·04	17·50	20·40	23·32	29·16
3¾	15·62	17·18	18·74	21·86	25·00	31·24
4	16·66	18·32	20·00	23·32	26·66	33·32
4¼	17·70	19·46	21·24	25·78	28·32	35·40
4½	18·74	20·62	22·50	26·24	30·00	37·48
4¾	19·78	21·76	23·74	27·70	31·67	39·56
5	20·82	22·90	25·00	29·16	33·32	41·64
5¼	21·86	24·06	26·24	30·62	35·00	43·72
5½	22·90	25·20	27·50	32·08	36·66	45·80
5¾	23·94	26·34	28·74	33·54	38·32	47·88
6	25·00	27·50	30·00	35·00	40·00	50·00
6½	27·08	29·76	32·48	37·88	43·32	54·16
7	29·16	32·08	35·00	40·80	46·64	58·32
7½	31·24	34·36	37·48	43·72	50·00	62·48
8	33·32	36·64	40·00	46·64	53·32	66·64
8½	35·40	38·92	42·48	51·56	56·64	70·80
9	37·48	41·24	45·00	52·48	60·00	74·96

MECHANICAL TABLES

FOR THE USE OF OPERATIVE SMITHS, MILLWRIGHTS, AND ENGINEERS.

The following Tables, originally dedicated to 'the National Association of the Forgers of Iron-Work,' are, with permission, added to the present edition: they will be found extremely useful to Smiths generally, and are accompanied by Observations and Practical Examples.

TABLE I.*

DIAMETERS AND CIRCUMFERENCES OF CIRCLES,

from One Inch to upwards of Twenty Feet, advancing by an Eighth.

Diameter.	Circumference.		Diameter.	Circumference.		Diameter.		Circumference.		Diameter.		Circumference.	
In.	Ft.	In.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
1	0	3⅛	5	1	3⅝	0	9	2	4¼	1	1	3	4¾
1⅛	0	3½	5⅛	1	4	0	9⅛	2	4⅝	1	1⅛	3	5⅛
1¼	0	3⅞	5¼	1	4⅜	0	9¼	2	5	1	1¼	3	5⅝
1⅜	0	4¼	5⅜	1	4⅞	0	9⅜	2	5⅜	1	1⅜	3	6
1½	0	4⅝	5½	1	5¼	0	9½	2	5¾	1	1½	3	6⅜
1⅝	0	5	5⅝	1	5⅝	0	9⅝	2	6⅛	1	1⅝	3	6¾
1¾	0	5⅜	5¾	1	6	0	9¾	2	6⅝	1	1¾	3	7⅛
1⅞	0	5⅞	5⅞	1	6⅜	0	9⅞	2	7	1	1⅞	3	7½
2	0	6¼	6	1	6¾	0	10	2	7⅜	1	2	3	7⅞
2⅛	0	6⅝	6⅛	1	7⅛	0	10⅛	2	7¾	1	2⅛	3	8⅜
2¼	0	7	6¼	1	7⅝	0	10¼	2	8⅛	1	2¼	3	8¾
2⅜	0	7⅜	6⅜	1	8	0	10⅜	2	8½	1	2⅜	3	9⅛
2½	0	7¾	6½	1	8⅜	0	10½	2	8⅞	1	2½	3	9½
2¾	0	8⅛	6⅝	1	8¾	0	10⅝	2	9⅜	1	2⅝	3	9⅞
2⅝	0	8⅝	6¾	1	9⅛	0	10¾	2	9¾	1	2¾	3	10¼
2⅞	0	9	6⅞	1	9½	0	10⅞	2	10⅛	1	2⅞	3	10⅝
3	0	9⅜	7	1	9⅞	0	11	2	10½	1	3	3	11
3⅛	0	9¾	7⅛	1	10⅜	0	11⅛	2	10⅞	1	3⅛	3	11½
3¼	0	10⅛	7¼	1	10¾	0	11¼	2	11¼	1	3¼	3	11⅞
3⅜	0	10½	7⅜	1	11⅛	0	11⅜	2	11⅝	1	3⅜	4	0¼
3½	0	10⅞	7½	1	11½	0	11½	3	0	1	3½	4	0⅝
3⅝	0	11⅜	7⅝	1	11⅞	0	11⅝	3	0½	1	3⅝	4	1
3¾	0	11¾	7¾	2	0¼	0	11¾	3	0⅞	1	3¾	4	1⅜
3⅞	1	0⅛	7⅞	2	0⅝	0	11⅞	3	1¼	1	3⅞	4	1⅞
4	1	0½	8	2	1⅛	1	0	3	1⅝	1	4	4	2¼
4⅛	1	0⅞	8⅛	2	1½	1	0⅛	3	2	1	4⅛	4	2⅝
4¼	1	1¼	8¼	2	1⅞	1	0¼	3	2⅜	1	4¼	4	3
4⅜	1	1⅝	8⅜	2	2¼	1	0⅜	3	2⅞	1	4⅜	4	3⅜
4½	1	2⅛	8½	2	2⅝	1	0½	3	3¼	1	4½	4	3¾
4⅝	1	2½	8⅝	2	3	1	0⅝	3	3⅝	1	4⅝	4	4⅛
4¾	1	2⅞	8¾	2	3⅜	1	0¾	3	4	1	4¾	4	4½
4⅞	1	3¼	8⅞	2	3⅞	1	0⅞	3	4⅜	1	4⅞	4	5

* James Foden.

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
1	5	4	5⅜	1	9⅜	5	7⅛	2	1¾	6	8⅞	2	6⅛	7	10⅝
1	5⅛	4	5¾	1	9½	5	7½	2	1⅞	6	9¼	2	6¼	7	11
1	5¼	4	6⅛	1	9⅝	5	8	2	2	6	9⅝	2	6⅜	7	11⅜
1	5⅜	4	6½	1	9¾	5	8⅜					2	6½	7	11¾
1	5½	4	6⅞	1	9⅞	5	8¾	2	2⅛	6	10	2	6⅝	8	0⅛
1	5⅝	4	7⅜	1	10	5	9	2	2¼	6	10⅜	2	6¾	8	0½
1	5¾	4	7¾					2	2⅜	6	10¾	2	6⅞	8	0⅞
1	5⅞	4	8⅛	1	10⅛	5	9½	2	2½	6	11¼	2	7	8	1⅜
1	6	4	8½	1	10¼	5	9⅞	2	2⅝	6	11⅝				
				1	10⅜	5	10¼	2	2¾	7	0	2	7⅛	8	1¾
1	6⅛	4	8⅞	1	10½	5	10⅝	2	2⅞	7	0⅜	2	7¼	8	2⅛
1	6¼	4	9¼	1	10⅝	5	11	2	3	7	0¾	2	7⅜	8	2½
1	6⅜	4	9⅝	1	10¾	5	11⅜					2	7½	8	2⅞
1	6½	4	10	1	10⅞	5	11¾	2	3⅛	7	1⅛	2	7⅝	8	3¼
1	6⅝	4	10⅜	1	11	6	0¼	2	3¼	7	1½	2	7¾	8	3¾
1	6¾	4	10⅞					2	3⅜	7	2	2	7⅞	8	4⅛
1	6⅞	4	11¼	1	11⅛	6	0⅝	2	3½	7	2⅜	2	8	8	4½
1	7	4	11⅝	1	11¼	6	1	2	3⅝	7	2¾				
				1	11⅜	6	1⅜	2	3¾	7	3⅛	2	8⅛	8	4⅞
1	7⅛	5	0	1	11½	6	1¾	2	3⅞	7	3½	2	8¼	8	5¼
1	7¼	5	0⅜	1	11⅝	6	2⅛	2	4	7	3⅞	2	8⅜	8	5⅝
1	7⅜	5	0⅞	1	11¾	6	2½					2	8½	8	6
1	7½	5	1¼	1	11⅞	6	3	2	4⅛	7	4¼	2	8⅝	8	6½
1	7⅝	5	1⅝	2	0	6	3⅜	2	4¼	7	4¾	2	8¾	8	6⅞
1	7¾	5	2					2	4⅜	7	5⅛	2	8⅞	8	7¼
1	7⅞	5	2⅜	2	0⅛	6	3¾	2	4½	7	5½	2	9	8	7⅝
1	8	5	2¾	2	0¼	6	4⅛	2	4⅝	7	5⅞				
				2	0⅜	6	4½	2	4¾	7	6¼	2	9⅛	8	8
1	8⅛	5	3⅛	2	0½	6	4⅞	2	4⅞	7	6⅝	2	9¼	8	8⅜
1	8¼	5	3⅝	2	0⅝	6	5¼	2	5	7	7	2	9⅜	8	8¾
1	8⅜	5	4	2	0¾	6	5¾					2	9½	8	9¼
1	8½	5	4⅜	2	0⅞	6	6⅛	2	5⅛	7	7½	2	9⅝	8	9⅝
1	8⅝	5	4¾	2	1	6	6½	2	5¼	7	7⅞	2	9¾	8	10
1	8¾	5	5⅛					2	5⅜	7	8¼	2	9⅞	8	10⅜
1	8⅞	5	5½	2	1⅛	6	6⅞	2	5½	7	8⅝	2	10	8	10¾
1	9	5	5⅞	2	1¼	6	7¼	2	5⅝	7	9				
				2	1⅜	6	7⅝	2	5¾	7	9⅜	2	10⅛	8	11⅛
1	9⅛	5	6⅜	2	1½	6	8	2	5⅞	7	9¾	2	10¼	8	11½
1	9¼	5	6¾	2	1⅝	6	8½	2	6	7	10⅛	2	10⅜	8	11⅞

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
2	10½	9	0⅜
2	10⅝	9	0¾
2	10¾	9	1⅛
2	10⅞	9	1½
2	11	9	1⅞
2	11⅛	9	2¼
2	11¼	9	2⅝
2	11⅜	9	3
2	11½	9	3½
2	11⅝	9	3⅞
2	11¾	9	4¼
2	11⅞	9	4⅝
3	0	9	5
3	0⅛	9	5⅜
3	0¼	9	5⅞
3	0⅜	9	6¼
3	0½	9	6⅝
3	0⅝	9	7
3	0¾	9	7⅜
3	0⅞	9	7¾
3	1	9	8⅛
3	1⅛	9	8⅝
3	1¼	9	9
3	1⅜	9	9⅜
3	1½	9	9¾
3	1⅝	9	10⅛
3	1¾	9	10½
3	1⅞	9	10⅞
3	2	9	11⅜
3	2⅛	9	11¾
3	2¼	10	0⅛
3	2⅜	10	0½
3	2½	10	0⅞
3	2⅝	10	1¼
3	2¾	10	1⅝
3	2⅞	10	2⅛
3	3	10	2½
3	3⅛	10	2⅞
3	3¼	10	3⅛
3	3⅜	10	3⅝
3	3½	10	4
3	3⅝	10	4½
3	3¾	10	4⅞
3	3⅞	10	5¼
3	4	10	5⅝
3	4⅛	10	6
3	4¼	10	6⅜
3	4⅜	10	6¾
3	4½	10	7⅛
3	4⅝	10	7⅝
3	4¾	10	8
3	4⅞	10	8⅜
3	5	10	8¾
3	5⅛	10	9⅛
3	5¼	10	9½
3	5⅜	10	9⅞
3	5½	10	10⅜
3	5⅝	10	10¾
3	5¾	10	11⅛
3	5⅞	10	11½
3	6	10	11⅞
3	6⅛	11	0¼
3	6¼	11	0⅝
3	6⅜	11	1⅛
3	6½	11	1½
3	6⅝	11	1⅞
3	6¾	11	2¼
3	6⅞	11	2⅝
3	7	11	3
3	7⅛	11	3⅜
3	7¼	11	3⅞
3	7⅜	11	4¼
3	7½	11	4⅝
3	7⅝	11	5
3	7¾	11	5⅜
3	7⅞	11	5¾
3	8	11	6⅛
3	8⅛	11	6½
3	8¼	11	7
3	8⅜	11	7⅜
3	8½	11	7¾
3	8⅝	11	8⅛
3	8¾	11	8½
3	8⅞	11	8⅞
3	9	11	9¼
3	9⅛	11	9¾
3	9¼	11	10⅛
3	9⅜	11	10½
3	9½	11	10⅞
3	9⅝	11	11¼
3	9¾	11	11⅝
3	9⅞	12	0
3	10	12	0½
3	10⅛	12	0⅞
3	10¼	12	1¼
3	10⅜	12	1⅝
3	10½	12	2
3	10⅝	12	2⅜
3	10¾	12	2¾
3	10⅞	12	3¼
3	11	12	3⅝
3	11⅛	12	4
3	11¼	12	4⅜
3	11⅜	12	4¾
3	11½	12	5⅛
3	11⅝	12	5½
3	11¾	12	6
3	11⅞	12	6⅜
4	0	12	6¾
4	0⅛	12	7⅛
4	0¼	12	7½
4	0⅜	12	7⅞
4	0½	12	8¼
4	0⅝	12	8¾
4	0¾	12	9⅛
4	0⅞	12	9½
4	1	12	9⅞
4	1⅛	12	10¼
4	1¼	12	10⅝
4	1⅜	12	11
4	1½	12	11½
4	1⅝	12	11⅞
4	1¾	13	0¼
4	1⅞	13	0⅝
4	2	13	1
4	2⅛	13	1½
4	2¼	13	1⅞
4	2⅜	13	2¼
4	2½	13	2⅝
4	2⅝	13	3
4	2¾	13	3⅜
4	2⅞	13	3¾
4	3	13	4⅛
4	3⅛	13	4½
4	3¼	13	5
4	3⅜	13	5⅜
4	3½	13	5¾
4	3⅝	13	6⅛
4	3¾	13	6½

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
4	3⅞	13	6⅞
4	4	13	7¼
4	4⅛	13	7¾
4	4¼	13	8⅛
4	4⅜	13	8½
4	4½	13	8⅞
4	4⅝	13	9¼
4	4¾	13	9⅝
4	4⅞	13	10
4	5	13	10½
4	5⅛	13	10⅞
4	5¼	13	11¼
4	5⅜	13	11⅝
4	5½	14	0
4	5⅝	14	0⅜
4	5¾	14	0⅞
4	5⅞	14	1¼
4	6	14	1⅝
4	6⅛	14	2
4	6¼	14	2⅜
4	6⅜	14	2¾
4	6½	14	3⅛
4	6⅝	14	3½
4	6¾	14	4
4	6⅞	14	4⅜
4	7	14	4¾
4	7⅛	14	5⅛
4	7¼	14	5½
4	7⅜	14	5⅞
4	7½	14	6¼
4	7⅝	14	6¾
4	7¾	14	7⅛
4	7⅞	14	7½
4	8	14	7⅞

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
4	8⅛	14	8¼
4	8¼	14	8⅝
4	8⅜	14	9
4	8½	14	9½
4	8⅝	14	9⅞
4	8¾	14	10¼
4	8⅞	14	10⅝
4	9	14	11
4	9⅛	14	11⅜
4	9¼	14	11¾
4	9⅜	15	0⅛
4	9½	15	0⅝
4	9⅝	15	1
4	9¾	15	1⅜
4	9⅞	15	1¾
4	10	15	2⅛
4	10⅛	15	2½
4	10¼	15	2⅞
4	10⅜	15	3⅜
4	10½	15	3¾
4	10⅝	15	4⅛
4	10¾	15	4½
4	10⅞	15	4⅞
4	11	15	5¼
4	11⅛	15	5⅝
4	11¼	15	6⅛
4	11⅜	15	6½
4	11½	15	6⅞
4	11⅝	15	7¼
4	11¾	15	7⅝
4	11⅞	15	8
5	0	15	8⅜
5	0⅛	15	8⅞
5	0¼	15	9¼
5	0⅜	15	9⅝

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
5	0½	15	10
5	0⅝	15	10⅜
5	0¾	15	10¾
5	0⅞	15	11⅛
5	1	15	11⅝
5	1⅛	16	0
5	1¼	16	0⅜
5	1⅜	16	0¾
5	1½	16	1⅛
5	1⅝	16	1½
5	1¾	16	1⅞
5	1⅞	16	2⅜
5	2	16	2¾
5	2⅛	16	3⅛
5	2¼	16	3½
5	2⅜	16	3⅞
5	2½	16	4¼
5	2⅝	16	4⅝
5	2¾	16	5⅛
5	2⅞	16	5½
5	3	16	5⅞
5	3⅛	16	6¼
5	3¼	16	6⅝
5	3⅜	16	7
5	3½	16	7⅜
5	3⅝	16	7⅞
5	3¾	16	8¼
5	3⅞	16	8⅝
5	4	16	9
5	4⅛	16	9⅝
5	4¼	16	9¾
5	4⅜	16	10⅛
5	4½	16	10⅝
5	4⅝	16	11
5	4¾	16	11⅜

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
5	4⅞	16	11¾
5	5	17	0⅛
5	5⅛	17	0⅝
5	5¼	17	1
5	5⅜	17	1⅜
5	5½	17	1¾
5	5⅝	17	2⅛
5	5¾	17	2½
5	5⅞	17	2⅞
5	6	17	3¼
5	6⅛	17	3⅝
5	6¼	17	4⅛
5	6⅜	17	4½
5	6½	17	4⅞
5	6⅝	17	5¼
5	6¾	17	5⅝
5	6⅞	17	6
5	7	17	6⅜
5	7⅛	17	6⅞
5	7¼	17	7¼
5	7⅜	17	7⅝
5	7½	17	8
5	7⅝	17	8⅜
5	7¾	17	8¾
5	7⅞	17	9⅛
5	8	17	9⅝
5	8⅛	17	10
5	8¼	17	10⅜
5	8⅜	17	10¾
5	8½	17	11⅛
5	8⅝	17	11½
5	8¾	17	11⅞
5	8⅞	18	0⅜
5	9	18	0¾

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
5	9⅛	18	1⅛	6	1½	19	2⅞	6	5⅞	20	4⅝	6	10⅛	21	6
5	9¼	18	1½	6	1⅝	19	3¼	6	6	20	5	6	10¼	21	6⅜
5	9⅜	18	1⅞	6	1¾	19	3⅝	6	6⅛	20	5⅜	6	10⅜	21	6¾
5	9½	18	2¼	6	1⅞	19	4	6	6¼	20	5¾	6	10½	21	7⅛
5	9⅝	18	2⅝	6	2	19	4⅜	6	6⅜	20	6⅛	6	10⅝	21	7½
5	9¾	18	3	6	2⅛	19	4¾	6	6½	20	6½	6	10¾	21	7⅞
5	9⅞	18	3½	6	2¼	19	5¼	6	6⅝	20	7	6	10⅞	21	8¼
5	10	18	3⅞	6	2⅜	19	5⅝	6	6¾	20	7⅜	6	11	21	8¾
5	10⅛	18	4¼	6	2½	19	6	6	6⅞	20	7¾	6	11⅛	21	9⅛
5	10¼	18	4⅝	6	2⅝	19	6⅜	6	7	20	8⅛	6	11¼	21	9½
5	10⅜	18	5	6	2¾	19	6¾	6	7⅛	20	8½	6	11⅜	21	9⅞
5	10½	18	5⅜	6	2⅞	19	7⅛	6	7¼	20	8⅞	6	11½	21	10¼
5	10⅝	18	5⅞	6	3	19	7½	6	7⅜	20	9¼	6	11⅝	21	10⅝
5	10¾	18	6¼	6	3⅛	19	8	6	7½	20	9¾	6	11¾	21	11
5	10⅞	18	6⅝	6	3¼	19	8⅜	6	7⅝	20	10⅛	6	11⅞	21	11½
5	11	18	7	6	3⅜	19	8¾	6	7¾	20	10½	7	0	21	11⅞
5	11⅛	18	7⅜	6	3½	19	9⅛	6	7⅞	20	10⅞	7	0⅛	22	0¼
5	11¼	18	7¾	6	3⅝	19	9½	6	8	20	11¼	7	0¼	22	0⅝
5	11⅜	18	8⅛	6	3¾	19	9⅞	6	8⅛	20	11⅝	7	0⅜	22	1
5	11½	18	8½	6	3⅞	19	10¼	6	8¼	21	0	7	0½	22	1⅜
5	11⅝	18	9	6	4	19	10¾	6	8⅜	21	0½	7	0⅝	22	1⅞
5	11¾	18	9⅜	6	4⅛	19	11⅛	6	8½	21	0⅞	7	0¾	22	2¼
5	11⅞	18	9¾	6	4¼	19	11½	6	8⅝	21	1¼	7	0⅞	22	2⅝
6	0	18	10⅛	6	4⅜	19	11⅞	6	8¾	21	1⅝	7	1	22	3
6	0⅛	18	10½	6	4½	20	0¼	6	8⅞	21	2	7	1⅛	22	3⅜
6	0¼	18	10⅞	6	4⅝	20	0⅝	6	9	21	2⅜	7	1¼	22	3¾
6	0⅜	18	11¼	6	4¾	20	1	6	9⅛	21	2⅞	7	1⅜	22	4⅛
6	0½	18	11¾	6	4⅞	20	1½	6	9¼	21	3¼	7	1½	22	4½
6	0⅝	19	0⅛	6	5	20	1⅞	6	9⅜	21	3⅝	7	1⅝	22	5
6	0¾	19	0½	6	5⅛	20	2¼	6	9½	21	4	7	1¾	22	5⅜
6	0⅞	19	0⅞	6	5¼	20	2⅝	6	9⅝	21	4⅜	7	1⅞	22	5¾
6	1	19	1¼	6	5⅜	20	3	6	9¾	21	4¾	7	2	22	6⅛
6	1⅛	19	1⅝	6	5½	20	3⅜	6	9⅞	21	5⅛	7	2⅛	22	6½
6	1¼	19	2	6	5⅝	20	3¾	6	10	21	5½	7	2¼	22	6⅞
6	1⅜	19	2½	6	5¾	20	4¼					7	2⅜	22	7¼

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
7	2½	22	7⅝
7	2⅝	22	8⅛
7	2¾	22	8½
7	2⅞	22	8⅞
7	3	22	9¼
7	3⅛	22	9⅝
7	3¼	22	10
7	3⅜	22	10⅜
7	3½	22	10⅞
7	3⅝	22	11¼
7	3¾	22	11⅝
7	3⅞	23	0
7	4	23	0⅜
7	4⅛	23	0¾
7	4¼	23	1⅛
7	4⅜	23	1⅝
7	4½	23	2
7	4⅝	23	2⅜
7	4¾	23	2¾
7	4⅞	23	3⅛
7	5	23	3½
7	5⅛	23	3⅞
7	5¼	23	4⅜
7	5⅜	23	4¾
7	5½	23	5⅛
7	5⅝	23	5½
7	5¾	23	5⅞
7	5⅞	23	6¼
7	6	23	6⅝
7	6⅛	23	7⅛
7	6¼	23	7½
7	6⅜	23	7⅞
7	6½	23	8¼
7	6⅝	23	8⅝
7	6¾	23	9
7	6⅞	23	9⅜
7	7	23	9⅞
7	7⅛	23	10¼
7	7¼	23	10⅝
7	7⅜	23	11
7	7½	23	11⅜
7	7⅝	23	11¾
7	7¾	24	0⅛
7	7⅞	24	0⅝
7	8	24	1
7	8⅛	24	1⅜
7	8¼	24	1¾
7	8⅜	24	2⅛
7	8½	24	2½
7	8⅝	24	2⅞
7	8¾	24	3⅜
7	8⅞	24	3¾
7	9	24	4⅛
7	9⅛	24	4½
7	9¼	24	4⅞
7	9⅜	24	5¼
7	9½	24	5⅝
7	9⅝	24	6⅛
7	9¾	24	6½
7	9⅞	24	6⅞
7	10	24	7¼
7	10⅛	24	7⅝
7	10¼	24	8
7	10⅜	24	8⅜
7	10½	24	8⅞
7	10⅝	24	9¼
7	10¾	24	9⅝
7	10⅞	24	10
7	11	24	10⅜
7	11⅛	24	10¾
7	11¼	24	11⅛
7	11⅜	24	11½
7	11½	25	0
7	11⅝	25	0⅜
7	11¾	25	0¾
7	11⅞	25	1⅛
8	0	25	1½
8	0⅛	25	1⅞
8	0¼	25	2⅜
8	0⅜	25	2¾
8	0½	25	3⅛
8	0⅝	25	3½
8	0¾	25	3⅞
8	0⅞	25	4¼
8	1	25	4⅝
8	1⅛	25	5⅛
8	1¼	25	5½
8	1⅜	25	5⅞
8	1½	25	6¼
8	1⅝	25	6⅝
8	1¾	25	7
8	1⅞	25	7⅜
8	2	25	7⅞
8	2⅛	25	8¼
8	2¼	25	8⅝
8	2⅜	25	9
8	2½	25	9⅜
8	2⅝	25	9¾
8	2¾	25	10⅛
8	2⅞	25	10½
8	3	25	11
8	3⅛	25	11⅜
8	3¼	25	11¾
8	3⅜	26	0⅛
8	3½	26	0½
8	3⅝	26	0⅞
8	3¾	26	1⅜
8	3⅞	26	1¾
8	4	26	2⅛
8	4⅛	26	2½
8	4¼	26	2⅞
8	4⅜	26	3¼
8	4½	26	3⅝
8	4⅝	26	4⅛
8	4¾	26	4½
8	4⅞	26	4⅞
8	5	26	5¼
8	5⅛	26	5⅝
8	5¼	26	6
8	5⅜	26	6⅜
8	5½	26	6¾
8	5⅝	26	7¼
8	5¾	26	7⅝
8	5⅞	26	8
8	6	26	8⅜
8	6⅛	26	8¾
8	6¼	26	9⅛
8	6⅜	26	9½
8	6½	26	10
8	6⅝	26	10⅜
8	6¾	26	10¾
8	6⅞	26	11⅛
8	7	26	11½
8	7⅛	26	11⅞
8	7¼	27	0¼
8	7⅜	27	0¾
8	7½	27	1⅛
8	7⅝	27	1½
8	7¾	27	1⅞

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
8	7⅞	27	2¼
8	8	27	2⅝
8	8⅛	27	3
8	8¼	27	3½
8	8⅜	27	3⅞
8	8½	27	4¼
8	8⅝	27	4⅝
8	8¾	27	5
8	8⅞	27	5⅜
8	9	27	5¾
8	9⅛	27	6¼
8	9¼	27	6⅝
8	9⅜	27	7
8	9½	27	7⅜
8	9⅝	27	7¾
8	9¾	27	8⅛
8	9⅞	27	8½
8	10	27	9
8	10⅛	27	9⅜
8	10¼	27	9¾
8	10⅜	27	10⅛
8	10½	27	10½
8	10⅝	27	10⅞
8	10¾	27	11¼
8	10⅞	27	11¾
8	11	28	0⅛
8	11⅛	28	0½
8	11¼	28	0⅞
8	11⅜	28	1¼
8	11½	28	1⅝
8	11⅝	28	2
8	11¾	28	2½
8	11⅞	28	2⅞
9	0	28	3¼

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
9	0⅛	28	3⅝
9	0¼	28	4
9	0⅜	28	4⅜
9	0½	28	4¾
9	0⅝	28	5¼
9	0¾	28	5⅝
9	0⅞	28	6
9	1	28	6⅜
9	1⅛	28	6¾
9	1¼	28	7⅛
9	1⅜	28	7½
9	1½	28	8
9	1⅝	28	8⅜
9	1¾	28	8¾
9	1⅞	28	9⅛
9	2	28	9½
9	2⅛	28	9⅞
9	2¼	28	10¼
9	2⅜	28	10¾
9	2½	28	11⅛
9	2⅝	28	11½
9	2¾	28	11⅞
9	2⅞	29	0¼
9	3	29	0⅝
9	3⅛	29	1
9	3¼	29	1½
9	3⅜	29	1⅞
9	3½	29	2¼
9	3⅝	29	2⅝
9	3¾	29	3
9	3⅞	29	3⅜
9	4	29	3¾
9	4⅛	29	4¼
9	4¼	29	4⅝
9	4⅜	29	5

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
9	4½	29	5⅜
9	4⅝	29	5¾
9	4¾	29	6⅛
9	4⅞	29	6½
9	5	29	7
9	5⅛	29	7⅜
9	5¼	29	7¾
9	5⅜	29	8⅛
9	5½	29	8½
9	5⅝	29	8⅞
9	5¾	29	9¼
9	5⅞	29	9¾
9	6	29	10⅛
9	6⅛	29	10½
9	6¼	29	10⅞
9	6⅜	29	11¼
9	6½	29	11⅝
9	6⅝	30	0
9	6¾	30	0½
9	6⅞	30	0⅞
9	7	30	1¼
9	7⅛	30	1⅝
9	7¼	30	2
9	7⅜	30	2⅜
9	7½	30	2¾
9	7⅝	30	3⅛
9	7¾	30	3⅝
9	7⅞	30	4
9	8	30	4⅜
9	8⅛	30	4¾
9	8¼	30	5⅛
9	8⅜	30	5½
9	8½	30	6
9	8⅝	30	6⅜
9	8¾	30	6¾

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
9	8⅞	30	7⅛
9	9	30	7½
9	9⅛	30	7⅞
9	9¼	30	8¼
9	9⅜	30	8⅝
9	9½	30	9⅛
9	9⅝	30	9½
9	9¾	30	9⅞
9	9⅞	30	10¼
9	10	30	10⅝
9	10⅛	30	11
9	10¼	30	11⅜
9	10⅜	30	11⅞
9	10½	31	0¼
9	10⅝	31	0⅝
9	10¾	31	1
9	10⅞	31	1⅜
9	11	31	1¾
9	11⅛	31	2¼
9	11¼	31	2⅝
9	11⅜	31	3
9	11½	31	3⅜
9	11⅝	31	3¾
9	11¾	31	4⅛
9	11⅞	31	4½
10	0	31	4⅞
10	0⅛	31	5⅜
10	0¼	31	5¾
10	0⅜	31	6⅛
10	0½	31	6½
10	0⅝	31	6⅞
10	0¾	31	7¼
10	0⅞	31	7⅝
10	1	31	8⅛

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
10	1⅛	31	8½
10	1¼	31	8⅞
10	1⅜	31	9¼
10	1½	31	9⅝
10	1⅝	31	10
10	1¾	31	10⅜
10	1⅞	31	10⅞
10	2	31	11¼
10	2⅛	31	11⅝
10	2¼	32	0
10	2⅜	32	0⅜
10	2½	32	0¾
10	2⅝	32	1⅛
10	2¾	32	1½
10	2⅞	32	2
10	3	32	2⅜
10	3⅛	32	2¾
10	3¼	32	3⅛
10	3⅜	32	3½
10	3½	32	3⅞
10	3⅝	32	4⅜
10	3¾	32	4¾
10	3⅞	32	5⅛
10	4	32	5½
10	4⅛	32	5⅞
10	4¼	32	6¼
10	4⅜	32	6⅝
10	4½	32	7
10	4⅝	32	7½
10	4¾	32	7⅞
10	4⅞	32	8¼
10	5	32	8⅝
10	5⅛	32	9
10	5¼	32	9⅜
10	5⅜	32	9⅞
10	5½	32	10¼
10	5⅝	32	10⅝
10	5¾	32	11
10	5⅞	32	11⅜
10	6	32	11¾
10	6⅛	33	0⅛
10	6¼	33	0⅝
10	6⅜	33	1
10	6½	33	1⅜
10	6⅝	33	1¾
10	6¾	33	2⅛
10	6⅞	33	2½
10	7	33	2⅞
10	7⅛	33	3⅜
10	7¼	33	3¾
10	7⅜	33	4⅛
10	7½	33	4½
10	7⅝	33	4⅞
10	7¾	33	5¼
10	7⅞	33	5⅝
10	8	33	6⅛
10	8⅛	33	6½
10	8¼	33	6⅞
10	8⅜	33	7¼
10	8½	33	7⅝
10	8⅝	33	8
10	8¾	33	8⅜
10	8⅞	33	8⅞
10	9	33	9¼
10	9⅛	33	9⅝
10	9¼	33	10
10	9⅜	33	10⅜
10	9½	33	10¾
10	9⅝	33	11⅛
10	9¾	33	11½
10	9⅞	34	0
10	10	34	0⅜
10	10⅛	34	0¾
10	10¼	34	1⅛
10	10⅜	34	1½
10	10½	34	1⅞
10	10⅝	34	2⅜
10	10¾	34	2¾
10	10⅞	34	3⅛
10	11	34	3½
10	11⅛	34	3⅞
10	11¼	34	4¼
10	11⅜	34	4⅝
10	11½	34	5
10	11⅝	34	5½
10	11¾	34	5⅞
10	11⅞	34	6¼
11	0	34	6⅝
11	0⅛	34	7
11	0¼	34	7⅜
11	0⅜	34	7¾
11	0½	34	8¼
11	0⅝	34	8⅝
11	0¾	34	9
11	0⅞	34	9⅜
11	1	34	9¾
11	1⅛	34	10⅛
11	1¼	34	10½
11	1⅜	34	11
11	1½	34	11⅜
11	1⅝	34	11¾
11	1¾	35	0⅛
11	1⅞	35	0½
11	2	35	0⅞
11	2⅛	35	1¼
11	2¼	35	1¾
11	2⅜	35	2⅛
11	2½	35	2½
11	2⅝	35	2⅞
11	2¾	35	3¼
11	2⅞	35	3⅝
11	3	35	4
11	3⅛	35	4½
11	3¼	35	4⅞
11	3⅜	35	5¼
11	3½	35	5⅝
11	3⅝	35	6
11	3¾	35	6⅜
11	3⅞	35	6¾
11	4	35	7¼
11	4⅛	35	7⅝
11	4¼	35	8
11	4⅜	35	8⅜
11	4½	35	8¾
11	4⅝	35	9⅛
11	4¾	35	9½
11	4⅞	35	10
11	5	35	10⅜
11	5⅛	35	10¾
11	5¼	35	11⅛
11	5⅜	35	11½
11	5½	35	11⅞
11	5⅝	36	0¼
11	5¾	36	0¾
11	5⅞	36	1⅛
11	6	36	1½
11	6⅛	36	1⅞
11	6¼	36	2¼
11	6⅜	36	2⅝

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
11	6½	36	3
11	6⅝	36	3½
11	6¾	36	3⅞
11	6⅞	36	4¼
11	7	36	4⅝
11	7⅛	36	5
11	7¼	36	5⅜
11	7⅜	36	5⅞
11	7½	36	6¼
11	7⅝	36	6⅝
11	7¾	36	7
11	7⅞	36	7⅜
11	8	36	7¾
11	8⅛	36	8⅛
11	8¼	36	8½
11	8⅜	36	9
11	8½	36	9⅜
11	8⅝	36	9¾
11	8¾	36	10⅛
11	8⅞	36	10½
11	9	36	10⅞
11	9⅛	36	11¼
11	9¼	36	11¾
11	9⅜	37	0⅛
11	9½	37	0½
11	9⅝	37	0⅞
11	9¾	37	1¼
11	9⅞	37	1⅝
11	10	37	2
11	10⅛	37	2½
11	10¼	37	2⅞
11	10⅜	37	3¼
11	10½	37	3⅝
11	10⅝	37	4
11	10¾	37	4⅜

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
11	10⅞	37	4¾
11	11	37	5¼
11	11⅛	37	5⅝
11	11¼	37	6
11	11⅜	37	6⅜
11	11½	37	6¾
11	11⅝	37	7⅛
11	11¾	37	7½
11	11⅞	37	7⅞
12	0	37	8⅜
12	0⅛	37	8¾
12	0¼	37	9⅛
12	0⅜	37	9½
12	0½	37	9⅞
12	0⅝	37	10¼
12	0¾	37	10⅝
12	0⅞	37	11⅛
12	1	37	11½
12	1⅛	37	11¾
12	1¼	38	0¼
12	1⅜	38	0⅝
12	1½	38	1
12	1⅝	38	1⅜
12	1¾	38	1⅞
12	1⅞	38	2¼
12	2	38	2⅝
12	2⅛	38	3
12	2¼	38	3⅜
12	2⅜	38	3¾
12	2½	38	4⅛
12	2⅝	38	4⅝
12	2¾	38	5
12	2⅞	38	5⅜
12	3	38	5¾

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
12	3⅛	38	6⅛
12	3¼	38	6½
12	3⅜	38	6⅞
12	3½	38	7⅜
12	3⅝	38	7¾
12	3¾	38	8⅛
12	3⅞	38	8½
12	4	38	8⅞
12	4⅛	38	9¼
12	4¼	38	9⅝
12	4⅜	38	10⅛
12	4½	38	10½
12	4⅝	38	10⅞
12	4¾	38	11¼
12	4⅞	38	11⅝
12	5	39	0
12	5⅛	39	0⅜
12	5¼	39	0⅞
12	5⅜	39	1¼
12	5½	39	1⅝
12	5⅝	39	2
12	5¾	39	2⅜
12	5⅞	39	2¾
12	6	39	3⅛
12	6⅛	39	3⅝
12	6¼	39	4
12	6⅜	39	4⅜
12	6½	39	4¾
12	6⅝	39	5⅛
12	6¾	39	5½
12	6⅞	39	5⅞
12	7	39	6⅜
12	7⅛	39	6¾
12	7¼	39	7⅛
12	7⅜	39	7½

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
12	7½	39	7⅞
12	7⅝	39	8¼
12	7¾	39	8⅝
12	7⅞	39	9⅛
12	8	39	9½
12	8⅛	39	9⅞
12	8¼	39	10¼
12	8⅜	39	10⅝
12	8½	39	11
12	8⅝	39	11⅜
12	8¾	39	11⅞
12	8⅞	40	0¼
12	9	40	0⅝
12	9⅛	40	1
12	9¼	40	1⅜
12	9⅜	40	1¾
12	9½	40	2⅛
12	9⅝	40	2⅝
12	9¾	40	3
12	9⅞	40	3⅜
12	10	40	3¾
12	10⅛	40	4⅛
12	10¼	40	4½
12	10⅜	40	4⅞
12	10½	40	5⅜
12	10⅝	40	5¾
12	10¾	40	6⅛
12	10⅞	40	6½
12	11	40	6⅞
12	11⅛	40	7¼
12	11¼	40	7⅝
12	11⅜	40	8⅛
12	11½	40	8½
12	11⅝	40	8⅞
12	11¾	40	9¼

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
12	11⅞	40	9⅝
13	0	40	10
13	0⅛	40	10⅜
13	0¼	40	10⅞
13	0⅜	40	11¼
13	0½	40	11⅝
13	0⅝	41	0
13	0¾	41	0⅜
13	0⅞	41	0¾
13	1	41	1⅛
13	1⅛	41	1½
13	1¼	41	2
13	1⅜	41	2⅜
13	1½	41	2¾
13	1⅝	41	3⅛
13	1¾	41	3½
13	1⅞	41	3⅞
13	2	41	4¼
13	2⅛	41	4¾
13	2¼	41	5⅛
13	2⅜	41	5½
13	2½	41	5⅞
13	2⅝	41	6¼
13	2¾	41	6⅝
13	2⅞	41	7
13	3	41	7½
13	3⅛	41	7⅞
13	3¼	41	8¼
13	3⅜	41	8⅝
13	3½	41	9
13	3⅝	41	9⅜
13	3¾	41	9¾
13	3⅞	41	10¼
13	4	41	10⅝

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
13	4⅛	41	11
13	4¼	41	11⅜
13	4⅜	41	11¾
13	4½	42	0⅛
13	4⅝	42	0½
13	4¾	42	1
13	4⅞	42	1⅜
13	5	42	1¾
13	5⅛	42	2⅛
13	5¼	42	2½
13	5⅜	42	2⅞
13	5½	42	3¼
13	5⅝	42	3¾
13	5¾	42	4⅛
13	5⅞	42	4½
13	6	42	4⅞
13	6⅛	42	5¼
13	6¼	42	5⅝
13	6⅜	42	6
13	6½	42	6½
13	6⅝	42	6⅞
13	6¾	42	7¼
13	6⅞	42	7⅝
13	7	42	8
13	7⅛	42	8⅜
13	7¼	42	8⅞
13	7⅜	42	9¼
13	7½	42	9⅝
13	7⅝	42	10
13	7¾	42	10⅜
13	7⅞	42	10¾
13	8	42	11⅛
13	8⅛	42	11½
13	8¼	43	0
13	8⅜	43	0⅜

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
13	8½	43	0¾
13	8⅝	43	1⅛
13	8¾	43	1½
13	8⅞	43	1⅞
13	9	43	2¼
13	9⅛	43	2¾
13	9¼	43	3⅛
13	9⅜	43	3½
13	9½	43	3⅞
13	9⅝	43	4¼
13	9¾	43	4⅝
13	9⅞	43	5
13	10	43	5½
13	10⅛	43	5⅞
13	10¼	43	6¼
13	10⅜	43	6⅝
13	10½	43	7
13	10⅝	43	7⅜
13	10¾	43	7¾
13	10⅞	43	8¼
13	11	43	8⅝
13	11⅛	43	9
13	11¼	43	9⅜
13	11⅜	43	9¾
13	11½	43	10⅛
13	11⅝	43	10½
13	11¾	43	11
13	11⅞	43	11⅜
14	0	43	11¾
14	0⅛	44	0⅛
14	0¼	44	0½
14	0⅜	44	0⅞
14	0½	44	1¼
14	0⅝	44	1¾
14	0¾	44	2⅛

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
14	0⅞	44	2½
14	1	44	2⅞
14	1⅛	44	3¼
14	1¼	44	3⅝
14	1⅜	44	4
14	1½	44	4½
14	1⅝	44	4⅞
14	1¾	44	5¼
14	1⅞	44	5⅝
14	2	44	6
14	2⅛	44	6⅜
14	2¼	44	6⅞
14	2⅜	44	7¼
14	2½	44	7⅝
14	2⅝	44	8
14	2¾	44	8⅜
14	2⅞	44	8¾
14	3	44	9⅛
14	3⅛	44	9½
14	3¼	44	9⅞
14	3⅜	44	10⅜
14	3½	44	10¾
14	3⅝	44	11⅛
14	3¾	44	11½
14	3⅞	44	11⅞
14	4	45	0¼
14	4⅛	45	0⅝
14	4¼	45	1⅛
14	4⅜	45	1½
14	4½	45	1⅞
14	4⅝	45	2¼
14	4¾	45	2⅝
14	4⅞	45	3
14	5	45	3⅜

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
11	6½	36	3	11	10⅞	37	4¾	12	3⅛	38	6⅛	12	7½	39	7⅞
11	6⅝	36	3½	11	11	37	5¼	12	3¼	38	6½	12	7⅝	39	8¼
11	6¾	36	3⅞	11	11⅛	37	5⅝	12	3⅜	38	6⅞	12	7¾	39	8⅝
11	6⅞	36	4¼	11	11¼	37	6	12	3½	38	7⅜	12	7⅞	39	9⅛
11	7	36	4⅝	11	11⅜	37	6⅜	12	3⅝	38	7¾	12	8	39	9½
11	7⅛	36	5	11	11½	37	6¾	12	3¾	38	8⅛	12	8⅛	39	9⅞
11	7¼	36	5⅜	11	11⅝	37	7⅛	12	3⅞	38	8½	12	8¼	39	10¼
11	7⅜	36	5⅞	11	11¾	37	7½	12	4	38	8⅞	12	8⅜	39	10⅝
11	7½	36	6¼	11	11⅞	37	7⅞	12	4⅛	38	9¼	12	8½	39	11
11	7⅝	36	6⅝	12	0	37	8⅜	12	4¼	38	9⅝	12	8⅝	39	11⅜
11	7¾	36	7	12	0⅛	37	8¾	12	4⅜	38	10⅛	12	8¾	39	11⅞
11	7⅞	36	7⅜	12	0¼	37	9⅛	12	4½	38	10½	12	8⅞	40	0¼
11	8	36	7¾	12	0⅜	37	9½	12	4⅝	38	10⅞	12	9	40	0⅝
11	8⅛	36	8⅛	12	0½	37	9⅞	12	4¾	38	11¼	12	9⅛	40	1
11	8¼	36	8½	12	0⅝	37	10¼	12	4⅞	38	11⅝	12	9¼	40	1⅜
11	8⅜	36	9	12	0¾	37	10⅝	12	5	39	0	12	9⅜	40	1¾
11	8½	36	9⅜	12	0⅞	37	11⅛	12	5⅛	39	0⅜	12	9½	40	2⅛
11	8⅝	36	9¾	12	1	37	11½	12	5¼	39	0⅞	12	9⅝	40	2⅝
11	8¾	36	10⅛	12	1⅛	37	11¾	12	5⅜	39	1¼	12	9¾	40	3
11	8⅞	36	10½	12	1¼	38	0¼	12	5½	39	1⅝	12	9⅞	40	3⅜
11	9	36	10⅞	12	1⅜	38	0⅝	12	5⅝	39	2	12	10	40	3¾
11	9⅛	36	11¼	12	1½	38	1	12	5¾	39	2⅜	12	10⅛	40	4⅛
11	9¼	36	11¾	12	1⅝	38	1⅜	12	5⅞	39	2¾	12	10¼	40	4½
11	9⅜	37	0⅛	12	1¾	38	1⅞	12	6	39	3⅛	12	10⅜	40	4⅞
11	9½	37	0½	12	1⅞	38	2¼	12	6⅛	39	3⅝	12	10½	40	5⅜
11	9⅝	37	0⅞	12	2	38	2⅝	12	6¼	39	4	12	10⅝	40	5¾
11	9¾	37	1¼	12	2⅛	38	3	12	6⅜	39	4⅜	12	10¾	40	6⅛
11	9⅞	37	1⅝	12	2¼	38	3⅜	12	6½	39	4¾	12	10⅞	40	6½
11	10	37	2	12	2⅜	38	3¾	12	6⅝	39	5⅛	12	11	40	6⅞
11	10⅛	37	2½	12	2½	38	4⅛	12	6¾	39	5½	12	11⅛	40	7¼
11	10¼	37	2⅞	12	2⅝	38	4⅝	12	6⅞	39	5⅞	12	11¼	40	7⅝
11	10⅜	37	3¼	12	2¾	38	5	12	7	39	6⅜	12	11⅜	40	8⅛
11	10½	37	3⅝	12	2⅞	38	5⅜	12	7⅛	39	6¾	12	11½	40	8½
11	10⅝	37	4	12	3	38	5¾	12	7¼	39	7⅛	12	11⅝	40	8⅞
11	10¾	37	4⅜					12	7⅜	39	7½	12	11¾	40	9¼

Diam.		Circum.	
Ft.	In.	Ft.	In.
12	11⅞	40	9⅝
13	0	40	10
13	0⅛	40	10⅜
13	0¼	40	10⅞
13	0⅜	40	11¼
13	0½	40	11⅝
13	0⅝	41	0
13	0¾	41	0⅜
13	0⅞	41	0¾
13	1	41	1⅛
13	1⅛	41	1½
13	1¼	41	2
13	1⅜	41	2⅜
13	1½	41	2¾
13	1⅝	41	3⅛
13	1¾	41	3½
13	1⅞	41	3⅞
13	2	41	4¼
13	2⅛	41	4¾
13	2¼	41	5⅛
13	2⅜	41	5½
13	2½	41	5⅞
13	2⅝	41	6¼
13	2¾	41	6⅝
13	2⅞	41	7
13	3	41	7½
13	3⅛	41	7⅞
13	3¼	41	8¼
13	3⅜	41	8⅝
13	3½	41	9
13	3⅝	41	9⅜
13	3¾	41	9¾
13	3⅞	41	10¼
13	4	41	10⅝

Diam.		Circum.	
Ft.	In.	Ft.	In.
13	4⅛	41	11
13	4¼	41	11⅜
13	4⅜	41	11¾
13	4½	42	0⅛
13	4⅝	42	0½
13	4¾	42	1
13	4⅞	42	1⅜
13	5	42	1¾
13	5⅛	42	2⅛
13	5¼	42	2½
13	5⅜	42	2⅞
13	5½	42	3¼
13	5⅝	42	3¾
13	5¾	42	4⅛
13	5⅞	42	4½
13	6	42	4⅞
13	6⅛	42	5¼
13	6¼	42	5⅝
13	6⅜	42	6
13	6½	42	6½
13	6⅝	42	6⅞
13	6¾	42	7¼
13	6⅞	42	7⅝
13	7	42	8
13	7⅛	42	8⅜
13	7¼	42	8⅞
13	7⅜	42	9¼
13	7½	42	9⅝
13	7⅝	42	10
13	7¾	42	10⅜
13	7⅞	42	10¾
13	8	42	11⅛
13	8⅛	42	11½
13	8¼	43	0
13	8⅜	43	0⅜

Diam.		Circum.	
Ft.	In.	Ft.	In.
13	8½	43	0¾
13	8⅝	43	1⅛
13	8¾	43	1½
13	8⅞	43	1⅞
13	9	43	2¼
13	9⅛	43	2¾
13	9¼	43	3⅛
13	9⅜	43	3½
13	9½	43	3⅞
13	9⅝	43	4¼
13	9¾	43	4⅝
13	9⅞	43	5
13	10	43	5½
13	10⅛	43	5⅞
13	10¼	43	6¼
13	10⅜	43	6⅝
13	10½	43	7
13	10⅝	43	7⅜
13	10¾	43	7¾
13	10⅞	43	8¼
13	11	43	8⅝
13	11⅛	43	9
13	11¼	43	9⅜
13	11⅜	43	9¾
13	11½	43	10⅛
13	11⅝	43	10½
13	11¾	43	11
13	11⅞	43	11⅜
14	0	43	11¾
14	0⅛	44	0⅛
14	0¼	44	0½
14	0⅜	44	0⅞
14	0½	44	1¼
14	0⅝	44	1¾
14	0¾	44	2⅛

Diam.		Circum.	
Ft.	In.	Ft.	In.
14	0⅞	44	2½
14	1	44	2⅞
14	1⅛	44	3¼
14	1¼	44	3⅝
14	1⅜	44	4
14	1½	44	4½
14	1⅝	44	4⅞
14	1¾	44	5¼
14	1⅞	44	5⅝
14	2	44	6
14	2⅛	44	6⅜
14	2¼	44	6⅞
14	2⅜	44	7¼
14	2½	44	7⅝
14	2⅝	44	8
14	2¾	44	8⅜
14	2⅞	44	8¾
14	3	44	9⅛
14	3⅛	44	9½
14	3¼	44	9⅞
14	3⅜	44	10⅜
14	3½	44	10¾
14	3⅝	44	11⅛
14	3¾	44	11½
14	3⅞	44	11⅞
14	4	45	0¼
14	4⅛	45	0⅝
14	4¼	45	1⅛
14	4⅜	45	1½
14	4½	45	1⅞
14	4⅝	45	2¼
14	4¾	45	2⅝
14	4⅞	45	3
14	5	45	3⅜

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
14	5⅛	45	3⅞
14	5¼	45	4¼
14	5⅜	45	4⅝
14	5½	45	5
14	5⅝	45	5⅜
14	5¾	45	5¾
14	5⅞	45	6¼
14	6	45	6⅝
14	6⅛	45	7
14	6¼	45	7⅜
14	6⅜	45	7¾
14	6½	45	8⅛
14	6⅝	45	8½
14	6¾	45	9
14	6⅞	45	9⅜
14	7	45	9¾
14	7⅛	45	10⅛
14	7¼	45	10½
14	7⅜	45	10⅞
14	7½	45	11¼
14	7⅝	45	11⅝
14	7¾	46	0⅛
14	7⅞	46	0½
14	8	46	0⅞
14	8⅛	46	1¼
14	8¼	46	1⅝
14	8⅜	46	2
14	8½	46	2⅜
14	8⅝	46	2⅞
14	8¾	46	3¼
14	8⅞	46	3⅝
14	9	46	4
14	9⅛	46	4⅜
14	9¼	46	4⅞
14	9⅜	46	5¼

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
14	9½	46	5⅝
14	9⅝	46	6
14	9¾	46	6⅜
14	9⅞	46	6¾
14	10	46	7⅛
14	10⅛	46	7½
14	10¼	46	7⅞
14	10⅜	46	8⅜
14	10½	46	8¾
14	10⅝	46	9⅛
14	10¾	46	9½
14	10⅞	46	9⅞
14	11	46	10¼
14	11⅛	46	10⅝
14	11¼	46	11⅛
14	11⅜	46	11½
14	11½	46	11⅞
14	11⅝	47	0¼
14	11¾	47	0⅝
14	11⅞	47	1
15	0	47	1½
15	0⅛	47	1⅞
15	0¼	47	2¼
15	0⅜	47	2⅝
15	0½	47	3
15	0⅝	47	3⅜
15	0¾	47	3¾
15	0⅞	47	4⅛
15	1	47	4⅝
15	1⅛	47	5
15	1¼	47	5⅜
15	1⅜	47	5¾
15	1½	47	6⅛
15	1⅝	47	6½
15	1¾	47	6⅞

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
15	1⅞	47	7⅜
15	2	47	7¾
15	2⅛	47	8⅛
15	2¼	47	8½
15	2⅜	47	8⅞
15	2½	47	9¼
15	2⅝	47	9⅝
15	2¾	47	10⅛
15	2⅞	47	10½
15	3	47	10⅞
15	3⅛	47	11¼
15	3¼	47	11⅝
15	3⅜	48	0
15	3½	48	0⅜
15	3⅝	48	0⅞
15	3¾	48	1¼
15	3⅞	48	1⅝
15	4	48	2
15	4⅛	48	2⅜
15	4¼	48	2¾
15	4⅜	48	3⅛
15	4½	48	3½
15	4⅝	48	4
15	4¾	48	4⅜
15	4⅞	48	4¾
15	5	48	5⅛
15	5⅛	48	5½
15	5¼	48	5⅞
15	5⅜	48	6⅜
15	5½	48	6¾
15	5⅝	48	7⅛
15	5¾	48	7½
15	5⅞	48	7⅞
15	6	48	8¼

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
15	6⅛	48	8⅝
15	6¼	48	9
15	6⅜	48	9½
15	6½	48	9⅞
15	6⅝	48	10¼
15	6¾	48	10⅝
15	6⅞	48	11
15	7	48	11⅜
15	7⅛	48	11¾
15	7¼	49	0¼
15	7⅜	49	0⅝
15	7½	49	1
15	7⅝	49	1⅜
15	7¾	49	1¾
15	7⅞	49	2⅛
15	8	49	2½
15	8⅛	49	3
15	8¼	49	3⅜
15	8⅜	49	3¾
15	8½	49	4⅛
15	8⅝	49	4½
15	8¾	49	4⅞
15	8⅞	49	5¼
15	9	49	5¾
15	9⅛	49	6⅛
15	9¼	49	6½
15	9⅜	49	6⅞
15	9½	49	7¼
15	9⅝	49	7⅝
15	9¾	49	8
15	9⅞	49	8½
15	10	49	8⅞
15	10⅛	49	9¼
15	10¼	49	9¾
15	10⅜	49	10⅛

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
15	10½	49	10½
15	10⅝	49	10⅞
15	10¾	49	11¼
15	10⅞	49	11⅝
15	11	50	0
15	11⅛	50	0½
15	11¼	50	0⅞
15	11⅜	50	1¼
15	11½	50	1⅝
15	11⅝	50	2
15	11¾	50	2⅜
15	11⅞	50	2¾
16	0	50	3⅛
16	0⅛	50	3½
16	0¼	50	3⅞
16	0⅜	50	4¼
16	0½	50	4¾
16	0⅝	50	5⅛
16	0¾	50	5½
16	0⅞	50	5⅞
16	1	50	6¼
16	1⅛	50	6⅝
16	1¼	50	7
16	1⅜	50	7½
16	1½	50	7⅞
16	1⅝	50	8¼
16	1¾	50	8⅝
16	1⅞	50	9
16	2	50	9⅜
16	2⅛	50	9¾
16	2¼	50	10¼
16	2⅜	50	10⅝
16	2½	50	11
16	2⅝	50	11⅜
16	2¾	50	11¾
16	2⅞	51	0⅛
16	3	51	0½
16	3⅛	51	1
16	3¼	51	1⅜
16	3⅜	51	1¾
16	3½	51	2⅛
16	3⅝	51	2½
16	3¾	51	2⅞
16	3⅞	51	3¼
16	4	51	3¾
16	4⅛	51	4⅛
16	4¼	51	4½
16	4⅜	51	4⅞
16	4½	51	5¼
16	4⅝	51	5⅝
16	4¾	51	6
16	4⅞	51	6½
16	5	51	6⅞
16	5⅛	51	7¼
16	5¼	51	7⅝
16	5⅜	51	8
16	5½	51	8⅜
16	5⅝	51	8¾
16	5¾	51	9¼
16	5⅞	51	9½
16	6	51	10
16	6⅛	51	10⅜
16	6¼	51	10¾
16	6⅜	51	11⅛
16	6½	51	11½
16	6⅝	52	0
16	6¾	52	0⅜
16	6⅞	52	0¾
16	7	52	1⅛
16	7⅛	52	1½
16	7¼	52	1⅞
16	7⅜	52	2¼
16	7½	52	2⅝
16	7⅝	52	3⅛
16	7¾	52	3½
16	7⅞	52	3⅞
16	8	52	4¼
16	8⅛	52	4⅝
16	8¼	52	5
16	8⅜	52	5⅜
16	8½	52	5⅞
16	8⅝	52	6¼
16	8¾	52	6⅝
16	8⅞	52	7
16	9	52	7⅜
16	9⅛	52	7¾
16	9¼	52	8¼
16	9⅜	52	8⅝
16	9½	52	9
16	9⅝	52	9⅜
16	9¾	52	9¾
16	9⅞	52	10⅛
16	10	52	10½
16	10⅛	52	11
16	10¼	52	11⅜
16	10⅜	52	11¾
16	10½	53	0⅛
16	10⅝	53	0½
16	10¾	53	0⅞
16	10⅞	53	1¼
16	11	53	1⅝
16	11⅛	53	2
16	11¼	53	2½
16	11⅜	53	2⅞
16	11½	53	3¼
16	11⅝	53	3⅝
16	11¾	53	4
16	11⅞	53	4½
17	0	53	4⅞
17	0⅛	53	5¼
17	0¼	53	5⅝
17	0⅜	53	6
17	0½	53	6⅜
17	0⅝	53	6¾
17	0¾	53	7¼
17	0⅞	53	7⅝
17	1	53	8
17	1⅛	53	8⅜
17	1¼	53	8¾
17	1⅜	53	9⅛
17	1½	53	9½
17	1⅝	53	10
17	1¾	53	10⅜
17	1⅞	53	10¾
17	2	53	11⅛
17	2⅛	53	11½
17	2¼	53	11⅞
17	2⅜	54	0¼
17	2½	54	0⅝
17	2⅝	54	1⅛
17	2¾	54	1½
17	2⅞	54	1⅞
17	3	54	2¼
17	3⅛	54	2⅝
17	3¼	54	3
17	3⅜	54	3½
17	3½	54	3⅞
17	3⅝	54	4¼
17	3¾	54	4⅝

Diam.		Circum.	
Ft.	In.	Ft.	In.
17	3⅞	54	5
17	4	54	5⅜
17	4⅛	54	5¾
17	4¼	54	6⅛
17	4⅜	54	6⅝
17	4½	54	7
17	4⅝	54	7⅜
17	4¾	54	7¾
17	4⅞	54	8⅛
17	5	54	8½
17	5⅛	54	8⅞
17	5¼	54	9⅜
17	5⅜	54	9¾
17	5½	54	10⅛
17	5⅝	54	10½
17	5¾	54	10⅞
17	5⅞	54	11¼
17	6	54	11⅝
17	6⅛	55	0⅛
17	6¼	55	0½
17	6⅜	55	0⅞
17	6½	55	1¼
17	6⅝	55	1⅝
17	6¾	55	2
17	6⅞	55	2⅜
17	7	55	2⅞
17	7⅛	55	3¼
17	7¼	55	3⅝
17	7⅜	55	4
17	7½	55	4⅜
17	7⅝	55	4¾
17	7¾	55	5⅛
17	7⅞	55	5½
17	8	55	6

Diam.		Circum.	
Ft.	In.	Ft.	In.
17	8⅛	55	6⅜
17	8¼	55	6¾
17	8⅜	55	7⅛
17	8½	55	7½
17	8⅝	55	7⅞
17	8¾	55	8⅜
17	8⅞	55	8¾
17	9	55	9⅛
17	9⅛	55	9½
17	9¼	55	9⅞
17	9⅜	55	10¼
17	9½	55	10⅝
17	9⅝	55	11⅛
17	9¾	55	11½
17	9⅞	55	11⅞
17	10	56	0¼
17	10⅛	56	0⅝
17	10¼	56	1
17	10⅜	56	1⅜
17	10½	56	1⅞
17	10⅝	56	2¼
17	10¾	56	2⅝
17	10⅞	56	3
17	11	56	3⅜
17	11⅛	56	3¾
17	11¼	56	4⅛
17	11⅜	56	4½
17	11½	56	5
17	11⅝	56	5⅜
17	11¾	56	5¾
17	11⅞	56	6⅛
18	0	56	6½
18	0⅛	56	6⅞
18	0¼	56	7¼
18	0⅜	56	7¾

Diam.		Circum.	
Ft.	In.	Ft.	In.
18	0½	56	8⅛
18	0⅝	56	8½
18	0¾	56	8⅞
18	0⅞	56	9¼
18	1	56	9⅝
18	1⅛	56	10
18	1¼	56	10½
18	1⅜	56	10⅞
18	1½	56	11¼
18	1⅝	56	11⅝
18	1¾	57	0
18	1⅞	57	0⅜
18	2	57	0¾
18	2⅛	57	1¼
18	2¼	57	1⅝
18	2⅜	57	2
18	2½	57	2⅜
18	2⅝	57	2¾
18	2¾	57	3⅛
18	2⅞	57	3½
18	3	57	4
18	3⅛	57	4⅜
18	3¼	57	4¾
18	3⅜	57	5⅛
18	3½	57	5½
18	3⅝	57	5⅞
18	3¾	57	6⅜
18	3⅞	57	6¾
18	4	57	7⅛
18	4⅛	57	7½
18	4¼	57	7⅞
18	4⅜	57	8¼
18	4½	57	8⅝
18	4⅝	57	9
18	4¾	57	9½

Diam.		Circum.	
Ft.	In.	Ft.	In.
18	4⅞	57	9⅞
18	5	57	10¼
18	5⅛	57	10⅝
18	5¼	57	11
18	5⅜	57	11⅜
18	5½	57	11¾
18	5⅝	58	0¼
18	5¾	58	0⅝
18	5⅞	58	1
18	6	58	1⅜
18	6⅛	58	1¾
18	6¼	58	2⅛
18	6⅜	58	2½
18	6½	58	3
18	6⅝	58	3⅜
18	6¾	58	3¾
18	6⅞	58	4⅛
18	7	58	4½
18	7⅛	58	4⅞
18	7¼	58	5¼
18	7⅜	58	5¾
18	7½	58	6⅛
18	7⅝	58	6½
18	7¾	58	6⅞
18	7⅞	58	7¼
18	8	58	7⅝
18	8⅛	58	8
18	8¼	58	8½
18	8⅜	58	8⅞
18	8½	58	9¼
18	8⅝	58	9⅝
18	8¾	58	10
18	8⅞	58	10⅜
18	9	58	10¾

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
18 9⅛	58 11¼	19 1⅛	59 11¾	19 5⅛	61 0⅜	19 9⅛	62 0⅞
18 9¼	58 11⅝	19 1¼	60 0⅛	19 5¼	61 0¾	19 9¼	62 1¼
18 9⅜	59 0	19 1⅜	60 0½	19 5⅜	61 1⅛	19 9⅜	62 1⅝
18 9½	59 0⅜	19 1½	60 1	19 5½	61 1½	19 9½	62 2⅛
18 9⅝	59 0¾	19 1⅝	60 1⅜	19 5⅝	61 1⅞	19 9⅝	62 2½
18 9¾	59 1⅛	19 1¾	60 1¾	19 5¾	61 2¼	19 9¾	62 2⅞
18 9⅞	59 1½	19 1⅞	60 2⅛	19 5⅞	61 2¾	19 9⅞	62 3¼
18 10	59 2	19 2	60 2½	19 6	61 3⅛	19 10	62 3⅝
18 10⅛	59 2⅜	19 2⅛	60 2⅞	19 6⅛	61 3½	19 10⅛	62 4
18 10¼	59 2¾	19 2¼	60 3¼	19 6¼	61 3⅞	19 10¼	62 4⅜
18 10⅜	59 3⅛	19 2⅜	60 3⅝	19 6⅜	61 4¼	19 10⅜	62 4⅞
18 10½	59 3½	19 2½	60 4⅛	19 6½	61 4⅝	19 10½	62 5¼
18 10⅝	59 3⅞	19 2⅝	60 4½	19 6⅝	61 5	19 10⅝	62 5⅝
18 10¾	59 4¼	19 2¾	60 4⅞	19 6¾	61 5½	19 10¾	62 6
18 10⅞	59 4¾	19 2⅞	60 5¼	19 6⅞	61 5⅞	19 10⅞	62 6⅜
18 11	59 5⅛	19 3	60 5⅝	19 7	61 6¼	19 11	62 6¾
18 11⅛	59 5½	19 3⅛	60 6	19 7⅛	61 6⅝	19 11⅛	62 7⅛
18 11¼	59 5⅞	19 3¼	60 6½	19 7¼	61 7	19 11¼	62 7½
8 11⅜	59 6¼	19 3⅜	60 6⅞	19 7⅜	61 7⅜	19 11⅜	62 8
8 11½	59 6⅝	19 3½	60 7¼	19 7½	61 7¾	19 11½	62 8⅜
8 11⅝	59 7	19 3⅝	60 7⅝	19 7⅝	61 8¼	19 11⅝	62 8¾
8 11¾	59 7½	19 3¾	60 8	19 7¾	61 8⅝	19 11¾	62 9⅛
8 11⅞	59 7⅞	19 3⅞	60 8⅜	19 7⅞	61 9	19 11⅞	62 9½
9 0	59 8¼	19 4	60 8¾	19 8	61 9⅜	20 0	62 9⅞
9 0⅛	59 8⅝	19 4⅛	60 9¼	19 8⅛	61 9¾	20 0⅛	62 10⅜
9 0¼	59 9	19 4¼	60 9⅝	19 8¼	61 10⅛	20 0¼	62 10¾
9 0⅜	59 9⅜	19 4⅜	60 10	19 8⅜	61 10½	20 0⅜	62 11⅛
9 0½	59 9¾	19 4½	60 10⅜	19 8½	61 11	20 0½	62 11½
9 0⅝	59 10¼	19 4⅝	60 10¾	19 8⅝	61 11⅜	20 0⅝	62 11⅞
9 0¾	59 10⅝	19 4¾	60 11⅛	19 8¾	61 11¾	20 0¾	63 0¼
9 0⅞	59 11	19 4⅞	60 11½	19 8⅞	62 0⅛	20 0⅞	63 0⅝
9 1	59 11⅜	19 5	60 11⅞	19 9	62 0½		

OBSERVATIONS ON TABLE I.

I do not intend to enter into any laboured argument to prove the general utility of these Tables, as their simplicity and clearness are sufficient to stamp their value to the artist and mechanic. It will be clearly perceived, on inspection, that the Table commences with as small a diameter as is generally used in hoops and rings, viz. one inch, and increases by the regular gradation of one-eighth of an inch, to upwards of twenty feet; and in the column marked Circumference, against each Diameter stand the respective circumferences: hence all that is necessary on inspecting these Tables is to enter into them with any proposed diameter or circumference, and an answer to the inquiry is immediately obtained.

Example.—Required the circumference of a circle the diameter being 11 feet $7\frac{7}{8}$ inches.

In the column of circumferences, opposite the given diameter, stands 36 feet $7\frac{3}{8}$ inches, the circumference required.

But it will be necessary to observe, that in the formation of hoops and rings a contraction of the metal takes place. Now, the just allowance for this contraction is the exact thickness of the metal which must be added to the diameter.

Ex. In making a hoop whose diameter inside is 6 feet $9\frac{1}{8}$ inches, the thickness of the iron being $\frac{1}{2}$ inch, this $\frac{1}{2}$ inch must be added to the given diameter, which will make it 6 feet $9\frac{5}{8}$ inches; this will allow $1\frac{5}{8}$ inch for the contraction in bending in a hoop of the above diameter, giving the circumference or length of iron required for the hoop, 21 feet $4\frac{3}{8}$ inches.

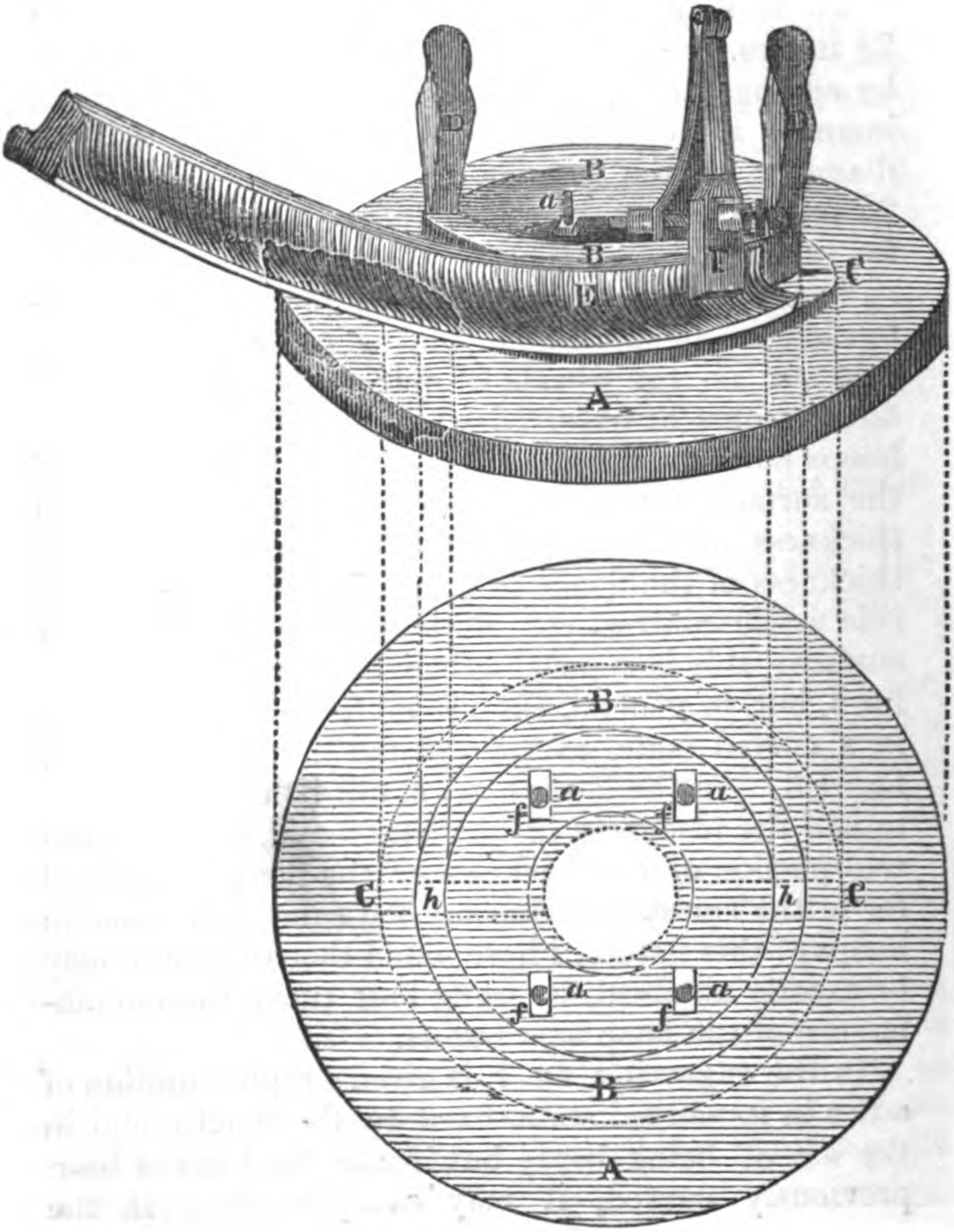
The foregoing example appertains to the formation of hoops or iron bent on the flat; but in the formation of rings or iron bent on the edge, the same rule must also be followed, only taking care to add the *breadth* instead of the thickness. As for example:

To make a ring whose inside diameter is 8 feet $2\frac{1}{4}$ inches, the *breadth* of the iron being $2\frac{1}{2}$ inches; by adding the $2\frac{1}{2}$ inches to the given diameter, will increase it to 8 feet $4\frac{3}{4}$ inches; opposite to this diameter in the column of circumferences stands 26 feet $4\frac{1}{2}$ inches, being the length of iron necessary for the ring.

The foregoing observations relate more particularly to plain hoops and rings; but as respects the hoops that are on the wheels of railway carriages, a difference must be observed, which is as follows: These hoops having a flange projecting on the one edge of the surface it will be necessary, in addition to the thickness of the metal, to add two-thirds of the thickness of the flange to the diameter, as the flange side would contract considerably more than the plain surface; this is supposing the tires are in a straight form, but, in general, they come from the iron-works in a curved state, as represented in the engraving, figure 3. In the latter case, it will be only necessary to add the thickness of the bare metal, as the aforesaid portion of the thickness of the flange is allowed for in the curve. By having had some experience in hoops of this nature, I have found that the curve may be exactly obtained, by using four times the circumference of the hoop as a radius.

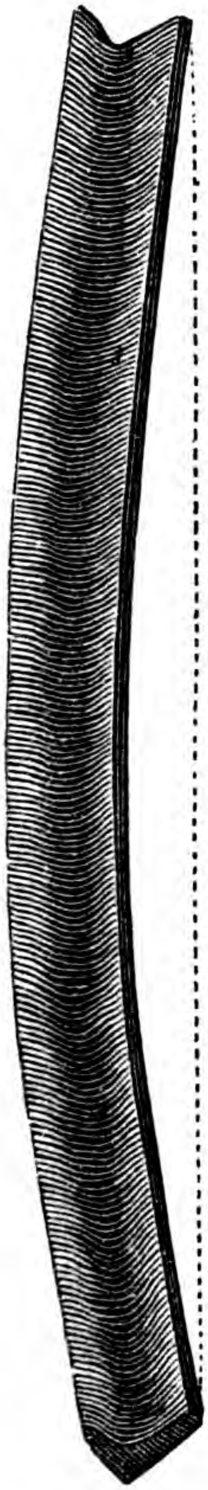
In the engraving, fig. 1, is given a representation of a tire in its curved state, fixed to the blocks, and in the act of being bent; but if the tire has not been previously curved, it may easily be done in the operation of bending: the smith must pay particular attention to this, or he will have his hoop bent in an angle.

Figures 1 and 2.



The following is a description of the figures 1 and 2: A is a strong cast-iron ground-plate, in which *f f f f* are four slot-holes for the bolts *a a a a* to slide in, and are for the purpose of screwing down the two semicircular blocks, to prevent them from moving whilst the tire is in the act of being bent. B B is the block in two halves, opening at C C; the aperture is cut in a conical form, for the reception of the two conical wedges D D, on which the tire E is represented. *h h* are two holes in the ground-plate, into which the wedges are driven whilst blocking the hoop. F is a strong cramp for screwing the tire firm to the block whilst in the act of being bent round it: it is made with a joint at the top, and secures the tire to the block by means of a strong square-threaded screw, which screws into a boss on the innermost leg.

Figure 3.



But the practical utility of this Table is not confined to smiths alone; to the millwright it will be found equally useful and expeditious, as on a bare inspection of the Table he may ascertain the diameter of any wheel that may be required to be made, the pitch and number of teeth being given.

Ex. Suppose a wheel were ordered to be made to contain sixty teeth, the pitch of the teeth to be $3\frac{7}{8}$ inches, the dimensions of the wheel may be ascertained simply as follows:

Multiply the pitch of the tooth by the

number of teeth the wheel is to contain, and the product will be the circumference of the wheel: thus

	Inches.		
		$3\frac{7}{8}$	the pitch of the tooth,
		$10 \times 6 = 60$,	the number of teeth,
	3	$2\frac{3}{4}$	
		6	
Feet	19	$4\frac{1}{2}$	the circumference of the wheel.

However, by inspecting the column marked Circumference, I find the nearest number to this is 19 feet $4\frac{3}{8}$ inches, which is the eighth of an inch less than the true circumference; but if this $\frac{1}{8}$ were divided into sixty equal parts, it would not make the difference of a single hair's-breadth in the size of each tooth; so that it is sufficiently near for any practical purpose. The diameter answering to this circumference is 6 feet 2 inches; consequently, with one half of this number as a radius, the circumference of the wheel will be described.

The manner in which the foregoing Table of Circumferences is found is as follows: Taking the diameter at unity, we have by decimal proportion

$$\text{As } 1 : 3{\cdot}1416 :: \overset{\text{In.}}{1{\cdot}} : \overset{\text{In.}}{3{\cdot}1416},$$

and the decimal 1416 multiplied by 8, gives the circumference for 1 inch of diameter $3\frac{1}{8}$ inches.

In these Tables the number 3·1416 is divided by 8, which gives ·3927. This decimal proportion has been used as a constant, and the sum multiplied by 8 gives the excess above the decimal value in eighths of an inch.

EXAMPLE.

Diam.	In.	Circum.	Eighths.
1	3	1416 × 8 =	$\frac{1}{8}$·1328
		+ ·3927	
$1\frac{1}{8}$	3	·5343 × 8 =	$\frac{1}{2}$·2744
		+ ·3927	
$1\frac{1}{4}$	3	·9270 × 8 =	$\frac{7}{8}$·4160
		+ ·3927	
$1\frac{3}{8}$	4	·3197 × 8 =	$\frac{1}{4}$·5576
		+ ·3927	
$1\frac{1}{2}$	4	·7124 × 8 =	$\frac{5}{8}$·6992
		+ ·3927	
$1\frac{5}{8}$	5	·1051 × 8 =	·8408
		+ ·3927	
$1\frac{3}{4}$	5	·4978 × 8 =	$\frac{3}{8}$·9824*
		+ ·3927	
$1\frac{7}{8}$	5	·8905 × 8 =	$\frac{7}{8}$·1240
		+ ·3927	
2	6	·2832 × 8 =	$\frac{1}{4}$·2656

Note.—The nearest eighth of an inch is only given, as I thought it quite unnecessary to add the first decimal figure in this Table.

J. F.

* This is nearly $\frac{4}{8}$, but the table is constructed on the uniform principle of never giving values in *excess*. The defect can never be so great as $\frac{1}{8}$ of an inch (*See Note A. at the end*).

TABLE II.*

SHOWING THE WEIGHT OF A LINEAL FOOT OF MALLEABLE RECTANGULAR OR FLAT IRON,

From an Eighth of an Inch to Three Inches thick; advancing by an Eighth and Quarter of an Inch in breadth.

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
⅛	¼	0	1·6	⅛	3⅞	1	9·7	⅛	7½	3	1·8
	⅜	0	2·4		4	1	10·5		7⅝	3	2·6
	½	0	3·3		4⅛	1	11·3		7¾	3	3·4
	⅝	0	4·1		4¼	1	12·2		7⅞	3	4·3
	¾	0	5·0		4⅜	1	13·0		8	3	5·1
	⅞	0	5·8		4½	1	13·8		8⅛	3	5·9
	1	0	6·6		4⅝	1	14·7		8¼	3	6·7
	1⅛	0	7·5		4¾	1	15·5		8⅜	3	7·6
	1¼	0	8·3		4⅞	2	0·3		8½	3	8·4
	1⅜	0	9·1		5	2	1·2		8⅝	3	9·2
	1½	0	9·9		5⅛	2	2·0		8¾	3	10·1
	1⅝	0	10·8		5¼	2	2·8		8⅞	3	11·0
	1¾	0	11·6		5⅜	2	3·7		9	3	11·7
	1⅞	0	12·4		5½	2	4·5		9⅛	3	12·6
	2	0	13·2		5⅝	2	5·3		9¼	3	13·4
	2⅛	0	14·1		5¾	2	6·1		9⅜	3	14·2
	2¼	0	14·9		5⅞	2	7·0		9½	3	15·0
	2⅜	0	15·7		6	2	7·8		9⅝	3	15·9
	2½	1	0·6		6⅛	2	8·6		9¾	4	0·7
	2⅝	1	1·4		6¼	2	9·5		9⅞	4	1·5
	2¾	1	2·2		6⅜	2	10·3		10	4	2·4
	2⅞	1	3·0		6½	2	11·1		10⅛	4	3·2
	3	1	3·9		6⅝	2	12·0		10¼	4	4·0
	3⅛	1	4·7		6¾	2	12·8		10⅜	4	4·9
	3¼	1	5·5		6⅞	2	13·6		10½	4	5·7
	3⅜	1	6·4		7	2	14·4		10⅝	4	6·5
	3½	1	7·2		7⅛	2	15·3		10¾	4	7·3
	3⅝	1	8·0		7¼	3	0·1		10⅞	4	8·2
	3¾	1	8·9		7⅜	3	1·0		11	4	9·0

* James Foden.

Thick.	Broad.	lbs.	oz.
in.	in.		
⅛	11⅛	4	9·8
	11¼	4	10·7
	11⅜	4	11·5
	11½	4	12·3
	11⅝	4	13·2
	11¾	4	14·0
	11⅞	4	14·8
	12	4	15·6
¼	½	0	6·6
	⅝	0	8·3
	¾	0	10·0
	⅞	0	11·6
	1	0	13·2
	1⅛	0	14·9
	1¼	1	0·6
	1⅜	1	2·2
	1½	1	3·9
	1⅝	1	5·5
	1¾	1	7·2
	1⅞	1	9·0
	2	1	10·5
	2⅛	1	12·2
	2¼	1	13·8
	2⅜	1	15·5
	2½	2	1·2
	2⅝	2	2·8
	2¾	2	4·5
	2⅞	2	6·1
	3	2	7·8
	3⅛	2	9·5
	3¼	2	11·1
	3⅜	2	12·8
	3½	2	14·4
	3⅝	3	0·1
	3¾	3	1·8
	3⅞	3	3·4
¼	4	3	5·1
	4⅛	3	6·7
	4¼	3	8·4
	4⅜	3	10·1
	4½	3	11·7
	4⅝	3	13·4
	4¾	3	15·0
	4⅞	4	0·7
	5	4	2·4
	5⅛	4	4·0
	5¼	4	5·7
	5⅜	4	7·3
	5½	4	9·0
	5⅝	4	10·7
	5¾	4	12·3
	5⅞	4	14·0
	6	4	15·6
	6⅛	5	1·3
	6¼	5	3·0
	6⅜	5	4·6
	6½	5	6·3
	6⅝	5	7·9
	6¾	5	9·6
	6⅞	5	11·3
	7	5	13·0
	7⅛	5	14·6
	7¼	6	0·2
	7⅜	6	2·0
	7½	6	3·6
	7⅝	6	5·2
	7¾	6	7·0
	7⅞	6	8·5
	8	6	10·2
	8⅛	6	12·0
	8¼	6	13·5
	8⅜	6	15·2
	8½	7	0·8
¼	8⅝	7	2·5
	8¾	7	4·2
	8⅞	7	5·8
	9	7	7·5
	9⅛	7	9·1
	9¼	7	10·8
	9⅜	7	12·5
	9½	7	14·1
	9⅝	7	15·8
	9¾	8	1·4
	9⅞	8	3·1
	10	8	4·8
	10⅛	8	6·4
	10¼	8	8·1
	10⅜	8	9·7
	10½	8	11·4
	10⅝	8	13·1
	10¾	8	14·7
	10⅞	9	0·4
	11	9	2·0
	11⅛	9	3·7
	11¼	9	5·4
	11⅜	9	7·0
	11½	9	8·7
	11⅝	9	10·3
	11¾	9	12·0
	11⅞	9	13·7
	12	9	15·3
⅜	¾	0	14·9
	⅞	1	1·3
	1	1	3·8
	1⅛	1	6·3
	1¼	1	8·8
	1⅜	1	11·3
	1½	1	13·8
	1⅝	2	0·3

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
⅜	1¾	2	2·7	⅜	6⅜	7	14·6	⅜	11	13	10·5
	1⅞	2	5·2		6½	8	1·1		11⅛	13	13·0
	2	2	7·7		6⅝	8	3·6		11¼	13	15·5
	2⅛	2	10·2		6¾	8	6·1		11⅜	14	2·0
	2¼	2	12·7		6⅞	8	8·6		11½	14	4·5
	2⅜	2	15·1		7	8	11·1		11⅝	14	7·0
	2½	3	1·6		7⅛	8	13·5		11¾	14	9·4
	2⅝	3	4·1		7¼	9	0·0		11⅞	14	11·9
	2¾	3	6·6		7⅜	9	2·5		12	14	14·4
	2⅞	3	9·1		7½	9	5·0				
	3	3	11·6		7⅝	9	7·5	½	1	1	10·4
	3⅛	3	14·1		7¾	9	10·0		1⅛	1	13·8
	3¼	4	0·5		7⅞	9	12·4		1¼	2	1·1
	3⅜	4	3·0		8	9	14·9		1⅜	2	4·4
	3½	4	5·5		8⅛	10	1·4		1½	2	7·7
	3⅝	4	8·0		8¼	10	3·9		1⅝	2	11·0
	3¾	4	10·5		8⅜	10	6·4		1¾	2	14·3
	3⅞	4	13·0		8½	10	8·9		1⅞	3	1·6
	4	4	15·4		8⅝	10	11·3		2	3	4·9
	4⅛	5	1·9		8¾	10	13·8		2⅛	3	8·3
	4¼	5	4·4		8⅞	11	0·3		2¼	3	11·6
	4⅜	5	6·9		9	11	2·8		2⅜	3	14·9
	4½	5	9·4		9⅛	11	5·3		2½	4	2·2
	4⅝	5	11·9		9¼	11	7·8		2⅝	4	5·5
	4¾	5	14·3		9⅜	11	10·3		2¾	4	8·8
	4⅞	6	0·8		9½	11	12·7		2⅞	4	12·1
	5	6	3·3		9⅝	11	15·2		3	4	15·4
	5⅛	6	5·8		9¾	12	1·7		3⅛	5	2·8
	5¼	6	8·3		9⅞	12	4·2		3¼	5	6·1
	5⅜	6	10·8		10	12	6·7		3⅜	5	9·4
	5½	6	13·2		10⅛	12	9·2		3½	5	12·7
	5⅝	6	15·7		10¼	12	11·6		3⅝	6	0·0
	5¾	7	2·2		10⅜	12	14·1		3¾	6	3·3
	5⅞	7	4·7		10½	13	0·6		3⅞	6	6·6
	6	7	7·2		10⅝	13	3·1		4	6	9·9
	6⅛	7	9·7		10¾	13	5·6		4⅛	6	13·3
	6¼	7	12·2		10⅞	13	8·1		4¼	7	0·6

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
½	4⅜	7	3·9	½	9	14	14·4	⅝	2⅝	5	6·9
	4½	7	7·2		9⅛	15	1·7		2¾	5	11·0
	4⅝	7	10·5		9¼	15	5·0		2⅞	5	15·2
	4¾	7	13·8		9⅜	15	8·4		3	6	3·3
	4⅞	8	1·1		9½	15	11·7		3⅛	6	7·5
	5	8	4·4		9⅝	15	15·0		3¼	6	11·6
	5⅛	8	7·7		9¾	16	2·3		3⅜	6	15·7
	5¼	8	11·1		9⅞	16	5·6		3½	7	3·9
	5⅜	8	14·4		10	16	8·9		3⅝	7	8·0
	5½	9	1·7		10⅛	16	12·2		3¾	7	12·2
	5⅝	9	5·0		10¼	16	15·5		3⅞	8	0·3
	5¾	9	8·3		10⅜	17	2·8		4	8	4·4
	5⅞	9	11·6		10½	17	6·2		4⅛	8	8·6
	6	9	14·9		10⅝	17	9·5		4¼	8	12·7
	6⅛	10	2·2		10¾	17	12·8		4⅜	9	0·9
	6¼	10	5·6		10⅞	18	0·1		4½	9	5·0
	6⅜	10	8·9		11	18	3·4		4⅝	9	9·1
	6½	10	12·2		11⅛	18	6·7		4¾	9	13·3
	6⅝	10	15·5		11¼	18	10·0		4⅞	10	1·4
	6¾	11	2·8		11⅜	18	13·3		5	10	5·6
	6⅞	11	6·1		11½	19	0·7		5⅛	10	9·7
	7	11	9·4		11⅝	19	4·0		5¼	10	13·8
	7⅛	11	12·7		11¾	19	7·3		5⅜	11	2·0
	7¼	12	0·0		11⅞	19	10·6		5½	11	6·1
	7⅜	12	3·4		12	19	13·9		5⅝	11	10·3
	7½	12	6·7						5¾	11	14·4
	7⅝	12	10·0	⅝	1¼	2	9·4		5⅞	12	2·5
	7¾	12	13·3		1⅜	2	13·5		6	12	6·7
	7⅞	13	0·6		1½	3	1·6		6⅛	12	10·8
	8	13	3·9		1⅝	3	5·8		6¼	12	15·0
	8⅛	13	7·2		1¾	3	9·9		6⅜	13	3·1
	8¼	13	10·5		1⅞	3	14·1		6½	13	7·2
	8⅜	13	13·9		2	4	2·2		6⅝	13	11·4
	8½	14	1·2		2⅛	4	6·3		6¾	13	15·5
	8⅝	14	4·5		2¼	4	10·5		6⅞	14	3·7
	8¾	14	7·8		2⅜	4	14·6		7	14	7·8
	8⅞	14	11·1		2½	5	2·8		7⅛	14	11·9

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
⅝	7¼	15	0·1	⅝	11⅞	24	9·3	¾	5¾	14	4·5
	7⅜	15	4·2		12	24	13·4		5⅞	14	9·5
	7½	15	8·4						6	14	14·4
	7⅝	15	12·5	¾	1½	3	11·6		6⅛	15	3·4
	7¾	16	0·6		1⅝	4	0·5		6¼	15	8·4
	7⅞	16	4·8		1¾	4	5·5		6⅜	15	13·3
	8	16	8·9		1⅞	4	10·5		6½	16	2·3
	8⅛	16	13·1		2	4	15·4		6⅝	16	7·3
	8¼	17	1·2		2⅛	5	4·4		6¾	16	12·2
	8⅜	17	5·3		2¼	5	9·4		6⅞	17	1·2
	8½	17	9·5		2⅜	5	14·3		7	17	6·2
	8⅝	17	13·6		2½	6	3·3		7⅛	17	11·1
	8¾	18	1·8		2⅝	6	8·3		7¼	18	0·1
	8⅞	18	5·9		2¾	6	13·2		7⅜	18	5·1
	9	18	10·0		2⅞	7	2·2		7½	18	10·0
	9⅛	18	14·2		3	7	7·2		7⅝	18	15·0
	9¼	19	2·3		3⅛	7	12·2		7¾	19	4·0
	9⅜	19	6·5		3¼	8	1·1		7⅞	19	8·9
	9½	19	10·6		3⅜	8	6·1		8	19	13·9
	9⅝	19	14·7		3½	8	11·1		8⅛	20	2·9
	9¾	20	2·9		3⅝	9	0·0		8¼	20	7·8
	9⅞	20	7·0		3¾	9	5·0		8⅜	20	12·8
	10	20	11·2		3⅞	9	10·0		8½	21	1·8
	10⅛	20	15·3		4	9	14·9		8⅝	21	6·7
	10¼	21	3·4		4⅛	10	3·9		8¾	21	11·7
	10⅜	21	7·6		4¼	10	8·9		8⅞	22	0·7
	10½	21	11·7		4⅜	10	13·8		9	22	5·7
	10⅝	21	15·9		4½	11	2·8		9⅛	22	10·6
	10¾	22	4·0		4⅝	11	7·8		9¼	22	15·6
	10⅞	22	8·1		4¾	11	12·7		9⅜	23	4·6
	11	22	12·3		4⅞	12	1·7		9½	23	9·5
	11⅛	23	0·4		5	12	6·7		9⅝	23	14·5
	11¼	23	4·6		5⅛	12	11·6		9¾	24	3·5
	11⅜	23	8·7		5¼	13	0·6		9⅞	24	8·4
	11½	23	12·8		5⅜	13	5·6		10	24	13·4
	11⅝	24	1·0		5½	13	10·6		10⅛	25	2·4
	11¾	24	5·1		5⅝	13	15·5		10¼	25	7·3

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
in.	in.				in.	in.			in.	in.			
3/4	10 3/8	0	25	12·3	7/8	4 1/2	13	0·6	7/8	9 1/8	0	26	7·1
	10 1/2	0	26	1·3		4 5/8	13	6·4		9 1/4	0	26	12·9
	10 5/8	0	26	6·2		4 3/4	13	12·2		9 3/8	0	27	2·7
	10 3/4	0	26	11·2		4 7/8	14	2·0		9 1/2	0	27	8·5
	10 7/8	0	27	0·2		5	14	7·8		9 5/8	0	27	14·3
	11	0	27	5·1		5 1/8	14	13·6		9 3/4	1	0	4·0
	11 1/8	0	27	10·1		5 1/4	15	3·4		9 7/8	1	0	9·8
	11 1/4	0	27	15·1		5 3/8	15	9·2		10	1	0	15·6
	11 3/8	1	0	4·0		5 1/2	15	15·0		10 1/8	1	1	5·4
	11 1/2	1	0	9·0		5 5/8	16	4·8		10 1/4	1	1	11·2
	11 5/8	1	0	14·0		5 3/4	16	10·6		10 3/8	1	2	1·0
	11 3/4	1	1	3·0		5 7/8	17	0·4		10 1/2	1	2	6·8
	11 7/8	1	1	7·9		6	17	6·2		10 5/8	1	2	12·6
	12	1	1	12·9		6 1/8	17	12·0		10 3/4	1	3	2·4
						6 1/4	18	1·8		10 7/8	1	3	8·2
7/8	1 3/4	0	5	1·1		6 3/8	18	7·6		11	1	3	14·0
	1 7/8	0	5	6·9		6 1/2	18	13·4		11 1/8	1	4	3·8
	2	0	5	12·7		6 5/8	19	3·1		11 1/4	1	4	9·6
	2 1/8	0	6	2·5		6 3/4	19	8·9		11 3/8	1	4	15·4
	2 1/4	0	6	8·3		6 7/8	19	14·7		11 1/2	1	5	5·2
	2 3/8	0	6	14·1		7	20	4·5		11 5/8	1	5	11·0
	2 1/2	0	7	3·9		7 1/8	20	10·3		11 3/4	1	6	0·8
	2 5/8	0	7	9·7		7 1/4	21	0·1		11 7/8	1	6	6·6
	2 3/4	0	7	15·5		7 3/8	21	5·9		12	1	6	12·4
	2 7/8	0	8	5·3		7 1/2	21	11·7					
	3	0	8	11·1		7 5/8	22	1·5	1	2	0	6	10·0
	3 1/8	0	9	0·9		7 3/4	22	7·3		2 1/8	0	7	0·6
	3 1/4	0	9	6·7		7 7/8	22	13·1		2 1/4	0	7	7·2
	3 3/8	0	9	12·4		8	23	2·9		2 3/8	0	7	13·8
	3 1/2	0	10	2·2		8 1/8	23	8·7		2 1/2	0	8	4·4
	3 5/8	0	10	8·0		8 1/4	23	14·5		2 5/8	0	8	11·1
	3 3/4	0	10	13·8		8 3/8	24	4·3		2 3/4	0	9	1·7
	3 7/8	0	11	3·6		8 1/2	24	10·1		2 7/8	0	9	8·3
	4	0	11	9·4		8 5/8	24	15·9		3	0	9	14·7
	4 1/8	0	11	15·2		8 3/4	25	5·7		3 1/8	0	10	5·6
	4 1/4	0	12	5·0		8 7/8	25	11·5		3 1/4	0	10	12·2
	4 3/8	0	12	10·8		9	26	1·3		3 3/8	0	11	2·8

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			in.	in.				in.	in.			
1	3½	11	9·4	1	6⅜	0	21	1·8	1	9¼	1	2	10·1
	3⅝	12	0·1		6½	0	21	8·4		9⅜	1	3	0·8
	3¾	12	6·7		6⅝	0	21	15·0		9½	1	3	7·4
	3⅞	12	13·3		6¾	0	22	5·7		9⅝	1	3	14·0
	4	13	3·9		6⅞	0	22	12·3		9¾	1	4	4·6
	4⅛	13	10·6		7	0	23	2·9		9⅞	1	4	11·2
	4¼	14	1·2		7⅛	0	23	9·5		10	1	5	1·9
	4⅜	14	7·8		7¼	0	24	0·2		10⅛	1	5	8·5
	4½	14	14·4		7⅜	0	24	6·6		10¼	1	5	15·1
	4⅝	15	5·0		7½	0	24	13·4		10⅜	1	6	5·8
	4¾	15	11·7		7⅝	0	25	4·0		10½	1	6	12·4
	4⅞	16	2·3		7¾	0	25	10·6		10⅝	1	7	3·0
	5	16	8·9		7⅞	0	26	1·3		10¾	1	7	9·6
	5⅛	16	15·5		8	0	26	7·9		10⅞	1	8	0·2
	5¼	17	6·2		8⅛	0	26	14·5		11	1	8	6·9
	5⅜	17	12·8		8¼	0	27	5·1		11⅛	1	8	13·5
	5½	18	3·4		8⅜	0	27	11·8		11¼	1	9	4·1
	5⅝	18	10·0		8½	1	0	2·4		11⅜	1	9	10·7
	5¾	19	0·7		8⅝	1	0	9·0		11½	1	10	1·4
	5⅞	19	7·3		8¾	1	0	15·6		11⅝	1	10	8·0
	6	19	13·9		8⅞	1	1	6·3		11¾	1	10	14·6
	6⅛	20	4·5		9	1	1	12·9		11⅞	1	11	5·2
	6¼	20	11·2		9⅛	1	2	3·5		12	1	11	11·9

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
1⅛	2¼	0	8	6·1
	2½	0	9	5·0
	2¾	0	10	3·9
	3	0	11	2·8
	3¼	0	12	1·7
	3½	0	13	0·6
	3¾	0	13	15·5
	4	0	14	14·4
	4¼	0	15	13·3
	4½	0	16	12·2
	4¾	0	17	11·1
	5	0	18	10·0
	5¼	0	19	8·9
	5½	0	20	7·8
	5¾	0	21	6·8
	6	0	22	5·7
	6¼	0	23	4·6
	6½	0	24	3·5
	6¾	0	25	2·4
	7	0	26	1·3
	7¼	0	27	0·2
	7½	0	27	15·1
	7¾	1	0	14·0
	8	1	1	12·9
	8¼	1	2	11·8
	8½	1	3	10·7
	8¾	1	4	9·6
	9	1	5	8·5
	9¼	1	6	7·4
	9½	1	7	6·3
	9¾	1	8	5·2
	10	1	9	4·1
	10¼	1	10	3·0
	10½	1	11	1·9
	10¾	1	12	0·8
	11	1	12	15·7
	11¼	1	13	14·6

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
1⅛	11½	1	14	13·5
	11¾	1	15	12·4
	12	1	16	11·4
1¼	2½	0	10	5·6
	2¾	0	11	6·1
	3	0	12	6·7
	3¼	0	13	7·2
	3½	0	14	7·8
	3¾	0	15	8·4
	4	0	16	8·9
	4¼	0	17	9·5
	4½	0	18	10·0
	4¾	0	19	10·6
	5	0	20	11·2
	5¼	0	21	11·7
	5½	0	22	12·3
	5¾	0	23	12·8
	6	0	24	13·4
	6¼	0	25	14·0
	6½	0	26	14·5
	6¾	0	27	15·1
	7	1	0	15·6
	7¼	1	2	0·2
	7½	1	3	0·8
	7¾	1	4	1·3
	8	1	5	1·9
	8¼	1	6	2·4
	8½	1	7	3·0
	8¾	1	8	3·6
	9	1	9	4·1
	9¼	1	10	4·7
	9½	1	11	5·2
	9¾	1	12	5·8
	10	1	13	6·4
	10¼	1	14	6·9
	10½	1	15	7·5

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
1¼	10¾	1	16	8·0
	11	1	17	8·6
	11¼	1	18	9·2
	11½	1	19	9·7
	11¾	1	20	10·3
	12	1	21	10·8
1⅜	2¾	0	12	8·3
	3	0	13	10·6
	3¼	0	14	12·8
	3½	0	15	15·0
	3¾	0	17	1·2
	4	0	18	3·4
	4¼	0	19	5·6
	4½	0	20	7·8
	4¾	0	21	10·1
	5	0	22	12·3
	5¼	0	23	14·5
	5½	0	25	0·7
	5¾	0	26	2·9
	6	0	27	5·1
	6¼	1	0	7·4
	6½	1	1	9·6
	6¾	1	2	11·8
	7	1	3	14·0
	7¼	1	5	0·2
	7½	1	6	2·4
	7¾	1	7	4·7
	8	1	8	6·9
	8¼	1	9	9·1
	8½	1	10	11·3
	8¾	1	11	13·5
	9	1	12	15·7
	9¼	1	14	2·0
	9½	1	15	4·2
	9¾	1	16	6·4
	10	1	17	8·6

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
1⅜	10¼	1	18	10·8
	10½	1	19	13·0
	10¾	1	20	15·2
	11	1	22	1·5
	11¼	1	23	3·7
	11½	1	24	5·9
	11¾	1	25	8·1
	12	1	26	10·3
1½	3	0	14	14·4
	3¼	0	16	2·3
	3½	0	17	6·2
	3¾	0	18	10·0
	4	0	19	13·9
	4¼	0	21	1·8
	4½	0	22	5·7
	4¾	0	23	9·5
	5	0	24	13·4
	5¼	0	26	1·3
	5½	0	27	5·1
	5¾	1	0	9·0
	6	1	1	12·9
	6¼	1	3	0·8
	6½	1	4	4·6
	6¾	1	5	8·5
	7	1	6	12·4
	7¼	1	8	0·2
	7½	1	9	4·1
	7¾	1	10	8·0
	8	1	11	11·9
	8¼	1	12	15·7
	8½	1	14	3·6
	8¾	1	15	7·5
	9	1	16	11·4
	9¼	1	17	15·2
	9½	1	19	3·1
	9¾	1	20	7·0

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
1½	10	1	21	10·8
	10¼	1	22	14·7
	10½	1	24	2·6
	10¾	1	25	6·5
	11	1	26	10·3
	11¼	1	27	14·2
	11½	2	1	2·1
	11¾	2	2	5·9
	12	2	3	9·8
1⅝	3¼	0	17	7·8
	3½	0	18	13·4
	3¾	0	20	2·9
	4	0	21	8·4
	4¼	0	22	13·9
	4½	0	24	3·5
	4¾	0	25	9·0
	5	0	26	14·5
	5¼	1	0	4·0
	5½	1	1	9·6
	5¾	1	2	15·1
	6	1	4	4·6
	6¼	1	5	10·2
	6½	1	6	15·7
	6¾	1	8	5·2
	7	1	9	10·7
	7¼	1	11	0·3
	7½	1	12	5·8
	7¾	1	13	11·3
	8	1	15	0·9
	8¼	1	16	6·4
	8½	1	17	11·9
	8¾	1	19	1·4
	9	1	20	7·0
	9¼	1	21	12·5
	9½	1	23	2·0
	9¾	1	24	7·6

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
1⅝	10	1	25	13·1
	10¼	1	27	2·6
	10½	2	0	8·1
	10¾	2	1	13·7
	11	2	3	3·2
	11¼	2	4	8·7
	11½	2	5	14·2
	11¾	2	7	3·8
	12	2	8	9·3
1¾	3½	0	20	4·5
	3¾	0	21	11·7
	4	0	23	2·9
	4¼	0	24	10·1
	4½	0	26	1·3
	4¾	0	27	8·5
	5	1	0	15·6
	5¼	1	2	6·8
	5½	1	3	14·0
	5¾	1	5	5·2
	6	1	6	12·4
	6¼	1	8	3·6
	6½	1	9	10·7
	6¾	1	11	1·9
	7	1	12	9·1
	7¼	1	14	0·3
	7½	1	15	7·5
	7¾	1	16	14·7
	8	1	18	5·8
	8¼	1	19	13·0
	8½	1	21	4·2
	8¾	1	22	11·4
	9	1	24	2·6
	9¼	1	25	9·8
	9½	1	27	1·0
	9¾	2	0	8·1
	10	2	1	15·5

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	ox.
in.	in.				in.	in.				in.	in.			
1¾	10¼	2	3	6·5	1⅞	10¾	2	10	12·1	2	11½	2	20	2·8
	10½	2	4	13·7		11	2	12	4·9		11¾	2	21	13·3
	10¾	2	6	4·9		11¼	2	13	13·8		12	2	23	7·8
	11	2	7	12·1		11½	2	15	6·6					
	11¼	2	9	3·2		11¾	2	16	15·4	2⅛	4¼	1	1	14·5
	11½	2	10	10·4		12	2	18	8·3		4½	1	3	10·7
	11¾	2	12	1·6							4¾	1	5	6·8
	12	2	13	8·8	2	4	0	26	7·9		5	1	7	3·0
						4¼	1	0	2·4		5¼	1	8	15·2
1⅞	3¾	0	23	4·6		4½	1	1	12·9		5½	1	10	11·3
	4	0	24	13·4		4¾	1	3	7·4		5¾	1	12	7·5
	4¼	0	26	6·2		5	1	5	1·9		6	1	14	3·6
	4½	0	27	15·1		5¼	1	6	12·4		6¼	1	15	15·8
	4¾	1	1	7·9		5½	1	8	6·9		6½	1	17	11·9
	5	1	3	0·8		5¾	1	10	1·4		6¾	1	19	8·1
	5¼	1	4	9·6		6	1	11	11·9		7	1	21	4·2
	5½	1	6	2·4		6¼	1	13	6·4		7¼	1	23	0·4
	5¾	1	7	11·3		6½	1	15	0·9		7½	1	24	12·5
	6	1	9	4·6		6¾	1	16	11·4		7¾	1	26	8·7
	6¼	1	10	13·0		7	1	18	5·8		8	2	0	4·8
	6½	1	12	5·8		7¼	1	20	0·3		8¼	2	2	1·0
	6¾	1	13	14·6		7½	1	21	10·8		8½	2	3	13·1
	7	1	15	7·5		7¾	1	23	5·3		8¾	2	5	9·3
	7¼	1	17	0·3		8	1	24	15·8		9	2	7	5·4
	7½	1	18	9·2		8¼	1	26	10·3		9¼	2	9	1·6
	7¾	1	20	2·0		8½	2	0	4·8		9½	2	10	13·7
	8	1	21	10·8		8¾	2	1	15·3		9¾	2	12	9·9
	8¼	1	23	3·7		9	2	3	9·0		10	2	14	6·0
	8½	1	24	12·5		9¼	2	5	4·3		10¼	2	16	2·2
	8¾	1	26	5·4		9½	2	6	14·8		10½	2	17	14·3
	9	1	27	14·2		9¾	2	8	9·3		10¾	2	19	10·5
	9¼	2	1	7·0		10	2	10	3·8		11	2	21	6·6
	9½	2	2	15·9		10¼	2	11	14·3		11¼	2	23	2·8
	9¾	2	4	8·7		10½	2	13	8·8		11½	2	24	15·0
	10	2	6	1·6		10¾	2	15	3·3		11¾	2	26	11·1
	10¼	2	7	10·4		11	2	16	13·8		12	3	0	7·3
	10½	2	9	3·2		11¼	2	18	8·3					

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
in.	in.				in.	in.				in.	in.			
2¼	4½	1	5	8·5	2⅜	6	1	19	3·1	2½	7¾	2	8	2·7
	4¾	1	7	6·3		6¼	1	21	2·6		8	2	10	3·8
	5	1	9	4·1		6½	1	23	2·0		8¼	2	12	4·9
	5¼	1	11	1·9		6¾	1	25	1·5		8½	2	14	6·0
	5½	1	12	15·7		7	1	27	1·0		8¾	2	16	7·2
	5¾	1	14	13·5		7¼	2	1	0·4		9	2	18	8·3
	6	1	16	11·4		7½	2	2	15·9		9¼	2	20	9·4
	6¼	1	18	9·2		7¾	2	4	15·3		9½	2	22	10·5
	6½	1	20	7·0		8	2	6	14·8		9¾	2	24	11·6
	6¾	1	22	4·8		8¼	2	8	14·3		10	2	26	12·8
	7	1	24	2·6		8½	2	10	13·7		10¼	3	0	13·9
	7¼	1	26	0·4		8¾	2	12	13·2		10½	3	2	15·0
	7½	1	27	14·2		9	2	14	12·7		10¾	3	5	0·1
	7¾	2	1	12·0		9¼	2	16	12·1		11	3	7	1·2
	8	2	3	9·8		9½	2	18	11·6		11¼	3	9	2·4
	8¼	2	5	7·6		9¾	2	20	11·1		11½	3	11	3·5
	8½	2	7	5·4		10	2	22	10·5		11¾	3	13	4·6
	8¾	2	9	3·2		10¼	2	24	10·0		12	3	15	5·7
	9	2	11	1·0		10½	2	26	9·4					
	9¼	2	12	14·9		10¾	3	0	8·9	2⅝	5¼	1	17	10·3
	9½	2	14	12·7		11	3	2	8·4		5½	1	19	13·0
	9¾	2	16	10·5		11¼	3	4	7·8		5¾	1	21	15·8
	10	2	18	8·3		11½	3	6	7·3		6	1	24	2·6
	10¼	2	20	6·1		11¾	3	8	6·8		6¼	1	26	5·4
	10½	2	22	3·9		12	3	10	6·2		6½	2	0	8·1
	10¾	2	24	1·7							6¾	2	2	10·9
	11	2	25	15·5	2½	5	1	13	6·4		7	2	4	13·7
	11¼	2	27	13·3		5¼	1	15	7·5		7¼	2	7	0·5
	11½	3	1	11·1		5½	1	17	8·6		7½	2	9	3·2
	11¾	3	3	8·9		5¾	1	19	9·7		7¾	2	11	6·0
	12	3	5	6·7		6	1	21	10·8		8	2	13	8·8
						6¼	1	23	12·0		8¼	2	15	11·6
2⅜	4¾	1	9	5·8		6½	1	25	13·1		8½	2	17	14·3
	5	1	11	5·2		6¾	1	27	14·2		8¾	2	20	1·1
	5¼	1	13	4·7		7	2	1	15·3		9	2	22	3·9
	5½	1	15	4·2		7¼	2	4	0·4		9¼	2	24	6·7
	5¾	1	17	3·6		7½	2	6	1·6		9½	2	26	9·4

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
in.	in.				in.	in.				in.	in.			
2⅝	9¾	3	0	12·2	2¾	10½	3	11	10·1	2⅞	11¼	3	23	1·9
	10	3	2	15·0		10¾	3	13	14·5		11½	3	25	8·0
	10¼	3	5	1·8		11	3	16	3·0		11¾	3	27	14·1
	10½	3	7	4·6		11¼	3	18	7·4		12	4	2	4·2
	10¾	3	9	7·3		11½	3	20	11·8					
	11	3	11	10·1		11¾	3	23	0·3	3	6	2	3	9·8
	11¼	3	13	12·9		12	3	25	4·7		6¼	2	6	1·6
	11½	3	15	15·7							6½	2	8	9·3
	11¾	3	18	2·4	2⅞	5¾	1	26	12·0		6¾	2	11	1·0
	12	3	20	5·2		6	2	1	2·1		7	2	13	8·8
						6¼	2	3	8·2		7¼	2	16	0·5
2¾	5½	1	22	1·5		6½	2	5	14·2		7½	2	18	8·3
	5¾	1	24	5·9		6¾	2	8	4·3		7¾	2	21	0·0
	6	1	26	10·3		7	2	10	10·4		8	2	23	7·8
	6¼	2	0	14·8		7¼	2	13	0·5		8¼	2	25	15·5
	6½	2	3	3·2		7½	2	15	6·6		8½	3	0	7·3
	6¾	2	5	7·6		7¾	2	17	12·7		8¾	3	2	15·0
	7	2	7	12·1		8	2	20	2·8		9	3	5	6·7
	7¼	2	10	0·5		8¼	2	22	8·9		9¼	3	7	14·5
	7½	2	12	4·9		8½	2	24	15·0		9½	3	10	6·2
	7¾	2	14	9·4		8¾	2	27	5·0		9¾	3	12	14·0
	8	2	16	13·8		9	3	1	11·1		10	3	15	5·7
	8¼	2	19	2·2		9¼	3	4	1·2		10¼	3	17	13·5
	8½	2	21	6·6		9½	3	6	7·3		10½	3	20	5·2
	8¾	2	23	11·1		9¾	3	8	13·4		10¾	3	22	13·0
	9	2	25	15·5		10	3	11	3·5		11	3	25	4·7
	9¼	3	0	3·9		10¼	3	13	9·6		11¼	3	27	12·4
	9½	3	2	8·4		10½	3	15	15·7		11½	4	2	4·2
	9¾	3	4	12·8		10¾	3	18	5·7		11¾	4	4	11·9
	10	3	7	1·2		11	3	20	11·8		12	4	7	3·7
	10¼	3	9	5·7										

The weights here given, are in pounds, ounces, and decimal parts, avoirdupois; and it will be seen, on inspecting the Table, that the first numbers in each page are those which apply to nut iron, and that the breadth increases by $\frac{1}{8}$ of an inch as far as page 86, after which they rise by $\frac{1}{4}$ of an inch in breadth to the end. The last numbers in each page show the weight of a square foot, according to the respective thickness of each bar. Hence the weight of any length of a bar of rectangular iron may be ascertained simply, as follows:

Rule.—Multiply the tabular weight, according to the thickness and breadth, by the number of feet in the bar, the product will be the weight required.

Example.—In a bar of iron whose thickness is $2\frac{5}{8}$ inches, the breadth $6\frac{3}{4}$ inches, and the length 18 feet, what is the weight thereof?

In the Table for $2\frac{5}{8}$ inches thick, and opposite $6\frac{3}{4}$ inches, stand 2qrs. 2lbs. 10·9oz., being the weight of one lineal foot. Multiply this number by 18 feet, and we have as follows:

cwt.	qrs.	lbs.	oz.	
0	2	2	10·9	
			6	× 3=18
3	0	16	1·4	
			3	
9	1	20	4·2	Answer.

The foregoing Table of weights is obtained by the following approximate rule:

Multiply the area of the end of the bar by the length of one foot, and multiply that product by 3·32, the product will be the weight in pounds avoirdupois, nearly.*

* By this rule the weight of any length of malleable rectangular iron may be ascertained nearly.

Ex.—Required the weight of one lineal foot of malleable iron, ½ inch thick, and 2¼ inches broad.

2·25 × ·5 = 1·125 × 1 × 1·125 × 3·32 = 3·735 lbs. or 3 lbs. 11·76 oz.

But for the sake of expedition these Tables have been constructed as follows. Having found by the above rule, the weight of one lineal foot for ⅛th of an inch according to the thickness, it has been constantly added until the breadth has attained to one foot.

Example.

·125 = ⅛, then
·125 × ·125 = ·015625 × 3·32 = ·05187500 lbs. × 16 = ·83 oz.

Here	·83
	+ ·83
Ounce	1·66 = ¼ inch broad.
	+ ·83
	2·49 = ⅜
	+ ·83
	3·32 = ½
	+ ·83
	4·15 = ⅝
	+ ·83
	4·98 = ¾
	+ ·83
	5·81 = ⅞
	+ ·83
	6·64 = 1 inch broad.

N.B. The Tables advancing by ¼ of an inch in breadth are constructed in the same manner as the above.

TABLE III.*

SHOWING THE WEIGHT OF A LINEAL FOOT OF ROUND BAR IRON,

In Avoirdupois qrs. lbs. oz., from ⅛th of an Inch to 12 Inches Diameter, advancing by ⅛th of an Inch.

Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.
⅛	0	0	0·4	4⅛	1	16	4·1	8⅛	6	3	10·1
¼	0	0	2·6	4¼	1	18	15·8	8¼	6	8	15·4
⅜	0	0	5·8	4⅜	1	21	12·6	8⅜	6	14	5·8
½	0	0	10·4	4½	1	24	10·8	8½	6	19	13·6
⅝	0	1	0·1	4⅝	1	27	10·2	8⅝	6	25	6·7
¾	0	1	7·3	4¾	2	2	11·0	8¾	7	3	1·0
⅞	0	1	15·8	4⅞	2	5	13·1	8⅞	7	8	12·7
1	0	2	9·4	5	2	9	0·6	9	7	14	9·6
1⅛	0	3	4·8	5⅛	2	12	5·2	9⅛	7	20	7·8
1¼	0	4	1·1	5¼	2	15	11·0	9¼	7	26	7·4
1⅜	0	4	14·7	5⅜	2	19	2·4	9⅜	8	4	8·2
1½	0	5	13·7	5½	2	22	11·0	9½	8	10	10·4
1⅝	0	6	13·9	5⅝	2	26	4·8	9⅝	8	16	13·8
1¾	0	7	15·5	5¾	3	2	0·1	9¾	8	23	2·6
1⅞	0	9	2·4	5⅞	3	5	12·6	9⅞	9	1	8·6
2	0	10	6·5	6	3	9	10·4	10	9	8	0·0
2⅛	0	11	12·0	6⅛	3	13	8·6	10⅛	9	14	8·6
2¼	0	13	1·7	6¼	3	17	9·0	10¼	9	21	2·6
2⅜	0	14	10·7	6⅜	3	21	10·6	10⅜	9	27	13·8
2½	0	16	4·1	6½	3	25	13·6	10½	10	6	10·4
2⅝	0	17	14·8	6⅝	4	2	1·8	10⅝	10	13	8·2
2¾	0	19	9·6	6¾	4	6	7·4	10¾	10	20	7·4
2⅞	0	21	8·0	6⅞	4	11	1·4	10⅞	10	27	7·8
3	0	23	6·5	7	4	15	6·4	11	11	6	9·6
3⅛	0	25	6·4	7⅛	4	19	15·5	11⅛	11	13	12·6
3¼	0	27	7·6	7¼	4	24	10·6	11¼	11	21	1·0
3⅜	1	1	10·0	7⅜	5	1	6·7	11⅜	12	0	6·6
3½	1	3	13·9	7½	5	6	4·0	11½	12	7	13·6
3⅝	1	6	2·8	7⅝	5	11	2·6	11⅝	12	15	5·8
3¾	1	8	9·2	7¾	5	16	2·7	11¾	12	22	15·4
3⅞	1	11	0·9	7⅞	5	21	3·7	11⅞	13	2	10·2
4	1	13	9·9	8	5	26	6·4	12	13	10	6·4

* James Foden.

TABLE IV.*

SHOWING THE WEIGHT OF A LINEAL FOOT OF SQUARE BAR IRON,

In Avoirdupois qrs. lbs. oz., from ⅛th of an Inch to 12 Inches advancing by ⅛th of an Inch.

Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.
⅛	0	0	0·8	4⅛	2	0	7·8	8⅛	7	23	2·7
¼	0	0	3·3	4¼	2	3	14·1	8¼	8	1	15·4
⅜	0	0	7·4	4⅜	2	7	6·4	8⅜	8	8	13·8
½	0	0	13·2	4½	2	11	3·7	8½	8	15	13·9
⅝	0	1	5·1	4⅝	2	14	13·6	8⅝	8	22	15·6
¾	0	1	13·8	4¾	2	18	14·3	8¾	9	2	2·0
⅞	0	2	8·6	4⅞	2	22	15·1	8⅞	9	9	8·0
1	0	3	4·9	5	2	27	0·0	9	9	16	14·7
1⅛	0	4	3·2	5⅛	3	3	3·2	9⅛	9	24	7·1
1¼	0	5	2·7	5¼	3	7	8·1	9¼	10	4	1·0
1⅜	0	6	4·1	3⅜	3	11	14·2	9⅜	10	11	12·7
1½	0	7	7·5	5½	3	16	6·8	9½	10	19	10·0
1⅝	0	8	12·0	5⅝	3	21	0·9	9⅝	10	27	9·0
1¾	0	10	1·6	5¾	3	25	12·2	9¾	11	7	9·7
1⅞	0	11	10·4	5⅞	4	2	8·1	9⅞	11	15	12·0
2	0	13	4·5	6	4	7	8·3	10	11	24	0·0
2⅛	0	14	15·4	6⅛	4	12	8·8	10⅛	12	4	5·6
2¼	0	16	12·9	6¼	4	17	11·0	10¼	12	12	12·9
2⅜	0	18	11·0	6⅜	4	22	14·8	10⅜	12	21	5·8
2½	0	20	12·0	6½	5	0	4·3	10½	13	2	0·4
2⅝	0	22	13·1	6⅝	5	5	11·4	10⅝	13	10	12·7
2¾	0	25	1·7	6¾	5	11	4·2	10¾	13	19	10·6
2⅞	0	27	6·4	6⅞	5	16	14·7	10⅞	14	0	10·2
3	1	1	14·1	7	5	22	10·8	11	14	9	11·5
3⅛	1	4	5·6	7⅛	6	0	8·6	11⅛	14	18	14·4
3¼	1	6	15·6	7¼	6	6	8·1	11¼	15	0	3·0
3⅜	1	9	11·6	7⅜	6	12	9·2	11⅜	15	9	9·2
3½	1	12	9·1	7½	6	18	12·0	11½	15	19	1·1
3⅝	1	15	8·3	7⅝	6	25	0·4	11⅝	16	0	10·6
3¾	1	18	9·1	7¾	7	3	6·5	11¾	16	10	5·8
3⅞	1	21	12·6	7⅞	7	9	14·2	11⅞	16	20	2·7
4	1	25	1·9	8	7	16	7·6	12	17	2	1·2

* James Foden.

OBSERVATIONS ON TABLES III. AND IV.

The Tables of the weight of round and square bars of malleable iron have been obtained by the following approximate rules :

Rule 1.—For round bars. Multiply the square of the diameter in inches by the length in feet, and that product by 2·6. The product will be the weight in pounds avoirdupois, nearly.

Rule 2.—For square bars. Multiply the area of the end of the bar in inches by the length in feet, and that by 3·32. The product will be the weight in pounds avoirdupois, nearly.

Example 1.—What is the weight of a round bar of malleable iron $4\frac{1}{2}$ feet long, and $2\frac{1}{4}$ inches in diameter?

$2{\cdot}25^2 \times 4{\cdot}5 = 22{\cdot}78125 \times 2{\cdot}6 = 59{\cdot}23125$ lbs. $= 59$ lbs. $3{\cdot}7$ oz.

Example 2.—Required the weight of a square bar of malleable iron whose length is $7\frac{1}{4}$ feet, and $1\frac{1}{2}$ inch square.

$1{\cdot}5^2 \times 7{\cdot}25 = 16{\cdot}3125 \times 3{\cdot}32 = 54{\cdot}1575$ lbs. $= 54$ lbs. $2{\cdot}52$ oz.

J. F.

TABLE V.*

CONTAINING THE CIRCUMFERENCES FOR ANGLED IRON HOOPS,

From 6 Inches to 6 Feet Diameter, advancing by an Eighth of an inch

ANGLE OUTSIDE.

Diam.	Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
6	1	5½		10	2	5¼	1	2	3	5	1	6	4	4¾
⅛	1	5⅞		⅛	2	5⅝		⅛	3	5⅛		⅛	4	5⅛
¼	1	6¼		¼	2	6		¼	3	5¾		¼	4	5⅜
⅜	1	6⅝		⅜	2	6⅜		⅜	3	6⅛		⅜	4	5¾
½	1	7		½	2	6¾		½	3	6½		½	4	6⅛
⅝	1	7⅜		⅝	2	7⅛		⅝	3	6⅞		⅝	4	6½
¾	1	7¾		¾	2	7½		¾	3	7⅛		¾	4	6⅞
⅞	1	8⅛		⅞	2	7⅞		⅞	3	7½		⅞	4	7¼
7	1	8½		11	2	8⅛	1	3	3	7⅞	1	7	4	7⅝
⅛	1	8⅞		⅛	2	8½		⅛	3	8¼		⅛	4	8
¼	1	9¼		¼	2	8⅞		¼	3	8⅝		¼	4	8⅜
⅜	1	9½		⅜	2	9¼		⅜	3	9		⅜	4	8¾
½	1	9⅞		½	2	9⅝		½	3	9⅜		½	4	9⅛
⅝	1	10¼		⅝	2	10		⅝	3	9¾		⅝	4	9½
¾	1	10⅝		¾	2	10⅜		¾	3	10⅛		¾	4	9⅞
⅞	1	11		⅞	2	10¾		⅞	3	10½		⅞	4	10¼
8	1	11⅜	1	0	2	11⅛	1	4	3	10⅞	1	8	4	10⅝
⅛	1	11¾		⅛	2	11½		⅛	3	11¼		⅛	4	11
¼	2	0⅛		¼	2	11⅞		¼	3	11⅝		¼	4	11⅜
⅜	2	0½		⅜	3	0¼		⅜	3	11⅞		⅜	4	11⅝
½	2	0⅞		½	3	0⅝		½	4	0¼		½	5	0
⅝	2	1¼		⅝	3	1		⅝	4	0⅝		⅝	5	0⅜
¾	2	1⅝		¾	3	1⅜		¾	4	1		¾	5	0¾
⅞	2	2		⅞	3	1¾		⅞	4	1⅜		⅞	5	1⅛
9	2	2⅜	1	1	3	2	1	5	4	1¾	1	9	5	1½
⅛	2	2⅝		⅛	3	2⅜		⅛	4	2⅛		⅛	5	1⅞
¼	2	3		¼	3	2¾		¼	4	2½		¼	5	2¼
⅜	2	3⅜		⅜	3	3⅛		⅜	4	2⅞		⅜	5	2⅝
½	2	3¾		½	3	3½		½	4	3¼		½	5	3
⅝	2	4⅛		⅝	3	3⅞		⅝	4	3⅝		⅝	5	3⅜
¾	2	4½		¾	3	4¼		¾	4	4		¾	5	3¾
⅞	2	4⅞		⅞	3	4⅝		⅞	4	4⅜		⅞	5	4

* James Foden.

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
1	10	5	4⅜	2	3	6	7⅛	2	8	7	9¾	3	1	9	0⅜
	⅛	5	4¾		⅛	6	7½		⅛	7	10⅛		⅛	9	0¾
	¼	5	5⅛		¼	6	7⅞		¼	7	10½		¼	9	1⅛
	⅜	5	5½		⅜	6	8⅛		⅜	7	10⅞		⅜	9	1½
	½	5	5⅞		½	6	8½		½	7	11¼		½	9	1⅞
	⅝	5	6¼		⅝	6	8⅞		⅝	7	11⅝		⅝	9	2¼
	¾	5	6⅝		¾	6	9¼		¾	8	0		¾	9	2⅝
	⅞	5	7		⅞	6	9⅝		⅞	8	0⅜		⅞	9	3
1	11	5	7⅜	2	4	6	10	2	9	8	0⅝	3	2	9	3⅜
	⅛	5	7¾		⅛	6	10⅜		⅛	8	1		⅛	9	3¾
	¼	5	8⅛		¼	6	10¾		¼	8	1⅜		¼	9	4⅛
	⅜	5	8½		⅜	6	11⅛		⅜	8	1¾		⅜	9	4⅜
	½	5	8⅞		½	6	11½		½	8	2⅛		½	9	4¾
	⅝	5	9¼		⅝	6	11⅞		⅝	8	2½		⅝	9	5⅛
	¾	5	9⅝		¾	7	0¼		¾	8	2⅞		¾	9	5½
	⅞	5	9⅞		⅞	7	0⅝		⅞	8	3¼		⅞	9	5⅞
2	0	5	10¼	2	5	7	1	2	10	8	3⅝	3	3	9	6¼
	⅛	5	10⅝		⅛	7	1⅜		⅛	8	4		⅛	9	6⅝
	¼	5	11		¼	7	1¾		¼	8	4⅜		¼	9	7
	⅜	5	11⅜		⅜	7	2		⅜	8	4¾		⅜	9	7⅜
	½	5	11¾		½	7	2⅜		½	8	5⅛		½	9	7¾
	⅝	6	0⅛		⅝	7	2¾		⅝	8	5½		⅝	9	8[illegible]
	¾	6	0½		¾	7	3⅛		¾	8	5¾		¾	9	8[illegible]
	⅞	6	0⅞		⅞	7	3½		⅞	8	6⅛		⅞	9	8[illegible]
2	1	6	1¼	2	6	7	3⅞	2	11	8	6½	3	4	9	9[illegible]
	⅛	6	1⅝		⅛	7	4¼		⅛	8	6⅞		⅛	9	9[illegible]
	¼	6	2		¼	7	4⅝		¼	8	7¼		¼	9	9[illegible]
	⅜	6	2⅜		⅜	7	5		⅜	8	7⅝		⅜	9	10[illegible]
	½	6	2¾		½	7	5⅜		½	8	8		½	9	10[illegible]
	⅝	6	3		⅝	7	5¾		⅝	8	8⅜		⅝	9	11[illegible]
	¾	6	3⅜		¾	7	6⅛		¾	8	8¾		¾	9	11[illegible]
	⅞	6	3¾		⅞	7	6½		⅞	8	9⅛		⅞	9	11[illegible]
2	2	6	4⅛	2	7	7	6⅞	3	0	8	9½	3	5	10	[illegible]
	⅛	6	4½		⅛	7	7⅛		⅛	8	9⅞		⅛	10	[illegible]
	¼	6	4⅞		¼	7	7½		¼	8	10¼		¼	10	[illegible]
	⅜	6	5¼		⅜	7	7⅞		⅜	8	10⅝		⅜	10	[illegible]
	½	6	5⅝		½	7	8¼		½	8	11		½	10	[illegible]
	⅝	6	6		⅝	7	8⅝		⅝	8	11¼		⅝	10	[illegible]
	¾	6	6⅜		¾	7	9		¾	8	11⅝		¾	10	[illegible]
	⅞	6	6¾		⅞	7	9⅜		⅞	9	0		⅞	10	[illegible]

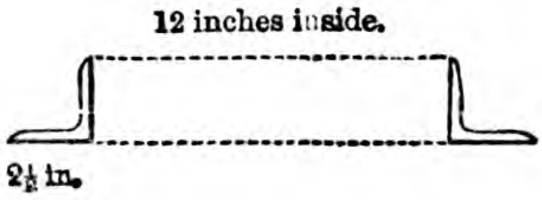
Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
6	10 3	3 11	11 5¾	4 4	12 8⅜	4 9	13 11
⅛	10 3⅜	⅛	11 6⅛	⅛	12 8¾	⅛	13 11⅜
¼	10 3¾	¼	11 6½	¼	12 9⅛	¼	13 11¾
⅜	10 4⅛	⅜	11 6⅞	⅜	12 9½	⅜	14 0⅛
½	10 4½	½	11 7⅛	½	12 9⅞	½	14 0½
⅝	10 4⅞	⅝	11 7½	⅝	12 10¼	⅝	14 0⅞
¾	10 5¼	¾	11 7⅞	¾	12 10½	¾	14 1¼
⅞	10 5⅝	⅞	11 8¼	⅞	12 10⅞	⅞	14 1⅝
7	10 6	4 0	11 8⅝	4 5	12 11¼	4 10	14 2
⅛	10 6⅜	⅛	11 9	⅛	12 11⅝	⅛	14 2⅜
¼	10 6¾	¼	11 9⅜	¼	13 0	¼	14 2¾
⅜	10 7⅛	⅜	11 9¾	⅜	13 0⅜	⅜	14 3
½	10 7½	½	11 10⅛	½	13 0¾	½	14 3⅜
⅝	10 7⅞	⅝	11 10½	⅝	13 1⅛	⅝	14 3¾
¾	10 8¼	¾	11 10⅞	¾	13 1½	¾	14 4⅛
⅞	10 8½	⅞	11 11¼	⅞	13 1⅞	⅞	14 4½
8	10 8⅞	4 1	11 11⅝	4 6	13 2¼	4 11	14 4⅞
⅛	10 9¼	⅛	12 0	⅛	13 2⅝	⅛	14 5¼
¼	10 9⅝	¼	12 0¼	¼	13 3	¼	14 5⅝
⅜	10 10	⅜	12 0⅝	⅜	13 3⅜	⅜	14 6
½	10 10⅜	½	12 1	½	13 3¾	½	14 6⅜
⅝	10 10¾	⅝	12 1⅜	⅝	13 4⅛	⅝	14 6¾
¾	10 11⅛	¾	12 1¾	¾	13 4⅜	¾	14 7⅛
⅞	10 11½	⅞	12 2⅛	⅞	13 4¾	⅞	14 7½
9	10 11⅞	4 2	12 2½	4 7	13 5⅛	5 0	14 7⅞
⅛	11 0¼	⅛	12 2⅞	⅛	13 5½	⅛	14 8⅛
¼	11 0⅝	¼	12 3¼	¼	13 5⅞	¼	14 8½
⅜	11 1	⅜	12 3⅝	⅜	13 6¼	⅜	14 8⅞
½	11 1⅜	½	12 4	½	13 6⅝	½	14 9¼
⅝	11 1¾	⅝	12 4⅜	⅝	13 7	⅝	14 9⅝
¾	11 2	¾	12 4¾	¾	13 7⅜	¾	14 10
⅞	11 2⅜	⅞	12 5⅛	⅞	13 7¾	⅞	14 10⅜
10	11 2¾	4 3	12 5½	4 8	13 8⅛	5 1	14 10¾
⅛	11 3⅛	⅛	12 5¾	⅛	13 8½	⅛	14 11⅛
¼	11 3½	¼	12 6⅛	¼	13 8⅞	¼	14 11½
⅜	11 3⅞	⅜	12 6½	⅜	13 9¼	⅜	14 11⅞
½	11 4¼	½	12 6⅞	½	13 9⅝	½	15 0¼
⅝	11 4⅝	⅝	12 7¼	⅝	13 9⅞	⅝	15 0⅝
¾	11 5	¾	12 7⅝	¾	13 10¼	¾	15 1
⅞	11 5⅜	⅞	12 8	⅞	13 10⅝	⅞	15 1⅜

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circu	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	
5	2	15	1⅝	5	5	15	10½	5	8	16	7¼	5	10	17	
	⅛	15	2		⅛	15	10⅞		⅛	16	7⅝		⅛	17	
	¼	15	2⅜		¼	15	11¼		¼	16	8		¼	17	
	⅜	15	2¾		⅜	15	11⅝		⅜	16	8⅜		⅜	17	
	½	15	3⅛		½	16	0		½	16	8¾		½	17	
	⅝	15	3½		⅝	16	0¼		⅝	16	9⅛		⅝	17	
	¾	15	3⅞		¾	16	0⅝		¾	16	9½		¾	17	
	⅞	15	4¼		⅞	16	1		⅞	16	9⅞		⅞	17	
5	3	15	4⅝	5	6	16	1⅜	5	9	16	10¼	5	11	17	
	⅛	15	5		⅛	16	1¾		⅛	16	10½		⅛	17	
	¼	15	5⅜		¼	16	2⅛		¼	16	10⅞		¼	17	
	⅜	15	5¾		⅜	16	2½		⅜	16	11¼		⅜	17	
	½	15	6⅛		½	16	2⅞		½	16	11⅝		½	17	
	⅝	15	6½		⅝	16	3¼		⅝	17	0		⅝	17	
	¾	15	6⅞		¾	16	3⅝		¾	17	0⅜		¾	17	
	⅞	15	7⅛		⅞	16	4		⅞	17	0¾		⅞	17	
5	4	15	7½	5	7	16	4⅜					6	0	17	
	⅛	15	7⅞		⅛	16	4¾								
	¼	15	8¼		¼	16	5⅛								
	⅜	15	8⅝		⅜	16	5⅜								
	½	15	9		½	16	5¾								
	⅝	15	9⅜		⅝	16	6⅛								
	¾	15	9¾		¾	16	6½								
	⅞	15	10⅛		⅞	16	6⅞								

OBSERVATIONS ON TABLE V.

As this Table, together with the following one, will be useful to those smiths who chiefly work angled iron, it will be necessary to remark, that the observation made on Table I., respecting adding the thickness of the iron to the diameter, must also be attended to in this, with this difference,—the breadth of the angle must be added to the diameter.

Example.—Suppose, as in the following sectional figure, a hoop is wanted to be made of 2½-inch angled iron, whose diameter inside must be 12 inches. Here the 2½ inches must be added to the 12 inches, which raises the number to 1 foot 2½ inches. Looking into the Table, I find the circumference, or length of iron requisite for the hoop, is 3 feet 6½ inches.



J. F.

TABLE VI.*

CONTAINING THE CIRCUMFERENCES FOR ANGLED IRON HOOPS,

From 6 Inches to 6 Feet Diameter, advancing by an Eighth of an Inch.

ANGLE INSIDE.

Diam.	Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
6	1	8½		10	2	10¼	1	2	3	11⅞	1	6	5	1⅝
⅛	1	8¾		⅛	2	10⅝		⅛	4	0⅜		⅛	5	2
¼	1	9⅜		¼	2	11		¼	4	0¾		¼	5	2½
⅜	1	9¾		⅜	2	11½		⅜	4	1⅛		⅜	5	2⅞
½	1	10¼		½	2	11⅞		½	4	1⅝		½	5	3¼
⅝	1	10⅝		⅝	3	0⅜		⅝	4	2		⅝	5	3¾
¾	1	11⅛		¾	3	0¾		¾	4	2½		¾	5	4⅛
⅞	1	11½		⅞	3	1¼		⅞	4	2⅞		⅞	5	4⅝
7	1	11⅞		11	3	1⅝	1	3	4	3⅜	1	7	5	5
⅛	2	0⅜		⅛	3	2		⅛	4	3¾		⅛	5	5½
¼	2	0¾		¼	3	2½		¼	4	4⅛		¼	5	5⅞
⅜	2	1¼		⅜	3	2⅞		⅜	4	4⅝		⅜	5	6¼
½	2	1⅝		½	3	3⅜		½	4	5		½	5	6¾
⅝	2	2		⅝	3	3¾		⅝	4	5½		⅝	5	7⅛
¾	2	2½		¾	3	4¼		¾	4	5⅞		¾	5	7½
⅞	2	2⅞		⅞	3	4⅝		⅞	4	6¼		⅞	5	8
8	2	3⅜	1	0	3	5	1	4	4	6¾	1	8	5	8½
⅛	2	3¾		⅛	3	5½		⅛	4	7⅛		⅛	5	8⅞
¼	2	4¼		¼	3	5⅞		¼	4	7⅝		¼	5	9¼
⅜	2	4⅝		⅜	3	6⅜		⅜	4	8		⅜	5	9¾
½	2	5		½	3	6¾		½	4	8½		½	5	10⅛
⅝	2	5½		⅝	3	7⅛		⅝	4	8⅞		⅝	5	10⅝
¾	2	5⅞		¾	3	7⅝		¾	4	9⅜		¾	5	11
⅞	2	6⅜		⅞	3	8		⅞	4	9¾		⅞	5	11½
9	2	6¾	1	1	3	8½	1	5	4	10⅛	1	9	5	11⅞
⅛	2	7¼		⅛	3	8⅞		⅛	4	10⅝		⅛	6	0¼
¼	2	7⅝		¼	3	9⅜		¼	4	11		¼	6	0¾
⅜	2	8		⅜	3	9¾		⅜	4	11½		⅜	6	1⅛
½	2	8½		½	3	10⅛		½	4	11⅞		½	6	1⅝
⅝	2	8⅞		⅝	3	10⅝		⅝	5	0¼		⅝	6	2
¾	2	9⅜		¾	3	11		¾	5	0¾		¾	6	[illegible]
⅞	2	9¾		⅞	3	11½		⅞	5	1⅛		⅞	6	[illegible]

* James Foden.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
1 10	6 3¼	2 3	7 8⅜	2 8	9 1½	3 1	10 6⅝
⅛	6 3¾	⅛	7 8⅞	⅛	9 2	⅛	10 7⅛
¼	6 4⅛	¼	7 9¼	¼	9 2⅜	¼	10 7½
⅜	6 4⅝	⅜	7 9¾	⅜	9 2⅞	⅜	10 8
½	6 5	½	7 10⅛	½	9 3¼	½	10 8⅜
⅝	6 5⅜	⅝	7 10½	⅝	9 3⅝	⅝	10 8¾
¾	6 5⅞	¾	7 11	¾	9 4⅛	¾	10 9¼
⅞	6 6¼	⅞	7 11⅜	⅞	9 4½	⅞	10 9⅝
1 11	6 6¾	2 4	7 11¾	2 9	9 5	3 2	10 10⅛
⅛	6 7⅛	⅛	8 0¼	⅛	9 5⅜	⅛	10 10½
¼	6 7⅝	¼	8 0¾	¼	9 5⅞	¼	10 11
⅜	6 8	⅜	8 1⅛	⅜	9 6¼	⅜	10 11⅜
½	6 8⅜	½	8 1½	½	9 6⅝	½	10 11¾
⅝	6 8⅞	⅝	8 2	⅝	9 7⅛	⅝	11 0¼
¾	6 9¼	¾	8 2⅜	¾	9 7½	¾	11 0⅝
⅞	6 9¾	⅞	8 2¾	⅞	9 8	⅞	11 1⅛
2 0	6 10⅛	2 5	8 3¼	2 10	9 8⅜	3 3	11 1½
⅛	6 10½	⅛	8 3⅝	⅛	9 8⅞	⅛	11 2
¼	6 11	¼	8 4⅛	¼	9 9¼	¼	11 2⅜
⅜	6 11⅜	⅜	8 4½	⅜	9 9⅝	⅜	11 2¾
½	6 11⅞	½	8 5	½	9 10⅛	½	11 3¼
⅝	7 0¼	⅝	8 5½	⅝	9 10½	⅝	11 3⅝
¾	7 0¾	¾	8 5⅞	¾	9 11	¾	11 4⅛
⅞	7 1⅛	⅞	8 6¼	⅞	9 11⅜	⅞	11 4½
2 1	7 1⅝	2 6	8 6¾	2 11	9 11⅞	3 4	11 5
⅛	7 2	⅛	8 7⅛	⅛	10 0¼	⅛	11 5⅜
¼	7 2⅜	¼	8 7½	¼	10 0⅝	¼	11 5¾
⅜	7 2⅞	⅜	8 8	⅜	10 1⅛	⅜	11 6¼
½	7 3¼	½	8 8⅜	½	10 1½	½	11 6⅝
⅝	7 3¾	⅝	8 8⅞	⅝	10 2	⅝	11 7⅛
¾	7 4⅛	¾	8 9¼	¾	10 2⅜	¾	11 7½
⅞	7 4½	⅞	8 9⅝	⅞	10 2¾	⅞	11 8
2 2	7 5	2 7	8 10⅛	3 0	10 3¼	3 5	11 8⅜
⅛	7 5⅜	⅛	8 10½	⅛	10 3⅝	⅛	11 8¾
¼	7 5⅞	¼	8 11	¼	10 4⅛	¼	11 9¼
⅜	7 6¼	⅜	8 11⅜	⅜	10 4½	⅜	11 9⅝
½	7 6¾	½	8 11⅞	½	10 5	½	11 10⅛
⅝	7 7⅛	⅝	9 0¼	⅝	10 5⅜	⅝	11 10½
¾	7 7½	¾	9 0⅝	¾	10 5⅞	¾	11 10⅞
⅞	7 8	⅞	9 1⅛	⅞	10 6¼	⅞	11 11⅜

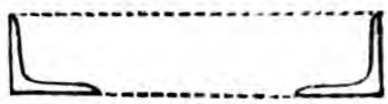
Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
3 6	11 11¾	3 11	13 4⅞	4 4	14 10	4 9	16 3⅛
⅛	12 0¼	⅛	13 5⅜	⅛	14 10½	⅛	16 3⅝
¼	12 0⅝	¼	13 5¾	¼	14 10⅞	¼	16 4
⅜	12 1⅛	⅜	13 6	⅜	14 11⅜	⅜	16 4½
½	12 1½	½	13 6⅝	½	14 11¾	½	16 4⅞
⅝	12 1⅞	⅝	13 7	⅝	15 0⅛	⅝	16 5¼
¾	12 2⅜	¾	13 7½	¾	15 0⅝	¾	16 5¾
⅞	12 2¾	⅞	13 7⅞	⅞	15 1	⅞	16 6⅛
3 7	12 3¼	4 0	13 8⅜	4 5	15 1½	4 10	16 6⅝
⅛	12 3⅝	⅛	13 8¾	⅛	15 1⅞	⅛	16 7
¼	12 4⅛	¼	13 9¼	¼	15 2¼	¼	16 7⅜
⅜	12 4½	⅜	13 9⅝	⅜	15 2¾	⅜	16 7⅞
½	12 4⅞	½	13 10	½	15 3⅛	½	16 8¼
⅝	12 5⅜	⅝	13 10½	⅝	15 3⅝	⅝	16 8¾
¾	12 5¾	¾	13 10⅞	¾	15 4	¾	16 9⅛
⅞	12 6¼	⅞	13 11⅜	⅞	15 4½	⅞	16 9⅝
3 8	12 6⅝	4 1	13 11¾	4 6	15 4⅞	4 11	16 10
⅛	12 7	⅛	14 0¼	⅛	15 5¼	⅛	16 10⅜
¼	12 7½	¼	14 0⅝	¼	15 5¾	¼	16 10⅞
⅜	12 7⅞	⅜	14 1	⅜	15 6⅛	⅜	16 11¼
½	12 8⅜	½	14 1½	½	15 6⅝	½	16 11¾
⅝	12 8¾	⅝	14 1⅞	⅝	15 7	⅝	17 0⅛
¾	12 9¼	¾	14 2⅜	¾	15 7½	¾	17 0⅝
⅞	12 9⅝	⅞	14 2¾	⅞	15 7⅞	⅞	17 1
3 9	12 10	4 2	14 3⅛	4 7	15 8¼	5 0	17 1½
⅛	12 10½	⅛	14 3½	⅛	15 8¾	⅛	17 1⅞
¼	12 10⅞	¼	14 4	¼	15 9⅛	¼	17 2¼
⅜	12 11⅜	⅜	14 4½	⅜	15 9⅝	⅜	17 2¾
½	12 11¾	½	14 4⅞	½	15 10	½	17 3⅛
⅝	13 0¼	⅝	14 5⅜	⅝	15 10½	⅝	17 3⅝
¾	13 0⅝	¾	14 5¾	¾	15 10⅞	¾	17 4
⅞	13 1	⅞	14 6⅛	⅞	15 11¼	⅞	17 4⅜
3 10	13 1½	4 3	14 6⅝	4 8	15 11¾	5 1	17 4⅞
⅛	13 1⅞	⅛	14 7	⅛	16 0⅛	⅛	17 5¼
¼	13 2⅜	¼	14 7⅜	¼	16 0⅝	¼	17 5¾
⅜	13 2¾	⅜	14 7⅞	⅜	16 1	⅜	17 6⅛
½	13 3¼	½	14 8⅜	½	16 1½	½	17 6½
⅝	13 3⅝	⅝	14 8¾	⅝	16 1⅞	⅝	17 7
¾	13 4	¾	14 9⅛	¾	16 2¼	¾	17 7⅜
⅞	13 4½	⅞	14 9⅝	⅞	16 2¾	⅞	17 7⅞

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
5	2	17	8¼	5	5	18	6½	5	8	19	4⅞	5	10	19	11⅝
	⅛	17	8¾		⅛	18	7		⅛	19	5¼		⅛	20	0⅛
	¼	17	9⅛		¼	18	7⅜		¼	19	5¾		¼	20	0½
	⅜	17	9½		⅜	18	7⅞		⅜	19	6⅛		⅜	20	1
	½	17	10		½	18	8¼		½	19	6½		½	20	1⅜
	⅝	17	10⅜		⅝	18	8¾		⅝	19	7		⅝	20	1⅞
	¾	17	10⅞		¾	18	9⅛		¾	19	7⅜		¾	20	2¼
	⅞	17	11¼		⅞	18	9½		⅞	19	7⅞		⅞	20	2⅝
5	3	17	11¾	5	6	18	10	5	9	19	8¼	5	11	20	3⅛
	⅛	18	0⅛		⅛	18	10⅜		⅛	19	8⅝		⅛	20	3½
	¼	18	0½		¼	18	10⅞		¼	19	9⅛		¼	20	4
	⅜	18	1		⅜	18	11¼		⅜	19	9½		⅜	20	4⅜
	½	18	1⅜		½	18	11¾		½	19	10		½	20	4¾
	⅝	18	1⅞		⅝	19	0⅛		⅝	19	10⅜		⅝	20	5¼
	¾	18	2¼		¾	19	0½		¾	19	10⅞		¾	20	5⅝
	⅞	18	2¾		⅞	19	1		⅞	19	11¼		⅞	20	6⅛
5	4	18	3⅛	5	7	19	1⅜					6	0	20	6½
	⅛	18	3½		⅛	19	1⅞								
	¼	18	4		¼	19	2¼								
	⅜	18	4⅜		⅜	19	2¾								
	½	18	4⅞		½	19	3⅛								
	⅝	18	5¼		⅝	19	3½								
	¾	18	5¾		¾	19	4								
	⅞	18	6⅛		⅞	19	4⅜								

OBSERVATIONS ON TABLE VI.

The observations respecting this Table are the reverse to those on the preceding one,—viz. the breadth of the angle must be taken from the diameter,—for this reason, that the diameter is taken from outside to outside of the ring, as in the following sectional figure:

12 inches outside.



2½ in.

Suppose a ring is to be made of angled iron, whose diameter outside is to be 12 inches, the breadth of the angle 2½ inches; then, by taking 2½ inches from 12 inches, we have left 9½ inches. Looking into the Table in the column of diameters, I find in the circumference column, opposite 9½ inches, 2 feet 8½ inches, which is the length of iron necessary for the ring.

It has been already observed, that between angled and plain iron a considerable difference exists with regard to the proportion of the circumference to the diameter: this is owing to the angle or flange on one side of the bar, and when the iron is formed into a hoop it contracts more or less, as the angle or flange may be inside or outside of the hoop. From repeated experiments on this subject, I have ascertained that the proportions of the diameters to the circumferences are as follows:—For the angle inside as 1 : 3·4248, and for the angle outside the hoop, as 1 : 2·9312 : : Diam : Circumf.

The method used in obtaining the numbers in these Tables of Circumferences of angled iron is, for the angle inside by adding $\frac{1}{8}$th of 3·4248, or ·4281 as a constant number; and for the angle outside, by constantly adding $\frac{1}{8}$th of 2·9312, or ·3664.

Example 1.—For a hoop with the angle or flange inside, beginning with 2 feet diameter.

3·4248 × 2 = 6·8496 feet, and ·8496 × 12 = 10·1952 inches, and this decimal ·1952 = $\frac{1}{8}$ nearly.

```
             in.
6 feet 10·1952 × 8 = 1/8
        + ·4281
        -------
          ·6233 × 8 = 1/2
        + ·4281                (See p. 79.)
        -------
        11·0514 × 8 = 0
        + ·4281
        -------
          ·4795 × 8 = 3/8, &c.
```

Ex. 2.—For a hoop whose angle or flange is outside, commencing with a diameter of 3 feet.

```
          ft.                     in.
2·9312 × 3 = 8·7936, and ·7936 × 12 = 9·5232, and
   ·5232 = 1/2 nearly.
       Hence, 8 feet 9 in. ·5232 × 8 = 1/2
                           ·3664
                           -----
                           ·8896 × 8 = 7/8
(See Note B. at            ·3664
   the end.)               -----
                    10 in. ·2560 × 8 = 1/4
                           ·3664
                           -----
                           ·6224 × 8 = 5/8, &c.
```

Problem.—To find the circumference of an ellipse, or an oval hoop or ring.

Rule.—Add the length of the two axes together, and multiply the sum by 1·5708 for the circumference; or as it may be used in the Table of Circumferences, take half the sum cf the axes as a diameter, with the breadth of the iron added, and enter the Table of Circumferences where it will be found.

Ex. Required the circumference of an elliptical hoop, whose axes are $18\frac{1}{2}$ and 13 inches, the thickness of the iron being $2\frac{1}{2}$ inches. (*Table* I).

$$\begin{array}{rl} 18\frac{1}{2} & \\ 13 & \\ \hline 2)31\frac{1}{2} & \\ \hline 15\frac{3}{4} & \\ +\ 2\frac{1}{2} & \text{thickness.} \\ \hline 18\frac{1}{4} & \text{inches, the diameter.} \end{array}$$

Entering into the Table of Diameter with $18\frac{1}{4}$ inches, the circumference will be found to be 4 feet $9\frac{1}{4}$ inches.

In constructing elliptical hoops of angled iron, with the angle outside, reference must be made to the Tables for hoops of angled iron: the operation will be similar to the above example. But in hoops where the angle is inside, the thickness of the iron must be taken from half the sum of the axes.

Note.—It must be observed, that in the examples given in the Observations on Table I., and also on hoops formed of angled iron, that those circumferences are nothing more than the ends of the iron meeting together: therefore every smith must allow for the thickening of the ends of the metal previous to scarving the same in order to weld it.

J. F.

Proportional breadths for hexagonal or six-sided Nuts for wrought-iron Bolts.

Dia. of bolts.	Breadth of nuts.	Dia. of bolts.	Breadth of nuts.
$\frac{3}{8}$	$\frac{3}{4}$ inch.	$1\frac{1}{8}$	$1\frac{15}{16}$ inch.
$\frac{1}{2}$	$\frac{7}{8}$ "	$1\frac{1}{4}$	$2\frac{3}{16}$ "
$\frac{5}{8}$	$1\frac{1}{8}$ "	$1\frac{3}{8}$	$2\frac{3}{8}$ "
$\frac{3}{4}$	$1\frac{5}{16}$ "	$1\frac{1}{2}$	$2\frac{9}{16}$ "
$\frac{7}{8}$	$1\frac{1}{2}$ "	$1\frac{5}{8}$	$2\frac{3}{4}$ "
1	$1\frac{3}{4}$ "	$1\frac{3}{4}$	3 "

Note.—The thickness of the nut is equal the bolt's diameter.

WEIGHT OF A SUPERFICIAL FOOT OF PLATE OR SHEET IRON, COPPER, AND BRASS, IN POUNDS.

Thickness in parts of an inch.	Iron.	Thickness by the wire gauge. No.	Iron.	Copper.	Brass.	Thickness by the wire gauge. No.	Iron.	Copper.	Brass.
$\frac{1}{32}$	1·25	1	12·5	14·5	13·75	16	2·5	2·9	2·75
$\frac{1}{16}$	2·5	2	12	13·9	13·2	17	2·18	2·52	2·4
$\frac{1}{8}$	5	3	11	12·75	12·1	18	1·86	2·15	2·04
$\frac{3}{16}$	7·5	4	10	11·6	11	19	1·7	1·97	1·87
$\frac{1}{4}$	10	5	8·74	1·01	9·61	20	1·54	1·78	1·69
$\frac{5}{16}$	12·5	6	8·12	9·4	8·93	21	1·4	1·62	1·54
$\frac{3}{8}$	15	7	7·5	8·7	8·25	22	1·25	1·45	1·37
$\frac{7}{16}$	17·5	8	6·86	7·9	7·54	23	1·12	1·3	1·23
$\frac{1}{2}$	20	9	6·24	7·2	6·86	24	1	1·16	1·1
$\frac{9}{16}$	22·5	10	5·62	6·5	6·18	25	·9	1·04	·99
$\frac{5}{8}$	25	11	5	5·8	5·5	26	·8	·92	·88
$\frac{11}{16}$	27·5	12	4·38	5·08	4·81	27	·72	·83	·79
$\frac{3}{4}$	30	13	3·75	4·34	4·12	28	·64	·74	·7
$\frac{7}{8}$	35	14	3·12	3·6	3·43	29	·56	·64	·61
1	40	15	2·82	3·27	3·1	30	·5	·58	·55

Note.—No. 1 wire gauge equal $\frac{5}{16}$ths of an inch.

„ 4	„	$\frac{1}{4}$	„
„ 7	„	$\frac{3}{16}$	„
„ 11	„	$\frac{1}{8}$	„
„ 16	„	$\frac{1}{16}$	„
„ 22	„	$\frac{1}{32}$	„

The great variety of thicknesses into which copper is manufactured, causes in trade the weight to be named whereby to determine the thickness required, the unit being that of a common sheet, so designated, viz., 4 feet by 2 feet, in lbs.; thus,

A 70lb plate is $\frac{3}{16}$ths of an inch in thickness.

$46\frac{1}{2}$	„	$\frac{1}{8}$	„
23	„	$\frac{1}{16}$	„
$11\frac{1}{2}$	„	$\frac{1}{32}$	„
6	„	$\frac{1}{64}$ &c., &c.	

The thickness of lead is also in common determined or understood by the weight, the unit being that of a square or superficial foot; thus,

4-lb lead is $\frac{1}{16}$th of an inch in thickness.

6	„	$\frac{1}{10}$	„
$7\frac{1}{2}$	„	$\frac{1}{8}$	„
11	„	$\frac{3}{16}$	„
15	„	$\frac{1}{4}$	„

COMPARATIVE WEIGHTS OF DIFFERENT BODIES.

Bar iron being 1.		Cast iron being 1.		Dry deal being 1.	
Cast iron	= ·95	Bar iron	=1·07	Cast iron	=11·0
Steel	=1·02	Steel	=1·08	Cast tin	=11·2
Copper	=1·16	Brass	=1·16	Brass	=12·7
Brass	=1·09	Copper	=1·21	Copper	=13·3
Lead	=1·48	Lead	=1·56	Lead	=17·1

1. Suppose I have an article of plate iron, the weight of which is 728lbs., but want the same of copper, and of similar dimensions, what will be its weight?

$$728 \times 1{\cdot}16 = 844{\cdot}48 \text{ lbs.}$$

2. A model of dry pine weighing $32\frac{1}{2}$ lbs., and in which the iron for its construction forms no material portion of the weight, what may I anticipate its weight to be in cast iron?

$$32{\cdot}5 \times 11 = 357{\cdot}5 \text{ lbs.}$$

Note.—It frequently occurs in the formation or construction of models, that neither the quality nor condition of the timber can be properly estimated, and in such cases it may be a near enough approximation to reckon 10 lbs. of cast iron to each lb. of model.

WEIGHTS OF 9-FEET LENGTHS OF CAST-IRON PIPES, OF VARIOUS DIAMETERS.

Diameter of bore.	Thickness of metal.	Diameter of flange.	Thickness of flange.	Diameter of circle through holes.	Diameter and	number of holes.	Weight in cwts.	qrs.	lbs.
in.	in.	in.	in.	in.	in.				
2	$\frac{3}{8}$	$6\frac{1}{2}$	$\frac{9}{16}$	$4\frac{3}{4}$	$\frac{5}{8}$	4	0	3	0
3	$\frac{3}{8}$	$7\frac{1}{2}$	$\frac{5}{8}$	6	$\frac{5}{8}$	4	1	0	3
4	$\frac{1}{2}$	$9\frac{1}{2}$	$\frac{3}{4}$	$7\frac{3}{4}$	$\frac{3}{4}$	4	1	3	5
5	$\frac{1}{2}$	$10\frac{1}{2}$	$\frac{7}{8}$	$8\frac{3}{4}$	$\frac{3}{4}$	4	2	1	12
6	$\frac{5}{8}$	12	$\frac{7}{8}$	10	$\frac{7}{8}$	4	3	2	1
7	$\frac{5}{8}$	14	1	$11\frac{3}{4}$	$\frac{7}{8}$	6	4	3	17
8	$\frac{3}{4}$	15	1	$12\frac{3}{4}$	1	6	5	2	9
9	$\frac{3}{4}$	$16\frac{1}{2}$	$1\frac{1}{16}$	$14\frac{1}{4}$	1	6	6	1	12
10	$\frac{3}{4}$	$17\frac{1}{2}$	$1\frac{1}{8}$	$15\frac{1}{2}$	1	6	7	0	0
11	$\frac{7}{8}$	19	$1\frac{3}{16}$	$16\frac{3}{4}$	1	6	8	3	24
12	$\frac{7}{8}$	20	$1\frac{1}{4}$	$17\frac{3}{4}$	$1\frac{1}{8}$	6	9	3	5
13	$\frac{7}{8}$	21	$1\frac{1}{4}$	$18\frac{3}{4}$	$1\frac{1}{8}$	6	10	2	0
14	$\frac{7}{8}$	22	$1\frac{1}{4}$	$19\frac{3}{4}$	$1\frac{1}{8}$	8	11	0	26
15	$\frac{7}{8}$	23	$1\frac{1}{4}$	$20\frac{3}{4}$	$1\frac{1}{8}$	8	12	0	25
16	$\frac{7}{8}$	$24\frac{1}{2}$	$1\frac{5}{16}$	22	$1\frac{1}{4}$	8	12	3	8
17	$\frac{7}{8}$	$25\frac{1}{2}$	$1\frac{5}{16}$	23	$1\frac{1}{4}$	8	13	2	17
18	1	$26\frac{1}{2}$	$1\frac{3}{8}$	24	$1\frac{1}{4}$	8	16	1	15
19	1	28	$1\frac{3}{8}$	25	$1\frac{3}{8}$	8	17	2	13
20	1	29	$1\frac{3}{8}$	26	$1\frac{3}{8}$	8	18	0	26

Weights of Leaden Pipes.

$\frac{3}{4}$-inch	bore	weighs	10 lbs.	per yard.
1	"	"	12	"
$1\frac{1}{4}$	"	"	16	"
$1\frac{1}{2}$	"	"	18	"
$1\frac{3}{4}$	"	"	21	"
2	"	"	24	"

TO ASCERTAIN THE WEIGHTS OF PIPES OF VARIOUS METALS, AND ANY DIAMETER REQUIRED.

Thickness in parts of an inch.	Wrought iron.	Copper.			Lead.		
$\frac{1}{32}$	·326	$11\frac{1}{2}$ lbs. plate		·38	2 lbs. lead		·483
$\frac{1}{16}$	·653	$23\frac{1}{2}$	"	·76	4	"	·967
$\frac{3}{32}$	·976	35	"	1·14	$5\frac{1}{2}$	"	1·45
$\frac{1}{8}$	1·3	$46\frac{1}{2}$	"	1·52	8	"	1·933
$\frac{5}{32}$	1·627	58	"	1·9	$9\frac{1}{4}$	"	2·417
$\frac{3}{16}$	1·95	70	"	2·28	11	"	2·9
$\frac{7}{32}$	2·277	$80\frac{1}{2}$	"	2·66	13	"	3·383
$\frac{1}{4}$	2·6	93	"	3·04	15	"	3·867

Rule.—To the interior diameter of the pipe, in inches, add the thickness of the metal; multiply the sum by the decimal numbers opposite the required thickness and under the metal's name; also by the length of the pipe in feet, and the product is the weight of the pipe in lbs.

1. Required the weight of a copper pipe whose interior diameter is $7\frac{1}{4}$ inches, its length $6\frac{1}{4}$ feet, and the metal $\frac{1}{8}$ of an inch in thickness.

$$7·5 + ·125 = 7·625 \times 1·52 \times 6·25 = 72·4 \text{ lbs.}$$

2. What is the weight of a leaden pipe $18\frac{1}{2}$ feet in length, 3 inches interior diameter, and the metal $\frac{1}{4}$ of an inch in thickness?

$$3 + ·25 = 3·25 \times 3·867 \times 18·5 = 232·5 \text{ lbs.}$$

Note.—Weight of a cubic inch of

Lead	equal	·4103	℔
Copper, sheet	„	·3225	„
Brass do.	„	·3037	„
Iron do.	„	·279	„
Iron, cast	„	·263	„
Tin do.	„	·2636	„
Zinc do.	„	·26	„
Water	„	·03617	„

WEIGHT OF CAST-IRON BALLS.

Diameter in inches.	Weight in ℔s.	Diameter in inches.	Weight in ℔s.	Diameter in inches.	Weight in ℔s.
2	1·10	6	29·72	10	137·71
$2\frac{1}{4}$	1·57	$6\frac{1}{4}$	33·62	$10\frac{1}{4}$	148·28
$2\frac{1}{2}$	2·15	$6\frac{1}{2}$	37·80	$10\frac{1}{2}$	159·40
$2\frac{3}{4}$	2·86	$6\frac{3}{4}$	42·35	$10\frac{3}{4}$	171·05
3	3·72	7	47·21	11	183·29
$3\frac{1}{4}$	4·71	$7\frac{1}{4}$	52·47	$11\frac{1}{4}$	196·10
$3\frac{1}{2}$	5·80	$7\frac{1}{2}$	58·06	$11\frac{1}{2}$	209·43
$3\frac{3}{4}$	7·26	$7\frac{3}{4}$	64·09	$11\frac{3}{4}$	223·40
4	8·81	8	70·49	12	237·94
$4\frac{1}{4}$	10·57	$8\frac{1}{4}$	77·32	$12\frac{1}{4}$	253·13
$4\frac{1}{2}$	12·55	$8\frac{1}{2}$	84·56	$12\frac{1}{2}$	268·97
$4\frac{3}{4}$	14·76	$8\frac{3}{4}$	92·24	$12\frac{3}{4}$	285·37
5	17·12	9	100·39	13	302·41
$5\frac{1}{4}$	19·93	$9\frac{1}{4}$	108·98	$13\frac{1}{4}$	320·80
$5\frac{1}{2}$	22·91	$9\frac{1}{2}$	118·06	$13\frac{1}{2}$	338·81
$5\frac{3}{4}$	26·18	$9\frac{3}{4}$	127·63	$13\frac{3}{4}$	357·93

1. What will be the weight of a hollow ball or shell of cast iron, the external diameter being $9\frac{1}{2}$ and internal diameter $8\frac{3}{4}$ inches?

Opposite $9\frac{1}{2}$ are 118·06, and
Opposite $8\frac{3}{4}$ are 92·24, subtract

25·82 ℔s., weight required.

2. Requiring to remove a cast-iron ball 37·8 ℔s. in

weight, and in diameter $6\frac{1}{2}$ inches, and replace it by one of lead of an equal weight, what must be the diameter of the leaden ball?

Weight of lead to that of cast iron=1·56 (see Table, page 110).
Then $\frac{6\cdot5^3}{1\cdot56}=\sqrt[3]{176}=5\cdot6$ inches, the diameter.

TABLES BY WHICH TO FACILITATE THE MENSURATION OF TIMBER.

1. *Flat or Board Measure.*

Breadth in inches.	Area of a lineal foot.	Breadth in inches.	Area of a lineal foot.	Breadth in inches.	Area of a lineal foot.
$\frac{1}{4}$	·0208	4	·3334	8	·6667
$\frac{1}{2}$	·0417	$4\frac{1}{4}$	·3542	$8\frac{1}{4}$	·6875
$\frac{3}{4}$	·0625	$4\frac{1}{2}$	·375	$8\frac{1}{2}$	·7084
1	·0834	$4\frac{3}{4}$	·3958	$8\frac{3}{4}$	·7292
$1\frac{1}{4}$	·1042	5	·4167	9	·75
$1\frac{1}{2}$	·125	$5\frac{1}{4}$	·4375	$9\frac{1}{4}$	·7708
$1\frac{3}{4}$	·1459	$5\frac{1}{2}$	·4583	$9\frac{1}{2}$	·7917
2	·1667	$5\frac{3}{4}$	·4792	$9\frac{3}{4}$	·8125
$2\frac{1}{4}$	·1875	6	·5	10	·8334
$2\frac{1}{2}$	·2084	$6\frac{1}{4}$	·5208	$10\frac{1}{4}$	·8542
$2\frac{3}{4}$	·2292	$6\frac{1}{2}$	·5416	$10\frac{1}{2}$	·875
3	·25	$6\frac{3}{4}$	·5625	$10\frac{3}{4}$	·8959
$3\frac{1}{4}$	·2708	7	·5833	11	·9167
$3\frac{1}{2}$	·2916	$7\frac{1}{4}$	·6042	$11\frac{1}{4}$	·9375
$3\frac{3}{4}$	·3125	$7\frac{1}{2}$	·625	$11\frac{1}{2}$	·9583
		$7\frac{3}{4}$	·6458	$11\frac{3}{4}$	·9792

Application and Use of the Table.

1. Required the number of square feet in a board or plank $16\frac{1}{2}$ feet in length and $9\frac{3}{4}$ inches in breadth.

Opposite $9\frac{3}{4}$ is $\cdot8125\times16\cdot5=13\cdot4$ square feet.

2. A board 1 foot $2\frac{3}{4}$ inches in breadth and 21 feet in length; what is its superficial content in square feet?

Opposite $2\frac{3}{4}$ is ·2292, to which add the 1 foot; then $1\cdot2292\times21=25\cdot8$ square feet.

3. In a board 15½ inches at one end, 9 inches at the other, and 14½ feet in length, how many square feet?

$\frac{15 \cdot 5 + 9}{2} = 12\frac{1}{4}$, or 1·0208; and $1 \cdot 0208 \times 14 \cdot 5 = 14 \cdot 8$ sq. ft.

2. *Cubic or Solid Measure.*

Mean ¼ girt in inches.	Cubic feet in each lineal foot.	Mean ¼ girt in inches.	Cubic feet in each lineal foot.	Mean ¼ girt in inches.	Cubic feet in each lineal foot.
6	·25	14	1·361	22	3·362
6¼	·272	14¼	1·41	22¼	3·438
6½	·294	14½	1·46	22½	3·516
6¾	·317	14¾	1·511	22¾	3·598
7	·340	15	1·562	23	3·673
7¼	·364	15¼	1·615	23¼	3·754
7½	·39	15½	1·668	23½	3·835
7¾	·417	15¾	1·722	23¾	3·917
8	·444	16	1·777	24	4
8¼	·472	16¼	1·833	24¼	4·084
8½	·501	16½	1·89	24½	4·168
8¾	·531	16¾	1·948	24¾	4·254
9	·562	17	2·006	25	4·34
9¼	·594	17¼	2·066	25¼	4·428
9½	·626	17½	2·126	25½	4·516
9¾	·659	17¾	2·187	25¾	4·605
10	·694	18	2·25	26	4·694
10¼	·73	18¼	2·313	26¼	4·785
10½	·766	18½	2·376	26½	4·876
10¾	·803	18¾	2·442	26¾	4·969
11	·84	19	2·506	27	5·062
11¼	·878	19¼	2·574	27¼	5·158
11½	·918	19½	2·64	27½	5·252
11¾	·959	19¾	2·709	27¾	5·348
12	1·	20	2·777	28	5·444
12¼	1·042	20¼	2·898	28¼	5·542
12½	1·085	20½	2·917	28½	5·64
12¾	1·129	20¾	2·99	28¾	5·74
13	1·174	21	3·062	29	5·84
13¼	1·219	21¼	3·136	29¼	5·941
13½	1·265	21½	3·209	29½	6·044
13¾	1·313	21¾	3·285	29¾	6·146

In the cubic estimation of timber, custom has established the rule of $\frac{1}{4}$ the mean girt being the side of the square considered as the cross sectional dimensions; hence, multiply the number of cubic feet per lineal foot as in the Table of Cubic Measure opposite the $\frac{1}{4}$ girt, and the product is the solidity of the given dimensions in cubic feet.

Suppose the mean $\frac{1}{4}$ girt of a tree $21\frac{1}{4}$ inches, and its length 16 feet, what are its contents in cubic feet?

$$3{\cdot}136 \times 16 = 50{\cdot}176 \text{ cubic feet.}$$

Battens, Deals, and Planks, as imported into this country, are each similar in their various lengths, but differing in their widths and thicknesses, and hence their principal distinction: thus, a batten is 7 inches by $2\frac{1}{2}$,—a deal 9 by 3,—and a plank 11 by 3,—these being what are termed the standard dimensions, by which they are bought and sold, the length of each being taken at 12 feet; therefore, in estimating for the proper value of any quantity, nothing more is required than their lineal dimensions, by which to ascertain the number of times 12 feet there are in the given whole.

Suppose I wish to purchase the following:

7 of	6 feet	6 × 7 =	42 feet
5 „	14 „	14 × 5 =	70 „
11 „	19 „	19 × 11 =	209 „
and 6 „	21 „	21 × 6 =	126 „

12)447(37·25 standard deals.

TABLE SHOWING THE NUMBER OF LINEAL FEET OF SCANTLING OF VARIOUS DIMENSIONS WHICH ARE EQUAL TO A CUBIC FOOT.

	In.		Ft.	In.
2 inches by	2	require in length	36	0
	2½		28	9
	3		24	0
	3½		20	7
	4		18	0
	4½		16	0
	5		14	5
	5½		13	1
	6		12	0
	6½		11	1
	7		10	3
	7½		9	7
	8		9	0
	8½		8	6
	9		8	0
	9½		7	7
	10		7	3
	10½		6	10
	11		6	6
	11½		6	4
	12		6	0
3 inches by	3		16	0
	3½		13	8
	4		12	0
	4½		10	8
	5		9	7
	5½		9	0
	6		8	0
	6½		7	4
	7		6	10
	7½		6	4
	8		6	0
	8½		5	8
	9		5	4
	9½		5	0
	10		4	10
	10½		4	6
	11		4	4
	11½		4	2
	12		4	0

	In.		Ft.	In.
4 inches by	4	require in length	9	0
	4½		8	0
	5		7	2
	5½		6	6
	6		6	0
	6½		5	6
	7		5	1
	7½		4	9
	8		4	6
	8½		4	3
	9		4	0
	9½		3	9
	10		3	7
	10½		3	5
	11		3	3
	11½		3	2
	12		3	0
5 inches by	5		5	9
	5½		5	3
	6		4	10
	6½		4	5
	7		4	1
	7½		3	10
	8		3	7
	8½		3	5
	9		3	2
	9½		3	0
	10		2	10
	10½		2	9
	11		2	8
	11½		2	6
	12		2	4
6 inches by	6		4	0
	6½		3	8
	7		3	5
	7½		3	2
	8		3	0
	8½		2	10
	9		2	8

	In.		Ft.	In.
6 inches by	9½	require in length	2	6
	10		2	5
	10½		2	3
	11		2	2
	11½		2	1
	12		2	0
7 inches by	7		2	11
	7½		2	9
	8		2	6
	8½		2	5
	9		2	3
	9½		2	2
	10		2	1
	10½		1	11
	11		1	10
	11½		1	9
	12		1	8
8 inches by	8		2	3
	8½		2	1
	9		2	0
	9½		1	10
	10		1	9
	10½		1	8
	11		1	7
	11½		1	7
	12		1	6
9 inches by	9		1	9
	9½		1	8
	10		1	7
	10½		1	6
	11		1	5
	11½		1	4
	12		1	4
10 in. by	10		1	5
	10½		1	4
	11		1	4
	11½		1	3

INSTRUMENTAL ARITHMETIC.

OR UTILITY OF THE SLIDE RULE.

The slide rule is an instrument by which the greater portion of operations in arithmetic and mensuration may be advantageously performed, provided the lines of division and gauge-points be made properly correct, and their several values familiarly understood.

The lines of division are distinguished by the letters A B C D; A B and C being each divided alike, and containing what is termed a double radius, or double series of logarithmic numbers, each series being supposed to be divided into 1000 equal parts, and distributed along the radius in the following manner:

From 1 to 2	contains	301	of those parts, being the log. of		2.
„	3	„	477	„	3.
„	4	„	602	„	4.
„	5	„	699	„	5.
„	6	„	778	„	6.
„	7	„	845	„	7.
„	8	„	903	„	8.
„	9	„	954	„	9.

1000 being the whole number.

The line D on the improved rules consists of only a single radius; and although of larger radius, the logarithmic series is the same, and disposed of along the line in a similar proportion, forming exactly a line of square roots to the numbers on the lines B C.

NUMERATION.

Numeration teaches us to estimate or properly value the numbers and divisions on the rule in an arithmetical form.

Their values are all entirely governed by the value set upon the first figure, and being decimally reckoned, advance tenfold from the commencement to the termination of each radius: thus, suppose 1 at the joint be one, the 1 in the middle of the rule is ten, and 1 at the end, one hundred: again, suppose 1 at the joint ten, 1 in the middle is 100, and 1 or 10 at the end is 1000, &c., the intermediate divisions on which complete the whole system of its notation.

TO MULTIPLY NUMBERS BY THE RULE.

Set 1 on B opposite to the multiplier on A; and against the number to be multiplied on B is the product on A.

Multiply 6 by 4.

Set 1 on B to 4 on A; and against 6 on B is 24 on A. The slide thus set, against 7 on B is 28 on A.

8	„	32	„
9	„	36	„
10	„	40	„
12	„	48	„
15	„	60	„
25	„	100, &c., &c.	

TO DIVIDE NUMBERS UPON THE RULE.

Set the divisor on B to 1 on A; and against the number to be divided on B is the quotient on A.

Divide 63 by 3.

Set 3 on B to 1 on A; and against 63 on B is 21 on A.

PROPORTION, OR RULE OF THREE DIRECT.

Rule.—Set the first term on B to the second on A; and against the third upon B is the fourth upon A.

1. If four yards of cloth cost 38 shillings, what will 30 yards cost at the same rate?

Set 4 on B to 38 on A; and against 30 on B is 285 shillings on A.

2. Suppose I pay 31*s.* 6*d.* for three cwt of iron, at what rate is that per ton? 1 *ton*=20 *cwt.*

Set 3 upon B to 31·5 upon A; and against 20 upon B is 210 upon A.

RULE OF THREE INVERSE.

Rule.—Invert the slide, and the operation is the same as direct proportion.

1. I know that six men are capable of performing a certain given portion of work in eight days, but I want the same performed in three; how many men must there be employed?

Set 6 upon C to 8 upon A; and against 3 upon C is 16 upon A.

2. The lever of a safety-valve is 20 inches in length, and 5 inches between the fixed end and centre of the valve; what weight must there be placed on the end of the lever to equipoise a force or pressure of 40 lbs. tending to raise the valve?

Set 5 upon C to 40 upon A; and against 20 on C is 10 on A.

3. If $8\frac{3}{4}$ yards of cloth, $1\frac{1}{2}$ yard in width, be a sufficient quantity, how much will be required of that which is only $\frac{7}{8}$ths in width, to effect the same purpose?

Set 1·5 on C to 8·75 on A: and against ·875 upon C is 15 yards upon A.

SQUARE AND CUBE ROOTS OF NUMBERS.

On the engineer's rule, when the lines C and D are equal at both ends, C is a table of squares, and D a table of roots, as

Squares	1	4	9	16	25	36	49	64	81	on C.
Roots	1	2	3	4	5	6	7	8	9	on D.

To find the geometrical mean proportion between two numbers.

Set one of the numbers upon C to the same number upon D; and against the other number upon C is the mean number or side of an equal square upon D.

Required the mean proportion between 20 and 45.

Set 20 upon C to 20 upon D; and against 45 upon C is 30 on D.

To cube any number, set the number upon C to 1 or 10 upon D; and against the same number upon D is the cube number upon C.

Required the cube of 4.

Set 4 upon C to 1 or 10 upon D; and against 4 upon D is 64 upon C.

To extract the cube root of any number, invert the slide, and set the number upon B to 1 or 10 upon D; and where two numbers of equal value coincide on the lines B D, is the root of the given number.

Required the cube root of 64.

Set 64 upon B to 1 or 10 upon D; and against 4 upon B is 4 upon D, or root of the given number.

On the common rule, when 1 in the middle of the line C is set opposite to 10 on D, then C is a table of squares, and D a table of roots.

To cube any number by this rule, set the number upon C to 10 upon D; and against the same number upon D is the cube upon C.

MENSURATION OF SURFACE.

1. *Squares, Rectangles, &c.*

Rule.—When the length is given in feet and the breadth in inches, set the breadth on B to 12 on A; and against the length on A is the content in square feet on B.

If the dimensions are all inches, set the breadth on B to 144 upon A; and against the length upon A is the number of square feet on B.

Required the content of a board 15 inches broad and 14 feet long.

Set 15 upon B to 12 upon A; and against 14 upon A is 17·5 square feet on B.

2. *Circles, Polygons, &c.*

Rule.—Set ·7854 upon C to 1 or 10 upon D, then will the lines C and D be a table of areas and diameters.

Areas	3·14	7·06	12·56	19·63	28·27	38·48	50·26	63·61	upon C.
Diam.	2	3	4	5	6	7	8	9	upon D.

In the common rule, set ·7854 on C to 10 on D; then C is a line or table of areas, and D of diameters, as before.

Set 7 upon B to 22 upon A; then B and A form or become a table of diameters and circumferences of circles.

Cir.	3·14	6·28	9·42	12·56	15·7	18·85	22	25·13	28·27	upon A.
Dia.	1	2	3	4	5	6	7	8	9	upon B.

Polygons from 3 *to* 12 *sides.*—Set the gauge-point upon C to 1 or 10 upon D; and against the length of one side upon D is the area upon C.

Sides	3	5	6	7	8	9	10	11	12
Gauge-points	·433	1·7	2·6	3·63	4·82	6·18	7·69	9·37	11·17

Required the area of an equilateral triangle, each side 12 inches in length.

Set ·433 upon C to 1 upon D; and against 12 upon D are 62·5 square inches upon C.

TABLE OF GAUGE-POINTS FOR THE ENGINEER'S RULE.

Names.	F, F, F.	F, I, I.	I, I, I.	F, I.	I, I.	F.	I.
Cubic inches	578	83	1728	106	1273	105	121
Cubic feet	1	144	1	1833	22	121	33
Imp. gallons	163	231	277	294	353	306	529
Water in ℔s.	16	23	276	293	352	305	528
Gold „	814	1175	141	149	178	155	269
Silver „	15	216	261	276	334	286	5
Mercury „	118	169	203	216	258	225	389
Brass „	193	177	333	354	424	369	637
Copper „	18	26	319	331	397	345	596
Lead „	141	203	243	258	31	27	465
Wro^t.iron „	207	297	357	338	453	394	682
Cast iron „	222	32	384	407	489	424	733
Tin „	219	315	378	401	481	419	728
Steel „	202	292	352	372	448	385	671
Coal „	127	183	22	33	28	242	42
Marble „	591	85	102	116	13	113	195
Freestone „	632	915	11	1162	14	141	21

FOR THE COMMON SLIDE RULE.

Names.	F, F, F.	F, I, I,	I, I, I.	F, I.	I, I.	F.	I.
Cubic inches	36	518	624	660	799	625	113
Cubic feet	625	9	108	114	138	119	206
Water in ℔s.	10	144	174	184	22	191	329
Gold „	507	735	88	96	118	939	180
Silver „	938	136	157	173	208	173	354
Mercury „	738	122	127	132	162	141	242
Brass „	12	174	207	221	265	23	397
Copper „	112	163	196	207	247	214	371
Lead „	880	126	152	162	194	169	289
Wro^t.iron „	129	186	222	235	283	247	423
Cast iron „	139	2	241	254	304	265	458
Tin „	137	135	235	25	300	261	454
Steel „	136	183	22	233	278	239	418
Coal ,	795	114	138	146	176	151	262
Marble „	370	53	637	725	81	72	121
Freestone „	394	57	69	728	873	755	132

MENSURATION OF SOLIDITY AND CAPACITY.

General rule.—Set the length upon B to the gauge-point upon A; and against the side of the square, or diameter on D, are the cubic contents, or weight in lbs. on C.

1. Required the cubic contents of a tree 30 feet in length, and 10 inches quarter girt.

Set 30 upon B to 144 (the gauge-point) upon A; and against 10 upon D is 20·75 feet upon C.

2. In a cylinder 9 inches in length, and 7 inches diameter, how many cubic inches?

Set 9 upon B to 1273 (the gauge-point) upon A; and against 7 on D is 346 inches on C.

3. What is the weight of a bar of cast iron 3 inches square, and 6 feet long?

Set 6 upon B to 32 (the gauge-point) upon A; and against 3 upon D is 168 lbs. upon C.

By the common rule.

4. Required the weight of a cylinder of wrought iron 10 inches long, and $5\frac{1}{2}$ diameter.

Set 10 upon B to 283 (G. P^{t}.) upon A; and against $5\frac{1}{2}$ upon D is 66·65 lbs. on C.

5. What is the weight of a dry rope 25 yards long, and 4 inches circumference?

Set 25 upon B to 47 (G. P^{t}.) upon A; and against 4 on D is 53·16 lbs. on C.

6. What is the weight of a short-linked chain 30 yards in length, and $\frac{6}{16}$ths of an inch in diameter?

Set 30 upon B to 52 (G. P^{t}.) upon A; and against 6 on D is 129·5 lbs. on C.

LAND SURVEYING.

If the dimensions taken are in chains, the gauge-point is 1 or 10; if in perches, 160; and if in yards, 4840.—*Rule.* Set the length upon B to the gauge-point on A; and against the breadth upon A is the content in acres upon B.

1. Required the number of acres or contents of a field 20 chains 50 links in length, and 4 chains 40 links in breadth.

Set 20·5 on B to 1 on A; and against 4·4 on A is 9 acres on B.

2. In a piece of ground 440 yards long, and 44 broad, how many acres?

Set 440 upon B to 4840 on A; and against 44 on A is 4 acres on B.

POWER OF STEAM ENGINES.

Condensing Engines.—Rule. Set 3·5 on C to 10 on D; then D is a line of diameters for cylinders, and C the corresponding number of horses' power; thus,

H.P^{t}.	$3\frac{1}{2}$	4	5	6	8	10	12	16	20	25	30	40	50	on C.
C.D.	10 in.	$10\frac{3}{4}$	12	$13\frac{1}{4}$	$15\frac{1}{2}$	17	$18\frac{3}{4}$	$21\frac{1}{2}$	24	$26\frac{3}{4}$	$29\frac{1}{2}$	$33\frac{3}{4}$	$37\frac{3}{4}$	on D.

The same is effected on the common rule by setting 5 on C to 12 on D.

Non-condensing Engines.—Rule. Set the pressure of steam in lbs. per square inch on B to 4 upon A; and against the cylinder's diameter on D is the number of horses' power upon C.

Required the power of an engine, when the cylinder is 20 inches diameter and steam 30 lbs. per square inch.

Set 30 on B to 4 on A; and against 20 on D is 30 horses' power on C.

The same is effected on the common rule by setting the force of the steam on B to 250 on A.

OF ENGINE BOILERS.

How many superficial feet are contained in a boiler 23 feet in length and 5½ in width?

Set 1 upon B to 23 upon A; and against 5·5 upon B is 126·5 square feet upon A.

If 5 square feet of boiler surface be sufficient for each horse-power, how many horses' power of engine is the boiler equal to?

Set 5 upon B to 126·5 upon A; and against 1 upon B is 25·5 upon A.

COMMERCIAL TABLES.

TABLE BY WHICH TO FACILITATE THE CALCULATION OF BRITISH MONEY.

No.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
	at ¼d.			at ½d.			at ¾d.			at 1d.			at 1¼d.			at 1½d.			at 1¾d.		
2	0	0	0½	0	0	1	0	0	1½	0	0	2	0	0	2½	0	0	3	0	0	3½
3	0	0	0¾	0	0	1½	0	0	2¼	0	0	3	0	0	3¾	0	0	4½	0	0	5¼
4	0	0	1	0	0	2	0	0	3	0	0	4	0	0	5	0	0	6	0	0	7
5	0	0	1¼	0	0	2½	0	0	3¾	0	0	5	0	0	6¼	0	0	7½	0	0	8¾
6	0	0	1½	0	0	3	0	0	4½	0	0	6	0	0	7½	0	0	9	0	0	10½
7	0	0	1¾	0	0	3½	0	0	5¼	0	0	7	0	0	8¾	0	0	10½	0	1	0¼
8	0	0	2	0	0	4	0	0	6	0	0	8	0	0	10	0	1	0	0	1	2
9	0	0	2¼	0	0	4½	0	0	6¾	0	0	9	0	0	11¼	0	1	1½	0	1	3¾
10	0	0	2½	0	0	5	0	0	7½	0	0	10	0	1	0½	0	1	3	0	1	5½
11	0	0	2¾	0	0	5½	0	0	8¼	0	0	11	0	1	1¾	0	1	4½	0	1	7¼
12	0	0	3	0	0	6	0	0	9	0	1	0	0	1	3	0	1	6	0	1	9
13	0	0	3¼	0	0	6½	0	0	9¾	0	1	1	0	1	4¼	0	1	7½	0	1	10¾
14	0	0	3½	0	0	7	0	0	10½	0	1	2	0	1	5½	0	1	9	0	2	0½
15	0	0	3¾	0	0	7½	0	0	11¼	0	1	3	0	1	6¾	0	1	10½	0	2	2¼
16	0	0	4	0	0	8	0	1	0	0	1	4	0	1	8	0	2	0	0	2	4
17	0	0	4¼	0	0	8½	0	1	0¾	0	1	5	0	1	9¼	0	2	1½	0	2	5¾
18	0	0	4½	0	0	9	0	1	1½	0	1	6	0	1	10½	0	2	3	0	2	7½
19	0	0	4¾	0	0	9½	0	1	2¼	0	1	7	0	1	11¾	0	2	4½	0	2	9¼
20	0	0	5	0	0	10	0	1	3	0	1	8	0	2	1	0	2	6	0	2	11
30	0	0	7½	0	1	3	0	1	10½	0	2	6	0	3	1½	0	3	9	0	4	4½
40	0	0	10	0	1	8	0	2	6	0	3	4	0	4	2	0	5	0	0	5	10
50	0	1	0½	0	2	1	0	3	1½	0	4	2	0	5	2½	0	6	3	0	7	3½
60	0	1	3	0	2	6	0	3	9	0	5	0	0	6	3	0	7	6	0	8	9
70	0	1	5½	0	2	11	0	4	4½	0	5	10	0	7	3½	0	8	9	0	10	2½
80	0	1	8	0	3	4	0	5	0	0	6	8	0	8	4	0	10	0	0	11	8
90	0	1	10½	0	3	9	0	5	7½	0	7	6	0	9	4½	0	11	3	0	13	1½
100	0	2	1	0	4	2	0	6	3	0	8	4	0	10	5	0	12	6	0	14	7
200	0	4	2	0	8	4	0	12	6	0	16	8	1	0	10	1	5	0	1	9	2
300	0	6	3	0	12	6	0	18	9	1	5	0	1	11	3	1	17	6	2	3	9
400	0	8	4	0	16	8	1	5	0	1	13	4	2	1	8	2	10	0	2	18	4
500	0	10	5	1	0	10	1	11	3	2	1	8	2	12	1	3	2	6	3	12	11
600	0	12	6	1	5	0	1	17	6	2	10	0	3	2	6	3	15	0	4	7	6
700	0	14	7	1	9	2	2	3	9	2	18	4	3	12	11	4	7	6	5	2	1
800	0	16	8	1	13	4	2	10	0	3	6	8	4	3	4	5	0	0	5	16	8
900	0	18	9	1	17	6	2	16	3	3	15	0	4	13	9	5	12	6	6	11	3
1000	1	0	10	2	1	8	3	2	6	4	3	4	5	4	2	6	5	0	7	5	10
2000	2	1	8	4	3	4	6	5	0	8	6	8	10	8	4	12	10	0	14	11	8
3000	3	2	6	6	5	0	9	7	6	12	10	0	15	12	6	18	15	0	21	17	6
4000	4	3	4	8	6	8	12	10	0	16	13	4	20	16	8	25	0	0	29	3	4
5000	5	4	2	10	8	4	15	12	6	20	16	8	26	0	10	31	5	0	36	9	2
6000	6	5	0	12	10	0	18	15	0	25	0	0	31	5	0	37	10	0	43	15	0
7000	7	5	10	14	11	8	21	17	6	29	3	4	36	9	2	43	15	0	51	0	10
8000	8	6	8	16	13	4	25	0	0	33	6	8	41	13	4	50	0	0	58	6	8
9000	9	7	6	18	15	0	28	2	6	37	10	0	46	17	6	56	5	0	65	12	6

MONEY TABLE—CONTINUED.

No.	at 2d.			at 2¼d.			at 2½d.			at 2¾d.			at 3d.			at 3¼d.			at 3½d.		
	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
2	0	0	4	0	0	4½	0	0	5	0	0	5½	0	0	6	0	0	6½	0	0	7
3	0	0	6	0	0	6¾	0	0	7½	0	0	8¼	0	0	9	0	0	9¾	0	0	10½
4	0	0	8	0	0	9	0	0	10	0	0	11	0	1	0	0	1	1	0	1	2
5	0	0	10	0	0	11¼	0	1	0½	0	1	1¾	0	1	3	0	1	4¼	0	1	5½
6	0	1	0	0	1	1½	0	1	3	0	1	4½	0	1	6	0	1	7½	0	1	9
7	0	1	2	0	1	3¾	0	1	5½	0	1	7¼	0	1	9	0	1	10¾	0	2	0½
8	0	1	4	0	1	6	0	1	8	0	1	10	0	2	0	0	2	2	0	2	4
9	0	1	6	0	1	8¼	0	1	10½	0	2	0¾	0	2	3	0	2	5¼	0	2	7½
10	0	1	8	0	1	10½	0	2	1	0	2	3½	0	2	6	0	2	8½	0	2	11
11	0	1	10	0	2	0¾	0	2	3½	0	2	6¼	0	2	9	0	2	11¾	0	3	2½
12	0	2	0	0	2	3	0	2	6	0	2	9	0	3	0	0	3	3	0	3	6
13	0	2	2	0	2	5¼	0	2	8½	0	2	11¾	0	3	3	0	3	6¼	0	3	9½
14	0	2	4	0	2	7½	0	2	11	0	3	2½	0	3	6	0	3	9½	0	4	1
15	0	2	6	0	2	9¾	0	3	1½	0	3	5¼	0	3	9	0	4	0¾	0	4	4½
16	0	2	8	0	3	0	0	3	4	0	3	8	0	4	0	0	4	4	0	4	8
17	0	2	10	0	3	2¼	0	3	6½	0	3	10¾	0	4	3	0	4	7¼	0	4	11½
18	0	3	0	0	3	4½	0	3	9	0	4	1½	0	4	6	0	4	10½	0	5	3
19	0	3	2	0	3	6¾	0	3	11½	0	4	4¼	0	4	9	0	5	1¾	0	5	6½
20	0	3	4	0	3	9	0	4	2	0	4	7	0	5	0	0	5	5	0	5	10
30	0	5	0	0	5	7½	0	6	3	0	6	10½	0	7	6	0	8	1½	0	8	9
40	0	6	8	0	7	6	0	8	4	0	9	2	0	10	0	0	10	10	0	11	8
50	0	8	4	0	9	4½	0	10	5	0	11	5½	0	12	6	0	13	6½	0	14	7
60	0	10	0	0	11	3	0	12	6	0	13	9	0	15	0	0	16	3	0	17	6
70	0	11	8	0	13	1½	0	14	7	0	16	0½	0	17	6	0	18	11½	1	0	5
80	0	13	4	0	15	0	0	16	8	0	18	4	1	0	0	1	1	8	1	3	4
90	0	15	0	0	16	10½	0	18	9	1	0	7½	1	2	6	1	4	4½	1	6	3
100	0	16	8	0	18	9	1	0	10	1	2	11	1	5	0	1	7	1	1	9	2
200	1	13	4	1	17	6	2	1	8	2	5	10	2	10	0	2	14	2	2	18	4
300	2	10	0	2	16	3	3	2	6	3	8	9	3	15	0	4	1	3	4	7	6
400	3	6	8	3	15	0	4	3	4	4	11	8	5	0	0	5	8	4	5	16	8
500	4	3	4	4	13	9	5	4	2	5	14	7	6	5	0	6	15	5	7	5	10
600	5	0	0	5	12	6	6	5	0	6	17	6	7	10	0	8	2	6	8	15	0
700	5	16	8	6	11	3	7	5	10	8	0	5	8	15	0	9	9	7	10	4	2
800	6	13	4	7	10	0	8	6	8	9	3	4	10	0	0	10	16	8	11	13	4
900	7	10	0	8	8	9	9	7	6	10	6	3	11	5	0	12	3	9	13	2	6
1000	8	6	8	9	7	6	10	8	4	11	9	2	12	10	0	13	10	10	14	11	8
2000	16	13	4	18	15	0	20	16	8	22	18	4	25	0	0	27	1	8	29	3	4
3000	25	0	0	28	2	6	31	5	0	34	7	6	37	10	0	40	12	6	43	15	0
4000	33	6	8	37	10	0	41	13	4	45	16	8	50	0	0	54	3	4	58	6	8
5000	41	13	4	46	17	6	52	1	8	57	5	10	62	10	0	67	14	2	72	18	4
6000	50	0	0	56	5	0	62	10	0	68	15	0	75	0	0	81	5	0	87	10	0
7000	58	6	8	65	12	6	72	18	4	80	4	2	87	10	0	94	15	10	102	1	8
8000	66	13	4	75	0	0	83	6	8	91	13	4	100	0	0	108	6	8	116	13	4
9000	75	0	0	84	7	6	93	15	0	103	2	6	112	10	0	121	17	6	131	5	0

MONEY TABLE—CONTINUED.

No.	L.	S.	D.	L.	S.	D	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
	at 3¾d.			at 4d.			at 4¼d.			at 4½d.			at 4¾d.			at 5d.			at 5¼d.		
2	0	0	7½	0	0	8	0	0	8½	0	0	9	0	0	9½	0	0	10	0	0	10½
3	0	0	11¼	0	1	0	0	1	0¾	0	1	1½	0	1	2¼	0	1	3	0	1	3¾
4	0	1	3	0	1	4	0	1	5	0	1	6	0	1	7	0	1	8	0	1	9
5	0	1	6¾	0	1	8	0	1	9¼	0	1	10½	0	1	11¾	0	2	1	0	2	2¼
6	0	1	10½	0	2	0	0	2	1½	0	2	3	0	2	4½	0	2	6	0	2	7½
7	0	2	2¼	0	2	4	0	2	5¾	0	2	7½	0	2	9¼	0	2	11	0	3	0¾
8	0	2	6	0	2	8	0	2	10	0	3	0	0	3	2	0	3	4	0	3	6
9	0	2	9¾	0	3	0	0	3	2¼	0	3	4½	0	3	6¾	0	3	9	0	3	11¼
10	0	3	1½	0	3	4	0	3	6½	0	3	9	0	3	11½	0	4	2	0	4	4½
11	0	3	5¼	0	3	8	0	3	10¾	0	4	1½	0	4	4¼	0	4	7	0	4	9¾
12	0	3	9	0	4	0	0	4	3	0	4	6	0	4	9	0	5	0	0	5	3
13	0	4	0¾	0	4	4	0	4	7¼	0	4	10½	0	5	1¾	0	5	5	0	5	8¼
14	0	4	4½	0	4	8	0	4	11½	0	5	3	0	5	6½	0	5	10	0	6	1½
15	0	4	8¼	0	5	0	0	5	3¾	0	5	7½	0	5	11¼	0	6	3	0	6	6¾
16	0	5	0	0	5	4	0	5	8	0	6	0	0	6	4	0	6	8	0	7	0
17	0	5	3¾	0	5	8	0	6	0¼	0	6	4½	0	6	8¾	0	7	1	0	7	5¼
18	0	5	7½	0	6	0	0	6	4½	0	6	9	0	7	1½	0	7	6	0	7	10½
19	0	5	11¼	0	6	4	0	6	8¾	0	7	1½	0	7	6¼	0	7	11	0	8	3¾
20	0	6	3	0	6	8	0	7	1	0	7	6	0	7	11	0	8	4	0	8	9
30	0	9	4½	0	10	0	0	10	7½	0	11	3	0	11	10½	0	12	6	0	13	1½
40	0	12	6	0	13	4	0	14	2	0	15	0	0	15	10	0	16	8	0	17	6
50	0	15	7½	0	16	8	0	17	8½	0	18	9	0	19	9½	1	0	10	1	1	10½
60	0	18	9	1	0	0	1	1	3	1	2	6	1	3	9	1	5	0	1	6	3
70	1	1	10½	1	3	4	1	4	9½	1	6	3	1	7	8½	1	9	2	1	10	7½
80	1	5	0	1	6	8	1	8	4	1	10	0	1	11	8	1	13	4	1	15	0
90	1	8	1½	1	10	0	1	11	10½	1	13	9	1	15	7½	1	17	6	1	19	4½
100	1	11	3	1	13	4	1	15	5	1	17	6	1	19	7	2	1	8	2	3	9
200	3	2	6	3	6	8	3	10	10	3	15	0	3	19	2	4	3	4	4	7	6
300	4	13	9	5	0	0	5	6	3	5	12	6	5	18	9	6	5	0	6	11	3
400	6	5	0	6	13	4	7	1	8	7	10	0	7	18	4	8	6	8	8	15	0
500	7	16	3	8	6	8	8	17	1	9	7	6	9	17	11	10	8	4	10	18	9
600	9	7	6	10	0	0	10	12	6	11	5	0	11	17	6	12	10	0	13	2	6
700	10	18	9	11	13	4	12	7	11	13	2	6	13	17	1	14	11	8	15	6	3
800	12	10	0	13	6	8	14	3	4	15	0	0	15	16	8	16	13	4	17	10	0
900	14	1	3	15	0	0	15	18	9	16	17	6	17	16	3	18	15	0	19	13	9
1000	15	12	6	16	13	4	17	14	2	18	15	0	19	15	10	20	16	8	21	17	6
2000	31	5	0	33	6	8	35	8	4	37	10	0	39	11	8	41	13	4	43	15	0
3000	46	17	6	50	0	0	53	2	6	56	5	0	59	7	6	62	10	0	65	12	6
4000	62	10	0	66	13	4	70	16	8	75	0	0	79	3	4	83	6	8	87	10	0
5000	78	2	6	83	6	8	88	10	10	93	15	0	98	19	2	104	3	4	109	7	6
6000	93	15	0	100	0	0	106	5	0	112	10	0	118	15	0	125	0	0	131	5	0
7000	109	7	6	116	13	4	123	19	2	131	5	0	138	10	10	145	16	8	153	2	6
8000	125	0	0	133	6	8	141	13	4	150	0	0	158	6	8	166	13	4	175	0	0
9000	140	12	6	150	0	0	159	7	6	168	15	0	178	2	6	187	10	0	196	17	6

MONEY TABLE—CONTINUED.

No.	at 5½d.			at 5¾d.			at 6d.			at 6¼d.			at 6½d.			at 6¾d.			at 7d.		
	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
2	0	0	11	0	0	11½	0	1	0	0	1	0½	0	1	1	0	1	1½	0	1	2
3	0	1	4½	0	1	5¼	0	1	6	0	1	6¾	0	1	7½	0	1	8¼	0	1	9
4	0	1	10	0	1	11	0	2	0	0	2	1	0	2	2	0	2	3	0	2	4
5	0	2	3½	0	2	4¾	0	2	6	0	2	7¼	0	2	8½	0	2	9¾	0	2	11
6	0	2	9	0	2	10½	0	3	0	0	3	1½	0	3	3	0	3	4½	0	3	6
7	0	3	2½	0	3	4¼	0	3	6	0	3	7¾	0	3	9½	0	3	11¼	0	4	1
8	0	3	8	0	3	10	0	4	0	0	4	2	0	4	4	0	4	6	0	4	8
9	0	4	1½	0	4	3¾	0	4	6	0	4	8¼	0	4	10½	0	5	0¾	0	5	3
10	0	4	7	0	4	9½	0	5	0	0	5	2½	0	5	5	0	5	7½	0	5	10
11	0	5	0½	0	5	3¼	0	5	6	0	5	8¾	0	5	11½	0	6	2¼	0	6	5
12	0	5	6	0	5	9	0	6	0	0	6	3	0	6	6	0	6	9	0	7	0
13	0	5	11½	0	6	2¾	0	6	6	0	6	9¼	0	7	0½	0	7	3¾	0	7	7
14	0	6	5	0	6	8½	0	7	0	0	7	3½	0	7	7	0	7	10½	0	8	2
15	0	6	10½	0	7	2¼	0	7	6	0	7	9¾	0	8	1½	0	8	5¼	0	8	9
16	0	7	4	0	7	8	0	8	0	0	8	4	0	8	8	0	9	0	0	9	4
17	0	7	9½	0	8	1¾	0	8	6	0	8	10¼	0	9	2½	0	9	6¾	0	9	11
18	0	8	3	0	8	7½	0	9	0	0	9	4½	0	9	9	0	10	1½	0	10	6
19	0	8	8½	0	9	1¼	0	9	6	0	9	10¾	0	10	3½	0	10	8¼	0	11	1
20	0	9	2	0	9	7	0	10	0	0	10	5	0	10	10	0	11	3	0	11	8
30	0	13	9	0	14	4½	0	15	0	0	15	7½	0	16	3	0	16	10½	0	17	6
40	0	18	4	0	19	2	1	0	0	1	0	10	1	1	8	1	2	6	1	3	4
50	1	2	11	1	3	11½	1	5	0	1	6	0½	1	7	1	1	8	1½	1	9	2
60	1	7	6	1	8	9	1	10	0	1	11	3	1	12	6	1	13	9	1	15	0
70	1	12	1	1	13	6½	1	15	0	1	16	5½	1	17	11	1	19	4½	2	0	10
80	1	16	8	1	18	4	2	0	0	2	1	8	2	3	4	2	5	0	2	6	8
90	2	1	3	2	3	1½	2	5	0	2	6	10½	2	8	9	2	10	7½	2	12	6
100	2	5	10	2	7	11	2	10	0	2	12	1	2	14	2	2	16	3	2	18	4
200	4	11	8	4	15	10	5	0	0	5	4	2	5	8	4	5	12	6	5	16	8
300	6	17	6	7	3	9	7	10	0	7	16	3	8	2	6	8	8	9	8	15	0
400	9	3	4	9	11	8	10	0	0	10	8	4	10	16	8	11	5	0	11	13	4
500	11	9	2	11	19	7	12	10	0	13	0	5	13	10	10	14	1	3	14	11	8
600	13	15	0	14	7	6	15	0	0	15	12	6	16	5	0	16	17	6	17	10	0
700	16	0	10	16	15	5	17	10	0	18	4	7	18	19	2	19	13	9	20	8	4
800	18	6	8	19	3	4	20	0	0	20	16	8	21	13	4	22	10	0	23	6	8
900	20	12	6	21	11	3	22	10	0	23	8	9	24	7	6	25	6	3	26	5	0
1000	22	18	4	23	19	2	25	0	0	26	0	10	27	1	8	28	2	6	29	3	4
2000	45	16	8	47	18	4	50	0	0	52	1	8	54	3	4	56	5	0	58	6	8
3000	68	15	0	71	17	6	75	0	0	78	2	6	81	5	0	84	7	6	87	10	0
4000	91	13	4	95	16	8	100	0	0	104	3	4	108	6	8	112	10	0	116	13	4
5000	114	11	8	119	15	10	125	0	0	130	4	2	135	8	4	140	12	6	145	16	8
6000	137	10	0	143	15	0	150	0	0	156	5	0	162	10	0	168	15	0	175	0	0
7000	160	8	4	167	14	2	175	0	0	182	5	10	189	11	8	196	17	6	204	3	4
8000	183	6	8	191	13	4	200	0	0	208	6	8	216	13	4	225	0	0	233	6	8
9000	206	5	0	215	12	6	225	0	0	234	7	6	243	15	0	253	2	6	262	10	0

MONEY TABLE—CONTINUED.

No.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
	at 7¼d.			at 7½d.			at 7¾d.			at 8d.			at 8¼d.			at 8½d.			at 8¾d.		
2	0	1	2½	0	1	3	0	1	3½	0	1	4	0	1	4½	0	1	5	0	1	5½
3	0	1	9¾	0	1	10½	0	1	11¼	0	2	0	0	2	0¾	0	2	1½	0	2	2¼
4	0	2	5	0	2	6	0	2	7	0	2	8	0	2	9	0	2	10	0	2	11
5	0	3	0¼	0	3	1½	0	3	2¾	0	3	4	0	3	5¼	0	3	6½	0	3	7¾
6	0	3	7½	0	3	9	0	3	10½	0	4	0	0	4	1½	0	4	3	0	4	4½
7	0	4	2¾	0	4	4½	0	4	6¼	0	4	8	0	4	9¾	0	4	11½	0	5	1¼
8	0	4	10	0	5	0	0	5	2	0	5	4	0	5	6	0	5	8	0	5	10
9	0	5	5¼	0	5	7½	0	5	9¾	0	6	0	0	6	2¼	0	6	4½	0	6	6¾
10	0	6	0½	0	6	3	0	6	5½	0	6	8	0	6	10½	0	7	1	0	7	3½
11	0	6	7¾	0	6	10½	0	7	1¼	0	7	4	0	7	6¾	0	7	9½	0	8	0¼
12	0	7	3	0	7	6	0	7	9	0	8	0	0	8	3	0	8	6	0	8	9
13	0	7	10¼	0	8	1½	0	8	4¾	0	8	8	0	8	11¼	0	9	2½	0	9	5¾
14	0	8	5½	0	8	9	0	9	0½	0	9	4	0	9	7½	0	9	11	0	10	2½
15	0	9	0¾	0	9	4½	0	9	8¼	0	10	0	0	10	3¾	0	10	7½	0	10	11¼
16	0	9	8	0	10	0	0	10	4	0	10	8	0	11	0	0	11	4	0	11	8
17	0	10	3¼	0	10	7½	0	10	11¾	0	11	4	0	11	8¼	0	12	0½	0	12	4¾
18	0	10	10½	0	11	3	0	11	7½	0	12	0	0	12	4½	0	12	9	0	13	1½
19	0	11	5¾	0	11	10½	0	12	3¼	0	12	8	0	13	0¾	0	13	5½	0	13	10¼
20	0	12	1	0	12	6	0	12	11	0	13	4	0	13	9	0	14	2	0	14	7
30	0	18	1½	0	18	9	0	19	4½	1	0	0	1	0	7½	1	1	3	1	1	10½
40	1	4	2	1	5	0	1	5	10	1	6	8	1	7	6	1	8	4	1	9	2
50	1	10	2½	1	11	3	1	12	3½	1	13	4	1	14	4½	1	15	5	1	16	5½
60	1	16	3	1	17	6	1	18	9	2	0	0	2	1	3	2	2	6	2	3	9
70	2	2	3½	2	3	9	2	5	2½	2	6	8	2	8	1½	2	9	7	2	11	0½
80	2	8	4	2	10	0	2	11	8	2	13	4	2	15	0	2	16	8	2	18	4
90	2	14	4½	2	16	3	2	18	1½	3	0	0	3	1	10½	3	3	9	3	5	7½
100	3	0	5	3	2	6	3	4	7	3	6	8	3	8	9	3	10	10	3	12	11
200	6	0	10	6	5	0	6	9	2	6	13	4	6	17	6	7	1	8	7	5	10
300	9	1	3	9	7	6	9	13	9	10	0	0	10	6	3	10	12	6	10	18	9
400	12	1	8	12	10	0	12	18	4	13	6	8	13	15	0	14	3	4	14	11	8
500	15	2	1	15	12	6	16	2	11	16	13	4	17	3	9	17	14	2	18	4	7
600	18	2	6	18	15	0	19	7	6	20	0	0	20	12	6	21	5	0	21	17	6
700	21	2	11	21	17	6	22	12	1	23	6	8	24	1	3	24	15	10	25	10	5
800	24	3	4	25	0	0	25	16	8	26	13	4	27	10	0	28	6	8	29	3	4
900	27	3	9	28	2	6	29	1	3	30	0	0	30	18	9	31	17	6	32	16	3
1000	30	4	2	31	5	0	32	5	10	33	6	8	34	7	6	35	8	4	36	9	2
2000	60	8	4	62	10	0	64	11	8	66	13	4	68	15	0	70	16	8	72	18	4
3000	90	12	6	93	15	0	96	17	6	100	0	0	103	2	6	106	5	0	109	7	6
4000	120	16	8	125	0	0	129	3	4	133	6	8	137	10	0	141	13	4	145	16	8
5000	151	0	10	156	5	0	161	9	2	166	13	4	171	17	6	177	1	8	182	5	10
6000	181	5	0	187	10	0	193	15	0	200	0	0	206	5	0	212	10	0	218	15	0
7000	211	9	2	218	15	0	226	0	10	233	6	8	240	12	6	247	18	4	255	4	2
8000	241	13	4	250	0	0	258	6	8	266	13	4	275	0	0	283	6	8	291	13	4
9000	271	17	6	281	5	0	290	12	6	300	0	0	309	7	6	318	15	0	328	2	6

MONEY TABLE—CONTINUED.

No.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
	at 9*d.*			at 9¼*d.*			at 9½*d.*			at 9¾*d.*			at 10*d.*			at 10¼*d.*			at 10½*d.*		
2	0	1	6	0	1	6½	0	1	7	0	1	7½	0	1	8	0	1	8½	0	1	9
3	0	2	3	0	2	3¾	0	2	4½	0	2	5¼	0	2	6	0	2	6¾	0	2	7½
4	0	3	0	0	3	1	0	3	2	0	3	3	0	3	4	0	3	5	0	3	6
5	0	3	9	0	3	10¼	0	3	11½	0	4	0¾	0	4	2	0	4	3¼	0	4	4½
6	0	4	6	0	4	7½	0	4	9	0	4	10½	0	5	0	0	5	1½	0	5	3
7	0	5	3	0	5	4¾	0	5	6½	0	5	8¼	0	5	10	0	5	11¾	0	6	1½
8	0	6	0	0	6	2	0	6	4	0	6	6	0	6	8	0	6	10	0	7	0
9	0	6	9	0	6	11¼	0	7	1½	0	7	3¾	0	7	6	0	7	8¼	0	7	10½
10	0	7	6	0	7	8½	0	7	11	0	8	1½	0	8	4	0	8	6½	0	8	9
11	0	8	3	0	8	5¾	0	8	8½	0	8	11¼	0	9	2	0	9	4¾	0	9	7½
12	0	9	0	0	9	3	0	9	6	0	9	9	0	10	0	0	10	3	0	10	6
13	0	9	9	0	10	0¼	0	10	3½	0	10	6¾	0	10	10	0	11	1¼	0	11	4½
14	0	10	6	0	10	9½	0	11	1	0	11	4½	0	11	8	0	11	11½	0	12	3
15	0	11	3	0	11	6¾	0	11	10½	0	12	2¼	0	12	6	0	12	9¾	0	13	1½
16	0	12	0	0	12	4	0	12	8	0	13	0	0	13	4	0	13	8	0	14	0
17	0	12	9	0	13	1¼	0	13	5½	0	13	9¾	0	14	2	0	14	6¼	0	14	10½
18	0	13	6	0	13	10½	0	14	3	0	14	7½	0	15	0	0	15	4½	0	15	9
19	0	14	3	0	14	7¾	0	15	0½	0	15	5¼	0	15	10	0	16	2¾	0	16	7½
20	0	15	0	0	15	5	0	15	10	0	16	3	0	16	8	0	17	1	0	17	6
30	1	2	6	1	3	1½	1	3	9	1	4	4½	1	5	0	1	5	7½	1	6	3
40	1	10	0	1	10	10	1	11	8	1	12	6	1	13	4	1	14	2	1	15	0
50	1	17	6	1	18	6½	1	19	7	2	0	7½	2	1	8	2	2	8½	2	3	9
60	2	5	0	2	6	3	2	7	6	2	8	9	2	10	0	2	11	3	2	12	6
70	2	12	6	2	13	11½	2	15	5	2	16	10½	2	18	4	2	19	9½	3	1	3
80	3	0	0	3	1	8	3	3	4	3	5	0	3	6	8	3	8	4	3	10	0
90	3	7	6	3	9	4½	3	11	3	3	13	1½	3	15	0	3	16	10½	3	18	9
100	3	15	0	3	17	1	3	19	2	4	1	3	4	3	4	4	5	5	4	7	6
200	7	10	0	7	14	2	7	18	4	8	2	6	8	6	8	8	10	10	8	15	0
300	11	5	0	11	11	3	11	17	6	12	3	9	12	10	0	12	16	3	13	2	6
400	15	0	0	15	8	4	15	16	8	16	5	0	16	13	4	17	1	8	17	10	0
500	18	15	0	19	5	5	19	15	10	20	6	3	20	16	8	21	7	1	21	17	6
600	22	10	0	23	2	6	23	15	0	24	7	6	25	0	0	25	12	6	26	5	0
700	26	5	0	26	19	7	27	14	2	28	8	9	29	3	4	29	17	11	30	12	6
800	30	0	0	30	16	8	31	13	4	32	10	0	33	6	8	34	3	4	35	0	0
900	33	15	0	34	13	9	35	12	6	36	11	3	37	10	0	38	8	9	39	7	6
1000	37	10	0	38	10	10	39	11	8	40	12	6	41	13	4	42	14	2	43	15	0
2000	75	0	0	77	1	8	79	3	4	81	5	0	83	6	8	85	8	4	87	10	0
3000	112	10	0	115	12	6	118	15	0	121	17	6	125	0	0	128	2	6	131	5	0
4000	150	0	0	154	3	4	158	6	8	162	10	0	166	13	4	170	16	8	175	0	0
5000	187	10	0	192	14	2	197	18	4	203	2	6	208	6	8	213	10	10	218	15	0
6000	225	0	0	231	5	0	237	10	0	243	15	0	250	0	0	256	5	0	262	10	0
7000	262	10	0	269	15	10	277	1	8	284	7	6	291	13	4	298	19	2	306	5	0
8000	300	0	0	308	6	8	316	13	4	325	0	0	333	6	8	341	13	4	350	0	0
9000	337	10	0	346	17	6	356	5	0	365	12	6	375	0	0	384	7	6	393	15	0

MONEY TABLE—CONTINUED.

No.	at 10¾d. L.	S.	D.	at 11d. L.	S.	D.	at 11¼d. L.	S.	D.	at 11½d. L.	S.	D.	at 11¾d. L.	S.	D.	at 1s. L.	S.	D.
2	0	1	9½	0	1	10	0	1	10½	0	1	11	0	1	11½	0	2	0
3	0	2	8¼	0	2	9	0	2	9¾	0	2	10½	0	2	11¼	0	3	0
4	0	3	7	0	3	8	0	3	9	0	3	10	0	3	11	0	4	0
5	0	4	5¾	0	4	7	0	4	8¼	0	4	9½	0	4	10¾	0	5	0
6	0	5	4½	0	5	6	0	5	7½	0	5	9	0	5	10½	0	6	0
7	0	6	3¼	0	6	5	0	6	6¾	0	6	8½	0	6	10¼	0	7	0
8	0	7	2	0	7	4	0	7	6	0	7	8	0	7	10	0	8	0
9	0	8	0¾	0	8	3	0	8	5¼	0	8	7½	0	8	9¾	0	9	0
10	0	8	11½	0	9	2	0	9	4½	0	9	7	0	9	9½	0	10	0
11	0	9	10¼	0	10	1	0	10	3¾	0	10	6½	0	10	9¼	0	11	0
12	0	10	9	0	11	0	0	11	3	0	11	6	0	11	9	0	12	0
13	0	11	7¾	0	11	11	0	12	2¼	0	12	5½	0	12	8¾	0	13	0
14	0	12	6½	0	12	10	0	13	1½	0	13	5	0	13	8½	0	14	0
15	0	13	5¼	0	13	9	0	14	0¾	0	14	4½	0	14	8¼	0	15	0
16	0	14	4	0	14	8	0	15	0	0	15	4	0	15	8	0	16	0
17	0	15	2¾	0	15	7	0	15	11¼	0	16	3½	0	16	7¾	0	17	0
18	0	16	1½	0	16	6	0	16	10½	0	17	3	0	17	7½	0	18	0
19	0	17	0¼	0	17	5	0	17	9¾	0	18	2½	0	18	7¼	0	19	0
20	0	17	11	0	18	4	0	18	9	0	19	2	0	19	7	1	0	0
30	1	6	10½	1	7	6	1	8	1½	1	8	9	1	9	4½	1	10	0
40	1	15	10	1	16	8	1	17	6	1	18	4	1	19	2	2	0	0
50	2	4	9½	2	5	10	2	6	10½	2	7	11	2	8	11½	2	10	0
60	2	13	9	2	15	0	2	16	3	2	17	6	2	18	9	3	0	0
70	3	2	8½	3	4	2	3	5	7½	3	7	1	3	8	6½	3	10	0
80	3	11	8	3	13	4	3	15	0	3	16	8	3	18	4	4	0	0
90	4	0	7½	4	2	6	4	4	4½	4	6	3	4	8	1½	4	10	0
100	4	9	7	4	11	8	4	13	9	4	15	10	4	17	11	5	0	0
200	8	19	2	9	3	4	9	7	6	9	11	8	9	15	10	10	0	0
300	13	8	9	13	15	0	14	1	3	14	7	6	14	13	9	15	0	0
400	17	18	4	18	6	8	18	15	0	19	3	4	19	11	8	20	0	0
500	22	7	11	22	18	4	23	8	9	23	19	2	24	9	7	25	0	0
600	26	17	6	27	10	0	28	2	6	28	15	0	29	7	6	30	0	0
700	31	7	1	32	1	8	32	16	3	33	10	10	34	5	5	35	0	0
800	35	16	8	36	13	4	37	10	0	38	6	8	39	3	4	40	0	0
900	40	6	3	41	5	0	42	3	9	43	2	6	44	1	3	45	0	0
1000	44	15	10	45	16	8	46	17	6	47	18	4	48	19	2	50	0	0
2000	89	11	8	91	13	4	93	15	0	95	16	8	97	18	4	100	0	0
3000	134	7	6	137	10	0	140	12	6	143	15	0	146	17	6	150	0	0
4000	179	3	4	183	6	8	187	10	0	191	13	4	195	16	8	200	0	0
5000	223	19	2	229	3	4	234	7	6	239	11	8	244	15	10	250	0	0
6000	268	15	0	275	0	0	281	5	0	287	10	0	293	15	0	300	0	0
7000	313	10	10	220	16	8	328	2	6	335	8	4	342	14	2	350	0	0
8000	358	6	8	366	13	4	375	0	0	383	6	8	391	13	4	400	0	0
9000	403	2	6	412	10	0	421	17	6	431	5	0	440	12	6	450	0	0

EQUIVALENT PRICES TO COMMON WEIGHTS AND NUMBERS.

Per ton or 2240 lbs.			cwt. or 112 lbs.			qr. or 28 lbs.			stone or 14 lbs.		lb. or 1.	doz. or 12.		score or 20.		per 100.			per 120.			gross or 144.			per 1000.		
L.	S.	D.	L.	S.	D.	L.	S.	D.	S.	D.	D.	S.	D.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
2	6	8	0	2	4	0	0	7	0	3½	¼	0	3	0	5	0	2	1	0	2	6	0	3	0	1	0	10
3	10	0	0	3	6	0	0	10½	0	5¼	⅜	0	4½	0	7½	0	3	1½	0	3	9	0	4	6	1	11	3
4	13	4	0	4	8	0	1	2	0	7	½	0	6	0	10	0	4	2	0	5	0	0	6	0	2	1	8
5	16	8	0	5	10	0	1	5½	0	8¾	⅝	0	7½	1	0½	0	5	2½	0	6	3	0	7	6	2	12	1
7	0	0	0	7	0	0	1	9	0	10½	¾	0	9	1	3	0	6	3	0	7	6	0	9	0	3	2	6
8	3	4	0	8	2	0	2	0½	1	0¼	⅞	0	10½	1	5½	0	7	3½	0	8	9	0	10	6	3	12	11
9	6	8	0	9	4	0	2	4	1	2	1d.	1	0	1	8	0	8	4	0	10	0	0	12	0	4	3	4
10	10	0	0	10	6	0	2	7½	1	3¾	1⅛	1	1½	1	10½	0	9	4½	0	11	3	0	13	6	4	13	9
11	13	4	0	11	8	0	2	11	1	5½	1¼	1	3	2	1	0	10	5	0	12	6	0	15	0	5	4	2
12	16	8	0	12	10	0	3	2½	1	7¼	1⅜	1	4½	2	3½	0	11	5½	0	13	9	0	16	6	5	14	7
14	0	0	0	14	0	0	3	6	1	9	1½	1	6	2	6	0	12	6	0	15	0	0	18	0	6	5	0
15	3	4	0	15	2	0	3	9½	1	10¾	1⅝	1	7½	2	8½	0	13	6½	0	16	3	0	19	6	6	15	5
16	6	8	0	16	4	0	4	1	2	0½	1¾	1	9	2	11	0	14	7	0	17	6	1	1	0	7	5	10
17	10	0	0	17	6	0	4	4½	2	2¼	1⅞	1	10½	3	1½	0	15	7½	0	18	9	1	2	6	7	16	3
18	13	4	0	18	8	0	4	8	2	4	2d.	2	0	3	4	0	16	8	1	0	0	1	4	0	8	6	8
19	16	8	0	19	10	0	4	11½	2	5¾	2⅛	2	1½	3	6½	0	17	8½	1	1	3	1	5	6	8	17	1
21	0	0	1	1	0	0	5	3	2	7½	2¼	2	3	3	9	0	18	9	1	2	6	1	7	0	9	7	6
22	3	4	1	2	2	0	5	6½	2	9¼	2⅜	2	4½	3	11½	0	19	9½	1	3	9	1	8	6	9	17	11
23	6	8	1	3	4	0	5	10	2	11	2½	2	6	4	2	1	0	10	1	5	0	1	10	0	10	8	4
24	10	0	1	4	6	0	6	1½	3	0¾	2⅝	2	7½	4	4½	1	1	10½	1	6	3	1	11	6	10	18	9
25	13	4	1	5	8	0	6	5	3	2½	2¾	2	9	4	7	1	2	11	1	7	6	1	13	0	11	9	2
26	16	8	1	6	10	0	6	8½	3	4¼	2⅞	2	10½	4	9½	1	3	11½	1	8	9	1	14	6	11	19	7
28	0	0	1	8	0	0	7	0	3	6	3d.	3	0	5	0	1	5	0	1	10	0	1	16	0	12	10	0
29	3	4	1	9	2	0	7	3½	3	7¼	3⅛	3	1½	5	2½	1	6	0½	1	11	3	1	17	6	13	0	5
30	6	8	1	10	4	0	7	7	3	9½	3¼	3	3	5	5	1	7	1	1	12	6	1	19	0	13	10	10
31	10	0	1	11	6	0	7	10½	3	11¼	3⅜	3	4½	5	7½	1	8	1½	1	13	9	2	0	6	14	1	3
32	13	4	1	12	8	0	8	2	4	1	3½	3	6	5	10	1	9	2	1	15	0	2	2	0	14	11	8
33	16	8	1	13	4	0	8	5½	4	2¾	3⅝	3	7½	6	0½	1	10	2½	1	16	3	2	3	6	15	2	1
35	0	0	1	15	0	0	8	9	4	4½	3¾	3	9	6	3	1	11	3	1	17	6	2	5	0	15	12	6
36	3	4	1	16	2	0	9	0½	4	6¼	3⅞	3	10½	6	5½	1	12	3½	1	18	9	2	6	6	16	2	11
37	6	8	1	17	4	0	9	4	4	8	4d.	4	0	6	8	1	13	4	2	0	0	2	8	0	16	13	4

38 10 0	1 18 6	0 9 7½	4 9¾	4⅛	4 1½	6 10½	1 14 4½	2 1 3	2 9 6	17 3 9
39 13 4	1 19 8	0 9 11	4 11½	4¼	4 3	7 1	1 15 5	2 2 6	2 11 0	17 14 2
40 16 8	2 0 10	0 10 2½	5 1¼	4⅜	4 4½	7 3½	1 16 5½	2 3 9	2 12 6	18 4 7
42 0 0	2 2 0	0 10 6	5 3	4½	4 6	7 6	1 17 6	2 5 0	2 14 0	18 15 0
43 3 4	2 3 2	0 10 9½	5 4¾	4⅝	4 7½	7 8½	1 18 6½	2 6 3	2 15 6	19 5 5
44 6 8	2 4 4	0 11 1	5 6½	4¾	4 9	7 11	1 19 7	2 7 6	2 17 0	19 15 10
45 10 0	2 5 6	0 11 4½	5 8¼	4⅞	4 10½	8 1½	2 0 7½	2 8 9	2 18 6	20 6 3
46 13 4	2 6 8	0 11 8	5 10	5*d.*	5 0	8 4	2 1 8	2 10 0	3 0 0	20 16 8
49 0 0	2 9 0	0 12 3	6 1½	5¼	5 3	8 9	2 3 9	2 12 6	3 3 0	21 17 6
51 6 8	2 11 4	0 12 10	6 5	5½	5 6	9 2	2 5 10	2 15 0	3 6 0	22 18 4
53 13 4	2 13 8	0 13 5	6 8½	5¾	5 9	9 7	2 7 11	2 17 6	3 9 0	23 19 2
56 0 0	2 16 0	0 14 0	7 0	6*d.*	6 0	10 0	2 10 0	3 0 0	3 12 0	25 0 0
58 6 8	2 18 4	0 14 7	7 3½	6¼	6 3	10 5	2 12 1	3 2 6	3 15 0	26 0 10
60 13 4	3 0 8	0 15 2	7 7	6½	6 6	10 10	2 14 2	3 5 0	3 18 0	27 1 8
63 0 0	3 3 0	0 15 9	7 10½	6¾	6 9	11 3	2 16 3	3 7 6	4 1 0	28 2 6
65 6 8	3 5 4	0 16 4	8 2	7*d.*	7 0	11 8	2 18 4	3 10 0	4 4 0	29 3 4
67 13 4	3 7 8	0 16 11	8 5½	7¼	7 3	12 1	3 0 5	3 12 6	4 7 0	30 4 2
70 0 0	3 10 0	0 17 6	8 9	7½	7 6	12 6	3 2 6	3 15 0	4 10 0	31 5 0
72 6 8	3 12 4	0 18 1	9 0½	7¾	7 9	12 11	3 4 7	3 17 6	4 13 0	32 5 10
74 13 4	3 14 8	0 18 8	9 4	8*d.*	8 0	13 4	3 6 8	4 0 0	4 16 0	33 6 8
77 0 0	3 17 0	0 19 3	9 7½	8¼	8 3	13 9	3 8 9	4 2 6	4 19 0	34 7 6
79 6 8	3 19 4	0 19 10	9 11	8½	8 6	14 2	3 10 10	4 5 0	5 2 0	35 8 4
81 13 4	4 1 8	1 0 5	10 2½	8¾	8 9	14 7	3 12 11	4 7 6	5 5 0	36 9 2
84 0 0	4 4 0	1 1 0	10 6	9*d.*	9 0	15 0	3 15 0	4 10 0	5 8 0	37 10 0
86 6 8	4 6 4	1 1 7	10 9½	9¼	9 3	15 5	3 17 1	4 12 6	5 11 0	38 10 10
88 13 4	4 8 8	1 2 2	11 1	9½	9 6	15 10	3 19 2	4 15 0	5 14 0	39 11 8
91 0 0	4 11 0	1 2 9	11 4½	9¾	9 9	16 3	4 1 3	4 17 6	5 17 0	40 12 6
93 6 8	4 13 4	1 3 4	11 8	10*d.*	10 0	16 8	4 3 4	5 0 0	6 0 0	41 13 4
95 13 4	4 15 8	1 3 11	11 11½	10¼	10 3	17 1	4 5 5	5 2 6	6 3 0	42 14 2
98 0 0	4 18 0	1 4 6	12 3	10½	10 6	17 6	4 7 6	5 5 0	6 6 0	43 15 0
100 6 8	5 0 4	1 5 1	12 6½	10¾	10 9	17 11	4 9 7	5 7 6	6 9 0	44 15 10
102 13 4	5 2 8	1 5 8	12 10	11*d.*	11 0	18 4	4 11 8	5 10 0	6 12 0	45 16 8
105 0 0	5 5 0	1 6 3	13 1½	11¼	11 3	18 9	4 13 9	5 12 6	6 15 0	46 17 6
107 6 8	5 7 4	1 6 10	13 5	11½	11 6	19 2	4 15 10	5 15 0	6 18 0	47 18 4
109 13 4	5 9 8	1 7 5	13 8½	11¾	11 9	19 7	4 17 11	5 17 6	7 1 0	48 19 2
112 0 0	5 12 0	1 8 0	14 0	12*d.*	12 0	20 0	5 0 0	6 0 0	7 4 0	50 0 0

Practical Utility of the Preceding Tables.

1. What will be the cost of 1 ton 2 cwts. 3qrs. 4 ℔s. at $7\frac{3}{4}d.$ per ℔.

1 ton	=	2240 ℔s.
2 cwts.	=	224 „
3 qrs.	=	84 „
4 ℔s.	=	4 „
Total	=	2552 „

And 2000 at $7\frac{3}{4}d.$ (as per Table, p. 131)	=£64	11	8
500 „	= 16	2	11
50 „	= 1	12	$3\frac{1}{2}$
2 „	= 0	1	$3\frac{1}{2}$
2552	£82	8	2

2. In the Table of Equivalent Prices, the fifth column from the left hand is the price per single article, or 1; hence the other columns on the right and left of that give the price at an equal rate, according to the various denominations by which the columns are headed.

Thus, suppose the price per ℔.$=3\frac{1}{4}d.$, the price per ton=£30. 6*s*. 8*d*. Again, suppose the price per gross =£1. 10*s*., the price per dozen=2*s*. 6*d*., &c.

STRENGTH OF MATERIALS.

Materials of construction are liable to four different kinds of strain; viz., stretching, crushing, transverse action, and torsion or twisting: the first of which depends upon the body's tenacity alone; the second, on its resistance to compression; the third, on its tenacity and compression combined; and the fourth, on that property by which it opposes any acting force tending to change from a straight line, to that of a spiral direction, the fibres of which the body is composed.

In bodies, the power of tenacity and resistance to compression in the direction of their length, is as the cross section of their area multiplied by the results of experiments on similar bodies, as exhibited in the following Table.

Table showing the Tenacities, Resistances to Compression, and other Properties of the common Materials of Construction.

Names of Bodies.	Absolute		Compared with Cast Iron		
	Tenacity in lbs. per sq. inch.	Resistance to compression in lbs. per sq. in.	Its strength is	Its extensibility is	Its stiffness is
Ash . . .	14130	—	0·23	2·6	0·089
Beech . . .	12225	8548	0·15	2·1	0·073
Brass . . .	17968	10304	0·435	0·9	0·49
Brick . . .	275	562	—	—	—
Cast iron . . .	13434	86397	1·000	1·0	1·000
Copper (wrought) .	33000	—	—	—	—
Elm . . .	9720	1033	0·21	2·9	0·073
Fir, or Pine, white .	12346	2028	0·23	2·4	0·1
„ „ red .	11800	5375	0·3	2·4	0·1
„ „ yellow .	11835	5445	0·25	2·9	0·087
Granite, Aberdeen .	—	10910	—	—	—
Gun-metal (copper 8, and tin 1) . .	35838	—	0·65	1·25	0·535
Malleable iron . .	56000	—	1·12	0·86	1·3
Larch . . .	12240	5568	0·136	2·3	0·058
Lead . . .	1824	—	0·096	2·5	0·0385
Mahogany, Honduras	11475	8000	0·24	2·9	0·487
Marble . . .	551	6060	—	—	—
Oak	11880	9504	0·25	2·8	0·093
Rope (1 in. in circum.)	200	—	—	—	—
Steel . . .	128000	—	—	—	—
Stone, Bath . .	478	—	—	—	—
„ Craigleith .	772	5490	—	—	—
„ Dundee . .	2661	6630	—	—	—
„ Portland .	857	3729	—	—	—
Tin (cast) . .	4736	—	0·182	0·75	0·25
Zinc (sheet) . .	9120	—	0·365	0·5	0·76

Comparative Strength and Weight of Ropes and Chains.

Circum. of rope in inches.	Weight per fathom in lbs.	Diameter of chain in inches.	Weight per fathom in lbs.	Proof strength in tons & cwt.		Circum. of rope in inches.	Weight per fathom in lbs.	Diameter of chain in inches.	Weight per fathom in lbs.	Proof strength in tons & cwt.	
$3\frac{1}{2}$	$2\frac{3}{4}$	$\frac{5}{16}$	$5\frac{1}{2}$	1	$5\frac{1}{2}$	10	23	$\frac{7}{8}$	43	10	0
$4\frac{1}{4}$	$4\frac{3}{4}$	$\frac{3}{8}$	8	1	$16\frac{3}{4}$	$10\frac{3}{4}$	28	$\frac{15}{16}$	49	11	11
5	$5\frac{3}{4}$	$\frac{7}{16}$	$10\frac{1}{2}$	2	10	$11\frac{1}{2}$	$30\frac{1}{2}$	1in.	56	13	8
$5\frac{3}{4}$	7	$\frac{1}{2}$	14	3	$5\frac{1}{2}$	$12\frac{1}{4}$	36	$1\frac{1}{16}$	63	14	18
$6\frac{1}{2}$	$9\frac{3}{4}$	$\frac{9}{16}$	18	4	$3\frac{1}{2}$	13	39	$1\frac{1}{8}$	71	16	14
7	$11\frac{1}{4}$	$\frac{5}{8}$	22	5	2	$13\frac{3}{4}$	45	$1\frac{3}{16}$	79	18	11
8	15	$\frac{11}{16}$	27	6	$4\frac{1}{2}$	$14\frac{1}{2}$	$48\frac{1}{2}$	$1\frac{1}{4}$	87	20	8
$8\frac{3}{4}$	19	$\frac{3}{4}$	32	7	7	$15\frac{1}{4}$	56	$1\frac{5}{16}$	96	22	13
$9\frac{1}{2}$	21	$\frac{13}{16}$	37	8	$13\frac{1}{2}$	16	60	$1\frac{3}{8}$	106	24	18

Note.—It must be understood and also borne in mind, that in estimating the amount of tensile strain to which a body is subjected, the weight of the body itself must also be taken into account; for according to its position so may it approximate to its whole weight, in tending to produce tension within itself; as in the almost constant application of ropes and chains to great depths, considerable heights, &c.

Alloys that are of greater Tenacity than the Sum of their Constituents, as determined by the Experiments of Muschenbroek.

Swedish copper 6 parts, Malacca tin 1;	tenacity per sq. inch	64,000 lbs.
Chili copper 6 parts, Malacca tin 1;	,, ,,	60,000 ,,
Japan copper 5 parts, Banca tin 1;	,, ,,	57,000 ,,
Anglesea copper 6 parts, Cornish tin 1;	,, ,,	41,000 ,,
Common block tin 4, lead 1, zinc 1;	,, ,,	13,000 ,,
Malacca tin 4, regulus of antimony 1;	,, ,,	12,000 ,,
Block tin 3, lead 1;	,, ,,	10,200 ,,
Block tin 8, zinc 1;	,, ,,	10,000 ,,
Lead 1, zinc 1;	,, ,,	4,500 ,,

RESISTANCE TO LATERAL PRESSURE, OR TRANSVERSE ACTION.

The strength of a square or rectangular beam to resist lateral pressure acting in a perpendicular direction to its length, is as the breadth and square of the depth, and inversely as the length;—thus, a beam twice the breadth of another, all other circumstances being alike, equal twice the strength of the other; or twice the depth, equal four times the strength, and twice the length, equal only one half the strength, &c., according to the rule.

Table of Data, containing the results of Experiments on the Elasticity and Strength of various Species of Timber, by Mr. Barlow.

Species of Timber.	Value of E.	Value of S.	Species of Timber.	Value of E.	Value of S.
Teak.........	174·7	2462	Elm	50·64	1013
Poona	122·26	2221	Pitch pine.........	88·68	1632
English oak	105	1672	Red pine	133	1341
Canadian do.	155·5	1766	New England fir	158·5	1102
Dantzic do.	86·2	1457	Riga fir	90	1100
Adriatic do.	70·5	1383	Mar Forest fir ...	63	1200
Ash	119	2026	Larch	76	900
Beech	98	1556	Norway spruce...	105·47	1474

To find the dimensions of a beam capable of sustaining a given weight, with a given degree of deflection, when supported at both ends.

Rule.—Multiply the weight to be supported in lbs. by the cube of the length in feet; divide the product by 32 times the tabular value of E, multiplied into the given deflection in inches, and the quotient is the breadth multiplied by the cube of the depth in inches.

Note 1.—When the beam is intended to be square, then the fourth root of the quotient is the breadth and depth required.

Note 2.—If the beam is to be cylindrical, multiply the quotient by 1·7, and the fourth root of the product is the diameter.

Ex. The distance between the supports of a beam of Riga fir is 16 feet, and the weight it must be capable of sustaining in the middle of its length is 8000 lbs., with a deflection of not more than $\frac{3}{4}$ of an inch; what must be the depth of the beam, supposing the breadth 8 inches?

$$\frac{16^3 \times 8000}{90 \times 32 \times \cdot 75} = 15171 \div 8 = \sqrt[3]{1896} = 12\cdot 35 \text{ inches the depth.}$$

To determine the absolute strength of a rectangular beam of timber when supported at both ends, and loaded in the middle of its length, as beams in general ought to be calculated to, so that they may be rendered capable of withstanding all accidental cases of emergency.

Rule.—Multiply the tabular value of s by four times the depth of the beam in inches, and by the area of the cross section in inches; divide the product by the distance between the supports in inches, and the quotient will be the absolute strength of the beam in lbs.

Note 1.—If the beam be not laid horizontally, the distance between the supports, for calculation, must be the horizontal distance.

Note 2.—One-fourth of the weight obtained by the rule is the greatest weight that ought to be applied in practice as permanent load.

Note 3.—If the load is to be applied at any other point than the middle, then the strength will be, as the product of the two distances is to the square of half the length of the beam between the supports;—or, twice the distance from one end, multiplied by twice from the other, and divided by the whole length, equal the effective length of the beam.

Ex. In a building 18 feet in width, an engine boiler of $5\frac{1}{2}$ tons is to be fixed, the centre of which to be 7 feet from the wall; and having two pieces of red pine 10 inches by 6, which I can lay across the two walls for the purpose of slinging it at each end,—may I with sufficient confidence apply them, so as to effect this object?

$$\frac{2240 \times 5{\cdot}5}{2} = 6160 \text{ lbs. to carry at each end.}$$

And 18 feet—7=11, double each, or 14 and 22, then

$$\frac{14 \times 22}{18} = 17 \text{ feet, or } 204 \text{ inches, effective length of beam.}$$

Tabular value of S, red pine $= \frac{1341 \times 4 \times 10 \times 60}{204} = 15776$ lbs., the absolute strength of each piece of timber at that point.

To determine the dimensions of a rectangular beam capable of supporting a required weight, with a given degree of deflection, when fixed at one end.

Rule.—Divide the weight to be supported, in lbs., by the tabular value of E, multiplied by the breadth and deflection, both in inches; and the cube root of the quotient, multiplied by the length in feet, equal the depth required in inches.

Ex. A beam of ash is intended to bear a load of 700 lbs. at its extremity; its length being 5 feet, its breadth 4 inches, and the deflection not to exceed $\frac{1}{2}$ an inch.

Tabular value of E $= 119 \times 4 \times {\cdot}5 = 238$, the divisor; then $700 \div 238 = \sqrt[3]{2{\cdot}94} \times 5 = 7{\cdot}25$ inches, depth of the beam.

To find the absolute strength of a rectangular *beam, when fixed at one end, and loaded at the other.*

Rule.—Multiply the value of s by the depth of the beam, and by the area of its section, both in inches; divide the product by the leverage in inches, and the quotient equal the absolute strength of the beam in lbs.

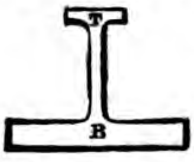
Ex. A beam of Riga fir, 12 inches by $4\frac{1}{2}$, and projecting $6\frac{1}{2}$ feet from the wall; what is the greatest weight it will support at the extremity of its length?

Tabular value of s=1100

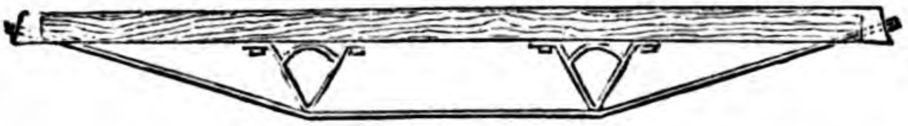
$12 \times 4{\cdot}5 = 54$ sectional area.

Then, $\frac{1100 \times 12 \times 54}{78} = 9138{\cdot}4$ lbs.

When fracture of a beam is produced by vertical pressure, the fibres of the lower section of fracture are separated by extension, whilst at the same time those of the upper portion are destroyed by compression; hence exists a point in section where neither the one nor the other takes place, and which is distinguished as the point of neutral axis. Therefore, by the law of fracture thus established, and proper data of tenacity and compression given, as in the Table (p. 137), we are enabled to form metal beams of strongest section with the least possible material: thus, in cast iron the resistance to compression is nearly as $6\frac{1}{2}$ to 1 of tenacity; consequently a beam of cast iron to be of strongest section must be of the following form,



and a parabola in the direction of its length, the quantity of material in the bottom flange being about $6\frac{1}{2}$ times that of the upper: but such is not the case with beams of timber; for although the tenacity of timber be on an average twice that of its resistance to compression, its flexibility is so great, that any considerable length of beam, where columns cannot be situated to its support, requires to be strengthened or trussed by iron rods, as in the following manner:



And these applications of principle not only tend to diminish deflection, but the required purpose is also more effectively attained, and that by lighter pieces of timber.

To ascertain the absolute strength of a cast-iron beam of the preceding form, or that of strongest section.

Rule.—Multiply the sectional area of the bottom flange in inches by the depth of the beam in inches, and divide the product by the distance between the supports also in inches; and 514 times the quotient equal the absolute strength of the beam in cwts.

The strongest form in which any given quantity of matter can be disposed is that of a hollow cylinder; and it has been demonstrated that the maximum of strength is obtained in cast iron when the thickness of the annulus or ring amounts to $\frac{1}{5}$th of the cylinder's external diameter; the relative strength of a solid to that of a hollow cylinder being as the diameters of their sections.

A Table showing the Weight or Pressure a Beam of Cast Iron, 1 inch in breadth, will sustain without destroying its elastic force, when it is supported at each end, and loaded in the middle of its length, and also the deflection in the middle which that weight will produce. By Mr. Hodgkinson, Manchester.

Length.	6 feet.		7 feet.		8 feet.		9 feet.		10 feet.	
Depth in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.
3	1278	·24	1089	·33	954	·426	855	·54	765	·66
3½	1739	·205	1482	·28	1298	·365	1164	·46	1041	·57
4	2272	·18	1936	·245	1700	·32	1520	·405	1360	·5
4½	2875	·16	2450	·217	2146	·284	1924	·36	1721	·443
5	3560	·144	3050	·196	2650	·256	2375	·32	2125	·4
6	5112	·12	4356	·163	3816	·213	3420	·27	3060	·33
7	6958	·103	5929	·14	5194	·183	4655	·23	4165	·29
8	9088	·09	7744	·123	6784	·16	6080	·203	5440	·25
9	—	—	9801	·109	8586	·142	7695	·18	6885	·22
10	—	—	12100	098	10600	·128	9500	·162	8500	·2
11	—	—	—	—	12826	·117	11495	·15	10285	·182
12	—	—	—	—	15264	·107	13680	·135	12240	·17
13	—	—	—	—	—	—	16100	·125	14400	·154
14	—	—	—	—	—	—	18600	·115	16700	·143
	12 feet.		14 feet.		16 feet.		18 feet.		20 feet.	
6	2548	·48	2184	·65	1912	·85	1699	1·08	1530	1·34
7	3471	·41	2975	·58	2603	·73	2314	·93	2082	1·14
8	4532	·36	3884	·49	3396	·64	3020	·81	2720	1·00
9	5733	·32	4914	·44	4302	·57	3825	·72	3438	·89
10	7083	·28	6071	·39	5312	·51	4722	·64	4250	·8
11	8570	·26	7346	·36	6428	·47	5714	·59	5142	·73
12	10192	·24	8736	·33	7648	·43	6796	·54	6120	·67
13	11971	·22	10260	·31	8978	·39	7980	·49	7182	·61
14	13883	·21	11900	·28	10412	·36	9255	·46	8330	·57
15	15937	·19	13660	·26	11952	·34	10624	·43	9562	·53
16	18128	·18	15536	·24	13584	·32	12080	·40	10880	·5
17	20500	·17	17500	·23	15353	·3	13647	·38	12282	·47
18	22932	·16	19656	·21	17208	·28	15700	·36	13752	·44

Note.—This Table shows the greatest weight that ever ought to be laid upon a beam for permanent load, and if there be any liability to jerks. &c., ample allowance must be made; also the weight of the beam itself must be included.

To find the weight of a cast-iron beam of given dimensions.

Rule.—Multiply the sectional area in inches by the length in feet, and by 3·2, the product equal the weight in lbs.

Ex. Required the weight of a uniform rectangular beam of cast iron, 16 feet in length, 11 inches in breadth, and $1\frac{1}{2}$ inch in thickness.

$$11 \times 1{\cdot}5 \times 16 \times 3{\cdot}2 = 844{\cdot}8 \text{ lbs.}$$

Resistance of bodies to Flexure by vertical Pressure.

When a piece of timber is employed as a column or support, its tendency to yielding by compression is different according to the proportion between its length and area of its cross section; and supposing the form that of a cylinder whose length is less than seven or eight times its diameter, it is impossible to bend it by any force applied longitudinally, as it will be destroyed by splitting before that bending can take place; but when the length exceeds this, the column will bend under a certain load, and be ultimately destroyed by a similar kind of action to that which has place in the transverse strain.

Columns of cast iron and of other bodies are also similarly circumstanced, this law having been fully developed by the experiments of Mr. Hodgkinson on columns of different diameters, and of different lengths.

When the length of a cast-iron column with flat ends equals about thirty times its diameter, fracture will be produced wholly by bending of the material;—when of less length, fracture takes place partly by crushing and partly by bending: but, when the column is enlarged in the middle of its length from one and a half to twice its diameter at the ends, by being cast hollow, the strength is greater by $\frac{1}{7}$th than in a solid column containing the same quantity of material.

To determine the dimensions of a support or column to bear without sensible curvature a given pressure in the direction of its axis.

Rule.—Multiply the pressure to be supported in lbs. by the square of the column's length in feet, and divide the product by twenty times the tabular value of E; and the quotient will be equal to the breadth multiplied by the cube of the least thickness, both being expressed in inches.

Note 1.—When the pillar or support is a square, its side will be the fourth root of the quotient.

2. If the pillar or column be a cylindar, multiply the tabular value of E by 12, and the fourth root of the quotient equal the diameter.

Ex. 1. What should be the least dimensions of an oak support, to bear a weight of 2240 lbs. without sensible flexure, its breadth being 3 inches, and its length 5 feet?

Tabular value of E=105,

$$\text{and } \frac{2240 \times 5^2}{20 \times 105 \times 3} = \sqrt[3]{8\cdot888} = 2\cdot05 \text{ inches.}$$

Ex. 2. Required the side of a square piece of Riga fir, 9 feet in length, to bear a permanent weight of 6000 lbs.

Tabular value of E=96,

$$\text{and } \frac{6000 \times 9^2}{20 \times 96} = \sqrt[4]{253} = 4 \text{ inches nearly.}$$

Dimensions of Cylindrical Columns of Cast Iron to sustain a given load or pressure with safety.

Diam. in inches.	Length or height in feet. 4	6	8	10	12	14	16	18	20	22	24
	Weight or load in cwts.										
2	72	60	49	40	32	26	22	18	15	13	11
2½	119	105	91	77	65	55	47	40	34	29	25
3	178	163	145	128	111	97	84	73	64	56	49
3½	247	232	214	191	172	156	135	119	106	94	83
4	326	310	288	266	242	220	198	178	160	144	130
4½	418	400	379	354	327	301	275	251	229	208	189
5	522	501	479	452	427	394	365	337	310	285	262
6	607	592	573	550	525	497	469	440	413	386	360
7	1032	1013	989	959	924	887	848	808	765	725	686
8	1333	1315	1289	1259	1224	1185	1142	1097	1052	1005	959
9	1716	1697	1672	1640	1603	1561	1515	1467	1416	1364	1311
10	2119	2100	2077	2045	2007	1964	1916	1865	1811	1755	1697
11	2570	2550	2520	2490	2450	2410	2358	2305	2248	2189	2127
12	3050	3040	3020	2970	2930	2900	2830	2780	2730	2670	2600

Practical Utility of the preceding Table.

Ex. Wanting to support the front of a building with cast-iron columns 18 ft. in length, 8 inches in diameter, and the metal 1 inch in thickness; what weight may

I confidently expect each column capable of supporting without tendency to deflection?

Opposite 8 inches diameter and under 18 feet=1097
Also opposite 6 in. diameter and under 18 feet= 440
= 657 cwts.

Note.—The strength of cast iron as a column being 1·0000

"	steel	"	= 2·518
"	wrought iron	"	= 1·745
"	oak (Dantzic)	"	= ·1088
"	red deal	"	= ·0785

Elasticity of torsion, or resistance of bodies to twisting.

The angle of flexure by torsion is as the length and extensibility of the body directly, and inversely as the diameter; hence, the length of a bar or shaft being given, the power, and the leverage the power acts with, being known, and also the number of degrees of torsion that will not affect the action of the machine, to determine the diameter in cast iron with a given angle of flexure.

Rule.—Multiply the power in lbs. by the length of the shaft in feet, and by the leverage in feet; divide the product by fifty-five times the number of degrees in the angle of torsion: and the fourth root of the quotient equal the shaft's diameter in inches.

Ex. Required the diameters for a series of shafts 35 feet in length, and to transmit a power equal to 1245 lbs., acting at the circumference of a wheel $2\frac{1}{2}$ feet radius, so that the twist of the shafts on the application of the power may not exceed one degree.

$$\frac{1245 \times 35 \times 2{\cdot}5}{55 \times 1} = \sqrt[4]{1981} = 6{\cdot}67 \text{ inches in diameter.}$$

Relative strength of metals to resist torsion.

Cast iron	=1	Swedish bar iron...	=1·05
Copper	= ·48	English do. ...	=1·12
Yellow brass......	= ·511	Sheer steel	=1·96
Gun metal.........	= ·55	Cast do.	=2·1

USEFUL DEFINITIONS AND EXPERIMENTAL RESULTS IN PRACTICAL SCIENCE.

Heat.—Heat or caloric, the matter of heat, in a general sense, is any indicated temperature above that of the human body, and is commonly designated sensible heat, in order to distinguish between that and latent or concealed heat. Natural heat from the sun's rays is variable, but may be increased to a very great degree of intensity by the aid of a convex lens, whereby to concentrate its rays into one particular point. Artificial heat for practical utility is the effect produced by the combustion of carbonaceous matter contained in any inflammable body, as wood, coal, etc., ignited in union with, and supported by the oxygen of the atmosphere, and not unfrequently estimated in beneficial value by the number of pounds of fresh water raised in temperature from 32° to 212° Fahr. during the combustion of one pound of the burning fuel. Thus

1 lb. of	coke will raise	78	lbs. of water	from 32° to 212° Fahr.
,,	charcoal ,,	75	,,	,,
,,	wood (dried)	36	,,	,,
,,	do. (undried)	27	,,	,,
,,	coal (average)	60	,,	,,
,,	peat (do.)	28	,,	,,

Continued increments of heat cause a change upon all material bodies. Water becomes vapourized, and steam is the ultimate result, containing an excess of heat beyond the indicated thermometric temperature; hence called latent or concealed heat, and from which it must be inferred that, as water requires and retains such an excess of caloric in its state as steam, cold must be generated by evaporation. Evaporation proceeds only from the surface of the fluid exposed: but, when a fluid is covered by a stratum of dry air, evaporation is rapid even when the temperature is low; and evaporation may be incited by artificial surfaces.

Heat also expands water in the liquid state. Thus, when water is at 42° Fahr., it is at its greatest density, or 1·00000 in bulk.

At 62° Fahr.	its bulk is	increased to	1·00083
„ 92	„	„	1·00477
„ 122	„	„	1·01116
„ 152	„	„	1·01934
„ 182	„	„	1·02916
„ 212	„	„	1·04012

Water also expands in nearly an equal ratio from 42° Fahr., by reduction of temperature through abstraction of heat, down to the freezing point.

Atmospheric air is increased in bulk by elevation of temperature, as in the following table:—

At 32°	Fahr.	vol. equal	1·000	At 100°	Fahr.	vol. equal	1·152
„ 35	„	„	1·007	„ 110	„	„	1·173
„ 40	„	„	1·021	„ 120	„	„	1·194
„ 45	„	„	1·032	„ 130	„	„	1·215
„ 50	„	„	1·043	„ 140	„	„	1·235
„ 55	„	„	1·055	„ 150	„	„	1·255
„ 60	„	„	1·066	„ 160	„	„	1·275
„ 65	„	„	1·077	„ 170	„	„	1·295
„ 70	„	„	1·089	„ 180	„	„	1·315
„ 75	„	„	1·099	„ 190	„	„	1·334
„ 80	„	„	1·110	„ 200	„	„	1·364
„ 85	„	„	1·121	„ 210	„	„	1·372
„ 90	„	„	1·132	„ 212	„	„	1·376
„ 95	„	„	1·142				

Lenear Expansion of Metals from 32° *to* 212° *Fahr.*

Zinc, 1 part in		322	Brass, 1 part in		584
Lead	„	351	Gold	„	682
Tin (av.)	„	439	Bismuth	„	719
Silver	„	524	Iron	„	812
Copper	„	581	Antimony	„	923

Flint Glass, only 1 part in 1248.

Radiation is the heating effects produced by direct rays from a hot body through space, as light is from that of a luminous body, the diminution of effect being as the square of the distance receded from. If at any given distance, a certain power of heat is produced; at twice that distance the power or effect will be one-fourth, and at three times the distance one-seventh, etc.; but the radiating powers of substances are varied in effect with the nature and colour of their surfaces. Thus polished iron does not at an equal temperature give out so much heat by radiation as when its surface is in a corroded state; neither will a white surface diffuse heat by radiation equal in quantity to that of a darker colour.

Suppose the radiating power of a black surface equal	100
The radiating power of the same extent of common lead	= 45
The surface of the lead brightened	= 19
Polished iron	= 15
Polished tin, silver, copper, and gold, each	= 12

Conduction is the power that substances are possessed of in conducting heat from other bodies in immediate contact with them; that of the following being their relative powers in a tabulated form:—

Substances.	Conducting powers.
Gold	1·000
Silver	·973
Copper	·899
Iron	·375
Zinc	·367
Tin	·304
Lead	·180

Non-conductors of heat, more properly, slow conductors or retainers of heat, are the following, viz.:—Stones, bricks, earthenware, glass, lint, sheep's wool, raw silk, and fur, each being successively lower in their conducting powers.

Specific heat (formerly, capacity for heat) is a term applied to the quantity of caloric any substance can absorb or give out by undergoing a change of temperature, the amount being determined by relation to the quantity which a substance of another kind, as water, absorbs or gives out by a like change. Thus the quantity of heat required to raise oil two degrees will only raise water one. Hence a pound of water at 212° is said to contain twice as much heat, or to have twice the capacity for heat, as that of oil.

The specific	heat of	water	being	1·000
"	"	oil	equal	·520
"	"	iron	"	·112
"	"	copper	"	·095
"	"	zinc	"	·093
"	"	mercury		·029

Gravity.—Gravity or gravitation is downward pressure or weight. All bodies possess this property, more or less, proportionate to their various degrees of density.

Specific gravity refers to the relative density or weight that one body bears to another of equal bulk. Thus a body of less specific gravity than water or other fluid will float upon that fluid, but of greater specific gravity will sink.

Centre of gravity is that point in a body or system of bodies on which, if rested or suspended, the whole will remain in a state of rest. Thus, if a wall or other structure be raised perpendicular to the base, it will remain secure whilst in that state; but if the foundation be not of sufficient solidity, and by degrees allow it to depart so far from the vertical position that the centre of gravity overhangs the base at the bottom, the structure must fall, unless restricted by cohesion of the parts of which it is composed.

Force of gravity or gravitation is an accelerated velocity which heavy bodies acquire in falling freely from a state of rest. Thus the velocity that a body will acquire in one second of time equals 32·2 feet, the distance fallen being 16·1 feet; and if the times or seconds be in an arithmetical ratio, as 1, 2, 3, 4, etc., the spaces fallen through will be successively as the numbers 1, 3, 5, 7, etc., and the total space passed through as the geometrical progression, 1, 4, 9, 16, etc. Also the velocity is 32·2 feet multiplied by the number of seconds in falling from rest; and the square of the velocity is equal to twice 32·2 times the space fallen through. Also the space fallen through is equal to 16·1 multiplied by the square of the number of seconds. Hence—

First, the velocity that a body will acquire in five seconds equals $32{\cdot}2 \times 5 = 161$ feet.

Second, the velocity that a body will acquire in falling through 120 feet equals $\sqrt{(120 \times 64{\cdot}4)} = \sqrt{7728} = 87{\cdot}9$ feet.

Third, the space fallen through in seven seconds equals $16{\cdot}1 \times 7^2 = 788{\cdot}9$ feet.

TABLE OF ACCELERATED MOTION.

Time in seconds during the body's fall.	Space in feet that a falling body passes through during each second.	Space through which a body will fall in the time.	Velocity that a falling body will acquire by falling during the time.
1	16·1	16·1	32·2
2	48·3	64·4	64·4
3	80·5	144·9	96·6
4	112·7	257·6	128·8
5	144·9	402·5	161·0
6	177·1	579·6	193·2
7	209·3	788·9	225·4
8	241·5	1030·4	257·6
9	273·7	1304·1	289·8
10	305·9	1610·0	322·0

The velocity acquired by a body falling through a given height is the same whether it fall freely or descend upon a plane any way inclined.

Force of gravity is the cause of retarded and of accelerated motion on inclined planes, the acting force being as the height of the plane to its length. On a level line of railway $9\frac{1}{2}$ lbs. traction will overcome 2240 lbs., or one ton of insistant weight; but on an incline or rise of 1 in 350, the amount of traction to overcome the same weight must be $\frac{2240}{350} = 6·4, + 9·5 = 15·9$ lbs. Again, if the weight be descending, then the force of traction is diminished in an equal ratio, and the weight accelerated by gravity; thus $9·5 - 6·4 = 3·1$ lbs. the force of traction on the descending plane.

Force of gravity is also the restrictive cause to a pendulum's motion. Consequently its motion at any place is dependent upon the energy of the force of gravity at that place.

Pendulums of the same length vibrate slower the nearer they are brought to the equator, because of the earth's spheroidal form (its polar axis being about twenty-six miles shorter than its equatorial diameter), for which reason gravity is lessened $\frac{1}{289}$th part, the centrifugal force arising from the diurnal motion of the earth being greater at the equator than at the poles.

The measure of the force of gravity in feet per second at any place is equal to the length of a pendulum in feet, divided by the square of the time in seconds between each of its oscillations, and the quotient multiplied by 9·8696, the product equals the number of feet by which gravity will at that place increase the velocity of the descent of a falling body in each second of time.

The space through which a heavy body will fall during the time of one vibration of a pendulum vibrating seconds, is to half the pendulum's length as the square of the circumference of a circle is to the square of its diameter; and twice the space fallen in one second, being the measure of gravity, we have the force of gravity in the latitude of London equal $39{\cdot}1393 \times 9{\cdot}8696 = 386{\cdot}289308$ inches, or 32·191 feet nearly.

The length of a Pendulum to vibrate Seconds, or Sixty Times in a Minute.

At the Equator, equals		39·0152	inches.
In the latitude of	London	39·1393	„
„	Edinburgh	39·1555	„
„	Paris	39·1286	„
„	New York	39·1011	„
„	Madras	39·0263	„
„	Greenland	39·2033	„

Centre of Oscillation is a certain point in a vibrating body into which all its force is collected, and at which, if an obstacle be applied, motion will instantly cease. The most simple means by which to ascertain the centre of oscillation in a compound pendulum is to suspend a small ball by a fine thread in front of that in which the centre of oscillation is required, then to lengthen or shorten the thread until the vibrations of each are alike, then stop both and let them hang freely. Opposite the centre of the ball is the centre of oscillation.

Of Motion.—Motion, in mechanical language, is a result or effect of a cause, acting in such a manner as to impart either linear or circular velocity by motive power. Thus, the piston of a steam-engine by the action of the steam is caused to produce alternate rectilinear or reciprocating motion. In the fly-wheel, through the medium of the crank, is produced uniform circular motion; and by means of eccentric cambs, etc., motions to any degree of distortion may easily be obtained.

Centrifugal force signifies the tendency that bodies acquire, by velocity of circular motion, to fly off in a tangential line from the centre of revolution, the amount of tendency being as the square of the velocity of the body in motion, hence the rule —Multiply the square of the number of revolutions per minute by the radius of the circle in feet, by the weight of the body, and by ·000331: the product is the centrifugal force in terms of the body's weight. Thus, suppose a body weighing 100 lbs. is describing a circle of 10 feet radius 300 times per minute, then $300^2 \times 10 \times 100 \times {\cdot}000331 = 29{,}790$ lbs., the accumulated tendency of centrifugal force.

Centripetal force is that by which a body would tend to the centre of motion if not urged from it by centrifugal force. Thus, the balls of the governor of a steam-engine conspicuously indicate this force when the velocity of the engine is becoming reduced by over resisting force, or by supply of steam of inferior density.

Centre of gyration, in a revolving body, is a certain point into which the whole momentum of the mass is concentrated, and from which point the greatest amount of effective energy is transmitted. Any point in the circumference of the circle whose radius is the distance of the centre of rotation from the centre of gyration, is equally entitled to be called a centre of gyration; the radius of this circle is the radius of gyration.

To find the distance of the centre (or radius of the circle) of gyration from the centre of revolution·

Rule.—Multiply the amount of acting force, the distance at which it is applied from the centre of revolution, by the time of revolution observed in seconds, and by 32; divide the product by the weight multiplied by its velocity, and the quotient is the distance from the centre of motion to centre of gyration.

Suppose a fly-wheel of 50 cwts. in the rim, with an acting force of 2 cwts. applied 7 feet from the centre of motion, the time observed being 10 seconds, and the velocity 8 feet per second—

$\frac{2\times7\times10\times32}{50\times8} = 11{\cdot}5$ feet is the distance between the centre of motion and that of gyration.

Momentum, in mechanics, signifies the product of the moving weight multiplied into the velocity, and is commonly estimated in lbs., or cwts., moving at the given velocity in feet per minute.

Level properly signifies points equidistant from the centre of the earth on its surface; hence, any level taken by an instrument is only a tangent line to the earth's curvature, and is generally termed the apparent level. The earth is nearly a sphere, with a mean diameter of 7925 miles, and if the square of the distance between any two points on its surface be divided by its diameter, the quotient will equal the excess of altitude between the summit of the vertical diameter and that of the other point; at one mile distance the excess by level with an instrument becomes 7·962 inches; at two miles it is 31·848, etc., being as the square of the distance; hence, the excess subtracted from the apparent level, equals the true level as required for extensive leveling operations.

Capillary attraction signifies a property observable in small tubes, flat, thin spaces, porous substances, as sponge, cotton-wick, worsted, threads, etc., of raising water or other fluids above the natural level; hence the application of the principle for obtaining a continued supply of lubricating fluid between surfaces in motion by a syphon form of worsted threads, one end of which is immersed in oil, the other end being inserted and supported by the tube through which the fluid is conducted.

Atmospheric air is a transparent, inodorous, subtle, elastic fluid, that naturally surrounds our globe, and in which we breathe for the support of our existence.

Dry atmospheric air consists of four volumes of nitrogen gas, and one of oxygen, with a slight admixture of carbonic acid and watery vapour. Its weight, bulk for bulk, is 816 times lighter than water, whose specific gravity is 1000, and its average pressure equals 15 lbs. per square inch; hence, when the indicated force of steam in a boiler is 20 lbs. per square inch, the actual force is 35 lbs. on the same area. When air is compressed, its bulk is inversely as the pressure, a double pressure reducing a given volume to half its bulk.

Air expands by increased temperature, the average rate of expansion above 32° Fahr. being $\frac{1}{480}$ part of its bulk for each degree of heat on the same scale.

The rarefaction of air is accompanied by a decrease of its temperature, and in its condensation or compression it gives out a proportional quantity of heat.

Air can take up and hold in solution a portion of water depending upon the temperature.

Atmospheric air is also the source and support of combustion, through its oxygen uniting with the constituents of the combustible substance; thus, the combustion of coal is due to the oxygen passing into a state of chemical union with the carbon, and the hydrogen of the coal forming carbonic acid and watery vapour.

Atmospheric air is a destructive element to the motive power of a steam-engine if allowed to enter the condenser, and equally so to the power of a bucketed water-wheel if some precautionary plan be not adopted, whereby to allow its escape from each bucket when the water is entering at its proper height in the revolution of the wheel.

Sound passes through atmospheric air of

medium density, at the rate of 1130 feet per second.

Hydrodynamics is the combined science of hydrostatics and hydraulics, the former of which treats of the pressure and equilibrium of liquids at rest, the latter of which explains the laws relative to liquids in motion.

Liquids, or fluids in general, are considered incompressible and non-elastic, but readily adapted to useful purposes through flowing freely by agitation and inequality of level, hence hydraulic machines are brought in to produce useful effects; and although the laws of hydrostatics and hydraulics are universally applicable to fluids in general, yet water being the most abundant in nature it is invariably had recourse to for purposes of motive power.

Fluids when confined exert a force equal in every direction, but when unconfined are subject to the same laws as falling bodies in general, modified by mechanical considerations and experimental results, so that through water rolling or falling by the force of gravity, the greatest amount of effect is produced, whether for turbines or water-wheels.

Liquids, because of their gravity and mobility, press equally in every direction; any vessel containing a liquid sustains a pressure on every portion of the vessel, equal to as many times the weight of the greatest column or height of that liquid, as the sectional area of the column is to its height. The amount of pressure sustained by walls, flood-gates, sluices, etc., for the retention of water, equals the amount of area exposed, multiplied by half the depth of the fluid, and by its weight in some known terms of unity: thus, one cubic foot of fresh water equals 62½ lbs. avoirdupois.

Of Specific Gravity.—The comparative density of various substances is expressed by the term specific gravity, which affords the means of readily determining the bulk from the known weight, or the weight from the known bulk; and this is found more especially useful in cases where the substance is too large to admit of being weighed, or too irregular in shape to allow of correct measurement. The standard with which all solids and liquids are thus compared, is that of distilled water, one cubic foot of which weighs 1000 ounces avoirdupois; and the specific gravity of a solid body is determined by the difference between its weight in the air and in water. Thus:—

If the body be heavier than water, it will displace a quantity of it equal to its own bulk, and will lose as much weight on immersion as that of an equal bulk of the water. Let it be weighed first, therefore, in the air, and then in the water, and its weight in the air be divided by the difference between the two weights, and the quotient will be its specific gravity, that of water being unity.

Example.—A piece of copper ore weighs 56¼ ounces in the air, and 43¾ ounces in water, required its specific gravity.

$56{\cdot}25 - 43{\cdot}75 = 12{\cdot}5$, and $56{\cdot}25 \div 12{\cdot}5 = 4{\cdot}5$ the specific gravity.

If the body be lighter than water, it will float, and displace a quantity of the water equal to it in weight, the bulk of which will be equal to that only of the part immersed. A heavier substance must therefore be attached to it, so that the two may sink in the fluid. Then the weight of the lighter substance in the air must be added to that of the heavier substance in water, and the weight of both united in water be subtracted from the sum; the weight of the lighter body in the air must then be divided by the difference, and the quotient will be the specific gravity of the lighter substance required.

Example.—A piece of yellow pine weighs 40 ounces in the air, and being immersed in water attached to a piece of iron weighing 30 ounces, the two together are found to weigh 3·3 ounces in water, and the iron alone 25·8 ounces in the water; required the specific gravity of the pine.

$40 + 25{\cdot}8 = 65{\cdot}8$, also $65{\cdot}8 - 3{\cdot}3 = 62{\cdot}5$ and $40 \div 62{\cdot}5 = {\cdot}64$ the specific gravity of the wood.

The specific gravity of a fluid may be determined by taking a solid body, heavy enough to sink in the fluid, and of known specific gravity, and weighing it both in the air and in the fluid. The difference between the two weights must be multiplied by the specific gravity of the solid body, and the product divided by the weight of the solid in the air; the quotient will be the specific gravity of the fluid, that of water being unity.

Example.—Required the specific gravity of a given mixture of muriatic acid and water; a piece of glass, the specific gravity of which is 3, weighing $3\frac{3}{4}$ ounces when immersed, and 6 ounces in the air.

$6 - 3{\cdot}75 = 2{\cdot}25, \times 3 = 6{\cdot}75, \div 6 = 1{\cdot}125$ the specific gravity.

Table of comparison between the breaking strains of wire rope, hemp rope, and chain, as tested by order of the Admiralty.

Breaking strain of each.	Size in inches.			Weight per fathom.			Admiralty proof Strains for Crane chains.
	Wire Rope. Circum.	Hemp. Circum.	Chain. Diam.	Wire.	Hemp.	Chain.	
				lbs. oz.	lbs. oz.	lbs.	
2 tons 5 cwts.	$1\frac{1}{2}$	3	$\frac{5}{16}$	2 3	3 4	5	$1\frac{1}{8}$ tons.
4 „ 6 „	$1\frac{3}{4}$	4	$\frac{3}{8}$	2 14	4 8	9	$1\frac{5}{8}$ „
6 „ 7 „	2	5	$\frac{1}{2}$	3 14	6 0	16	3 „
7 „ 8 „	$2\frac{1}{4}$	6	$\frac{19}{32}$	4 15	9 8	21	
8 „ 11 „	$2\frac{1}{2}$	7	$\frac{11}{16}$	6 14	12 3	27	5 „
10 „ 4 „	$2\frac{3}{4}$	$7\frac{1}{2}$	$\frac{12}{16}$	7 4	13 2	31	6 „
12 „ 0 „	3	8	$\frac{13}{16}$	8 8	14 3	36	$7\frac{7}{8}$ „
13 „ 12 „	$3\frac{1}{4}$	$8\frac{1}{2}$	$\frac{14}{16}$	9 14	16 0	41	$9\frac{1}{8}$ „
15 „ 6 „	$3\frac{1}{2}$	9	$\frac{29}{32}$	11 3	19 6	46	
17 „ 0 „	$3\frac{3}{4}$	$9\frac{1}{2}$	$\frac{15}{16}$	12 11	22 0	50	$10\frac{1}{2}$ „
19 „ 6 „	4	10	$\frac{31}{32}$	14 7	25 0	53	
21 „ 10 „	$4\frac{1}{4}$	$10\frac{1}{2}$	$1\frac{1}{8}$	16 7	27 4	58	12 „
24 „ 8 „	$4\frac{1}{2}$	11	$1\frac{1}{16}$	18 12	30 0	62	
27 „ 10 „	$4\frac{3}{4}$	$11\frac{1}{2}$	1_{8}	21 7	32 8	69	$15\frac{1}{4}$ „
32 „ 5 „	5	12	$1\frac{3}{16}$	24 9	36 0	78	

Dilatation or Expansion of bodies by increased temperature, is a certain amount of enlarged dimensions they exhibit proportionate to the degrees of sensible heat attained:—thus, suppose water at its greatest density, viz., 42° Fahr., its bulk equal 100,000, then at 212°, its bulk will be increased to 104,012. Or, suppose a bar of iron in length at 32° Fahr. is 100,000, at 212° its length will be increased to 100,122. Again, nearly all uniform bodies or gases expand equally on receiving an equal increase of temperature in the proportion of the $\frac{1}{493}$rd part for every degree of Fahr. upwards from 32°; hence if a volume of air at 32° measures 493 parts, at 525° it will have become 986 parts, being $\frac{1}{493}$rd part for each degree of increased temperature from 32°.

Table of linear expansion of Solids by elevation of temperature from 32° to 212° Fahr.

Factors for increase of length.		Factors for increase of length.	
Glass tube . .	·000861	Gold, to . .	·001555
Platina . . .	·000884	Copper . .	·001722
„ . . .	·000992	Silver . . .	·001909
Iron	·001220	Lead . . .	·002848
Gold, from . .	·001466	Zinc . . .	·003011

Hence, the length of a bar of any of the above named substances will be increased to the extent of its original length at 32°, multiplied by its factor in the table, when raised to a temperature of 212°: thus, a bar of iron 50 inches in length at 32°, will become expanded at 212°, to $\cdot 00122 \times 50 + 50 = 50\cdot 0061$ inches.

Liquefaction, Melting, and Fusion are closely synonymous terms, but in some instances properly different: they each signify a change from that of a solid to a liquid state by heat. In various cases of liquefaction, a solvent, as hot water, is required, thus, neither salt nor sugar can be liquefied by heat alone. To ice, mercury, tallow, phosphorus, etc., "melting" is the common appellation, no solvent being required to liquefy; but to those, the term fusion is never applied; hence, fusion is the distinction of metals alone in their liquefied state, some requiring a greater intensity of heat than others to effect this purpose.

Fusing points of Metals in degrees of Fahrenheit.

Tin	442	Gun metal	1900°
Bismuth	476°	Copper	1996°
Lead	594°	Gold	2016°
Zinc	700°	Cast steel	2500°
Antimony	810°	Cast iron	2786°
Brass	1869°	Wrought iron	2910°
Silver	1873°	Platinum	3080°

Latent or *concealed heat,* occasionally designated heat of fluidity, is an excess of caloric in bodies which is undiscoverable by a thermometer, consequently the amount of latent heat or hidden caloric in the steam of water can only be obtained by a measurable amount of practical effect: but it has been satisfactorily ascertained that the total amount of latent and indicated caloric in steam of water at all temperatures is a constant sum, viz., 1212° Fahr., the latent heat at 212° being 1000°, or nearly so. One unit of water converted to steam at 212°, will raise 5½ units of water from a temperature of 32° to that of 212°; hence, because of this property, for the purposes of heating, drying, etc., steam at a low temperature is equally efficient to that of steam at a greater degree of density.

Condensation of Steam, or the causing of a closer approach of its particles through the abstraction of heat, is the means by which a vacuum is formed in the condenser of a steam engine, and one of the most essential requisites to be attended to for the production of mechanical effect through a steam engine on the condensing principle; nearly one cubic foot of steam at the common pressure of the atmosphere is produced from one cubic inch of water: hence, by the condensation of, or abstraction of the caloric of one cubic foot, nearly an equal capacity of empty space or vacuum is obtained, and consequently an effect of power approximating to 14·7 lbs. per square inch, with the perfection of the means employed.

Table of Round Shafts of Cast Iron, and also of Wrought Iron, to resist torsion at a given Velocity by a given Power.

Horse Power.	Number of revolutions per minute of cast iron shafts.												
	20	25	30	35	40	45	50	55	60	65	70	75	80
	Diameters of the shafts in inches.												
10	5⅞	5¾	5⅛	4⅞	4⅝	4½	4⅜	4⅛	4	4	3⅞	3¾	3⅝
20	7⅜	6⅞	6⅝	6⅛	5⅞	5⅝	5½	5⅜	5⅛	5	4⅞	4¾	4⅝
30	8⅜	7⅞	7⅜	7	6¾	6½	6¼	6	5⅞	5⅝	5½	5⅜	5¼
40	9¼	8⅝	8⅛	7¾	7¼	7	6⅞	6⅝	6⅜	6¼	6⅛	6	5⅞
50	10	9¼	8¾	8¼	8	7⅝	7⅜	7⅛	7	6¾	6½	6⅜	6¼
60	10⅝	9⅞	9¼	8⅞	8¾	8⅛	7⅞	7⅝	7⅜	7⅛	7	6⅞	6⅝
70	11¼	10⅜	9¾	9¼	8⅞	8½	8¼	8	7¾	7½	7⅜	7⅛	7
80	11¾	10⅞	10¼	9¾	9¼	8⅞	8⅝	8⅜	8⅛	7⅞	7¾	7½	7⅜
90	12⅛	11¼	10⅝	10⅛	9⅝	9¼	9	8⅝	8½	8¼	8	7¾	7⅝
100	12⅝	11¾	11	10½	10	9⅝	9¼	9	8¾	8½	8¼	8⅛	8
125	13½	12⅝	11⅞	11¼	10¾	10⅜	10	9¾	9⅜	9⅛	9	8¾	8½
150	14⅜	13⅜	12⅝	12	11½	11	10⅝	10¼	10	9¾	19½	9¼	9⅛
175	15⅛	14⅛	13¼	12⅜	12	11½	11⅛	10⅞	10½	10¼	10	9¾	9½
200	15⅞	14¾	13⅞	13⅛	12⅝	12⅛	11¾	11⅜	11	10¾	10½	10¼	10
	Number of revolutions per minute of wrought iron shafts.												
	20	25	30	35	40	45	50	55	60	65	70	75	80
10	5	4¾	4⅜	4¼	4	3⅞	3¾	3⅝	3½	3⅜	3¼	3¼	3⅛
20	6⅜	5⅞	5½	5¼	5	4⅞	4¾	4½	4⅜	4¼	4⅛	4⅛	4
30	7⅜	6¾	6⅜	6	5¾	5⅝	5⅜	5⅛	5	4⅞	4¾	4⅝	4½
40	8	7½	7	6⅝	6⅜	6⅛	6	5¾	5½	5⅜	5¼	5⅛	5
50	8⅝	8	7½	7⅜	7¼	6½	6⅜	6⅛	6	5⅞	5⅝	5½	5⅜
60	9¼	8½	8	7⅝	7⅜	6⅞	6¾	6½	6⅜	6¼	6⅛	6	5⅞
70	9⅝	9	8½	8	7¾	7⅜	7⅛	7	6¾	6½	6⅜	6¼	6⅛
80	10⅛	9½	8⅞	8½	8	7¾	7½	7¼	7⅛	7	6¾	6½	6⅜
90	10½	9¾	9¼	8¾	8⅜	8	7¾	7½	7⅜	7¼	7	6¾	6⅝
100	10⅞	10⅛	9½	9	8⅝	8⅜	8	7¾	7½	7⅜	7¼	7	6⅞
125	11¾	10⅞	10¼	9¾	9¼	9	8⅝	8⅜	8⅛	8	7¾	7½	7¼
150	12½	11½	11	10⅜	10	9⅜	9⅛	9	8⅝	8½	8⅜	8	7¾
175	13⅛	12¼	11½	10⅞	10½	10	9⅝	9⅜	9	8⅞	8⅝	8⅜	8¼
200	13¾	12¾	12	11⅜	10⅞	10½	10⅛	9⅞	9½	9¼	9	8⅞	8⅝
225	14⅜	13¼	12½	11⅞	11⅜	11	10½	10¼	10	9⅝	9⅜	9¼	9
250	14⅞	13¾	13	12¼	11¾	11⅜	11	10½	10¼	10	9¾	9½	9¼
275	15¼	14¼	13⅜	12¾	12⅛	11¾	11¼	11	10⅝	10⅜	10¼	10	9⅝
300	15¾	14⅝	13¾	13	12½	12¼	11⅝	11¼	11	10⅝	10⅜	10⅛	10

Note.—The diameters of the shafts strictly mean, the diameters of the necks, bearings, or journals, the proportionate lengths of which may be in accordance with the following rule:—

Multiply the diameter of bearing in inches by 1·84, the product equals the length, in inches. Thus, a bearing or shaft of 8 inches, equals $1·84 \times 8 = 14·92$, or 15 inches in length.

The bearings in engine work and small parts of machinery in general, are not of necessity longer than those of the crank shaft.

Recent experiments on the wrenching asunder of metals by torsion for the purpose of determining relative effect.

Lead . .	1·0000	Swedish iron, wrot.	9·5000
Tin . . .	1·4375	English „ „	10·1250
Copper . .	4·5000	Blistered steel	16·6875
Yellow brass .	4·6875	Shear „	17·0625
Gun metal .	5·0000	Cast „	19·5625

To find the angle or twist that must be given to the tool in a screw-cutting lathe, by which to cut a square-threaded screw without injury to the sides of the threads.

Rule.—Draw a right angle the base of which equals half the pitch of the screw to be cut, and the perpendicular equals the diameter of the screw minus the depth of the thread; then, the hypothenuse of the triangle, drawn from the end of the base to the end of the perpendicular, gives the angle or twist for the tool from a vertical line with the bed of the lathe.

To find the amount of heating surface of Boiler-tubes in square feet.

Rule.—Multiply the decimal number in the following table, opposite the diameter of the tube in inches, by the length of the tube in feet, the product is the area of each tube in square feet; hence, multiply by the number of tubes, and the product is the whole heating surface of the tubes in square feet; but only about two-thirds can be taken as effective heating surface for the production of steam.

Diameter of tubes in inches.	Decimal Numbers.	Diameter of tubes in inches.	Decimal Numbers.
$1\frac{1}{2}$	·3926	$3\frac{1}{4}$	·8508
$1\frac{3}{4}$	·4580	$3\frac{1}{2}$	·9163
2	·5234	$3\frac{3}{4}$	·9817
$2\frac{1}{4}$	·5888	4	1·0471
$2\frac{1}{2}$	·6543	$4\frac{1}{2}$	1·1778
$2\frac{3}{4}$	·7197	5	1·3088
3	·7854	6	1·5708

Example.—Required the whole tube surface and effective heating tube surface of a boiler containing 400 tubes $2\frac{1}{4}$ inches diameter, and 6 feet in length.

$·5888 \times 6 = 3·5328 \times 400 = 1413·12$ square feet, total surface.

then $1413·12 \times 2 = 2826·24 \div 3 = 942$ square feet, effective heating surface.

Approximate rules relative to non-condensing Steam-engines.

1. To find the power of an engine, the diameter of cylinder, and pressure or force of steam being given.

Rule.—Multiply the square of the cylinder's diameter in inches by the force of the steam in lbs. per square inch, and by ·003, the product is the number of horses' power the engine is equal to nominally.

Example.—Required the power of an engine with a cylinder of 9 inches in diameter, and steam at 35 lbs. per square inch.

$9^2 = 81 \times 35 = 2835 \times {\cdot}003 = 8{\cdot}5$ horses' power.

2. To determine the diameter of the cylinder for an engine of a required power, with a given pressure of steam.

Rule.—Multiply the required number of horses' power by 334, and divide the product by the force of the steam in lbs. per square inch, the square root of the quotient is the cylinder's diameter in inches.

Example.—What must be the diameter of the cylinder for a six horse power, with steam at 30 lbs. per square inch?

$$334 \times 6 \div 30 = \frac{2004}{30} = 66{\cdot}8, \text{ and } \sqrt{66{\cdot}8} = 8{\cdot}173 \text{ or } 8\tfrac{3}{16}$$

inches the diameter.

The table which follows will be found useful in questions of this kind, as calculation is dispensed with by the aid of it: thus, suppose the horse power to be the same as above, and that the steam pressure is 35 lbs. per square inch, by calculation we have

$$334 \times 6 \div 35 = 57{\cdot}257, \text{ and } \sqrt{57{\cdot}257} = 7{\cdot}57 \text{ in the diameter}$$

By the table, the diameter is $7\frac{1}{2}$ inches, differing from this result by only ·07 in. And in general, the results in the table are true to the nearest *eighth* of the unit.

Table of the Powers of non-condensing Engines with cylinders of given diameter, and steam at various densities per square inch.

Diameter of Cylinders in inches.	Force of steam in lbs. per square inch.						
	30	35	40	45	50	55	60
	Horses power.						
3½	1	1¼	1½	1⅝	1¾	2	2¼
3¾	1¼	1½	1⅝	1⅞	2⅛	2¼	2½
4	1½	1⅝	1⅞	2¼	2½	2⅝	2⅞
4¼	1⅝	1⅞	2⅛	2½	2¾	3	3¼
4½	1¾	2⅛	2½	2¾	3	3¼	3⅝
4¾	2	2⅜	2¾	3	3⅜	3¾	4
5	2¼	2⅝	3	3⅜	3¾	4⅛	4½
5¼	2½	3	3¼	3¾	4⅛	4½	5
5½	2¾	3¼	3½	4	4½	5	5½
5¾	3	3½	4	4½	5	5½	6
6	3¼	3¾	4¼	5	5½	6	6½
6½	3¾	4½	5	5¾	6¼	7	7½
7	4½	5⅛	5¾	6½	7⅜	8	8¾
7½	5	6	6¾	7½	8½	9¼	10⅛
8	5¾	6¾	7½	8½	9½	10½	11½
8½	6½	7½	8½	9¾	10¾	12	13
9	7¼	8½	9¾	11	12⅛	13⅜	14½
9½	8⅛	9½	10¾	12⅛	13½	15	16¼
10	9	10½	12	13½	15	16½	18
11	10¾	12⅝	14½	16¼	18⅛	20	21¾
11½	12	13¾	15¾	17¾	19¾	21¾	23¾
12	13	15	17¼	19½	21½	23¾	26

Table of transverse strengths of different sorts of useful timber.

Names of the Timber.	Specific Gravity.	Streng.	Names of Timbers.	pecifi Gravity	Streng.
African Oak	988	2523	Pine, American white	432	1229
Ash, English	760	2026	Pine, American red	576	1527
Ash, American	626	1795	Pine, American yellow	508	1185
Beech, English	696	1556	Pine, American pitch	740	1727
Beech, American white	711	1380	Pine, Virginia	590	1456
Beech, American red	775	1739	Pine, Archangel	551	1370
Birch, English	711	1928	Pine, Dantzic	649	1426
Birch, American black	670	2061	Pine, Memel	601	1348
Birch, American yellow	756	1335	Pine, Prussian	593	1445
Cedar, Bermuda	748	1443	Pine, Riga	654	1383
Cedar, American white	354	766	Spruce	503	1346
Cedar of Lebanon	330	1493	Spruce, American	772	1036
Elm, English	579	782	Mar Forest Fir	698	1232
Elm, Canadian	725	1970	Norway Spar	577	1474
Hiccory, American	831	2129	Deal, Christiana	689	1562
Oak, English	829	1694	Canadian Balsam	548	1123
Oak, American white	779	1743	Larch	556	1335
Oak, American red	952	1687	Larch, American	433	911
Oak, American live	1160	1862	Mahogany, Nassau	668	1719
Oak, Adriatic	855	1471	Teak	729	2108
Oak, Dantzic	720	1518	Poona	673	1954
Oak, Italian	796	1688	Acacia	710	1867
Oak, Memel	727	1665	Soft Maple	675	1694

On the double cylinder Engine, or high and low pressure combined.

Steam-engine is a term of general application to all machines in which steam, or vapour of water, is the motive power; hence the usually familiar distinctions, viz., *Low pressure*, or condensing engines, which are almost universally employed in marine navigation, and for factory purposes where great power is required and water for condensation is sufficiently abundant. *Non-condensing* engines, where water is not easily obtained, and for locomotive purposes invariably. And *double engines*, or engines upon the high and low pressure principle combined where considerable power is required, and water for condensation can be obtained; but economy of fuel is of the greatest importance to be attended to. Condensing engines require about $3\frac{1}{2}$ gallons, or ·56 of a cubic foot of water for condensation per minute for each nominal horse power, and from 7 to $9\frac{1}{2}$ lbs. of coal, average quality, when the engine is not working to any greater degree of expansion than the common slide will efficiently permit. Non-condensing engines require no more water than a proper supply to the boiler otherwise than an addition for leakage, waste, etc., and the consumption of fuel is as the quantity of water evaporated, requiring on an average from 9 to 11 lbs. of coal per nominal horse power. Because of the double-cylinder engine combining both principles, and only requiring a similar quantity of water for condensation as in the condensing-engine, and extra fuel as those on the non-condensing principle, but to produce the same amount of power, neither the one nor the other is at all of equal proportions; hence its economical features. Thus, an engine with a cylinder of 22 inches diameter, and steam at 7 lbs. per square inch, equals 16 horses' power nominally, condensing; and a cylinder of 12 inches diameter with steam at 40 lbs. per square inch, equals 16 horses' power nominally on the non-condensing principle; but an engine on the combined principle, with steam at 40 lbs. per square inch, and cut off after the piston has passed through about $\frac{6}{7}$ths of the stroke in a non-condensing cylinder of $8\frac{1}{4}$ inches diameter, equals 8 horses' power, the steam from which being admitted to a cylinder $16\frac{1}{2}$ inches diameter, on the condensing principle, is also 8 horses' power; hence, the power of 16 horses is obtained by the quantity of steam for the small cylinder, the expenditure of steam required being as 68 to 144, and the quantity of water for condensation as 1·42 to 2·64.

The proportions that various fuels bear to each other in the economical production of steam are nearly as follows:—

Coke with blast, as in locomotives	·375	Culm, or slack from coal	1·875
Coal, medium quality	1·000	Wood, average	2·875

On the Relative sizes of Pulleys for transference of circular motion with straps or belts of uniform lengths.

When motion is to be communicated from one shaft to another by means of a belt passing over pulleys, to find the diameter of either pulley to suit that of another with increased or diminished velocity, so that the same length of belt may be suitable without alteration.

The question unavoidably divides itself into two, as the pulley whose diameter is required is less or greater than that of a pulley which is known. When this point is uncertain, multiply the radius of the known pulley by 3·1416, and increase the product by the distance between centre and centre of the shafts in inches. If this sum (which may be called the trial number) is greater than half the length of the belt, the required pulley is less than the given one; but if less, then the required pulley is the greater. In both of these cases, divide the difference between the trial number and half the length of the belt by the distance between the centres of the shafts. In the first case call the quotient A, and in the second call it B, you have then the following rules:—

1. When the required pulley is less than the given one.

Rule.—Take double the number A from 2·4674, and subtract the square root of the remainder from 1·5708, and call the difference D. Multiply the number D by the distance between the centres of the shafts, and the remainder, taken from the radius of the large pulley, will give the radius of the less one.

2. When the required pulley is greater than the given one.

Rule.—Add double the number B to 2·4674, and from the square root of the sum subtract 1·5708, and call the remainder E. Multiply the number E by the distance between the centres, of the shafts, and the product, added to the radius of the given or less pulley, will give the radius of the required, or greater pulley.

Ex. 1. Let the distance between the centres of the shafts equal 36 inches, the radius of one pulley 30 inches, and half the length of belt 98·55 inches, to find the radius of the other pulley.

3·1416 multiplied by 30 ....=94·248
Add distance between shafts 36

130·248 trial number.
Subtract half length of belt ...... 98·55

Divide by distance between shafts 36)31·698(·8805 equal to A.

From 2 4674
Subtract twice A, or ·8805 × 2 = 1·761

= ·7064 square root of which = ·8404, which subtract from 1 5708 = ·7304, or D. Multiply D, or ·7304 by 36 = 26·2944, and 30—26 2944 = 3·7056 in., radius of less pulley.

Ex. 2. Let the distance between the centres of the shafts be 36 inches, half the length of belt 92·5 inches, and the radius of the given pulley 15 inches.

3·1416 multiplied by 15............ = 47·124
Add distance between shafts......... 36

83·124 trial number.
Subtract from half length of belt 92·5

9·376
and 9·376 ÷ 36 = ·2604 equal to B.
So 2·4674 +
Twice B, or ·5208

2·9882 square root of which = 1·7286
Subtract 1·5708

Gives E, equal to ·1578
Then E multiplied by 36 = 5·6829, to which add 15, = 20·6829 inches, the radius of the larger pulley.

To determine the amount of screw disc surface for the Propeller of a steam vessel.

Rule.—Multiply the midship immersed section of the vessel in square feet by ·213, the product is the area of the whole disc surface in square feet.

Ex. Required the diameter for the propeller of a steamer whose midship section equals 164 sq. ft.

164 × ·213 = 35 square feet area. And $\sqrt{35}$ = 5·916 × 1·12837 = 6·675 feet diameter.

To find the pitch for the Screw propeller.

Rule.—Divide the velocity in feet per minute, plus the assumed amount of slip, by the number of revolutions the screw is intended to make per minute, and the quotient will be the pitch of the screw in feet.

Ex. The intended speed of a vessel is 10 miles per hour, or 860 feet per minute, the expected slip 2 miles per hour, or 172 feet per minute, and the number of revolutions of the screw 120 per minute, required the pitch.

$$860 + 172 = 1032 \text{ feet, then } 120 : 1032 :: 1 : 8{\cdot}6 \text{ feet.}$$

On customary measurement and true measurement of standing and felled timber unsquared.

Rule.—In each case multiply the square of the circumference in inches by the length of the tree in feet, and use the divisors as follows, viz.—

For customary measure	2304	For the true contents	1800
When $\frac{1}{8}$ the girth is allowed for bark	3009	„ „	2360
When $\frac{1}{10}$th the girth is allowed for bark	2845	„ „	2231

Note.—The mean girth is taken for the circumference.

Ex. 1. Required the contents of a tree, customary measure, when $\frac{1}{8}$th of the girth is allowed for bark, circumference of mean girth being 48 inches, and length of tree 18 feet.

$$48^2 \times 18 = 41472 \div 3009 = 13 \text{ feet.}$$

Ex. 2. Required the true contents of the same dimensions when no allowance for bark is made.

$$41472 \div 1800 = 23 \text{ feet.}$$

On Windmills as as a Motive-power.

Wind, or air in motion becomes a beneficial source of motive power through impulsive force on the sails of a windmill, and although generally not trustworthy for stability of motion, is well adapted for corn and flour mills, pumping of water, etc.

The shaft or axle that lies transversely across the top of the tower, and on which the sails are fixed, may have a variable angle with the horizon between 10 and 15 degrees, and still retain an equal effect.

The whip (technically) or radial arms of the sails in length, are guided by the power, situation, and velocity required, but commonly for the purposes of flour mills, pumping water, etc., the sails are made rectangles, and in length five times the breadth.

The number of sails may be 4, 5, or 6, but the total amount of sail-surface ought not to exceed one-fourth of the whole disc surface described by the whip or radial arms of the sail.

The whip is divided into seven equal parts, six of those parts, from the extremity, being the length of the sails.

The weather-board or wind-board is one-fifth of the sail's breadth.

The angles for the bars that constitute and give to the sails their proper form, are the following, and commencing at one-seventh from the centre of the shaft, 24°, 21°, 18°, 14°, 9°, 3° from the plane of motion.

A windmill with four sails, each 24 feet in length, and 6 in. breadth, with a wind at a velocity of 20 feet per second, is estimated to be equal to four horses' power—hence, required the sail-surface for a windmill with five sails, to be equal to four horses' power, with a reduced force of wind, and estimated at a velocity of only 16 feet per second.

Co eff. of power $1062500 \times 4 = 4250000$ and $16^3 = 4096$.

Then, $\frac{4250000}{4096} = \frac{1037}{5} = 207$ feet of surface in each sail.

and $207 \div 5 = \sqrt{41 \cdot 4} = 6 \cdot 4$ feet the breadth.

Also $6 \cdot 4 \times 5 = 32$ feet, the length of sail.

No.	Square.	Cube.	Sq. Root.	Cube Root.
1	1	1	1·0000000	1·000000
2	4	8	1·4142136	1·259921
3	9	27	1·7320508	1·442250
4	16	64	2·0000000	1·587401
5	25	125	2·2360680	1·709976
6	36	216	2·4494897	1·817121
7	49	343	2·6457513	1·912931
8	64	512	2·8284271	2·000000
9	81	729	3·0000000	2·080084
10	100	1000	3·1622777	2·154435
11	121	1331	3·3166248	2·223980
12	144	1728	3·4641016	2·289429
13	169	2197	3·6055513	2·351335
14	196	2744	3·7416574	2·410142
15	225	3375	3·8729833	2·466212
16	256	4096	4·0000000	2·519842
17	289	4913	4·1231056	2·571282
18	324	5832	4·2426407	2·620741
19	361	6859	4·3588989	2·668402
20	400	8000	4·4721360	2·714418
21	441	9261	4·5825757	2·758924
22	484	10648	4·6904158	2·802039
23	529	12167	4·7958315	2·843867
24	576	13824	4·8989795	2·884499
25	625	15625	5·0000000	2·924018
26	676	17576	5·0990195	2·962496
27	729	19683	5·1961524	3·000000
28	784	21952	5·2915026	3·036589
29	841	24389	5·3851648	3·072317
30	900	27000	5·4772256	3·107232
31	961	29791	5·5677644	3·141381
32	1024	32768	5·6568542	3·174802
33	1089	35937	5·7445626	3·207534
34	1156	39304	5·8309519	3·239612
35	1225	42875	5·9160798	3·271066
36	1296	46656	6·0000000	3·301927
37	1369	50653	6·0827625	3·332222
38	1444	54872	6·1644140	3·361975
39	1521	59319	6·2449980	3·391211
40	1600	64000	6·3245553	3·419952

No.	Square.	Cube.	Sq. Root.	Cube Root.
41	1681	68921	6·4031242	3·448217
42	1764	74088	6·4807407	3·476027
43	1849	79507	6·5574385	3·503398
44	1936	85184	6·6332496	3·530348
45	2025	91125	6·7082039	3·556893
46	2116	97336	6·7823300	3·583048
47	2209	103823	6·8556546	3·608826
48	2304	110592	6·9282032	3·634241
49	2401	117649	7·0000000	3·659306
50	2500	125000	7·0710678	3·684031
51	2601	132651	7·1414284	3·708430
52	2704	140608	7·2111026	3·732511
53	2809	148877	7·2801099	3·756286
54	2916	157464	7·3484692	3·779763
55	3025	166375	7·4161985	3·802952
56	3136	175616	7·4833148	3·825862
57	3249	185193	7·5498344	3·848501
58	3364	195112	7·6157731	3·870877
59	3481	205379	7·6811457	3·892996
60	3600	216000	7·7459667	3·914868
61	3721	226981	7·8102497	3·936497
62	3844	238328	7·8740079	3·957891
63	3969	250047	7·9372539	3·979057
64	4096	262144	8·0000000	4·000000
65	4225	274625	8·0622577	4·020726
66	4356	287496	8·1240384	4·041240
67	4489	300763	8·1853528	4·061548
68	4624	314432	8·2462113	4·081655
69	4761	328509	8·3066239	4·101566
70	4900	343000	8·3666003	4·121285
71	5041	357911	8·4261498	4·140818
72	5184	373248	8·4852814	4·160168
73	5329	389017	8·5440037	4·179339
74	5476	405224	8·6023253	4·198336
75	5625	421875	8·6602540	4·217163
76	5776	438976	8·7177979	4·235824
77	5929	456533	8·7749644	4·254321
78	6084	474552	8·8317609	4·272659
79	6241	493039	8·8881944	4·290840
80	6400	512000	8·9442719	4·308869

No.	Square.	Cube.	Sq. Root.	Cube Root.
81	6561	531441	9·0000000	4·326749
82	6724	551368	9·0553851	4·344481
83	6889	571787	9·1104336	4·362071
84	7056	592704	9·1651514	4·379519
85	7225	614125	9·2195445	4·396830
86	7396	636056	9·2736185	4·414005
87	7569	658503	9·3273791	4·431048
88	7744	681472	9·3808315	4·447960
89	7921	704969	9·4339811	4·464745
90	8100	729000	9·4868330	4·481405
91	8281	753571	9·5393920	4·497941
92	8464	778688	9·5916630	4·514357
93	8649	804357	9·6436508	4·530655
94	8836	830584	9·6953597	4·546836
95	9025	857375	9·7467943	4·562903
96	9216	884736	9·7979590	4·578857
97	9409	912673	9·8488578	4·594701
98	9604	941192	9·8994949	4·610436
99	9801	970299	9·9498744	4·626065
100	10000	1000000	10·0000000	4·641589
101	10201	1030301	10·0498756	4·657009
102	10404	1061208	10·0995049	4·672329
103	10609	1092727	10·1488916	4·687548
104	10816	1124864	10·1980390	4·702669
105	11025	1157625	10·2469508	4·717694
106	11236	1191016	10·2956301	4·732623
107	11449	1225043	10·3440804	4·747459
108	11664	1259712	10·3923048	4·762203
109	11881	1295029	10·4403065	4·776856
110	12100	1331000	10·4880885	4·791420
111	12321	1367631	10·5356538	4·805895
112	12544	1404928	10·5830052	4·820284
113	12769	1442897	10·6301458	4·834588
114	12996	1481544	10·6770783	4·848808
115	13225	1520875	10·7238053	4·862944
116	13456	1560896	10·7703296	4·876999
117	13689	1601613	10·8166538	4·890973
118	13924	1643032	10·8627805	4·904868
119	14161	1685159	10·9087121	4·918685
120	14400	1728000	10·954[illegible]512	4·932424

No.	Square.	Cube.	Sq. Root.	Cube Root.
121	14641	1771561	11·0000000	4·946087
122	14884	1815848	11·0453610	4·959676
123	15129	1860867	11·0905365	4·973190
124	15376	1906624	11·1355287	4·986631
125	15625	1953125	11·1803399	5·000000
126	15876	2000376	11·2249722	5·013298
127	16129	2048383	11·2694277	5·026526
128	16384	2097152	11·3137085	5·039684
129	16641	2146689	11·3578167	5·052774
130	16900	2197000	11·4017543	5·065797
131	17161	2248091	11·4455231	5·078753
132	17424	2299968	11·4891253	5·091643
133	17689	2352637	11·5325626	5·104469
134	17956	2406104	11·5758369	5·117230
135	18225	2460375	11·6189500	5·129928
136	18496	2515456	11·6619038	5·142563
137	18769	2571353	11·7046999	5·155137
138	19044	2628072	11·7473401	5·167649
139	19321	2685619	11·7898261	5·180101
140	19600	2744000	11·8321596	5·192494
141	19881	2803221	11·8743422	5·204828
142	20164	2863288	11·9163753	5·217103
143	20449	2924207	11·9582607	5·229321
144	20736	2985984	12·0000000	5·2[illegible]1483
145	21025	3048625	12·0415946	5·253588
146	21316	3112136	12·0830460	5·265637
147	21609	3176523	12·1243557	5·277632
148	21904	3241792	12·1655251	5·289572
149	22201	3307949	12·2065556	5·301459
150	22500	3375000	12·2474487	5·313293
151	22801	3442951	12·2882057	5·325074
152	23104	3511808	12·3288280	5·336803
153	23409	3581577	12·3693169	5·348481
154	23716	3652264	12·4096736	5·360108
155	24025	3723875	12·4498996	5·371685
156	24336	3796416	12·4899960	5·383213
157	24649	3869893	12·5299641	5·394691
158	24964	3944312	12·5698051	5·406120
159	25281	4019679	12·6095202	5·417501
160	25600	4096000	12·6491106	5·428835

No.	Square.	Cube.	Sq. Root.	Cube Root.
161	25921	4173281	12·6885775	5·440122
162	26244	4251528	12·7279221	5·451362
163	26569	4330747	12·7671453	5·462556
164	26896	4410944	12·8062485	5·703704
165	27225	4492125	12·8452326	5·484807
166	27556	4574296	12·8840987	5·495865
167	27889	4657463	12·9228480	5·506878
168	28224	4741632	12·9614814	5·517848
169	28561	4826809	13·0000000	5·528775
170	28900	4913000	13·0384048	5·539658
171	29241	5000211	13·0766968	5·550499
172	29584	5088448	13·1148770	5·561298
173	29929	5177717	13·1529464	5·572055
174	30276	5268024	13·1909060	5·582770
175	30625	5359375	13·2287566	5·593445
176	30976	5451776	13·2664992	5·604079
177	31329	5545233	13·3041347	5·614672
178	31684	5639752	13·3416641	5·625226
179	32041	5735339	13·3790882	5·635741
180	32400	5832000	13·4164079	5·646216
181	32761	5929741	13·4536240	5·656653
182	33124	6028568	13·4907376	5·667051
183	33489	6128487	13·5277493	5·677411
184	33856	6229504	13·5646600	5·687734
185	34225	6331625	13·6014705	5·698019
186	34596	6434856	13·6381817	5·708267
187	34969	6539203	13·6747943	5·718479
188	35344	6644672	13·7113092	5·728654
189	35721	6751269	13·7477271	5·738794
190	36100	6859000	13·7840488	5·748897
191	36481	6967871	13·8202750	5·758965
192	36864	7077888	13·8564065	5·768998
193	37249	7189057	13·8924440	5·778996
194	37636	7301384	13·9283883	5·788960
195	38025	7414875	13·9642400	5·798890
196	38416	7529536	14·0000000	5·808786
197	38809	7645373	14·0356688	5·818648
198	39204	7762392	14.0712473	5·828477
199	39601	7880599	14·1067360	5·838272
200	40000	8000000	14·1421356	5·848035

No.	Square.	Cube.	Sq. Root.	Cube Root.
201	40401	8120601	14·1774469	5·857766
202	40804	8242408	14·2126704	5·867464
203	41209	8365427	14·2478068	5·877131
204	41616	8489664	14·2828569	5·886765
205	42025	8615125	14·3178211	5·896368
206	42436	8741816	14·3527001	5·905941
207	42849	8869743	14·3874946	5·915482
208	43264	8998912	14·4222051	5·924992
209	43681	9129329	14·4568323	5·934473
210	44100	9261000	14·4913767	5·943922
211	44521	9393931	14·5258390	5·953342
212	44944	9528128	14·5602198	5·962732
213	45369	9663597	14·5945195	5·972093
214	45796	9800344	14·6287388	5·981424
215	46225	9938375	14·6628783	5·990726
216	46656	10077696	14·6969385	6·000000
217	47089	10218313	14 7309199	6·009245
218	47524	10360232	14·7648231	6·018462
219	47961	10503459	14·7986486	6·027650
220	48400	10648000	14·8323970	6·036811
221	48841	10793861	14·8660687	6·045943
222	49284	10941048	14·8996644	6·055049
223	49729	11089567	14·9331845	6·064127
224	50176	11239424	14·9666295	6·073178
225	50625	11390625	15·0000000	6·082202
226	51076	11543176	15·0332964	6·091199
227	51529	11697083	15·0665192	6·100170
228	51984	11852352	15 0996689	6·109115
229	52441	12008989	15·1327460	6·118033
230	52900	12167000	15·1657509	6·126926
231	53361	12326391	15·1986842	6·135792
232	53824	12487168	15·2315462	9·144634
233	54289	12649337	15·2643375	6·153449
234	54756	12812904	15·2970585	6·162240
235	55225	12977875	15·3297097	6·171006
236	55696	13144256	15·3622915	6·179747
237	56169	13312053	15·3948043	5·188463
238	56644	13481272	15·4272486	6·197154
239	57121	13651919	15·4596248	6·205822
240	57600	13824000	15·4919334	6·214465

No.	Square	Cube.	Sq. Root.	Cube Root
241	58081	13997521	15·5241747	6·223084
242	58564	14172488	15·5563492	6·231680
243	59049	14348907	15·5884573	6·240251
244	59536	14526784	15·6204994	6·248800
245	60025	14706125	15·6524758	6·257325
246	60516	14886936	15·6843871	6·265827
247	61009	15069223	15·7162336	6·274305
248	61504	15252992	15·7480157	6·282761
249	62001	15438249	15·7797338	6·291195
250	62500	15625000	15·8113883	6·299605
251	63001	15813251	15·8429795	6·307994
252	63504	16003008	15·8745079	6·316360
253	64009	16194277	15·9059737	6·324704
254	64516	16387064	15·9373775	6·333026
255	65025	16581375	15·9687194	6·341326
256	65536	16777216	16·0000000	6·349604
257	66049	16974593	16·0312195	6·357861
258	66564	17173512	16·0623784	6·366097
259	67081	17373979	16·0934769	6·374311
260	67600	17576000	16·1245155	6·382504
261	68121	17779581	16·1554944	6·390676
262	68644	17984728	16·1864141	6·398828
263	69169	18191447	16·2172747	6·406958
264	69696	18399744	16·2480768	6·415069
265	70225	18609625	16·2788206	6·423158
266	70756	18821096	16·3095064	6·431228
267	71289	19034163	16·3401346	6·439277
268	71824	19248832	16·3707055	6·447306
269	72361	19465109	16·4012195	6·455315
270	72900	19683000	16·4316767	6·463304
271	73441	19902511	16·4620776	6·471274
272	73984	20123648	16·4924225	6·479224
273	74529	20346417	16·5227116	6·487154
274	75076	20570824	16·5529454	6·495065
275	75625	20796875	16·5831240	6·502957
276	76176	21024576	16·6132477	6·510830
277	76729	21253933	16·6433170	6·518684
278	77284	21484952	16·6733320	6·526519
279	77841	21717639	16·7032931	6·534335
280	78400	21952000	16·7332005	6·542133

No.	Square.	Cube.	Sq. Root.	Cube Root.
281	78961	22188041	16·7630546	6·549912
282	79524	22425768	16·7928556	6·557672
283	80089	22665187	16·8226038	6·565414
284	80656	22906304	16·8522995	6·573139
285	81225	23149125	16·8819430	6·580844
286	81796	23393656	16·9115345	6·588532
287	82369	23639903	16·9410743	6·596202
288	82944	23887872	16·9705627	6·603854
289	83521	24137569	17·0000000	6·611489
290	84100	24389000	17·0293864	6·619106
291	84681	24642171	17·0587221	6·626705
292	85264	24897088	17·0880075	6·634287
293	85849	25153757	17·1172428	6·641852
294	86436	25412184	17·1464282	6·649400
295	87025	25672375	17·1755640	6·656930
296	87616	25934336	17·2046505	6·664444
297	88209	26198073	17·2336879	6·671940
298	88804	26463592	17·2626765	6·679420
299	89401	26730899	17·2916165	6·686883
300	90000	27000000	17·3205081	6·694329
301	90601	27270901	17·3493516	6·701759
302	91204	27543608	17·3781472	6·709173
303	91809	27818127	17·4068952	6·716570
304	92416	28094464	17·4355958	6·723951
305	93025	28372625	17·4642492	6·731316
306	93636	28652616	17·4928557	6·738664
307	94249	28934443	17·5214155	6·745997
308	94864	29218112	17·5499288	6·753313
309	95481	29503629	17·5783958	6·760614
310	96100	29791000	17·6068169	6·767899
311	96721	30080231	17·6351921	6·775169
312	97344	30371328	17·6635217	6·782423
313	97969	30664297	17·6918060	6·789661
314	98596	30959144	17·7200451	6·796884
315	99225	31255875	17·7482393	6·804092
316	99856	31554496	17·7763888	6·811285
317	100489	31855013	17·8044938	5·818462
318	101124	32157432	17·8325545	6·825624
319	101761	32461759	17·8605711	6·832771
320	102400	32768000	17·8885438	6·839904

No.	Square.	Cube.	Sq. Root.	Cube Root.
321	103041	33076161	17·9164729	6·847021
322	103684	33386248	17·9443584	6·854124
323	104329	33698267	17·9722008	6·861212
324	104976	34012224	18·0000000	6·868285
325	105625	34328125	18·0277564	6·875344
326	106276	34645976	18·0554701	6·882389
327	106929	34965783	18·0831413	6·889419
328	107584	35287552	18·1107703	6·896435
329	108241	35611289	18·1383571	6·903436
330	108900	35937000	18·1659021	6·910423
331	109561	36264691	18·1934054	6·917396
332	110224	36594368	18·2208672	6·924356
333	110889	36926037	18·2482876	6·931301
334	111556	37259704	18·2756669	6·938232
335	112225	37595375	18·3030052	6·945150
336	112896	37933056	18·3303028	6·952053
337	113569	38272753	18·3575598	6·958943
338	114244	38614472	18·3847763	6·965820
339	114921	38958219	18·4119526	6·972683
340	115600	39304000	18·4390889	6·979532
341	116281	39651821	18·4661853	6·986368
342	116964	40001688	18·4932420	6·993191
343	117649	40353607	18·5202592	7·000000
344	118336	40707584	18·5472370	7·006796
345	119025	41063625	18·5741756	7·013579
346	119716	41421736	18·6010752	7·020349
347	120409	41781923	18·6279360	7·027106
348	121104	42144192	18·6547581	7·033850
349	121801	42508549	18·6815417	7·040581
350	122500	42875000	18·7082869	7·047299
351	123201	43243551	18·7349940	7·054004
352	123904	43614208	18·7616630	7·060697
353	124609	43986977	18·7882942	7·067377
354	125316	44361864	18·8148877	7·074044
355	126025	44738875	18·8414437	7·080699
356	126736	45118016	18·8679623	7·087341
357	127449	45499293	18·8944436	7·093971
358	128164	45882712	18·9208879	7·100588
359	128881	46268279	18·9472953	7·107194
360	129600	46656000	18·9736660	7·113787

No.	Square.	Cube.	Sq. Root.	Cube Root.
361	130321	47045881	19·0000000	7·120376
362	131044	47437928	19·0262976	7·126936
363	131769	47832147	19·0525589	7·133492
364	132496	48228544	19·0787840	7·140037
365	133225	48627125	19·1049732	7·146569
366	133956	49027896	19·1311265	7·153090
367	134689	49430863	19·1572441	7·159599
368	135424	49836032	19·1833261	7·166096
369	136161	50243409	19·2093727	7·172581
370	136900	50653000	19·2353841	7·179054
371	137641	51064811	19·2613603	7·185516
372	138384	51478848	19·2873015	7·191966
373	139129	51895117	19·3132079	7·198405
374	139876	52313624	19·3390796	7·204832
375	140625	52734375	19·3649167	7·211248
376	141376	53157376	19·3907194	7·217652
377	142129	53582633	19·4164878	7·224045
378	142884	54010152	19·4422221	7·230427
379	143641	54439939	19·4679223	7·236797
380	144400	54872000	19·4935887	7·243156
381	145161	55306341	19·5192213	7·249504
382	145924	55742968	19·5448203	7·255841
383	146689	56181887	19·5703858	7·262167
384	147456	56623104	19·5959179	7·268482
385	148225	57066625	19·6214169	7·274786
386	148996	57512456	19·6468827	7·281079
387	149769	57960603	19·6723156	7·287362
388	150544	58411072	19·6977156	7·293633
389	151321	58863869	19·7230829	7·299894
390	152100	59319000	19·7484177	7·306144
391	152881	59776471	19·7737199	7·312383
392	153664	60236288	19·7989899	7·318611
393	154449	60698457	19·8242276	7·324829
394	155236	61162984	19·8494332	7·331037
395	156025	61629875	19·8746069	7·337234
396	156816	62099136	19·8997487	7·343420
397	157609	62570773	19·9248588	7 349597
398	158404	63044792	19·9499373	7·355762
399	159201	63521199	19·9749844	7·361918
400	160000	64000000	20·0000000	7·368063

No.	Square.	Cube.	Sq. Root.	Cube Root
401	160801	64481201	20·0249844	7·374198
402	161604	64964808	20·0499377	7·380323
403	162409	65450827	20·0748599	7·386437
404	163216	65939264	20·0997512	7·392542
405	164025	66430125	20·1246118	7·398636
406	164836	66923416	20·1494417	7·404721
407	165649	67419143	20·1742410	7·410795
408	166464	67917312	20·1990099	7·416859
409	167281	68417929	20·2237484	7·422914
410	168100	68921000	20·2484567	7·428959
411	168921	69426531	20·2731349	7·434994
412	169744	69934528	20·2977831	7·441019
413	170569	70444997	20·3224014	7·447034
414	171396	70957944	20·3469899	7·453040
415	172225	71473375	20·3715488	7·459036
416	173056	71991296	20·3960781	7·465022
417	173889	72511713	20·4205779	7·470999
418	174724	73034632	20·4450483	7·476966
419	175561	73560059	20·4694895	7·482924
420	176400	74088000	20·4939015	7·488872
421	177241	74618461	20·5182845	7·494811
422	178084	75151448	20·5426386	7·500741
423	178929	75686967	20·5669638	7·506661
424	179776	76225024	20·5912603	7·512571
425	180625	76765625	20·6155281	7·518473
426	181476	77308776	20·6397674	7·524365
427	182329	77854483	20·6639783	7·530248
428	183184	78402752	20·6881609	7·536122
429	184041	78953589	20·7123152	7·541987
430	184900	79507000	20·7364414	7·547842
431	185761	80062991	20·7605395	7·553689
432	186624	80621568	20·7846097	7·559526
433	187489	81182737	20·8086520	7·565355
434	188356	81746504	20·8326667	7·571174
435	189225	82312875	20·8566536	7·576985
436	190096	82881856	20·8806130	7·582786
437	190969	83453453	20·9045450	7·588579
438	191844	84027672	20·9284495	7·594363
439	192721	84604519	20·9523268	7·600138
440	193600	85184000	20·9761770	7·605905

No.	Square.	Cube.	Sq. Root.	Cube Root.
441	194481	85766121	21·0000000	7·611663
442	195364	86350888	21·0237960	7·617412
443	196249	86938307	21·0475652	7·623152
444	197136	87528384	21·0713075	7·628884
445	198025	88121125	21·0950231	7·634607
446	198916	88716536	21·1187121	7·640321
447	199809	89314623	21·1423745	7·646027
448	200704	89915392	21·1660105	7·651725
449	201601	90518849	21·1896201	7·657414
450	202500	91125000	21·2132034	7·663094
451	203401	91733851	21·2367606	7·668766
452	204304	92345408	21·2602916	7·674430
453	205209	92959677	21·2837967	7·680086
454	206116	93576664	21·3072758	7.685733
455	207025	94196375	21·3307290	7·691372
456	207936	94818816	21 3541565	7·697002
457	208849	95443993	21·3775583	7·702625
458	209764	96071912	21·4009346	7 708239
459	210681	96702579	21·4242853	7·713845
460	211600	97336000	21·4476106	7·719443
461	212521	97972181	21·4709106	7·725032
462	213444	98611128	21·4941853	7·730614
463	214369	99252847	21·5174348	7·736188
464	215296	99897344	21·5406592	7·741753
465	216225	100544625	21·5638587	7·747311
466	217156	101194696	21·5870331	7·752861
467	218089	101847563	21·6101828	7·758402
468	219024	102503232	21·6333077	7·763936
469	219961	103161709	21·6564078	7.769462
470	220900	103823000	21·6794834	7·774980
471	221841	104487111	21·7025344	7·780490
472	222784	105154048	21·7255610	7·785993
473	223729	105823817	21·7485632	7·791487
474	224676	106496424	21·7715411	7·796974
475	225625	107171875	21·7944947	7·802454
476	226576	107850176	21·8174242	7·807925
477	227529	108531333	21·8403297	7·813389
478	228484	109215352	21·8632111	7·818846
479	229441	109902239	21·8860686	7·824294
480	230400	110592000	21·9089023	7·829735

No.	Square.	Cube.	Sq. Root.	Cube Root.
481	231361	111284641	21·9317122	7·835169
482	232324	111980168	21·9544984	7·840595
483	233289	112678587	21·9772610	7·846013
484	234256	113379904	22·0000000	7·851424
485	235225	114084125	22·0227155	7·856828
486	236196	114791256	22·0454077	7·862224
487	237169	115501303	22·0680765	7·867613
488	238144	116214272	22·0907220	7·872994
489	239121	116930169	22·1133444	7·878368
490	240100	117649000	22·1359436	7·883735
491	241081	118370771	22·1585198	7·889095
492	242064	119095488	22·1810730	7·894447
493	243049	119823157	22·2036033	7·899792
494	244036	120553784	22·2261108	7·905129
495	245025	121287375	22·2485955	7·910460
496	246016	122023936	22·2710575	7·915783
497	247009	122763473	22·2934968	7·921099
498	248004	123505992	22·3159136	7·926408
499	249001	124251499	22·3383079	7·931710
500	250000	125000000	22·3606798	7·937005
501	251001	125751501	22·3830293	7·942293
502	252004	126506008	22·4053565	7·947574
503	253009	127263527	22·4276615	7·952848
504	254016	128024064	22·4499443	7·958114
505	255025	128787625	22·4722051	7·963374
506	256036	129554216	22·4944438	7·968627
507	257049	130323843	22·5166605	7·973873
508	258064	131096512	22·5388553	7·979112
509	259081	131872229	22·5610283	7·984344
510	260100	132651000	22·5831796	7·989570
511	261121	133432831	22·6053091	7·994788
512	262144	134217728	22·6274170	8·000000
513	263169	135005697	22·6495033	8·005205
514	264196	135796744	22·6715681	8·010403
515	265225	136590875	22·6936114	8·015595
516	266256	137388096	22·7156334	8·020779
517	267289	138188413	22·7376340	8·025957
518	268324	138991832	22·7596134	8·031129
519	269361	139798359	22·7815715	8·036293
520	270400	140608000	22·8035085	8·041451

No.	Square.	Cube.	Sq. Root.	Cube Root.
521	271441	141420761	22·8254244	8·046603
522	272484	142236648	22·8473193	8·051748
523	273529	143055667	22·8691933	8·056886
524	274576	143877824	22·8910463	8·062018
525	275625	144703125	22·9128785	8·067143
526	276676	145531576	22·9346899	8·072262
527	277729	146363183	22·9564806	8·077374
528	278784	147197952	22·9782506	8·082480
529	279841	148035889	23·0000000	8·087579
530	280900	148877000	23·0217289	8·092672
531	281961	149721291	23·0434372	8·097759
532	283024	150568768	23·0651252	8·102839
533	284089	151419437	23·0867928	8·107913
534	285156	152273304	23·1084400	8·112980
535	286225	153130375	23·1300670	8·118041
536	287296	153990656	23·1516738	8·123096
537	288369	154854153	23·1732605	8·128145
538	289444	155720872	23·1948270	8 133187
539	290521	156590819	23·2163735	8·138223
540	291600	157464000	23·2379001	8·143253
541	292681	158340421	23·2594067	8·148276
542	293764	159220088	23·2808935	8·153294
543	294849	160103007	23·3023604	8·158305
544	295936	160989184	23·3238076	8·163310
545	297025	161878625	23·3452351	8·168309
546	298116	162771336	23·3666429	8·173302
547	299209	163667323	23·3880311	8·178289
548	300304	164566592	23·4093998	8·183269
549	301401	165469149	23·4307490	8·188244
550	302500	166375000	23·4520788	8·193213
551	303601	167284151	23·4733892	8·198175
552	304704	168196608	23·4946802	8·203132
553	305809	169112377	23·5159520	8·208082
554	306916	170031464	23·5372046	8·213027
555	308025	170953875	23·5584380	8·217966
556	309136	171879616	23·5796522	8·222898
557	310249	172808693	23·6008474	8·227825
558	311364	173741112	23·6220236	8·232746
559	312481	174676879	23·6431808	8·237661
560	313600	175616000	23·6643191	8·242571

No.	Square.	Cube.	Sq. Root.	Cube Root.
561	314721	176558481	23·6854386	8·247474
562	315844	177504328	23·7065392	8·252371
563	316969	178453547	23·7276210	8 257263
564	318096	179406144	23.7486842	8·262149
565	319225	180362125	23·7697286	8 267029
566	320356	181321496	23·7907545	8·271904
567	321489	182284263	23·8117618	8·276773
568	322624	183250432	23·8327506	8·281635
569	323761	184220009	23·8537209	8·286493
570	324900	185193000	23·8746728	8·291344
571	326041	186169411	23·8956063	8·296190
572	327184	187149248	23·9165215	8·301030
573	328329	188132517	23 9374184	8 305865
574	329476	189119224	23·9582971	8·310694
575	330625	190109375	23·9791576	8·315517
576	331776	191102976	24·0000000	8 320335
577	332929	192100033	24·0208243	8·325147
578	334084	193100552	24·0416306	8·329954
579	335241	194104539	24·0624188	8·334755
580	336400	195112000	24·0831891	8·339551
581	337561	196122941	24·1039416	8·344341
582	338724	197137368	24·1246762	8·349126
583	339889	198155287	24·1453929	8·353905
584	341056	199176704	24·1660919	8·358678
585	342225	200201625	24·1867732	8·363447
586	343396	201230056	24·2074369	8·368209
587	344569	202262003	24·2280829	8·372967
588	345744	203297472	24·2487113	8·377719
589	346921	204336469	24·2693222	8·382465
590	348100	205379000	24·2899156	8·387206
591	349281	206425071	24·3104916	8·391942
592	350464	207474688	24·3310501	8·396673
593	351649	208527857	24·3515913	8·401398
594	352836	209584584	24·3721152	8·406118
595	354025	210644875	24·3926218	8·410833
596	355216	211708736	24·4131112	8·415542
597	356409	212776173	24·4335834	8·420246
598	357604	213847192	24·4540385	8·424945
599	358801	214921799	24·4744765	8·429638
600	360000	216000000	24·4948974	8·434327

No.	Square.	Cube.	Sq. Root.	Cube Root.
601	361201	217081801	24·5153013	8·439010
602	362404	218167208	24·5356883	8·443688
603	363609	219256227	24·5560583	8·448360
604	364816	220348864	24·5764115	8·453028
605	366025	221445125	24·5967478	8·457691
606	367236	222545016	24·6170673	8·462348
607	368449	223648543	24·6373700	8·467000
608	369664	224755712	24·6576560	8·471647
609	370881	225866529	24·6779254	8·476289
610	372100	226981000	24·6981781	8·480926
611	373321	228099131	24·7184142	8·485558
612	374544	229220928	24·7386338	8·490185
613	375769	230346397	24·7588368	8·494806
614	376996	231475544	24·7790234	8·499423
615	378225	232608375	24·7991935	8·504035
616	379456	233744896	24·8193473	8·508642
617	380689	234885113	24·8394847	8·513243
618	381924	236029032	24·8596058	8·517840
619	383161	237176659	24·8797106	8·522132
620	384400	238328000	24·8997992	8·527019
621	385641	239483061	24·9198716	8·531601
622	386884	240641848	24·9399278	8·536178
623	388129	241804367	24·9599679	8·540750
624	389376	242970624	24·9799920	8·545317
625	390625	244140625	25·0000000	8·549880
626	391876	245314376	25·0199920	8·554437
627	393129	246491883	25·0399681	8·558990
628	394384	247673152	25·0599282	8·563538
629	395641	248858189	25·0798724	8.568081
630	396900	250047000	25·0998008	8·572619
631	398161	251239591	25·1197134	8·577152
632	399424	252435968	25·1396102	8·581681
633	400689	253636137	25·1594913	8·586205
634	401956	254840104	25·1793566	8·590724
635	403225	256047875	25·1992063	8·595238
636	404496	257259456	25·2190404	8·599748
637	405769	258474853	25·2388589	8·604252
638	407044	259694072	25·2586619	8·608753
639	408321	260917119	25·2784493	8·613248
640	409600	262144000	25·2982213	8·617739

No.	Square.	Cube.	Sq. Root.	Cube Root.
641	410881	263374721	25·3179778	8·622225
642	412164	264609288	25·3377189	8·626706
643	413449	265847707	25·3574447	8·631183
644	414736	267089984	25·3771551	8·635655
645	416025	268336125	25·3968502	8·640123
646	417316	269586136	25·4165301	8·644585
647	418609	270840023	25·4361947	8·649044
648	419904	272097792	25·4558441	8·653497
649	421201	273359449	25·4754784	8·657946
650	422500	274625000	25·4950976	8·662391
651	423801	275894451	25·5147016	8·666831
652	425104	277167808	25·5342907	8·671266
653	426409	278445077	25·5538647	8·675697
654	427716	279726264	25·5734237	8·680124
655	429025	281011375	25·5929678	8·684546
656	430336	282300416	25·6124969	8·688963
657	431649	283593393	25·6320112	8·693376
658	432964	284890312	25·6515107	8·697784
659	434281	286191179	25·6709953	8·702188
660	435600	287496000	25·6904652	8·706588
661	436921	288804781	25·7099203	8·710983
662	438244	290117528	25·7293607	8·715373
663	439569	291434247	25·7487864	8·719760
664	440896	292754944	25·7681975	8·724141
665	442225	294079625	25·7875939	8·728518
666	443556	295408296	25·8069758	8·732892
667	444889	296740963	25·8263431	8·737260
668	446224	298077632	25·8456960	8·741625
669	447561	299418309	25·8650343	8·745985
670	448900	300763000	25·8843582	8·750340
671	450241	302111711	25·9036677	8·754691
672	451584	303464448	25·9229628	8·759038
673	452929	304821217	25·9422435	8·763381
674	454276	306182024	25·9615100	8·767719
675	455625	307546875	25·9807621	8·772053
676	456976	308915776	26·0000000	8·776383
677	458329	310288733	26·0192237	8·780708
678	459684	311665752	26·0384331	8·785030
679	461041	313046839	26·0576284	8·789347
680	462400	314432000	36·0768096	8·793659

No.	Square.	Cube.	Sq. Root.	Cube Root.
681	463761	315821241	26·0959767	8·797968
682	465124	317214568	26·1151297	8·802272
683	466489	318611987	26·1342687	8·806572
684	467856	320013504	26·1533937	8·810868
685	469225	321419125	26·1725047	8·815160
686	470596	322828856	26·1916017	8·819447
687	471969	324242703	26·2106848	8·823731
688	473344	325660672	26·2297541	8·828010
689	474721	327082769	26·2488095	8·832285
690	476100	328509000	26·2678511	8·836556
691	477481	329939371	26·2868789	8·840823
692	478864	331373888	26·3058929	8·845085
693	480249	332812557	26·3248932	8·849344
694	481636	334255384	26·3438797	8·853598
695	483025	335702375	26·3628527	8·857849
696	484416	337153536	26·3818119	8·862095
697	485809	338608873	26·4007576	8.866337
698	487204	340068392	26·4196896	8·870576
699	488601	341532099	26·4386081	8·874810
700	490000	343000000	26·4575131	8·879040
701	491401	344472101	26·4764046	8·883266
702	492804	345948408	26·4952826	8·887488
703	494209	347428927	26·5141472	8·891706
704	495616	348913664	26·5329983	8·895920
705	497025	350402625	26·5518361	8·900130
706	498436	351895816	26·5706605	8·904337
707	499849	353393243	26·5894716	8·908539
708	501264	354894912	26·6082694	8·912737
709	502681	356400829	26·6270539	8·916931
710	504100	357911000	26·6458252	8·921121
711	505521	359425431	26·6645833	8·925308
712	506944	360944128	26·6833281	8·929490
713	508369	362467097	26·7020598	8·933669
714	509796	363994344	26·7207784	8·937843
715	511225	365525875	26·7394839	8·942014
716	512656	367061696	26·7581763	8·946181
717	514089	368601813	26·7768557	8·950344
718	515524	370146232	26·7955220	8·954503
719	516961	371694959	26·8141754	8·958658
720	518400	373248000	26·8328157	8·962809

No.	Square.	Cube.	Sq. Root.	Cube Root.
721	519841	374805361	26·8514432	8·966957
722	521284	376367048	26·8700577	8·971101
723	522729	377933067	26·8886593	8·975241
724	524176	379503424	26·9072481	8·979377
725	525625	381078125	26·9258240	8·983509
726	527076	382657176	26·9443872	8·987637
727	528529	384240583	26·9629375	8·991762
728	529984	385828352	26·9814751	8·995883
729	531441	387420489	27·0000000	9·000000
730	532900	389017000	27·0185122	9·004113
731	534361	390617891	27·0370117	9·008223
732	535824	392223168	27·0554985	9·012329
733	537289	393832837	27·0739727	9·016431
734	538756	395446904	27·0924344	9·020529
735	540225	397065375	27·1108834	9·024624
736	541696	398688256	27·1293199	9·028715
737	543169	400315553	27·1477439	9·032802
738	544644	401947272	27·1661554	9·036886
739	546121	403583419	27·1845544	9·040965
740	547600	405224000	27·2029410	9·045042
741	549081	406869021	27·2213152	9·049114
742	550564	408518488	27·2396769	9·053183
743	552049	410172407	27·2580263	9·057248
744	553536	411830784	27·2763634	9·061310
745	555025	413493625	27·2946881	9 065368
746	556516	415160936	27·3130006	9·069422
747	558009	416832723	27·3313007	9·073473
748	559504	418508992	27·3495887	9·077520
749	561001	420189749	27·3678644	9·081563
750	562500	421875000	27·3861279	9·085603
751	564001	423564751	27·4043792	9·089639
752	565504	425259008	27·4226184	9·093672
753	567009	426957777	27·4408455	9·097701
754	568516	428661064	27·4590604	9·101726
755	570025	430368875	27·4772633	9·105748
756	571536	432081216	27·4954542	9·109767
757	573049	433798093	27·5136330	9·113782
758	574564	435519512	27·5317998	9·117793
759	576081	437245479	27·5499546	9·121801
760	577600	438976000	27·5680975	9·125805

No.	Square.	Cube.	Sq. Root.	Cube Root.
761	579121	440711081	27·5862284	9·129806
762	580644	442450728	27·6043475	9·133803
763	582169	444194947	27·6224546	9·137797
764	583696	445943744	27·6405499	9·141787
765	585225	447697125	27·6586334	9·145774
766	586756	449455096	27·6767050	9·149758
767	588289	451217663	27·6947648	9·153737
768	589824	452984832	27·7128129	9·157714
769	591361	454756609	27·7308492	9·161687
770	592900	456533000	27·7488739	9·165656
771	594441	458314011	27·7668868	9·169622
772	595984	460099648	27·7848880	9·173585
773	597529	461889917	27·8028775	9·177544
774	599076	463684824	27·8208555	9·181500
775	600625	465484375	27·8388218	9·185453
776	602176	467288576	27·8567766	9·189402
777	603729	469097433	27·8747197	9·193347
778	605284	470910952	27·8926514	9·197290
779	606841	472729139	27·9105715	9·201229
780	608400	474552000	27·9284801	9·205164
781	609961	476379541	27·9463772	9·209096
782	611524	478211768	27·9642629	9·213025
783	613089	480048687	27·9821372	9·216950
784	614656	481890304	28·0000000	9·220873
785	616225	483736625	28·0178515	9·224791
786	617796	485587656	28·0356915	9·228707
787	619369	487443403	28·0535203	9·232619
788	620944	489303872	28·0713377	9·236528
789	622521	491169069	28·0891438	9·240433
790	624100	493039000	28·1069386	9·244335
791	625681	494913671	28·1247222	9·248234
792	627264	496793088	28·1424946	9·252130
793	628849	498677257	28·1602557	9·256022
794	630436	500566184	28·1780056	9·259911
795	632025	502459875	28·1957444	9·263797
796	633616	504358336	28·2134720	9·267680
797	635209	506261573	28·2311884	9·271559
798	636804	508169592	28·2488938	9·275435
799	638401	510082399	28·2665881	9·279308
800	640000	512000000	28·2842712	9·283178

No.	Square.	Cube.	Sq. Root.	Cube Root.
801	641601	513922401	28·3019434	9·287044
802	643204	515849608	28·3196045	9·290907
803	644809	517781627	28·3372546	9·294767
804	646416	519718464	28·3548938	9·298624
805	648025	521660125	28·3725219	9·302477
806	649636	523606616	28·3901391	9·306328
807	651249	525557943	28·4077454	9·310175
808	652864	527514112	28·4253408	9·314019
809	654481	529475129	28·4429253	9·317860
810	656100	531441000	28·4604989	9·321697
811	657721	533411731	28·4780617	9·325532
812	659344	535387328	28·4956137	9·329363
813	660969	537367797	28·5131549	9·333192
814	662596	539353144	28·5306852	9·337017
815	664225	541343375	28·5482048	9·340839
816	665856	543338496	28·5657137	9·344657
817	667489	545338513	28·5832119	9·348473
818	669124	547343432	28·6006993	9·352286
819	670761	549353259	28·6181760	9·356095
820	672400	551368000	28·6356421	9·359902
821	674041	553387661	28·6530976	9·363705
822	675684	555412248	28·6705424	9·367505
823	677329	557441767	28·6879766	9·371302
824	678976	559476224	28·7054002	9·375096
825	680625	561515625	28·7228132	9·378887
826	682276	563559976	28·7402157	9·382675
827	683929	565609283	28·7576077	9·386460
828	685584	567663552	28·7749891	9·390242
829	687241	569722789	28·7923601	9·394021
830	688900	571787000	28·8097206	9·397796
831	690561	573856191	28·8270706	9·401569
832	692224	575930368	28·8444102	9·405339
833	693889	578009537	28·8617394	9·409105
834	695556	580093704	28·8790582	9·412869
835	697225	582182875	28·8963666	9·416630
836	698896	584277056	28·9136646	9·420387
837	700569	586376253	28·9309523	9·424142
838	702244	588480472	28·9482297	9·427894
839	703921	590589719	28·9654967	9·431642
840	705600	592704000	28·9827535	9·435388

No.	Square.	Cube.	Sq. Root.	Cube Root.
841	707281	594823321	29·0000000	9·439131
842	708964	596947688	29·0172363	9·442870
843	710649	599077107	29·0344623	9·446607
844	712336	601211584	29·0516781	9·450341
845	714025	603351125	29·0688837	9·454072
846	715716	605495736	29·0860791	9·457800
847	717409	607645423	29·1032644	9·461525
848	719104	609800192	29·1204396	9·465247
849	720801	611960049	29·1376046	9·468966
850	722500	614125000	29·1547595	9·472682
851	724201	616295051	29·1719043	9·476396
852	725904	618470208	29·1890390	9·480106
853	727609	620650477	29·2061637	9·483814
854	729316	622835864	29·2232784	9·487518
855	731025	625026375	29·2403830	9·491220
856	732736	627222016	29·2574777	9·494919
857	734449	629422793	29·2745623	9·498615
858	736164	631628712	29·2916370	9·502308
859	737881	633839779	29·3087018	9·505998
860	739600	636056000	29·3257566	9·509685
861	741321	638277381	29·3428015	9·513370
862	743044	640503928	29·3598365	9·517051
863	744769	642735647	29·3768616	9·520730
864	746496	644972544	29·3938769	9·524406
865	748225	647214625	29·4108823	9·528079
866	749956	649461896	29·4278779	9·531750
867	751689	651714363	29·4448637	9·535417
868	753424	653972032	29·4618397	9·539082
869	755161	656234909	29·4788059	9·542744
870	756900	658503000	29·4957624	9·546403
871	758641	660776311	29·5127091	9·550059
872	760384	663054848	29·5296461	9·553712
873	762129	665338617	29·5465734	9·557363
874	763876	667627624	29·5634910	9·561011
875	765625	669921875	29·5803989	9·564656
876	767376	672221376	29·5972972	9·568298
877	769129	674526133	29·6141858	9·571938
878	770884	676836152	29·6310648	9·575574
879	772641	679151439	29·6479342	9·579208
880	774400	681472000	29·6647939	9·582840

No.	Square.	Cube.	Sq. Root.	Cube Root.
881	776161	683797841	29·6816442	9·586468
882	777924	686128968	29·6984848	9·590094
883	779689	688465387	29·7153159	9·593717
884	781456	690807104	29·7321375	9·597337
885	783225	693154125	29·7489496	9·600955
886	784996	695506456	29·7657521	9·604570
887	786769	697864103	29·7825452	9·608182
888	788544	700227072	29·7993289	9·611791
889	790321	702595369	29·8161030	9·615398
890	792100	704969000	29·8328678	9·619002
891	793881	707347971	29·8496231	9·622603
892	795664	709732288	26·8663690	9·626202
893	797449	712121957	29·8831056	9·629797
894	799236	714516984	29·8998328	9·633391
895	801025	716917375	29·9165506	9·636981
896	802816	719323136	29·9332591	9·640569
897	804609	721734273	29·9499583	9·644154
898	806404	724150792	29·9666481	9·647737
899	808201	726572699	29·9833287	9·651317
900	810000	729000000	30·0000000	9·654894
901	811801	731432701	30·0166620	9·658468
902	813604	733870808	30·0333148	9·662040
903	815409	736314327	30·0499584	9·665610
904	817216	738763264	30·0665928	9·669176
905	819025	741217625	30·0832179	9·672740
906	820836	743677416	30·0998339	9·676302
907	822649	746142643	30·1164407	9·679860
908	824464	748613312	30·1330383	9·683417
909	826281	751089429	30·1496269	9·686970
910	828100	753571000	30·1662063	9·690521
911	829921	756058031	30·1827765	9·694069
912	831744	758550528	30·1993377	9·697615
913	833569	761048497	30·2158899	9·701158
914	835396	763551944	30·2324329	9·704699
915	837225	766060875	30·2489669	9·708237
916	839056	768575296	30·2654919	9·711772
917	840889	771095213	30·2820079	9·715305
918	842724	773620632	30·2985148	9·718835
919	844561	776151559	30·3150128	9·722363
920	846400	778688000	30·3315018	9·725888

No.	Square.	Cube.	Sq. Root.	Cube Root.
921	848241	781229961	30·3479818	9·729411
922	850084	783777448	30·3644529	9·732931
923	851929	786330467	30·3809151	9·736448
924	853776	788889024	30·3973683	9·739963
925	855625	791453125	30·4138127	9·743476
926	857476	794022776	30·4302481	9·746986
927	859329	796597983	30·4466747	9·750493
928	861184	799178752	30·4630924	9·753998
929	863041	801765089	30·4795013	9·757500
930	864900	804357000	30·4959014	9·761000
931	866761	806954491	30·5122926	9·764497
932	868624	809557568	30·5286750	9·767992
933	870489	812166237	30·5450487	9·771484
934	872356	814780504	30·5614136	9·774974
935	874225	817400375	30·5777697	9·778462
936	876096	820025856	30·5941171	9·781947
937	877969	822656953	30·6104557	9·785429
938	879844	825293672	30·6267857	9·788909
939	881721	827936019	30·6431069	9·792386
940	883600	830584000	30·6594194	9·795861
941	885481	833237621	30·6757233	9·799334
942	887364	835896888	30·6920185	9·802804
943	889249	838561807	30·7083051	9·806271
944	891136	841232384	30·7245830	9·809736
945	893025	843908625	30·7408523	9·813199
946	894916	846590536	30·7571130	9·816659
947	896809	849278123	30·7733651	9·820117
948	898704	851971392	30·7896086	9·823572
949	900601	854670349	30·8058436	9·827025
950	902500	857375000	30·8220700	9·830476
951	904401	860085351	30·8382879	9·833924
952	906304	862801408	30·8544972	9·837369
953	908209	865523177	30·8706981	9·840813
954	910116	868250664	30·8868904	9·844254
955	912025	870983875	30·9030743	9·847692
956	913936	873722816	30·9192497	9·851128
957	915849	876467493	30·9354166	9·854562
958	917764	879217912	30·9515751	9·857993
959	919681	881974079	30·9677251	9·861422
960	921600	884736000	30·9838668	9·864848

No.	Square.	Cube.	Sq. Root.	Cube Root.
961	923521	887503681	31·0000000	9·868272
962	925444	890277128	31·0161248	9·871694
963	927369	893056347	31·0322413	9·875113
964	929296	895841344	31·0483494	9·878530
965	931225	898632125	31·0644491	9·881945
966	933156	901428696	31·0805405	9·885357
967	935089	904231063	31·0966236	9·888767
968	937024	907039232	31·1126984	0·892175
969	938961	909853209	31·1287648	9·895580
970	940900	912673000	31·1448230	9·898983
971	942841	915498611	31·1608729	9·902383
972	944784	918330048	31·1769145	9·905782
973	946729	921167317	31·1929479	9·909178
974	948676	924010424	31·2089731	9·912571
975	950625	926859375	31·2249900	9·915962
976	952576	929714176	31·2409987	9·919351
977	954529	932574833	31·2569992	9·922738
978	956484	935441352	31·2729915	9·926122
979	958441	938313739	31·2889757	9·929504
980	960400	941192000	31·3049517	9·932884
981	962361	944076141	31·3209195	9·936261
982	964324	946966168	31·3368792	9·939636
983	966289	949862087	31·3528308	9·943009
984	968256	952763904	31·3687743	9·946380
985	970225	955671625	31·3847097	9·949748
986	972196	958585256	31·4006369	9·953114
987	974169	961504803	31·4165561	9·956477
988	976144	964430272	31·4324673	9·959839
989	978121	967361669	31·4483704	9·963198
990	980100	970299000	31·4642654	9·966555
991	982081	973242271	31·4801525	9·969909
992	984064	976191488	31·4960315	6·973262
993	986049	979146657	31·5119025	6·976612
994	988036	982107784	31·5277655	9·979960
995	990025	985074875	31·5436206	9·983305
996	992016	988047936	31·5594677	9·986649
997	994009	991026973	31·5753068	9·989990
998	996004	994011992	31·5911380	9·993329
999	998001	997002999	31·6069613	9·996666
1000	1000000	1000000000	31·6227766	10·000000

Table of Squares, Cubes, and Fourth Power of Numbers.

Root.	Square.	Cube.	4th Power.	Root.	Square.	Cube.	4th Power.
1	1	1	1	7	49	343	2401
·1	1·21	1·331	1·4641	·1	50·41	357·911	2541·1681
·2	1·44	1·728	2·0736	·2	51·84	373·248	2687·3856
·3	1·69	2·197	2·8561	·3	53·29	389·017	2839·8241
·4	1·96	2·744	3·8416	·4	54·76	405·224	2998·6576
·5	2·25	3·375	5·0625	·5	56·25	421·875	3163·8625
·6	2·56	4·096	6·5536	·6	57·76	438·976	3346·2176
·7	2·89	4·913	8·3521	·7	59·29	456·533	3515·3041
·8	3·24	5·832	10·5876	·8	60·84	474·552	3701·4756
·9	3·61	6·859	13·0321	·9	62·41	493·039	3895·0081
2	4	8	16	8	64	512	4096
·1	4·41	9·261	19·4481	·1	65·61	531·441	4304·6721
·2	4·84	10·648	23·4256	·2	67·24	551·368	4521·2176
·3	5·29	12·167	27·8841	·3	68·89	571·787	4745·8221
·4	5·76	13·824	33·1776	·4	70·56	592·704	4979·5836
·5	6·25	15·625	39·0625	·5	72·25	614·125	5220·0625
·6	6·76	17·576	45·6976	·6	73·96	636·056	5470·0816
·7	7·29	19·683	53·1441	·7	75·69	658·503	5728·9761
·8	7·84	21·952	61·4656	·8	77·44	681·472	5996·9536
·9	8·41	24·389	70·7281	·9	79·21	704·969	6274·2141
3	9	27	81	9	81	729	6561
·1	9·61	29·791	92·3521	·1	82·81	753·571	6857·4961
·2	10·24	32·768	104·8576	·2	84·64	778·688	7173·9296
·3	10·89	35·937	118·5921	·3	86·49	804·357	7479·5201
·4	11·56	39·304	133·6336	·4	88·36	830·584	7807·4896
·5	12·25	42·875	150·0625	·5	90·25	857·375	8075·0525
·6	12·96	46·656	167·9616	·6	92·16	884·736	8493·6656
·7	13·69	50·653	187·4161	·7	94·09	912·673	8751·9281
·8	14·44	54·872	208·5136	·8	96·04	941·192	9231·6816
·9	15·21	59·319	231·3441	·9	98·01	970·299	9308·9601
4	16	64	256	10	100	1000	10000
·1	16·81	68·921	282·5761	·1	102·01	1030·301	10406·0401
·2	17·64	74·088	311·1696	·2	104·04	1061·208	10624·3216
·3	18·49	79·507	341·8801	·3	106·09	1092·727	11255·0881
·4	19·36	85·184	374·8096	·4	108·16	1124·864	11698·5856
·5	20·25	91·125	410·0625	·5	110·25	1157·625	12155·0625
·6	21·16	97·336	447·7456	·6	112·36	1191·016	12624·7696
·7	22·09	103·823	487·9681	·7	114·49	1225·043	13107·9601
·8	23·04	110·592	530·8416	·8	116·64	1259·712	13604·8896
·9	24·01	117·649	576·4801	·9	118·81	1295·029	14115·8161
5	25	125	625	11	121	1331	·14641
·1	26·01	132·651	676·5201	·1	123·21	1367·631	15180·7041
·2	27·04	140·608	731·1616	·2	125·44	1404·928	15735·1936
·3	28·09	148·877	789·0481	·3	127·69	1442·897	16314·7361
·4	29·16	157·464	850·3056	·4	129·96	1481·544	16899·6016
·5	30·25	166·375	915·0625	·5	132·25	1520·875	17490·0625
·6	31·36	175·616	983·4496	·6	134·56	1560·896	18106·3936
·7	32·49	185·193	1055·6001	·7	136·89	1601·613	18749·9721
·8	33·64	195·112	1131·6496	·8	139·24	1643·032	19387·7776
·9	34·81	205·379	1211·7361	·9	141·61	1685·159	20153·3921
6	36	216	1296	12	144	1728	20736
·1	37·21	226·981	1384·5841	·1	146·41	1771·561	21345·8881
·2	38·44	238·328	1477·6336	·2	148·84	1815·848	22253·4556
·3	39·69	250·047	1575·2961	·3	151·29	1860·867	22898·6641
·4	40·96	262·144	1677·7216	·4	153·76	1906·624	23642·1376
·5	42·25	274·625	1785·0625	·5	156·25	1953·125	24414·0625
·6	43·56	287·496	1897·4736	·6	158·76	2000·376	25204·7376
·7	44·89	300·763	2015·1121	·7	161·29	2048·383	26011·6641
·8	46·24	314·432	2138·1376	·8	163·84	2097·152	26843·5456
·9	47·61	328·509	2266·7121	·9	166·41	2146·689	27692·3881

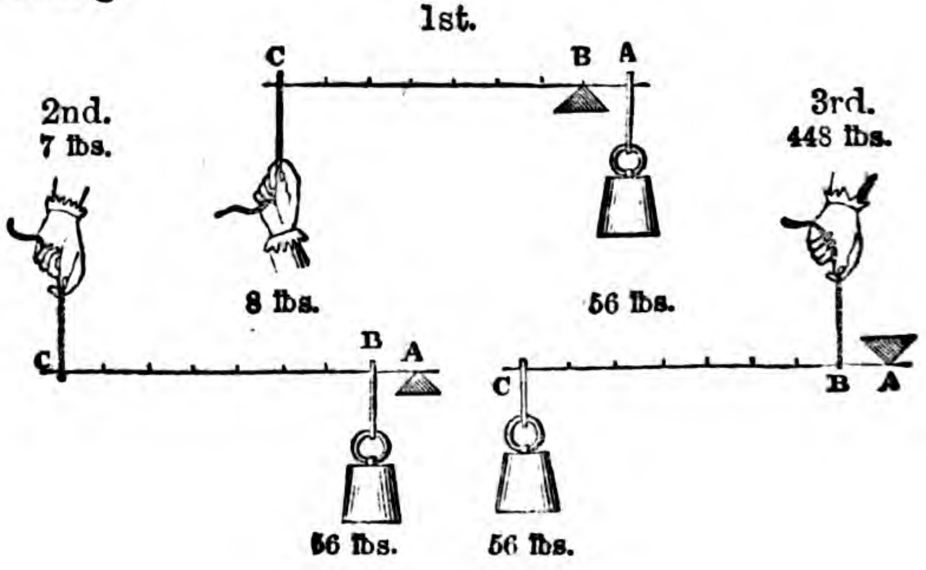
PRINCIPLES & PRACTICAL APPLICATIONS OF MECHANIC POWERS.

Mechanic Powers, or the Elements of Machinery, are certain simple mechanical arrangements whereby weights may be raised or resistances overcome with the exertion of less power or strength than is necessary without them.

They are usually accounted six in number, viz. the *lever*, the *wheel* and *axle*, the *pulley*, the *inclined plane*, the *wedge*, and the *screw;* but properly two of these comprise the whole, namely, the *lever* and *inclined plane*,—the wheel and axle being only a lever of the first kind, and the pulley a lever of the second, —the wedge and the screw being also similarly allied to that of the inclined plane; however, although such seems to be the case in these respects, yet they each require, on account of their various modifications, a peculiar rule of estimation adapted expressly to the different circumstances in which they are individually required to act.

1. THE LEVER.

Levers, according to mode of application, as the following,



are distinguished as being of the first, second, or third kind; and although levers of equal lengths produce different effects, the general principles of estimation in all are the same; namely, the power is to the weight or resistance, as the distance of the one end of the fulcrum is to the distance of the other end to the same point.

In the *first kind*, the power is to the resistance, as the distance A B is to the distance B C.

In the *second*, the power is to the resistance, as the distance A B is to that of A C; and,

In the *third*, the resistance is to the power, as the distance A B is to that of A C.

Rule, first kind.—Divide the longer by the shorter end of the lever from the fulcrum, and the quotient is the effective force that the power supplied is equal to.

Ex. 1. Let the handle of a pump equal 65 inches in length, and 10 inches from the shortest end to centre of motion; what is the amount of effective leverage thereby obtained?

$$65-10=55, \text{ and } \frac{55}{10}=5\tfrac{1}{2} \text{ to } 1.$$

Ex. 2. Required the situation of the fulcrum on which to rest a lever of 15 feet, so that $2\frac{1}{2}$ cwt. placed at one end may equipoise 30 cwt. at the other, the weight of the lever not being taken into account.

$\frac{15 \times 2{\cdot}5}{2{\cdot}5+30}=1{\cdot}154$ feet from the end on which the 30 cwt. is to be placed.

The common steelyard, or Roman balance, as represented in fig. 1, Plate D, is a lever of the first kind, and so divided that one weight w, moved to or from the axis of motion, will equipoise and there indicate the weight of any article required to be known.

It is by the second kind of lever that the greatest effect is obtained from any given amount of power; hence the propriety of the application of this principle to the working of force-pumps, and shearing of iron, as by the lever of a punching-press, &c.

Rule, second kind.—Divide the whole length of lever, or distance from power to fulcrum, by the distance from fulcrum to weight, and the quotient is the proportion of effect that the power is to the weight or resistance to be overcome.

Ex. Required the amount of effect or force produced by a power of 50lbs. on the ram of a Bramah's pump, the length of the lever being 3 feet, and distance from ram to fulcrum $4\frac{1}{2}$ inches.

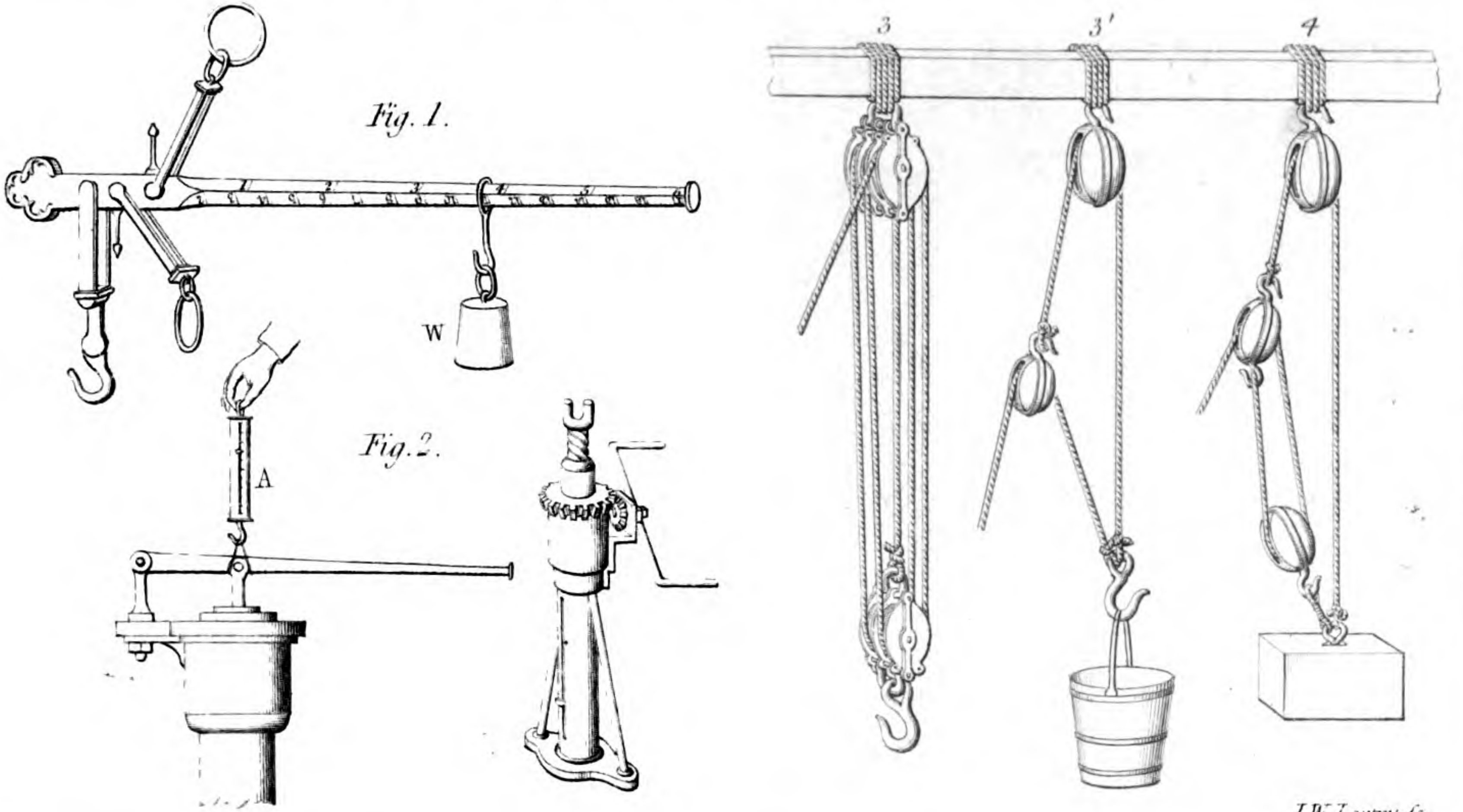
3 feet=36 inches, and $\frac{36}{4 \cdot 5}=8$, or the power and resistance are to each other as 8 to 1; hence $50 \times 8=400$ lbs. force upon the ram.

The lever on the safety-valve of a steam boiler is of the *third kind*, the action of the steam being the power, and the weight or spring-balance attached the resistance; but in such application the action of the lever's weight must also be taken into account, and may be simply ascertained by such means as represented in fig 2, plate D, where A is a *Salter's balance* attached to the lever by a light line, immediately at the point of pressure on the valve, and which, raised by hand or otherwise, will indicate the lever's action at that point.

This is perhaps the most frequent application of the third kind of lever to mechanical advantage, and that in which great nicety is required in estimation of effect: hence observe, as in other levers, there are three distinct points that require to be particularly attended to; namely, the *weight*, *fulcrum*, and *re-*

Plate D.

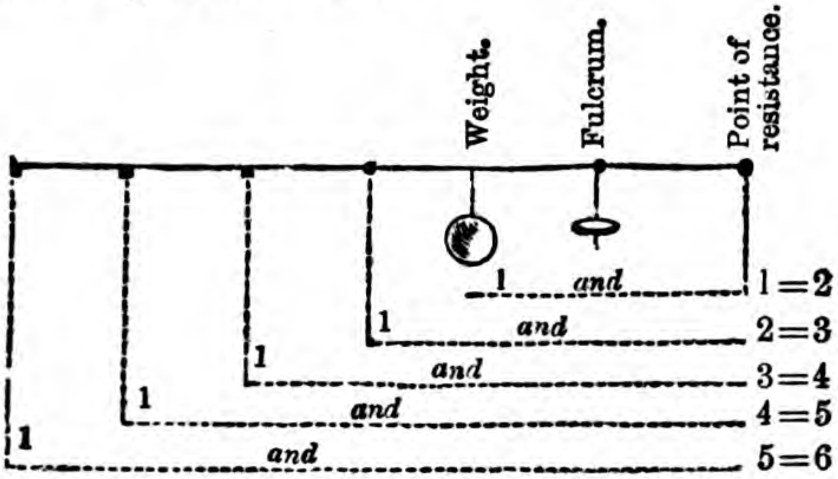
APPLICATIONS OF MECHANIC POWERS.



J. W. Lowry fc.

London: Lockwood & Co. Stationers' Hall Court.

sistance, as shown in the annexed diagram to illustrate this particular case.



Thus, suppose the weight to be placed on any one of the divisions, it is still the same weight, or 1; but because of the principle of the lever, the resistance is increased equal to the number of times the weight is distant from the fulcrum; consequently the action of the lever tends to press down the valve equal the sum of the weight and resistance, or the number of times the weight is distant from the resistance.

2. THE WHEEL AND PINION, OR CRANE.

The mechanical advantage of the wheel and axle, or crane, is as the velocity of the weight to the velocity of the power; and being only a modification of the first kind of lever, it of course partakes of the same principles.

1. *To determine the amount of effective power produced from a given power by means of a crane with known peculiarities.*

Rule.—Multiply together the diameter of the circle described by the winch, or handle, and the number of revolutions of the pinion to 1 of the wheel; divide the product by the barrel's diameter in equal terms of dimensions, and the quotient is the effective power to 1 of exertive force.

Ex. Let there be a crane, the winch of which describes a circle of 30 inches in diameter; the pinion makes 8 revolutions for 1 of the wheel, and the barrel is 11 inches in diameter; required the effective power in principle, also the weight that 36lbs. would raise, friction not being taken into account.

$\frac{30 \times 8}{11} = 21 \cdot 8$ to 1 of exertive force; and $21 \cdot 8 \times 36 = 784 \cdot 8$ lbs.

2. *Given any two parts of a crane, to find the third, that shall produce any required proportion of mechanical effect.*

Rule.—Multiply the two given parts together, and divide the product by the required proportion of effect; the quotient is the dimensions of the other parts in equal terms of unity.

Ex. Suppose that a crane is required, the ratio of power to effect being as 40 to 1, and that a wheel and pinion 11 to 1 is unavoidably compelled to be employed, also the throw of each handle to be 16 inches; what must be the barrel's diameter on which the rope or chain must coil?

$16 \times 2 = 32$ inches diameter of circle described by handle.

And $\frac{32 \times 11}{40} = 8 \cdot 8$ inches, the barrel's diameter.

3. THE PULLEY.

The principle of the pulley, or more practically the block and tackle, is the distribution of weight on various points of support; the mechanical advantage derived depending entirely upon the flexibility and tension of the rope, and the number of pulleys or sheives in the lower or rising block: hence, by blocks and tackle of the usual kind, as shown in fig. 3, Pl. D, the power is to the weight as the number of cords attached to the lower block; whence the following rules.

1. Divide the weight to be raised by the number of cords leading *to*, *from*, or *attached* to the lower block; and the quotient is the power required to produce an equilibrium, provided friction did not exist.

2. Divide the weight to be raised by the power to be applied; the quotient is the number of sheives in, or cords attached to the rising block.

Ex. Required the power necessary to raise a weight of 3000 ℔s. by a four and five-sheived block and tackle, the four being the moveable or rising block.

Necessarily there are nine cords leading to and from the rising block.

Consequently $\frac{3000}{9}=333$ ℔s., the power required.

Ex. 2. I require to raise a weight of 1 ton 18 cwt., or 4256 ℔s.; the amount of my power to effect this object being 500 ℔s., what kind of block and tackle must I of necessity employ?

$\frac{4256}{500}=8{\cdot}51$ cords; of necessity there must be 4 sheives or 9 cords in the rising block.

As the effective power of the crane may, by additional wheels and pinions, be increased to any required extent, so may the pulley and tackle be similarly augmented by purchase upon purchase; two of the most useful of such applications being represented in figs. 3 and 4, Plate D, the first of which is known by the term *runner and tackle*, and the second by that of *Spanish burton*.

4. THE INCLINED PLANE.

The *inclined plane* is properly the second elementary power, and may be defined the lifting of a load by regular instalments. In principle it consists of any right line not coinciding with, but laying in a sloping direction to, that of the horizon; the standard of comparison of which commonly consists in referring the rise to so many parts in a certain length or distance, as 1 in 100, 1 in 200, &c., the first number representing the perpendicular height, and the latter the horizontal length in attaining such height, both numbers being of the same denomination, unless otherwise expressed; but it may be necessary to remark, that the inclination of a plane, the sine of inclination, the height per mile, or the height for any length, the ratio, &c., are all synonymous terms.

The advantage gained by the inclined plane, when the power acts in a parallel direction to the plane, is as the length to the height. Hence the rule. Divide the weight by the ratio of inclination, and the quotient equal the power that will just support that weight upon the plane. Or, multiply the weight by the height of the plane, and divide by the length,—the quotient is the power.

Ex. Required the power or equivalent weight capable of supporting a load of 350 lbs. upon a plane of 1 in 12, or 3 feet in height and 36 feet in length.

$$\frac{350}{12} = 29 \cdot 16 \text{ lbs., or } \frac{350 \times 3}{36} = 29 \cdot 16 \text{ lbs. power, as before.}$$

Note.—The weight multiplied by the length of the base, and the product divided by the length of the incline, the quotient equal the pressure or downward weight upon the incline.

Table showing the Resistance opposed to the Motion of Carriages on different Inclinations of Ascending or Descending Planes, whatever part of the insistent weight they are drawn by.

Tens.		Hundreds.								
		100	200	300	400	500	600	700	800	900
		·01	·005	·00333	·0025	·002	·00167	·00143	·00125	·00111
10	·1	·00909	·00476	·00322	·00244	·00196	·00164	·00141	·00123	·0011
20	·05	·00833	·00454	·00312	·00238	·00192	·00161	·00139	·00122	·00109
30	·0333	·00769	·00435	·00303	·00232	·00189	·00159	·00137	·0012	·00107
40	·025	·00714	·00417	·00294	·00227	·00185	·00156	·00135	·00119	·00106
50	·02	·00667	·004	·00286	·00222	·00182	·00154	·00133	·00118	·00105
60	·0166	·00625	·00385	·00278	·00217	·00178	·00151	·00131	·00116	·00104
70	·0143	·00588	·0037	·0027	·00213	·00175	·00149	·0013	·00115	·00103
80	·0125	·00555	·00357	·00263	·00208	·00172	·00147	·00128	·00114	·00102
90	·0111	·00526	·00345	·00256	·00204	·00169	·00145	·00126	·00112	·00101

Note.—Although this Table has been calculated particularly for carriages on railway inclines, it may with equal propriety be applied to any other incline, the amount of traction on a level being known.

Application of the preceding Table.

1. What weight will a tractive power of 150 lbs. draw up an incline of 1 in 340, the resistance on the level being estimated at $\frac{1}{240}$th part of the insistent weight?

In a line with 40 in the left-hand column and under 200 is......	·00417
Also in the same line and under 300 is	·00294
Added together=	·00711

Then $\frac{150}{\cdot 00711}$=21097 lbs. weight drawn up the plane.

2. What weight would a force of 150 lbs. draw down the same plane, the friction on the level being the same as before?

Friction on the level=·00417
Gravity of the plane=·00294 subtract

=·00123

And $\frac{150}{\cdot 00123}$=121915 lbs. weight drawn down the plane.

Example of incline when velocity is taken into account.

A power of 230 lbs., at a velocity of 75 feet per minute, is to be employed for moving weights up an inclined plane 12 feet in height and 163 feet in length, the least velocity of the weight to be 8 feet per minute; required the greatest weight that the power is equal to.

$$\frac{230 \times 75 \times 163}{12 \times 8} = \frac{2811750}{96} = 29288 \text{ lbs., or } 13\cdot 25 \text{ tons.}$$

TABLE OF INCLINED PLANES,

Showing the ascent or descent per yard, and the corresponding ascent or descent per chain, per mile; and also the ratio.

Per yard.		Per chain.	Per mile.	Ratio.	Per yard.		Per chain.	Per mile.	Ratio.
In parts of an in.	In decls. of an inch.	Inches.	Feet.	One in	In parts of an in.	In decls. of an inch.	Inches.	Feet.	One in
$\frac{1}{64}$	·0156	·344	2·29	2304	$\frac{7}{16}$	·4375	9·625	64·17	82
$\frac{1}{48}$	·0208	·458	3·06	1728	$\frac{1}{2}$	·5	11	73·33	72
$\frac{1}{32}$	·0312	·687	4·58	1152	$\frac{9}{16}$	·5625	12·375	82·5	64
$\frac{1}{24}$	·0417	·917	6·11	864	$\frac{7}{12}$	·5833	12·833	85·56	62
$\frac{1}{16}$	·0625	1·375	9·17	576	$\frac{3}{5}$	·6	13·2	88	60
$\frac{1}{12}$	·0833	1·833	12·22	432	$\frac{5}{8}$	·625	13·75	91·67	58
$\frac{1}{10}$	·1	2·2	14·67	360	$\frac{2}{3}$	·6667	14·667	97·78	54
$\frac{1}{8}$	·125	2·75	18·33	288	$\frac{11}{16}$	·6875	15·125	100·83	52
$\frac{1}{6}$	·1667	3·667	24·44	216	$\frac{7}{10}$	·7	15·4	102·67	51
$\frac{3}{16}$	·1875	4·125	27·50	192	$\frac{3}{4}$	·75	16·5	110	48
$\frac{1}{5}$	·2	4·4	29·33	180	$\frac{4}{5}$	·8	17·6	117·33	45
$\frac{1}{4}$	·25	5·5	36·67	144	$\frac{13}{16}$	·8125	17·875	119·17	44
$\frac{3}{10}$	·3	6·6	44	120	$\frac{5}{6}$	·8333	18·333	122·22	43
$\frac{5}{16}$	·3125	6·875	45·83	115	$\frac{7}{8}$	·875	19·25	128·33	41
$\frac{1}{3}$	·3333	7·333	48·89	108	$\frac{9}{10}$	·9	19·8	132	40
$\frac{3}{8}$	·375	8·25	55	96	$\frac{11}{12}$	·9167	20·167	134·44	39
$\frac{2}{5}$	·4	8·8	58·67	20	$\frac{15}{16}$	·9375	20·625	137·5	38
$\frac{5}{12}$	·4167	9·167	61·11	86	1	1	22	146·67	36

THE WEDGE.

The wedge is a double inclined plane, consequently its principles are the same: Hence when two bodies are forced asunder by means of the wedge in a direction parallel to its head,—Multiply the resisting power by half the thickness of the head or back of the wedge, and divide the product by the length of one of its inclined sides; the quotient is the force equal to the resistance.

Ex. The breadth of the back or head of a wedge being 3 inches, and its inclined sides each 10 inches, required the power necessary to act upon the wedge so as to separate two substances whose resisting force is equal to 150 lbs.

$$\frac{150 \times 1{\cdot}5}{10} = 22{\cdot}5 \text{ lbs.}$$

Note.—When only one of the bodies is moveable, the whole breadth of the wedge is taken for the multiplier.

THE SCREW.

The screw, in principle, is that of an inclined plane wound around a cylinder which generates a spiral of uniform inclination, each revolution producing a rise or traverse motion equal to the pitch of the screw, or distance between two consecutive threads,—the pitch being the height or angle of inclination, and the circumference the length of the plane when a lever is not applied; but the lever being a necessary qualification of the screw, the circle which it describes is taken, instead of the screw's circumference, as the length of the plane: hence the mechanical advantage is, as the circumference of the circle described by the lever where the power acts, is to the pitch of the screw, so is the force to the resistance.

Ex. 1. Required the effective power obtained by a screw of $\frac{7}{8}$ inch pitch, and moved by a force equal to 50 ℔s. at the extremity of a lever 30 inches in length.

$$\frac{30 \times 2 \times 3{\cdot}1416 \times 50}{{\cdot}875} = 10760 \text{ ℔s.}$$

Ex. 2. Required the power necessary to overcome a resistance equal to 7000 ℔s. by a screw of $1\frac{1}{4}$ inch pitch, and moved by a lever 25 inches in length.

$$\frac{7000 \times 1{\cdot}25}{25 \times 2 \times 3{\cdot}1416} = 55{\cdot}73 \text{ ℔s. power.}$$

In the case of a screw acting on the periphery of a toothed wheel, the power is to the resistance as the product of the circle's circumference described by the winch or lever, and radius of the wheel, to the product of the screw's pitch, and radius of the axle, or point whence the power is transmitted; but observe, that if the screw consist of more than one helix or thread, the apparent pitch must be increased so many times as there are threads in the screw. *Hence, to find what weight a given power will equipoise:*

Rule.—Multiply together the radius of the wheel, the length of the lever at which the power acts, the magnitude of the power, and the constant number 6·2832; divide the product by the radius of the axle into the pitch of the screw, and the quotient is the weight that the power is equal to.

Ex. What weight will be sustained in equilibrio by a power of 100 ℔s. acting at the end of a lever 24 inches in length, the radius of the axle, or point whence the power is transmitted, being 8 inches, the radius of the wheel 14 inches, the screw consisting of a double thread, and the apparent pitch equal $\frac{5}{8}$ of an inch?

$$\frac{14 \times 24 \times 100 \times 6{\cdot}2832}{{\cdot}625 \times 2 \times 8} = 21111{\cdot}55 \text{ lbs., or } 9{\cdot}4 \text{ tons, the power sustained.}$$

Note.—It is estimated that about one-third more power must be added to overcome the friction of the screw when loaded, than is necessary to constitute a balance between power and weight.

OF CONTINUOUS CIRCULAR MOTION.

In mechanics, circular motion is transmitted by means of *wheels*, *drums*, or *pulleys*; and accordingly as the driving and driven are of equal or unequal diameters, so are equal or unequal velocities produced: hence the principle on which the following rules are founded.

1. WHEN TIME IS NOT TAKEN INTO ACCOUNT.

Rule.—Divide the greater diameter, or number of teeth, by the lesser diameter, or number of teeth, and the quotient is the number of revolutions the lesser will make for 1 of the greater.

Ex. How many revolutions will a pinion of 20 teeth make for 1 of a wheel with 125?

$125 \div 20 = 6{\cdot}25$, or $6\frac{1}{4}$ revolutions.

Note.—Intermediate wheels of whatever diameters, so as to connect communication at any required distance apart, cause no variation of velocity more than otherwise would result were the first and last in immediate contact.

To find the number of revolutions of the last, to 1 *of the first, in a train of wheels and pinions.*

Rule.—Divide the product of all the teeth in the driving by the product of all the teeth in the driven, and the quotient equal the ratio of velocity required.

Ex. 1. Required the ratio of velocity of the last, to 1 of the first, in the following train of wheels and pinions; viz., *pinions driving,*—the first of which contains 10 teeth, the second 15, and third 18;—*wheels driven,* —first 15 teeth, second 25, and third 32.

$$\frac{10 \times 15 \times 18}{15 \times 25 \times 32} = \cdot 225$$ of a revolution the wheel will make to 1 of the pinion.

Ex. 2. A wheel of 42 teeth giving motion to one of 12, on which shaft is a pulley of 21 inches diameter, driving one of 6; required the number of revolutions of the last pulley to one of the first wheel.

$$\frac{42 \times 21}{12 \times 6} = 12 \cdot 25, \text{ or } 12\tfrac{1}{4} \text{ revolutions.}$$

Note.—Where increase or decrease of velocity is required to be communicated by wheel-work, it has been demonstrated that the number of teeth on each pinion should not be less than 1 to 6 of its wheel, unless there be some other important reason for a higher ratio.

2. WHEN TIME MUST BE REGARDED.

Rule.—Multiply the diameter, or number of teeth in the driver, by its velocity in any given time, and divide the product by the required velocity of the driven; the quotient equal the number of teeth, or diameter of the driven, to produce the velocity required.

Ex. 1. If a wheel containing 84 teeth makes 20 revolutions per minute, how many must another contain to work in contact, and make 60 revolutions in the same time?

$$\frac{84 \times 20}{60} = 28 \text{ teeth.}$$

Ex. 2. From a shaft making 45 revolutions per minute, and with a pinion 9 inches diameter at the pitch line, I wish to transmit motion at 15 revolutions per minute; what at the pitch line must be the diameter of the wheel?

$$\frac{45 \times 9}{15} = 27 \text{ inches.}$$

Ex. 3. Required the diameter of a pulley to make 16 revolutions in the same time as one of 24 inches making 36.

$$\frac{24 \times 36}{16} = 54 \text{ inches.}$$

The distance between the centres and velocities of two wheels being given, to find their proper diameters.

Rule.—Divide the greatest velocity by the least; the quotient is the ratio of diameter the wheels must bear to each other. Hence, divide the distance between the centres by the ratio plus 1; the quotient equal the radius of the smaller wheel; and subtract the radius thus obtained from the distance between the centres; the remainder equal the radius of the other.

Ex. The distance of two shafts from centre to centre is 50 inches, and the velocity of the one 25 revolutions per minute, the other is to make 80 in the same time; the proper diameters of the wheels at the pitch lines are required.

$80 \div 25 = 3{\cdot}2$, ratio of velocity, and $\frac{50}{3{\cdot}2+1} = 11{\cdot}9$, the radius of the smaller wheel; then $50 - 11{\cdot}9 = 38{\cdot}1$, radius of larger; their diameters are $11{\cdot}9 \times 2 = 23{\cdot}8$, and $38{\cdot}1 \times 2 = 76{\cdot}2$ inches.

To obtain or diminish an accumulated velocity by means of wheels and pinions, or wheels, pinions, and pulleys, it is necessary that a proportional ratio of velocity should exist, and which is simply thus attained :—Multiply the given and required velocities together, and the square root of the product is the mean or proportionate velocity.

Ex. Let the given velocity of a wheel containing 54 teeth equal 16 revolutions per minute, and the given diameter of an intermediate pulley equal 25 inches, to obtain a velocity of 81 revolutions in a machine; required the number of teeth in the intermediate wheel, and diameter of the last pulley.

$\sqrt{81 \times 16}=36$ mean velocity.

$\frac{54 \times 16}{36}=24$ teeth, and $\frac{25 \times 36}{81}=11{\cdot}1$ inches, diameter of pulley.

To determine the proportion of wheels for screw-cutting by a Lathe.

In a lathe properly adapted, screws to any degree of pitch, or number of threads in a given length, may be cut by means of a leading screw of any given pitch, accompanied with change wheels and pinions; course pitches being effected generally by means of one wheel and one pinion with a *carrier*, or *intermediate wheel,* which cause no variation or change of motion to take place: hence the following

Rule.—Divide the number of threads in a given length of the screw which is to be cut, by the number of threads in the same length of the leading screw attached to the lathe; and the quotient is the ratio that the wheel on the end of the screw must bear to that on the end of the lathe spindle.

Ex. Let it be required to cut a screw with 5 threads in an inch, the leading screw being of $\frac{1}{2}$ inch pitch, or containing two threads in an inch; what must be the ratio of wheels applied?

$5 \div 2=2{\cdot}5$, the ratio they must bear to each other.

Then suppose a pinion of 40 teeth be fixed upon for the spindle,—

$40 \times 2{\cdot}5 = 100$ teeth for the wheel on the end of the screw.

But screws of a greater degree of fineness than about 8 threads in an inch are more conveniently cut by an additional wheel and pinion, because of the proper degree of velocity being more effectively attained; and these, on account of revolving upon a stud, are commonly designated the *stud-wheels*, or *stud-wheel* and *pinion*; but the mode of calculation and ratio of screw are the same as in the preceding rule;—hence, all that is further necessary is to fix upon any 3 wheels at pleasure, as those for the spindle and stud-wheels,—then multiply the number of teeth in the spindle-wheel by the ratio of the screw, and by the number of teeth in that wheel or pinion which is in contact with the wheel on the end of the screw; divide the product by the stud-wheel in contact with the spindle-wheel, and the quotient is the number of teeth required in the wheel on the end of the leading screw.

Ex. Suppose a screw is required to be cut containing 25 threads in an inch, the leading screw as before having 2 threads in an inch, and that a wheel of 60 teeth is fixed upon for the end of the spindle, 20 for the pinion in contact with the screw wheel, and 100 for that in contact with the wheel on the end of the spindle;—required the number of teeth in the wheel for the end of the leading screw.

$$25 \div 2 = 12{\cdot}5, \text{ and } \frac{60 \times 12{\cdot}5 \times 20}{100} = 150 \text{ teeth.}$$

Or suppose the spindle and screw-wheels to be those fixed upon, also any one of the stud-wheels, to find the number of teeth in the other.

$$\frac{60 \times 12{\cdot}5}{150 \times 100} = 20 \text{ teeth, or } \frac{60 \times 12{\cdot}5 \times 20}{150} = 100 \text{ teeth.}$$

Table of Change Wheels for Screw Cutting, the leading screw being of ½-inch pitch, or containing 2 threads in an inch.

Number of threads in inch of screw.	Numb. of teeth in		Number of threads in inch of screw.	Number of teeth in				Number of threads in inch of screw.	Number of teeth in			
	Lathe spindle-wheel.	Leading screw-wheel.		Lathe spindle-wheel.	Wheel in contact with spindle-wheel.	Pinion in contact with screw-wheel.	Leading screw-wheel.		Lathe spindle-wheel.	Wheel in contact with spindle-wheel.	Pinion in contact with screw-wheel.	Leading screw-wheel.
1	80	40	8¼	40	55	20	60	19	50	95	20	100
1¼	80	50	8½	90	85	20	90	19½	80	120	20	130
1½	80	60	8¾	60	70	20	75	20	60	100	20	120
1¾	80	70	9½	90	90	20	95	20¼	40	90	20	90
2	80	90	9¾	40	60	20	65	21	80	120	20	140
2¼	80	90	10	60	75	20	80	22	60	110	20	120
2½	80	100	10½	50	70	20	75	22½	80	120	20	150
2¾	80	110	11	60	55	20	120	22¾	80	130	20	140
3	80	120	12	90	90	20	120	23¾	40	95	20	100
3¼	80	130	12¾	60	85	20	90	24	65	120	20	130
3½	80	140	13	90	90	20	130	25	60	100	20	150
3¾	80	150	13½	60	90	20	90	25½	30	85	20	90
4	40	80	13¾	80	100	20	110	26	70	130	20	140
4¼	40	85	14	90	90	20	140	27	40	90	20	120
4½	40	90	14¼	60	90	20	95	27½	40	100	20	110
4¾	40	95	15	90	90	20	150	28	75	140	20	150
5	40	100	16	60	80	20	120	28½	30	90	20	95
5½	40	110	16¼	80	100	20	130	30	70	140	20	150
6	40	120	16½	80	110	20	120	32	30	80	20	120
6½	40	130	17	45	85	20	90	33	40	110	20	120
7	40	140	17½	80	100	20	140	34	30	85	20	120
7½	40	150	18	40	60	20	120	35	60	140	20	150
8	30	120	18¾	80	100	20	150	36	30	90	20	120

Table by which to determine the Number of Teeth, or Pitch of Small Wheels, by what is commonly called the Manchester principle.

Diametral pitch.	Circular pitch.	Diametral pitch.	Circular pitch.
3	1·047	9	·349
4	·785	10	·314
5	·628	12	·262
6	·524	14	·224
7	·449	16	·196
8	·393	20	·157

Ex. 1. Required the number of teeth that a wheel of 16 inches diameter will contain of a 10 pitch.

16 × 10 = 160 teeth, and the circular pitch = ·314 inch.

Ex. 2. What must be the diameter of a wheel for a 9 pitch of 126 teeth?

$\frac{126}{9}$ = 14 inches diameter, circular pitch ·349 inch.

Note.—The pitch is reckoned on the diameter of the wheel instead of the circumference, and designated wheels of 8 pitch, 12 pitch, &c.

Strength of the Teeth of Cast-Iron Wheels at a given velocity.

Pitch of teeth in inches.	Thickness of teeth in inches.	Breadth of teeth in inches.	Strength of teeth in horse-power, at			
			3 ft. per second.	4 ft. per second.	6 ft. per second.	8 ft. per second.
3·99	1·9	7·6	20·57	27·43	41·14	54·85
3·78	1·8	7·2	17·49	23·32	34·98	46·64
3·57	1·7	6·8	14·73	19·65	29·46	39·28
3·36	1·6	6·4	12·28	16·38	24·56	32·74
3·15	1·5	6	10·12	13·50	20·24	26·98
2·94	1·4	5·6	8·22	10·97	16·44	21·92
2·73	1·3	5·2	6·58	8·78	13·16	17·54
2·52	1·2	4·8	5·18	6·91	10·36	13·81
2·31	1·1	4·4	3·99	5·32	7·98	10·64
2·1	1·0	4	3·00	4·00	6·00	8·00
1·89	·9	3·6	2·18	2·91	4·36	5·81
1·68	·8	3·2	1·53	2·04	3·06	3·08
1·47	·7	2·8	1·027	1·37	2·04	2·72
1·26	·6	2·4	·64	·86	1·38	1·84
1·05	·5	2	·375	·50	·75	1·00

Table of the Diameters of Wheels at their pitch circle, to contain a required number of teeth at a given pitch.

Number of teeth.	Pitch of the teeth in inches.													
	1 inch	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2 inch	2⅛	2¼	2½	2¾	3 inch
	Diameter at the pitch circle in feet and inches.													
10	0 3¼	0 3⅝	0 4	0 4½	0 4⅞	0 5¼	0 5⅝	0 6	0 6½	0 6⅞	0 7¼	0 8	0 8⅞	0 9⅝
11	0 3½	0 4	0 4⅜	0 5	0 5⅜	0 5¾	0 6¼	0 6⅝	0 7	0 7½	0 7⅞	0 8¾	0 9¾	0 10⅝
12	0 3⅞	0 4⅜	0 4⅞	0 5⅜	0 5⅞	0 6⅜	0 6¾	0 7⅛	0 7⅝	0 8⅛	0 8⅝	0 9⅝	0 10⅝	0 11½
13	0 4⅛	0 4¾	0 5¼	0 5¾	0 6¼	0 6⅞	0 7⅜	0 7⅞	0 8⅜	0 8⅞	0 9⅜	0 10⅜	0 11½	1 0½
14	0 4½	0 5	0 5⅝	0 6¼	0 6¾	0 7⅜	0 7⅞	0 8½	0 9	0 9½	0 10	0 11¼	1 0⅜	1 1½
15	0 4⅞	0 5⅜	0 6	0 6⅝	0 7¼	0 7⅞	0 8½	0 9	0 9⅝	0 10¼	0 10¾	1 0	1 1¼	1 2⅜
16	0 5⅛	0 5¾	0 6⅜	0 7	0 7⅝	0 8⅜	0 9	0 9⅝	0 10¼	0 10⅞	0 11½	1 0¾	1 2	1 3⅜
17	0 5½	0 6⅛	0 6¾	0 7½	0 8¼	0 8⅞	0 9⅝	0 10¼	0 10⅞	0 11½	1 0¼	1 1½	1 2⅞	1 4¼
18	0 5¾	0 6½	0 7⅛	0 8	0 8⅝	0 9⅜	0 10	0 10¾	0 11½	1 0¼	1 0⅞	1 2⅜	1 3¾	1 5¼
19	0 6	0 6⅞	0 7½	0 8⅜	0 9⅛	0 9⅞	0 10⅝	0 11⅜	1 0⅛	1 0⅞	1 1⅝	1 3⅛	1 4⅝	1 6¼
20	0 6⅜	0 7⅛	0 8	0 8⅞	0 9⅝	0 10⅜	0 11¼	1 0	1 0¾	1 1½	1 2⅜	1 4	1 5½	1 7⅛
21	0 6¾	0 7½	0 8⅜	0 9¼	0 10	0 11	0 11¾	1 0½	1 1½	1 2¼	1 3	1 4¾	1 6⅜	1 8⅛
22	0 7	0 7⅞	0 8¾	0 9⅝	0 10⅝	0 11½	1 0⅜	1 1⅛	1 2	1 2⅞	1 3¾	1 5½	1 7¼	1 9
23	0 7⅜	0 8¼	0 9⅛	0 10	0 11	1 0	1 0⅞	1 1¾	1 2⅝	1 3½	1 4½	1 6⅜	1 8	1 10
24	0 7⅝	0 8⅝	0 9½	0 10½	0 11½	1 0½	1 1½	1 2⅜	1 3⅜	1 4¼	1 5¼	1 7⅛	1 9	1 10⅞
25	0 8	0 9	0 10	0 11	1 0	1 1	1 2	1 2⅞	1 3⅞	1 4⅞	1 6	1 8	1 9⅞	1 11⅞
26	0 8¼	0 9¼	0 10⅜	0 11½	1 0½	1 1½	1 2½	1 3½	1 4½	1 5½	1 6⅝	1 8¾	1 10¾	2 0⅞
27	0 8⅝	0 9⅝	0 10¾	0 11⅞	1 1	1 2	1 3	1 4⅛	1 5¼	1 6¼	1 7⅜	1 9½	1 11⅝	2 1¾
28	0 9	0 10	0 11¼	1 0¼	1 1¼	1 2½	1 3⅝	1 4⅝	1 5¾	1 6⅞	1 8	1 10¼	2 0½	2 2¾
29	0 9¼	0 10⅜	0 11⅝	1 0¾	1 1⅞	1 3	1 4⅛	1 5⅜	1 6½	1 7⅝	1 8¾	1 11⅛	2 1⅜	2 3¾

Table of the Diameters of Wheels—continued.

Number of teeth.	Pitch of the teeth in inches.													
	1 inch	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2 inch	2⅛	2¼	2½	2¾	3 inch
	Diameter at the pitch circle in feet and inches.													
30	0 9½	0 10¾	1 0	1 1⅛	1 2⅜	1 3½	1 4½	1 6	1 7⅛	1 8¼	1 9½	2 0	2 2¼	2 4⅝
31	0 9⅞	0 11⅛	1 0⅜	1 1⅝	1 2⅞	1 4	1 5⅜	1 6½	1 7¾	1 9	1 10¼	2 0¾	2 3⅛	2 5⅝
32	0 10¼	0 11½	1 0¾	1 2	1 3⅜	1 4⅝	1 5⅞	1 7⅛	1 8⅜	1 9⅝	1 11	2 1½	2 4	2 6½
33	0 10½	0 11⅞	1 1⅛	1 2½	1 3¾	1 5⅛	1 6½	1 7¾	1 9	1 10⅜	1 11⅝	2 2¼	2 4⅞	2 7½
34	0 10⅞	1 0⅛	1 1⅝	1 3	1 4¼	1 5⅝	1 7	1 8⅜	1 9⅝	1 11	2 0⅜	2 3	2 5¾	2 8½
35	0 11⅛	1 0⅝	1 2	1 3⅜	1 4¾	1 6⅛	1 7½	1 9	1 10⅛	1 11¾	2 1	2 3⅞	2 6⅝	2 9½
36	0 11½	1 1	1 2⅜	1 3¾	1 5¼	1 6⅝	1 8	1 9½	1 10⅞	2 0⅜	2 2	2 4⅝	2 7½	2 10⅜
37	0 11¾	1 1¼	1 2¾	1 4¼	1 5⅝	1 7¼	1 8⅝	1 10	1 11½	2 1	2 2½	2 5½	2 8⅜	2 11⅜
38	1 0⅛	1 1⅝	1 3¼	1 4⅝	1 6¼	1 7⅝	1 9¼	1 10¾	2 0¼	2 1¾	2 3¼	2 6¼	2 9¼	3 0¼
39	1 0⅜	1 2	1 3½	1 5	1 6⅝	1 8¼	1 9¾	1 11⅜	2 0⅞	2 2⅜	2 4	2 7	2 10⅛	3 1¼
40	1 0¾	1 2⅜	1 4	1 5½	1 7⅜	1 8¾	1 10⅜	1 11⅞	2 1½	2 3	2 4⅝	2 7⅞	2 10¾	3 2¼
41	1 1	1 2¾	1 4⅜	1 6	1 7⅝	1 9¼	1 10⅞	2 0½	2 2⅛	2 3¾	2 5⅜	2 8⅝	2 11⅞	3 3⅛
42	1 1⅜	1 3	1 4¾	1 6⅜	1 8	1 9¾	1 11½	2 1	2 2¾	2 4½	2 6	2 9⅜	3 0¾	3 4⅛
43	1 1⅝	1 3½	1 5⅛	1 6⅞	1 8⅝	1 10¼	2 0	2 1⅝	2 3⅜	2 5	2 6¾	2 10¼	3 1⅝	3 5
44	1 2	1 3¾	1 5⅝	1 7¼	1 9	1 10¾	2 0½	2 2¼	2 4	2 5¾	2 7½	2 11	3 2½	3 6
45	1 2⅜	1 4⅛	1 6	1 7¾	1 9½	1 11⅜	2 1	2 2⅞	2 4⅝	2 6½	2 8¼	2 11¾	3 3⅜	3 7
46	1 2⅝	1 4½	1 6⅜	1 8⅛	1 10	1 11⅞	2 1⅝	2 3½	2 5¼	2 7⅛	2 9	3 0⅝	3 4¼	3 7⅞
47	1 2⅞	1 4⅞	1 6¾	1 8⅝	1 10½	2 0⅜	2 1⅞	2 4	2 6	2 7⅞	2 9⅝	3 1½	3 5⅛	3 8⅞
48	1 3¼	1 5¼	1 7⅛	1 9	1 11	2 0⅞	2 2¾	2 4⅝	2 6½	2 8½	2 10⅜	3 2¼	3 6	3 9⅞
49	1 3½	1 5⅝	1 7½	1 9½	1 11½	2 1⅜	2 3⅜	2 5¼	2 7¼	2 9⅛	2 11	3 3	3 6⅞	3 10⅞
50	1 3⅞	1 6	1 8	1 9⅞	2 0	2 1⅞	2 3⅞	2 5⅞	2 7⅞	2 9¾	2 11¾	3 3¾	3 7¾	3 11¾

51	1	4¼	1	6¼	1	8⅜	1	10⅜	2	0⅜	2	2⅜	2	4½	2	6½	2	8½	2	10½	3	0½	3	4½	3	8⅝	4	0¾
52	1	4½	1	6⅝	1	8¾	1	10¾	2	0⅞	2	2⅞	2	4⅞	2	7⅛	2	9⅛	2	11⅛	3	1¼	3	5⅜	3	9½	4	1⅝
53	1	4⅞	1	6⅞	1	9⅛	1	11¼	2	1¼	2	3⅜	2	5⅜	2	7⅝	2	9¾	2	11⅞	3	2	3	6¼	3	10½	4	2⅝
54	1	5⅛	1	7⅜	1	9½	1	11⅝	2	1¾	2	3⅞	2	6	2	8¼	2	10⅜	3	0½	3	2⅝	3	7	3	11	4	3½
55	1	5½	1	7¾	1	9⅞	2	0	2	2¼	2	4½	2	6⅝	2	8⅞	2	11	3	1¼	3	3½	3	7¾	4	0⅛	4	4½
56	1	5⅞	1	8⅛	1	10¼	2	0½	2	2¾	2	4⅞	2	7⅛	2	9⅜	2	11⅝	3	1⅞	3	4⅛	3	8½	4	1	4	5½
57	1	6⅛	1	8½	1	10⅝	2	0⅞	2	3¼	2	5¼	2	7¾	2	10	3	0¼	3	2½	3	4⅞	3	9⅜	4	1⅞	4	6⅜
58	1	6½	1	8¾	1	11	2	1⅜	2	3⅝	2	6	2	8¼	2	10⅝	3	0⅞	3	3¼	3	5½	3	10⅛	4	2¾	4	7⅜
59	1	6¾	1	9⅛	1	11½	2	1⅞	2	4⅛	2	6½	2	8⅞	2	11¼	3	1½	3	4	3	6¼	3	11⅛	4	3⅝	4	8⅜
60	1	7⅛	1	9⅜	1	11⅞	2	2¼	2	4⅝	2	7	2	9⅜	2	11¾	3	2¼	3	4⅝	3	7	3	11¾	4	4½	4	9¼
61	1	7½	1	9⅞	2	0¼	2	2¾	2	5¼	2	7½	2	10	3	0⅜	3	2⅞	3	5¼	3	7¾	4	0½	4	5⅜	4	10¼
62	1	7¾	1	10¼	2	0⅝	2	3⅛	2	5⅝	2	8	2	10½	3	1	3	3½	3	6	3	8½	4	1⅜	4	6¼	4	11¼
63	1	8	1	10½	2	1	2	3½	2	6	2	8⅝	2	11	3	1⅝	3	4⅛	3	6⅝	3	9⅛	4	2⅛	4	7⅛	5	0⅛
64	1	8⅜	1	10⅞	2	1½	2	4	2	6½	2	9⅛	2	11⅝	3	2¼	3	4¾	3	7¼	3	9⅞	4	3	4	8	5	1⅛
65	1	8⅝	1	11¼	2	1⅞	2	4½	2	7	2	9⅝	3	0¼	3	2⅞	3	5⅜	3	8	3	10½	4	3¾	4	8⅞	5	2
66	1	9	1	11⅝	2	2¼	2	4⅞	2	7½	2	10⅛	3	0⅞	3	3⅜	3	6	3	8⅝	3	11¼	4	4½	4	9¾	5	3
67	1	9⅜	2	0	2	2⅝	2	5¼	2	8	2	10⅝	3	1⅜	3	4	3	6½	3	9⅜	4	0	4	5⅜	4	10⅝	5	4
68	1	9⅝	2	0⅜	2	3	2	5¾	2	8½	2	11⅛	3	1¾	3	4⅝	3	7¼	3	10	4	0¾	4	6⅛	4	11½	5	5
69	1	9⅞	2	0¾	2	3½	2	6¼	2	8⅞	2	11¾	3	2⅜	3	5⅛	3	7⅞	3	10⅝	4	1½	4	7	5	0⅜	5	6
70	1	10¼	2	1	2	3⅞	2	6⅝	2	9⅜	3	0¼	3	3	3	5¾	3	8½	3	11⅜	4	2⅛	4	7¾	5	1¼	5	6⅞
71	1	10⅝	2	1½	2	4¼	2	7	2	9⅞	3	0¾	3	3½	3	6⅜	3	9¼	4	0	4	2⅞	4	8½	5	2⅛	5	7¾
72	1	10⅞	2	1¾	2	4⅝	2	7½	2	10⅜	3	1¼	3	4⅛	3	6¾	3	9⅞	4	0¾	4	3½	4	9¼	5	3	5	8¾
73	1	11¼	2	2⅛	2	5	2	8	2	10⅞	3	1¾	3	4⅝	3	7½	3	10½	4	1⅜	4	4¼	4	10	5	3⅞	5	9¾
74	1	11½	2	2½	2	5½	2	8⅜	2	11⅜	3	2¼	3	5¼	3	7⅞	3	11⅛	4	2	4	5	4	10⅞	5	4¾	5	10⅝
75	1	11⅞	2	2⅞	2	5⅞	2	8⅞	2	11⅞	3	2¾	3	5¾	3	8¾	3	11¾	4	2¾	4	5¾	4	11¾	5	5⅜	5	11⅝
76	2	0⅛	2	3¼	2	6¼	2	9¼	3	0¼	3	3¼	3	6⅜	3	9⅜	4	0⅜	4	3½	4	6½	5	0½	5	6½	6	0½
77	2	0½	2	3½	2	6⅝	2	9¾	3	0¾	3	3⅞	3	6⅞	3	9⅞	4	1	4	4	4	7⅛	5	1¼	5	7⅜	6	1½
78	2	0⅞	2	3⅞	2	7	2	10⅛	3	1½	3	4⅜	3	7½	3	10½	4	1⅝	4	4¾	4	7⅞	5	2	5	8¼	6	2½
79	2	1⅛	2	4⅛	2	7⅜	2	10½	3	1¾	3	4⅞	3	8	3	11⅛	4	2¼	4	5½	4	8½	5	2⅞	5	9⅛	6	3½

Table of the Diameters of Wheels—continued.

Number of teeth.	Pitch of the teeth in inches.																											
	1 inch		1⅛		1¼		1⅜		1½		1⅝		1¾		1⅞		2 inch		2⅛		2¼		2½		2¾		3 inch	
	Diameter at the pitch circle in feet and inches.																											
80	2	1½	2	4⅝	2	7¾	2	11	3	2¼	3	5⅜	3	8½	3	11¾	4	3	4	6⅛	4	9¼	5	3⅝	5	10	6	4⅜
81	2	1¾	2	5	2	8¼	2	11½	3	2⅝	3	5⅞	3	9⅛	4	0⅜	4	3½	4	6⅞	4	10	5	4½	5	10⅞	6	5⅜
82	2	2⅛	2	5⅜	2	8⅝	2	11⅞	3	3⅛	3	6⅜	3	9⅝	4	0⅞	4	4¼	4	7½	4	10¾	5	5¼	5	11¾	6	6⅜
83	2	2½	2	5¾	2	9	3	0⅜	3	3⅝	3	6⅞	3	10¼	4	1½	4	4⅞	4	8⅛	4	11½	5	6	6	0⅝	6	7¼
84	2	2¾	2	6	2	9⅜	3	0¾	3	4	3	7½	3	10¾	4	2⅛	4	5½	4	8⅞	5	0⅛	5	6⅞	6	1½	6	8⅛
85	2	3	2	6⅜	2	9¾	3	1¼	3	4½	3	7⅞	3	11¼	4	2¾	4	6⅛	4	9½	5	0⅞	5	7⅝	6	2⅜	6	9⅛
86	2	3⅜	2	6¾	2	10¼	3	1⅝	3	5¼	3	8½	3	11⅞	4	3¼	4	6¾	4	10⅛	5	1⅝	5	8½	6	3¼	6	10½
87	2	3⅝	2	7⅛	2	10⅝	3	2	3	5½	3	9	4	0½	4	3⅞	4	7⅜	4	10⅞	5	2¼	5	9¼	6	4⅛	6	11
88	2	4	2	7½	2	11	3	2½	3	6	3	9½	4	1	4	4½	4	8	4	11½	5	3	5	10	6	5	7	0
89	2	4⅜	2	7⅞	2	11⅜	3	2⅞	3	6½	3	10	4	1½	4	5⅛	4	8⅝	5	0¼	5	3¼	5	10¾	6	5⅞	7	1
90	2	4⅝	2	8¼	2	11¾	3	3¼	3	7	3	10½	4	2⅛	4	5¾	4	9¼	5	0⅞	5	4¼	5	11⅝	6	6¾	7	2
91	2	4⅞	2	8½	3	0¼	3	3⅞	3	7½	3	11	4	2¾	4	6¼	4	9⅞	5	1½	5	5⅛	6	0⅜	6	7⅝	7	2⅞
92	2	5¼	2	8⅞	3	0⅝	3	4¼	3	7⅞	3	11⅝	4	3¼	4	7	4	10½	5	2⅛	5	5⅞	6	1	6	8½	7	3⅞
93	2	5⅝	2	9¼	3	1	3	4¾	3	8⅜	4	0⅛	4	3⅞	4	7½	4	11¼	5	2⅞	5	6⅝	6	2	6	9⅜	7	4⅞
94	2	5⅞	2	9⅝	3	1⅜	3	5⅛	3	8⅞	4	0⅝	4	4⅜	4	8⅛	4	11¾	5	3½	5	7⅜	6	2¾	6	10¼	7	5¾
95	2	6¼	2	10	3	1¾	3	5½	3	9⅜	4	1⅛	4	4⅞	4	8¾	5	0½	5	4¼	5	8	6	3½	6	11⅛	7	6¾
96	2	6½	2	10⅜	3	2⅛	3	6	3	9¾	4	1⅝	4	5½	4	9⅜	5	1⅛	5	5	5	8¾	6	4⅜	7	0	7	7⅝
97	2	6⅞	2	10¾	3	2⅝	3	6½	3	10¼	4	2⅛	4	6	4	10	5	1¾	5	5⅝	5	9½	6	5¼	7	0⅞	7	8⅝
98	2	7⅛	2	11	3	3	3	6⅞	3	10¾	4	2⅝	4	6½	4	10½	5	2⅜	5	6¼	5	10⅛	6	6	7	1¾	7	9½
99	2	7½	2	11⅜	3	3⅜	3	7⅜	3	11¼	4	3¼	4	7⅛	4	11	5	3	5	7	5	11	6	6¾	7	2⅝	7	10½
100	2	7⅞	2	11⅞	3	3¾	3	7¾	3	11¾	4	3¾	4	7¾	4	11⅝	5	3⅝	5	7⅝	5	11⅝	6	7½	7	3⅝	7	11½
101	2	8¼	3	0⅛	3	4⅛	3	8¼	4	0¼	4	4¼	4	8¼	5	0¼	5	4¼	5	8¼	6	0¼	6	8⅜	7	4⅜	8	0½
102	2	8½	3	0½	3	4½	3	8⅝	4	0⅝	4	4¾	4	8⅞	5	1	5	5	5	9	6	1	6	9⅛	7	5¼	8	1⅜

FRICTION.

Friction is an effect produced by bodies rubbing one upon another, which acts as a retarding influence in the motion of all mechanical contrivances, but might not unfrequently be considerably diminished by a due regard to its laws, and a proper attention to the selection of those materials on which a uniform smooth surface may be attained, and which, according to experiments, are least liable to tear or become hot, and cause a roughness to arise when in working contact.

Several doubts existed a few years since respecting the laws of friction; but those doubts were entirely removed through the experiments of Mr. G. Rennie, on his own account, and those of M. Morin, acting for and under the sanction of the French Government, from or by which the following laws have been fully established.

1. That when no unguent is interposed, the friction of any two surfaces (whether of quiescence or of motion) is directly proportional to the force with which they are pressed perpendicularly together; so that for any two given surfaces of contact, there is a constant ratio of the friction to the perpendicular pressure; that is, a double pressure will produce a double amount of friction, a triple pressure a triple amount, &c., of any other proportionate increase of the load.

2. That when no unguent is interposed, the amount of the friction is in every case wholly independent of the extent of the surfaces in contact; so that the force

with which two surfaces are pressed together being the same, their friction is the same, whatever may be the extent of their surfaces of contact.

3. That the friction of motion is wholly independent of the velocity of the motion; that is, supposing two shafts or axles of equal bearings and of equal weights or pressures, but the one making 100 revolutions while the other makes but 50, the amount of friction in each is alike.

4. That when unguents are interposed, the amount of friction depends more upon the nature of the unguent than upon that of the surfaces of contact; and hence, that the nature of the unguent to be applied must be governed by the pressure or insistent weight. Mr. Rennie found, that with the unguents tallow and anti-attrition, on axles under a pressure of from 1 to 5 cwt., the friction did not exceed $\frac{1}{39}$th of the whole pressure; but when softer unguents were applied, as oil, hog's-lard, &c., the ratio of the friction to the pressure considerably increased; from which it is naturally inferred that the consistence of an unguent ought just to prevent the bodies coming into contact with each other.

5. That the friction of metals, without a stratum of unguent interposed, varies as their hardness, the hard metals producing less friction than the soft ones.

6. That without unguents, and within the limits of $32\frac{1}{2}$lbs. pressure per square inch, the friction of hard metals upon hard metals may very generally be estimated at about $\frac{1}{6}$th of the whole pressure.

7. That within the limits of their abrasion, the friction of metals is nearly alike; but from 1·66 cwt. per square inch to 6 cwt. per square inch, the resistance increases in a very considerable ratio, being the greatest with steel on cast iron, and the least with brass on wrought iron.

PRACTICAL PROPERTIES OF WATER AND AIR;

OR OF LIQUIDS AND FLUIDS IN GENERAL.

WATER is the most abundant liquid we possess, and air is the most abundant fluid,—their properties contributing largely to the subserviency of man, not only as the support of his existence and the comforts of his domestic enjoyments, but because of inherent energies which render them exceedingly advantageous, both as an efficient and disposable source of motive power.

By analysis it is ascertained that water is composed of the gases *oxygen* and *hydrogen* in a state of chemical union; its distinguishing properties, like that of other liquids, being incompressibility,* gravity, capability of flowing, and constant tendency to press outwards in every direction; also that of being easily changed by the absorption of caloric to an aëriform state of any required density or degree of elastic force: hence the principle of the *hydraulic press*, the *water-wheel*, the *steam engine*, &c.

Atmospheric air, like water, is also a gaseous compound: of 100 parts of air, reckoning by weight, 75·55 parts are nitrogen, 23·32 oxygen, and 1·13 carbonic acid and watery vapour; and in such proportions

* Exact experiments have determined that water is not entirely incompressible, but the degree of compressibility is so small, being only about 46½ millionth parts per atmosphere, that the terms incompressible and non-elastic fluid are not at all in practice inappropriate.

it is most conducive to animal existence. It also in this state possesses many important mechanical properties, a few of which are the following: viz., gravity, fluidity, compressibility, force or pressure, and elasticity; also expansibility by rarefaction or heat; and it is because of the oxygen it contains that combustion is supported. By change of temperature in the atmosphere, currents and winds are created; hence the means by which vessels are enabled to make distant voyages; also the cause which produces circular motion through the medium of the sails of a wind-mill: and it may likewise be observed, that without the pressure of the atmosphere the common pump would be without effect. Such preliminaries being properly considered, tend much to pave the way to an efficient knowledge of those elements, *water* and *air*, either as regards the production of, or retarding mechanical effects in their application as motive power.

1. *Effects produced by water in its natural state.*

Because of liquids possessing the properties of gravity and capability of flowing freely in every direction, sides of vessels, flood-gates, sluices, &c., sustain a pressure equal to the product of the area multiplied by half the depth of the fluid, and by its gravity, in equal terms of unity.

But when a sluice or opening through which a liquid may issue is under any given continued head, the pressure is equal the product of the area multiplied into the height from the centre of the opening to the surface of the fluid.

Ex. 1. Required the pressure of water on the sides of a rectangular cistern 18 feet in length, 13 in width, and 9 in depth.

The terms of measurement or unity are in feet; 1 cubic foot of water=62·5 lbs.; hence $\overline{18 \times 9 \times 2} + \overline{13 \times 9 \times 2} = 558 \times 4{\cdot}5 \times 62{\cdot}5 = 156937{\cdot}5$ lbs. = pressure on the sides.

Weight of water on bottom $=18 \times 13 \times 9 \times 62{\cdot}5 = 131625$ lbs.

Ex. 2. Required the pressure on a sluice 3 feet square, and its centre 30 feet from the surface of the water.

$$3 \times 3 \times 30 \times 62{\cdot}5 = 16875 \text{ lbs. pressure.}$$

The weight of water or other fluid is as the quantity, but the pressure exerted is as the vertical height; hence, as fluids press equally in every direction, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid, as the area of the vessel is to the sectional area of the column.

Ex. Let a cubical vessel whose sides are each 4 square feet have a tube inserted 1 inch in diameter and 6 feet in height, and let both vessel and tube be filled with water; required the whole weight of the water therein contained, and also the whole pressure exerted in tending to burst the vessel.

Cubic contents of the vessel=8 feet, and each foot=62·5 lbs. (see page 55).

Then, $62{\cdot}5 \times 8 = 500$. Area of pipe's section=·7854 inches and height 72 in., also a cubic inch of water=·03617 lbs.; hence $\cdot 7854 \times 72 \times \cdot 03617 = 2$ lbs. $+ 500 = 502$ lbs. total weight of the water.

Again, the whole height of the column=96 inches; then $\cdot 7854 \times 96 \times \cdot 03617 = 2{\cdot}33$ lbs., pressure of column on an equal area. 144 square inches=1 square foot, and $\frac{144 \times 4 \times 6 \text{ sides}}{\cdot 7854} = 4400{\cdot}4$ times the area of the pipe's diameter in the whole surface; therefore $4400{\cdot}4 \times 2{\cdot}33 = 10253$ lbs., or total amount of pressure exerted.

Upon the preceding principles of water rests the utility of the hydraulic press. Thus, into a uniform cylinder of suitable strength is fitted a piston or ram moveable in a parallel direction, around which are properly fitted leather collars, to prevent any possibility of the water's escape; the water being injected by means of a force-pump, and, by its non-compressible property, repelling the ram with a force equal to the number of times the end of the ram exceeds the area of the pump.

Ex. Required the repulsive force of a 6-inch ram, when a power of 50 lbs. is applied to the end of the lever, which is as 12 to 1 in effect, and the diameter of the pump or plunger $\frac{7}{8}$ths of an inch.

$$\frac{\text{Area of ram} = 28{\cdot}2744}{\text{Area of pump} = {\cdot}6013} = 47\,;$$

and $50 \times 12 \times 47 = 28200$ lbs., or 12 tons nearly.

When a body is partly or wholly immersed in water or other fluid, the vertical pressure of the fluid tends to raise the body with a force equal to the weight of the fluid displaced; hence the weight of any displaced quantity of a fluid by a buoyant body equals the weight of that body.

Ex. 1. Suppose a vessel with all its masts, stores, and general equipments, is found to displace 35,000 cubic feet of sea water, what is the whole weight of the vessel?

Sea water average 64 lbs. per cubic foot.

$$\frac{35000 \times 64}{2240} = 1000 \text{ tons.}$$

Ex. 2. What must be the thickness of sheet iron whereby to form a rectangular vessel 5 feet in length, 2 in width, and $1\frac{1}{4}$ in depth, that will just sink 3 inches in common water; laps, seams, and rivets not being taken into account?

5 ft. or 60 in. × 15=900 × 2=	1800	in., or sum of the	sides.
" 60 " × 15=	1440	"	bottom.
2 " 24 " × 15=360 × 2=	720	"	ends.
Total	3960		

And 3960 × ·281 (see page 30)=1112·7, the divisor.

Then 60 in. × 15 × 3 × ·03617 = 156·254 lbs. of water to displace.

Hence 156·254 ÷ 1112·7 = ·14 in., thickness required.

The resistance by which a moving body is opposed in passing through water, is as the cube of the body's velocity; hence, if 25 horses' power will impel a vessel at a rate of five miles an hour, to effect a speed of 6 miles per hour will require 43 horse-power;

7	"	"	69	"
8	"	"	102	"
9	"	"	146	"
10	"	"	200	"

Thus $5^3 : 6^3 :: 25 : 43$, or $5 : 6^3 :: 1 : 43$ horse-power.

Water in flowing through an aperture under any given head, is governed by the same law of gravity as that of a solid body in vacuo descending through the same space; but as friction is created by the motion of two hard bodies in contact, so is friction also created by the action of the water in passing through an aperture: hence an aperture twice the width of another will discharge more than a double quantity, because of the area advancing in a much greater ratio to that of the resistance. Thus, suppose an opening of 4 square feet be required: in a circular form its diameter would be about 2 feet 3 inches, and its circumference, or cause of friction, 7 feet; in a square form, 2 feet by 2 feet, and the amount of its sides 8 feet; but in a rectangular form, 4 feet in length and 1 in breadth, the cause of resistance is increased to 10 feet; thus showing that the circular form is that which ought to be adopted in preference to any other for the conduction of water where practicability will admit.

When water issues out of a circular orifice in a thin plate at the bottom or side of a reservoir, the issuing stream tends to converge to a point at the distance of about half its diameter outside the orifice, and this contraction of the stream reduces the area of its section from 1 to ·619, or nearly $\frac{5}{8}$ths. If a short parallel tube be attached, the vein of the stream is less contracted, and the area will equal ·762. But if the tube attached be the frustum of a cone whose greater end is the aperture, the length equal half the diameter of the aperture, and the area of the small end to the area of the larger as 1 to 1·6, there will be no contraction of the vein: hence the propriety of making the pipe in this form from a reservoir or other head of water, through which the greatest quantity, according to its area, is required to pass.

To find the velocity of water issuing through a circular orifice at any given depth from the surface.

Rule.—Multiply the square root of the height or depth to the centre of the orifice by 8·1, and the product is the velocity of the issuing fluid in feet per second.

Ex. Required the velocity of water issuing through an orifice under a head of 11 feet from the surface.

$\sqrt{11} = 3{\cdot}3166 \times 8{\cdot}1 = 26{\cdot}864$ feet, velocity per second.

In the discharge of water by a rectangular aperture in the side of a reservoir, and extending to the surface, the velocity varies nearly as the square root of the height, and the quantity discharged per second equal

⅔rds of the velocity due to the mean height, allowing for the contraction of the fluid according to the form of the opening, which renders the co-efficient in this case equal to 5·1; whence the following general rules.

1. *When the aperture extends to the surface of the fluid.* Multiply the area of the opening in feet by the square root of its depth, also in feet, and that product by 5·1; then will ⅔rds of the last product equal the quantity discharged in cubic feet per second.

2. *When the aperture is under a given head.* Multiply the area of the aperture in feet by the square root of the depth also in feet, and by 5·1; the product is the quantity discharged in cubic feet per second.

Ex. 1. Required the quantity of water in cubic feet per second discharged through an opening in the side of a dam or weir, the width or length of the opening being 6½ feet, and depth 9 inches, or ·75 of a foot.

Square root of ·75=·866.

Then $\frac{6·5 \times ·75 \times ·866 \times 5·1 \times 2}{3} = 14·3839$ cubic feet.

Ex. 2. What would be the quantity discharged through the above opening if under a head of water 4 feet in height?

Square root of 4=2, and 2×5·1=10·2 feet, velocity of the water per second.

And 6·5 × ·75 × 2 × 5·1=49·725 cubic feet discharged in the same time.

PRACTICAL RULES BY WHICH TO DETERMINE THE NECESSARY HEAD, AND QUANTITY OF WATER DISCHARGED THROUGH CIRCULAR PIPES IN A GIVEN TIME.

Rule 1.—To the product of the pipe's length in feet, multiplied by the square of the quantity required in cubic feet per second, add the product of 50 times the pipe's diameter in feet, multiplied into the square of the required quantity per second; divide the sum by the product of 1542·133 into the fifth power of the diameter, and the quotient equal the *head* in feet to produce the velocity required.

Rule 2.—Multiply 1542·133 times the fifth power of the pipe's diameter in feet by the head of water in feet, and divide the product by the sum of the pipe's length and 50 times its diameter; the square root of the quotient equal the *quantity* discharged in cubic feet per second.

Ex. 1. Required the head of water necessary to produce a velocity of 2·988 feet, or 9·387 cubic feet per second, by a pipe of 2 feet in diameter and 180 feet in length.

$$\frac{\overline{9{\cdot}387^2 \times 180} + \overline{50 \times 2 \times 9{\cdot}387^2}}{1542{\cdot}133 \times 2^5} = \frac{25860{\cdot}8}{49348} = {\cdot}5 \text{ of a foot head.}$$

Ex. 2. What quantity of water per second will be discharged through a pipe of 2 feet diameter and 180 feet in length, when pressed by a head of water ·5 of a foot in height.

$$\frac{1542{\cdot}133 \times 2^5 \times {\cdot}5}{180 + \overline{50 \times 2}} = \sqrt{88{\cdot}1219} = 9{\cdot}387 \text{ feet per second.}$$

And the area of the end of the pipe in feet, multiplied into the velocity, equal the quantity in cubic feet.

Note.—The above rules apply strictly only to straight pipes; bends in a pipe diminish the velocity of a fluid equal to ·0038 times the sum of the sines of the several angles of inflection; hence, a bend in a pipe should not be sudden, and on no account should an angle be admitted.

Table of the Diameters of Pipes through which a required quantity of water may be discharged in a given time.

Cubic feet per minute.	Diameter in inches.	Cubic feet per minute.	Diameter in inches.	Cubic feet per minute.	Diameter in inches.
1	1	25	4¾	160	12⅛
2	1⅜	30	5¼	170	12½
3	1⅝	35	5⅝	180	12¾
4	1⅞	40	6	190	13¼
5	2⅛	45	6½	200	13⅝
6	2⅜	50	6¾	225	14⅜
7	2⅝	55	7⅛	250	15⅛
8	2¾	60	7½	275	16
9	2⅞	65	7¾	300	16⅝
10	3	70	8	350	18
11	3⅛	80	8⅝	400	19¼
12	3¼	90	9⅛	441	20⅛
13	3½	100	9⅝	529	22
14	3⅝	110	10	625	24
15	3¾	120	10½	729	26
16	.3⅞	130	11	841	28
18	4	140	11⅜	900	29
20	4¼	150	11¾	1000	30

The combined properties of gravity and fluidity which water possesses render it so available as a source of motive power; *gravity* being the property by which the power is produced, and *fluidity* that by which it is so commodiously qualified to the various modifications in which it is employed.

Water, it is ascertained, is subject to the same laws of gravity as those of solid bodies, and thereby accumulates velocity or effect in an equal ratio when falling though an equal space, or descending from an equal height: hence the velocity attained is as the square root of the height of its fall; and it is now quite satisfactorily decided, that because of the non-elastic property of water, its greatest effect is obtained when acting by gravity throughout its whole height, whether it be applied on a water-wheel, turbine, or other machine, through which circular motion is to be the immediate result.

In regard to *Water-Wheels* and other Machines through which motion is produced by the effort of water, considerable discrepancy of opinion formerly existed, both as to form and velocity, besides other essential points requisite in gaining a maximum of effect with the least possible strain; but these doubts are now in a great measure removed through experiments by the Franklin Institute in America, added to those in France by Morin, and the results of a patented machine by Whitelaw and Stirrat, Scotland, combined with pertinent observations and remarks by interested parties in this as well as in other countries: hence have been deduced the following demonstrative conclusions.

1. That to gain a maximum of effect by a horizontal water-wheel, the water must be laid upon the wheel on the stream side, and the diameter of the wheel so proportioned to the height of the fall, that the water may be laid on about $52\frac{3}{4}$ degrees distant from the summit of the wheel; or the height of the fall being 1, the height or diameter of the wheel equal 1·108.

2. That the periphery of a water-wheel ought to move at a velocity equal to about twice the square root of the fall of the water in feet per second, and the number of buckets equal 2·1 times the wheel's diameter in feet; also, that precautionary means be adopted for the escape of the air out of the buckets,

either by making the stream of water a few inches narrower than the wheel, or otherwise.

3. That because of water producing a less efficient power by impulse than gravity, turbines, or machines through which the motion is obtained by reaction, are greatly preferable to undershot, or low breast wheels.

4. That a head* of water is required sufficient to cause the velocity of its flowing to be as 3 to 2 of the wheel; $\frac{1}{9}$th of the wheel's diameter being an approximate height, near enough for practical purposes.

5. That the effective power of a wheel constructed according to these restrictions is equal to the product of the number of cubic feet, and velocity in feet per minute, multiplied into ·001325.

Example for general illustration

Suppose a fall of water 25 feet in height, over which is delivered 112 cubic feet per minute; required the various peculiar requisites for a wheel to be in accordance with the preceding rules.

1st. $25 \times 1{\cdot}08 = 27$ feet, the wheel's diameter.

2nd. $\sqrt{25} \times 2 = 10$ feet, velocity of the wheel in ft. per second. Also $27 \times 2{\cdot}1 = 56{\cdot}7$, say 57 buckets.

3rd. $27 \div 9 = 3$ feet, head of water required.

4th. $112 \times 10 \times 60 \times {\cdot}001325 = 89$ horses' power.

The *turbine* of Fourneyron, in France, and the patented *Water-Mill* of Whitelaw and Stirrat, Scotland, have of late years attracted a considerable share of public attention, their simplicity of construction and asserted effects in like situations being equal to those of the best applied water-wheels. In their manner of construction, they differ, but in principle they are the same; the action of each being created by a centrifugal and tangential force, caused by the weight or impulsion of a column

* By head is meant the distance from the surface of the water to that point at which it strikes upon the wheel.

of water whose height or altitude is equal to twice the height of the fall due to the water's velocity; and in order to produce a maximum of effect in either the one or the other by the pressure and centrifugal force of the effluent water, it is necessary that the emitting tubes, or helical channels of the machine, be so curved that the apertures shall be in a right line with the radius of the wheel.

In 1838 a number of experiments were made in France by Morin, with a view to the more general introduction of turbines, and a positive proof of their merited qualities in preference to wheels of impulse, which terminated considerably in favour of turbines, and from which the following deductions were made.

1. That turbines are equally adapted to great as to small falls of water.

2. That they are capable of transmitting a useful effect to from 70 to 78 per cent. of the absolute power.

3. That their velocities may vary very considerably from the maximum effect, without differing very sensibly from it.

4. That they will work nearly as effectually when drowned to the depth of 5 or 6 feet, as when free, and consequently, they will make use of the whole of the fall when placed below the level of extreme low water.

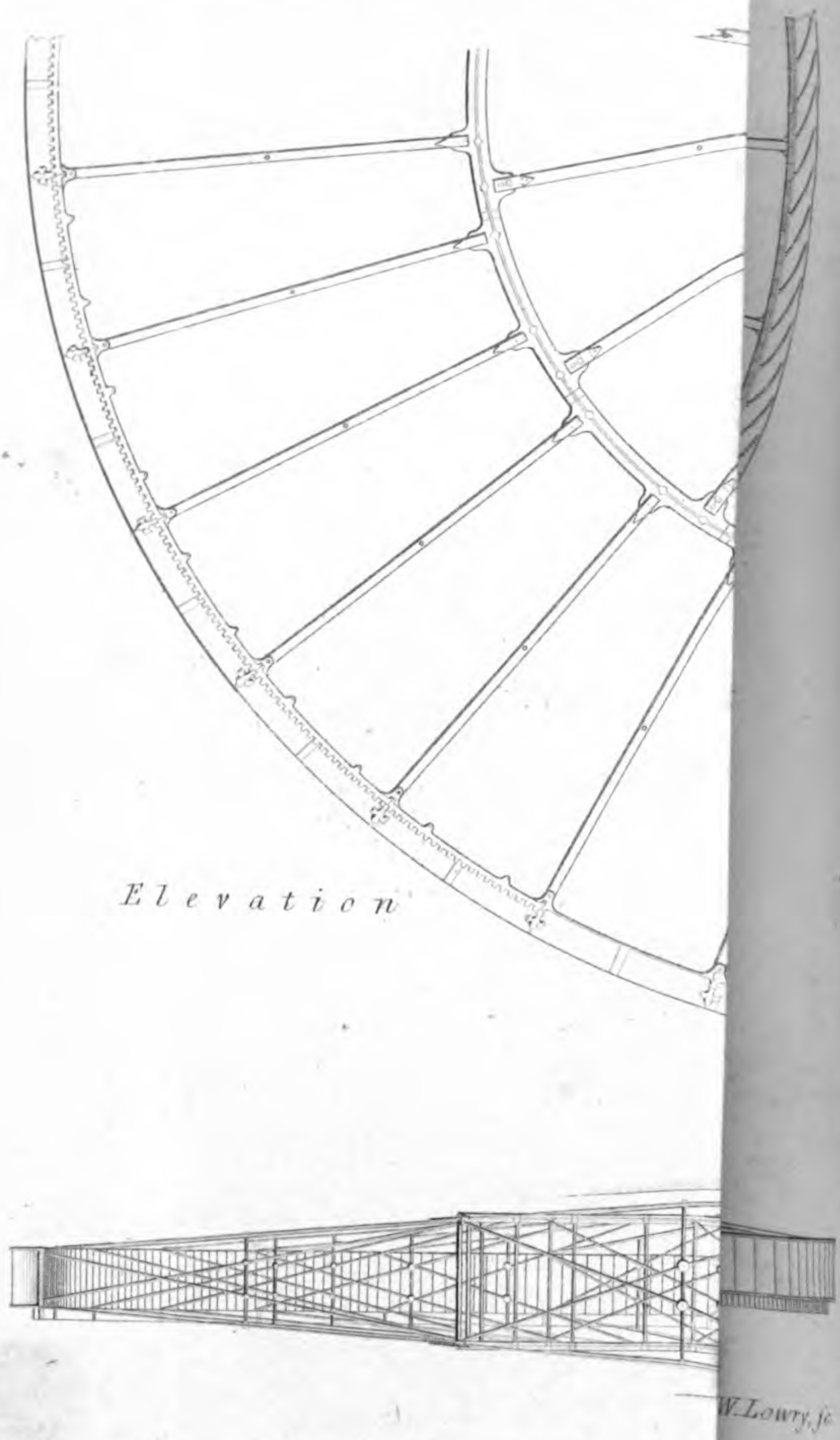
5. That they may receive variable quantities of water without altering the ratio of the power to the effect. Corresponding results have also been realized by Whitelaw and Stirrat's machine: hence what is said of the one is equally applicable to the other.

General Rule by Mr. Whitelaw, whereby to compute the power of their Turbine, or Water-Mill.

Rule.—Multiply the effective quantity of water flowing in cubic feet per minute by the height of the fall of the water in feet, and divide the product by 700;

AN OVERSHOT WATER WHEEL, CON DON.

Plate (



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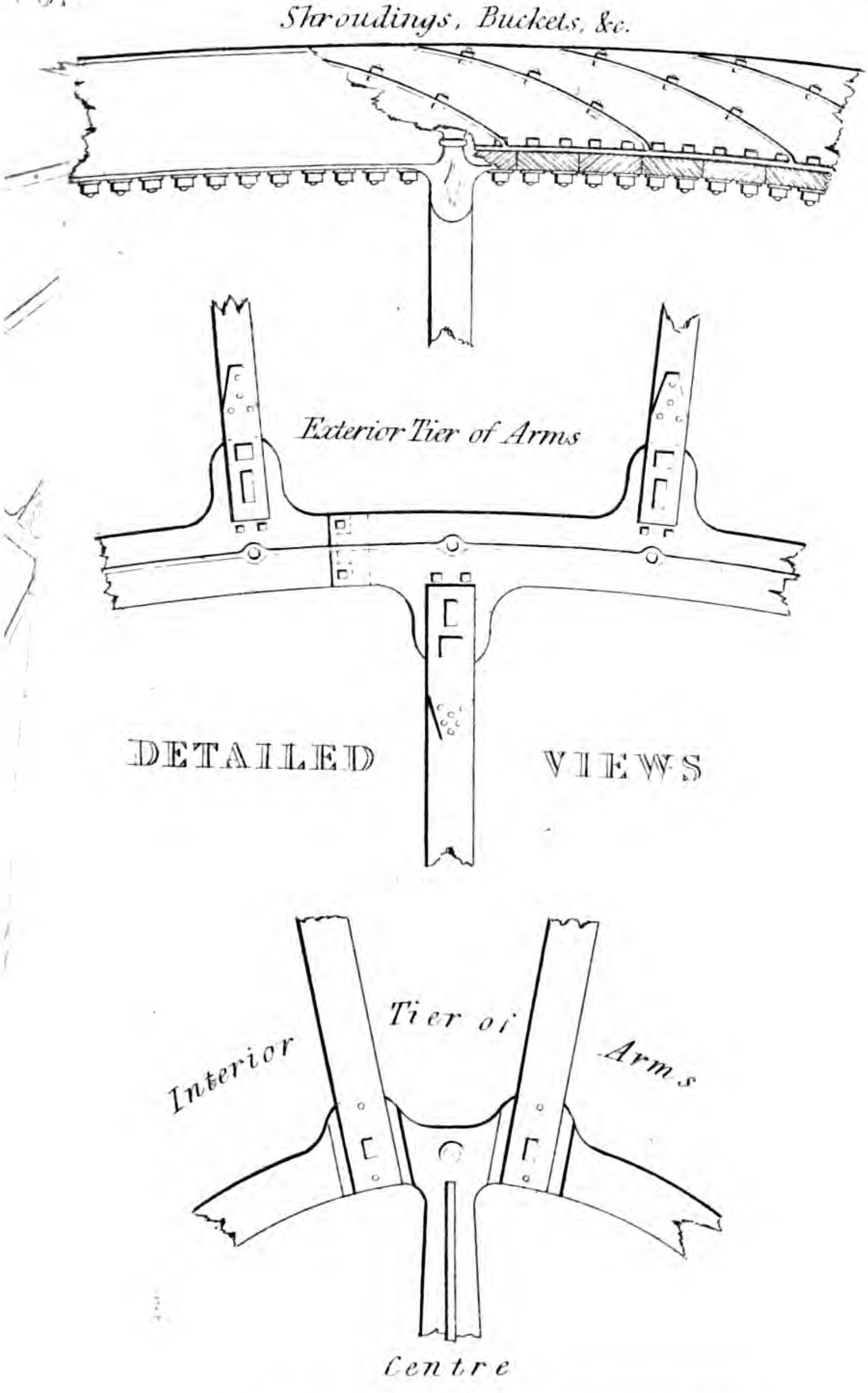


London: Lockwood & Co. Stationers' Hall Court.

the quotient equal the effect produced in horses' power.

Ex. Required the power produced by 1400 cubic feet per minute over a fall of 30 feet.

$$\frac{1400 \times 30}{700} = 60 \text{ horses' power.}$$

Plates G and H exhibit miniature views of a ponderous overshot water-wheel, chiefly of wrought iron, and in which novelty of construction, immense diameter, and great efficiency, have rendered it an object of universal interest throughout the district in which it is situated : its nominal power is that of 30 horses, but upwards of 40 of indicated resistance seems not materially to diminish its velocity ; and no doubt, on account of the improved form of the buckets, the greatest amount of the water's effect is obtained.

TABLE OF THE RADII OF WHEELS, FROM TEN TO THREE HUNDRED TEETH, THE PITCH* BEING TWO INCHES.

BY B. DONKIN, ESQ., CIVIL ENGINEER, LONDON.

No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.
10	3·236	20	6·392	30	9·567	40	12·746	50	15·926
11	3·549	21	6·710	31	9·885	41	13·064	51	16·244
12	3·864	22	7·027	32	10·202	42	13·382	52	16·562
13	4·179	23	7·344	33	10·520	43	13·700	53	16·880
14	4·494	24	7·661	34	10·838	44	14·018	54	17·198
15	4·810	25	7·979	35	11·156	45	14·336	55	17·517
16	5·126	26	8·296	36	11·474	46	14·654	56	17·835
17	5·442	27	8·614	37	11·792	47	14·972	57	18·153
18	5·759	28	8·931	38	12·110	48	15·290	58	18·471
19	6·076	29	9·249	39	12·428	49	15·608	59	18·789

* By the pitch is understood the distance between the centres of two contiguous teeth ; and by the radius is understood the distance between the centre of the wheel and the centre of each tooth. For any other pitch, say, as two inches is to the radius in the table, so is the given pitch to the radius required.

TABLE OF THE RADII OF WHEELS—*continued.*

No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No of teeth.	Radius in inches.
60	19·107	109	34·700	157	49·978	205	65·256	253	80·534
61	19·425	110	35·018	158	50·296	206	65·574	254	80·853
62	19·744	111	35·337	159	50·615	207	65·893	255	81·171
63	20·062	112	35·655	160	50·933	208	66·211	256	81·489
64	20·380	113	35·974	161	51·251	209	66·529	257	81·808
65	20·698	114	36·292	162	51·569	210	66·848	258	82·126
66	21·016	115	36·611	163	51·888	211	67·166	259	82·444
67	21·335	116	36·929	164	52·206	212	67·484	260	82·763
68	21·653	117	37·247	165	52·524	213	67·803	261	83·081
69	21·971	118	37·565	166	52·843	214	68·121	262	83·399
70	22·289	119	37·883	167	53·161	215	68·439	263	83·717
71	22·607	120	38·202	168	53·479	216	68·757	264	84·036
72	22·926	121	38·520	169	53·798	217	69·075	265	84·354
73	23·244	122	38·838	170	54·116	218	69·394	266	84·673
74	23·562	123	39·156	171	54·434	219	69·712	267	84·991
75	23·880	124	39·475	172	54·752	220	70·031	268	85·309
76	24·198	125	39·793	173	55·071	221	70·349	269	85·627
77	24·517	126	40·111	174	55·389	222	70·667	270	85·946
78	24·835	127	40·429	175	55·707	223	70·985	271	86·264
79	25·153	128	40·748	176	56·026	224	71·304	272	86·582
80	25·471	129	41·066	177	56·344	225	71·622	273	86·900
81	25·790	130	41·384	178	56·662	226	71·941	274	87·219
82	26·108	131	41·703	179	56·980	227	72·258	275	87·537
83	26·426	132	42·021	180	57·299	228	72·577	276	87·855
84	26·741	133	42·339	181	57·617	229	72·895	277	88·174
85	27·063	134	42·657	182	57·935	230	73·214	278	88·492
86	27·381	135	42·976	183	58·253	231	73·532	279	88·810
87	27·699	136	43·294	184	58·572	232	73·850	280	89·129
88	28·017	137	43·612	185	58·890	233	74·168	281	89·447
89	28·336	138	43·931	186	59·209	234	74·487	282	89·765
90	28·654	139	44·249	187	59·527	235	74·805	283	90·084
91	28·972	140	44·567	188	59·845	236	75·123	284	90·402
92	29·290	141	44·885	189	60·163	237	75·441	285	90·720
93	29·608	142	45·204	190	60·482	238	75·760	286	91·038
94	29·927	143	45·522	191	60·800	239	76·078	287	91·357
95	30·245	144	45·840	192	61·118	240	76·397	288	91·675
96	30·563	145	46·158	193	61·436	241	76·715	289	91·993
97	30·881	146	46·477	194	61·755	242	77·033	290	92·312
98	31·200	147	46·795	195	62·073	243	77·351	291	92·630
99	31·518	148	47·113	196	62·392	244	77·670	292	92·948
100	31·836	149	47·432	197	62·710	245	77·988	293	93·267
101	32·155	150	47·750	198	63·028	246	78·306	294	93·585
102	32·473	151	48·068	199	63·346	247	78·625	295	93·903
103	32·791	152	48·387	200	63·665	248	78·943	296	94·222
104	33·109	153	48·705	201	63·983	249	79·261	297	94·540
105	33·427	154	49·023	202	64·301	250	79·580	298	94·858
106	33·746	155	49·341	203	64·620	251	79·898	299	95·177
107	34·064	156	49·660	204	64·938	252	80·216	300	95·495
108	34·382								

TABLE OF DIMENSIONS, AND ESTIMATED POWERS OF WATER-WHEELS.

Diameter of wheel in feet.	Breadth of wheel in feet.	Depth of back in feet and inches.	Revolutions of wheel per minute.	Fall of water in feet.	Speed of periphery in feet per second.	Cubic feet of water per second.	Diameter of driving segment.	Estimated horse-power.
20	17	1 8	3·64	16½	3·82	46	18	60
18	20	1 6	4·75	16	4·50	36	16	52
18	18	1 10	6·15	10	3·75	24	14	45
18	12	1 5	4·56	16	4·30	20	14	30
16	21	2 0	7·80	9	6·50	45	14	20
15	6	0 10	9·00	14½	7·00	8	12¾	12

PRICES OF MILL WORK, MACHINERY, AND LABOUR,

APPROXIMATELY VARYING,

WITH THE PRICES OF IRON AND OF LABOUR.

		£	s.	d.
Mill,				
Bean, from 3*l*. 13*s*. 6*d*. to	each	6	16	6
Bones, to crush 3 tons per day, 105*l*.; 4 tons, 125*l*.; 5 tons, 150*l*.; 6 tons, 165*l*.; 7 tons, 180*l*.; 8 tons, 210*l*.; 9 tons, 220*l*.; 10 tons, 250*l*.				
Brick, including the horse's wheel and every requisite for making large quantities in little time, about,	each	1200	0	0
Bruising, for corn, malt, pulse, &c.	do.	8	8	0
Coffee	do.	1	5	0
Corn, Indian, small size, with two handles	do.	2	10	0
Corn, Indian, large, with fly wheel	do.	5	15	6
Corn, Indian, with cast iron bed and runner, machinery, &c., complete	each	180	0	0
Corn, 4-horse power, with stones 3 feet 2 inches diameter, not including the horse wheel	each	140	0	0
Corn, including the horse wheel	do.	310	0	0
Drug, with the machinery complete for ditto	do.	180	0	0
Flour, *the improved family mill*, with French burr stones, for grinding flour by hand	each	18	18	0
Flour, &c., to work by horse	do.	25	0	0
Flour, portable, 15 inches square	do.	6	6	0
Furze or gorst, from 6*l*. 6*s*. to	do.	10	10	0
Irish wheat	do.	4	4	0
Kibbling, with fly wheels, with or without frames, from 2*l*. 10*s*. to	each	5	10	0
Lead, with cast iron bed, 7 feet 9 inches long, and 3 feet 2 inches wide, rollers 5 feet long, and 12 inches diameter, with square threaded screws, and the whole of the machinery complete, except the power	each	1000	0	0
Linseed, with two rollers 5 feet long, and 12 inches diameter, fitted up with spur pinions, brasses, set screws, cast iron frame, &c.	each	65	0	0
Malt, with fly wheel	do.	6	0	0
do. of 1-horse power	do.	16	16	0
Pug, of 2-horse power, for making bricks, &c.	do.	42	0	0

Mill,		£	s.	d.
Saw, an upright saw mill, with frame and shifting do., guide rods, brasses, and guides, spindles, rollers, ratchett wheel, rods, catch, &c., connecting rod, brasses, set of saws, buckles, &c., for cutting deals, not including the power, about	each	180	0	0
Saw, do., for planks, &c.	do.	230	0	0
do. do. for cutting timber 2 feet deep, about	do.	450	0	0
do. do. 3 feet deep	do.	570	0	0
Circular saw, with cast iron frame and bench, sliding rule, bearings, rigger, extra carriage, clutch, and lever, including a set of saws, do. do.	each	100	0	0
For cutting veneers, 12 feet diameter	do.	600	0	0
For cross cutting, round or square timber, upon the principle of the stone mill, framed, with three spur wheels, &c.	each	150	0	0
Steel, for wheat, barley, oats, peas, beans, &c.	do.	3	13	6
do. do. do.	do.	6	16	6
Sugar, cattle, for the West Indies, &c. The rollers in a strong iron frame 5 feet long, and 2 feet diameter, to work in a horizontal position, including the machinery to work the mill, with the wood arms, sweeps, &c., for the cattle to draw from, complete	each	670	0	0
rollers, $4\frac{1}{2}$ feet long, and 2 feet diameter	do.	610	0	0
do. 4 do. $1\frac{3}{4}$ do.	do.	560	0	0
do. $3\frac{1}{2}$ do. $1\frac{1}{2}$ do.	do.	525	0	0
do. 3 do. $1\frac{1}{2}$ do.	do.	450	0	0
Sugar, for a steam engine,				
rollers, 5 feet long, and 2 feet diameter	do.	510	0	0
do. $4\frac{1}{2}$ do. 2 do.	do.	485	0	0
do. 4 do. 2 do.	do.	420	0	0
do. $3\frac{1}{2}$ do. 2 do.	do.	375	0	0
do. 3 do. 2 do.	do.	325	0	0
The machinery for connecting the engine to the mill, for working it, in addition	each	210	0	0
Sugar, for a windmill,				
rollers, 5 feet long, and 2 feet diameter	do.	510	0	0
do. $4\frac{1}{2}$ do. 2 do.	do.	480	0	0
do. 4 do. 2 do.	do.	420	0	0
do. $3\frac{1}{2}$ do. 2 do.	do.	370	0	0
do. 3 do. 2 do.	do.	320	0	0
A pair of wheels to connect the spindle of windmill to the sugar mill, will be, in addition to the foregoing	each	75	0	0
Sugar, for a water wheel,				
rollers, 5 feet long, and 2 feet diameter	do.	500	0	0
do. $4\frac{1}{2}$ do. 2 do.	do.	480	0	0
do. 4 do. 2 do.	do.	420	0	0
do. $3\frac{1}{2}$ do. 2 do.	do.	370	0	0
do. 3 do. 2 do.	do.	320	0	0
The machinery to connect the shaft of the water wheel, will be, in addition to the above to each mill	each	180	0	0
The rollers in an iron frame, 3 feet long, and 2 feet diameter, to work in a vertical position	each	460	0	0

	£	s.	d.
M'LL,			
Sugar, for a water wheel,			
rollers, 3 feet long, and 1 foot 10 in. diameter, each	430	0	0
do. 3 feet long, and 1 foot 8 inches do. do.	400	0	0
do. 2 feet 10 in. long, and 2 feet do. do.	450	0	0
do. 2 ft. 10 in. long, and 1 ft. 10 in. do. do.	420	0	0
do. 2 ft. 10 in. long, and 1 ft. 8 in. do. do.	400	0	0
do. 2 feet 8 inches long, and 2 ft. do. do.	440	0	0
do. 2 ft. 8 in. long, and 1 ft. 10 in. do. do.	410	0	0
do. 2 ft. 8 in long, and 1 ft. 8 in. do. do.	380	0	0
do. 2 feet 6 inches long, and 2 ft. do. do.	430	0	0
do. 2 ft. 6 in. long, and 1 ft. 10 in. do. do.	400	0	0
do. 2 ft. 6 in. long, and 1 ft. 8 in. do. do.	370	0	0
Wheat, from 3*l*. 3*s*. to .... do.	20	0	0
portable, 15 inches square .... do.	6	6	0
do. with bolting machine attached .... do.	10	10	0
do. patent hand, with French burrstones do.	18	18	0
do. for 1-horse power................. do.	31	0	0
MILLSTONE,			
Specific gravity, per foot cube, 157 lbs.			
French burr, 2 ft. 2 in. diam., flat way of the burrs, per pair	20	0	0
do. 3 feet diameter .... do.	30	0	0
do. 4 feet diameter .... do.	36	0	0
do. 4 feet diameter, bedstone, flat, and the runner edgeway of the burrs .. per pair	50	0	0
do. 4 feet 6 inches in diameter........ do.	60	0	0
do. 5 feet diameter .... do.	70	0	0
malt cologne, 3 ft. diameter, and 5 in. thick do.	3	13	6
making ditto .... per stone	3	3	0
do. 2 feet 8 inches .... per pair	2	12	6
do. 2 feet 6 inches .... do.	2	0	0
moor edge stones, 4 feet .... do.	24	0	0
bed stone to ditto .... each	10	10	0
4 feet 6 inches .... per pair	27	0	0
bed stone to ditto .... each	11	0	0
5 feet .... per pair	30	0	0
bed stone to ditto .... each	12	12	0
5 feet 6 inches .... per pair	38	0	0
bed stone to ditto .... each	13	13	0
6 feet .... per pair	50	0	0
bed stone to ditto .... each	14	14	0
peak, 3 feet diameter.................... per pair	18	0	0
do. 3 feet 6 inches diameter .... do.	21	0	0
do. 4 feet do. .... do.	24	0	0
do. 4 feet 6 inches do. .... do.	27	0	0
do. 5 feet do. .... do.	30	0	0
MILLWRIGHT'S WORK,			
Millwright, per day	0	8	4
Colour mill work,			
a hand colour mill, stones 18 or 20 ins. diam., with an oak frame, two iron cog wheels, two spindles, a fly wheel, handle, tub, scraper, iron hopper, &c., each	22	10	0
Corn mill work,			
a full sized bolting mill, including reel, pannel case, pannels, beaters, iron and brass work...... each	31	10	0
a reel with shaft hoop, gudgeons, and iron work do.	4	4	0
prepared beech beaters .... per foot run	0	1	0

		£	s.	d.
Millwright's Work,				
Corn mill work,				
a machine cylinder, 4 feet long, and 18 inches diameter, exclusive of wire	each	8	8	0
brushes, rings, spindles, and beaters	do.	11	11	0
a cylinder 5 feet long, exclusive of wire	do.	16	16	0
brushes, spindles, &c.	do.	12	12	0
a machine case to a 5 feet cylinder	do.	22	10	0
a cylinder 6 feet long, and 18 inches diameter	do.	25	0	0
a hoop, hopper, shoe, and ladder for 4 ft. stones	do.	9	9	0
ditto for 5 feet ditto	do.	10	10	0
ditto for malt mill stones	do.	7	7	0
a hoop for 4 feet stones	do.	4	0	0
ladder for ditto	do.	1	4	0
shoe for ditto	do.	0	14	0
inch elm hopper for ditto	do.	1	9	0
damsels	do.	1	1	0
steel mill bills	per lb.	0	2	0
Mustard mill work, for a pair of cast iron carriages, brasses, and set of screws to ditto for rollers		11	11	0
turning a pair of rollers when out of order		3	15	0
Oil mill work,				
a rough cast iron oil press	per cwt.	1	5	0
wood stampers	each	3	3	0
a pair of cast iron rollers 2 feet 2 inches long, 12½ inches diameter, solid, with cast iron carriages, brasses, bolts, &c.	per pair	84	0	0
turning a pair of old rollers and chipping down the pinions		5	5	0
Patterns for wheels above 18 inches diameter, width of cog 1 inch	per foot diameter	1	18	0
2 inches	do.	2	2	0
3 do.	do.	2	4	0
4 do.	do.	2	8	0
5 do.	do.	2	14	0
6 do.	do.	3	0	0
7 do.	do.	3	8	0
8 do.	do.	4	0	0
9 do.	do.	4	16	0
10 do.	do.	5	5	0
11 do.	do.	5	15	0
12 do.	do.	6	0	0
All patterns under 18 inches to be charged extra.				
for rigger wheels, to be charged less than wheels	pr. ft.	0	8	0
for ratchett wheels	do.	0	8	0
Pipe, cast iron, of 2 inch bore	per yard	0	3	9
do. 3 do.	do.	0	4	9
do. 4 do.	do.	0	6	0
do. 5 do.	do.	0	8	6
do. 6 do.	do.	0	9	6
do. 7 do.	do.	0	11	6
do. 8 do.	do.	0	15	0
do. 9 do.	do.	1	2	0
do. 10 do.	do.	1	5	0
do. 11 do.	do.	1	8	0
do. 12 do.	do.	1	13	0
curved pipes, from 16s. to	per cwt.	0	18	0

The Weight of Cast Iron Pipes 12 Inches Long.

Diameter of bore.	Thickness.								
	¼-in.	⅜-in.	½-in.	¾-in.	1-in.	1¼-in.	1½-in.	1¾-in.	2-in.
in.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	3·05	5·85	7·35	12·9	19·7	—	—	—	—
1½	4·28	6·9	10·6	16·6	24·4	—	—	—	—
2	5·5	8·7	12·2	20·2	29·25	39·5	—	—	—
2½	6·73	10·5	14·6	23·5	34·2	46·6	—	—	—
3	7·95	12·5	17·1	27·4	39·0	51·75	—	—	—
3½	9·15	14·25	19·5	31·0	43·9	58·0	—	—	—
4	10·4	16·0	22·0	34·7	48·8	64·75	80·5	—	—
4½	11 62	17·9	24·4	38·3	53·7	70·5	87·5	—	—
5	12·8	20·	26·8	42·0	58·6	76·3	95·4	—	—
5½	··	21·8	29·3	45·6	63·5	82·5	103·0	—	—
6	··	23·6	31·75	49·5	68·5	88·2	110·0	133·	156·
6½	··	25·4	34·2	52·8	73·2	94·6	117·0	141·	166·
7	··	27·	36·5	56·6	78·0	101·0	125·0	150·	176
7½	··	28·8	39·	60·3	83·0	107·0	132·0	158·	186·
8	··	31·0	41·4	64 0	87·5	112·8	139·	166·	196·
8½	··	··	43·8	67·5	92·4	119·	146·	175·	206·
9	··	··	46·3	71 2	97·5	125·	154·	183·	216·
9½	··	··	48·6	74·8	102·5	131·	161·	192·	226·
10	··	··	51·1	78·5	107·	137·	169·	200·	236·
10½	··	··	53·6	82·5	112·4	143·	176·	209·	246·
11	··	··	56·2	86·0	117·0	149·	183·	217·	255·
11½	··	··	58·5	89·5	122·	155·	191·	227·	265·
12	··	··	61·0	93·5	127·	161·	198·	235·	275·
12½	··	··	63·5	97·3	132·	167·	205·	243·	285·
13	··	··	66·0	101·0	137·	173·5	212·	252·	294·
13½	··	··	68·4	104 8	141·5	179·	219·	260·	304·
14	··	··	71·0	108·2	146·	185·	227·	269·	314·
14½	··	··	73·4	112·3	151·	192·	234·	277·	324·
15	··	··	75·8	115·7	156·	198·	242·	286·	334·
15½	··	··	78·1	119·0	161·	204·	250·	295·	344·
16	··	··	80·7	123·	166·	211·	257·	303·	353·
16½	··	··	83·1	126·5	170·5	217·	264·	312·	363·
17	··	··	85·5	130·	175·5	223·	271·	322·	373·
17½	··	··	87·8	133·5	180·5	229·	278·	330·	383·
18	··	··	90·5	137·	185·	235·	285·	338·	393·
18½	··	··	93·0	140·5	190·	241·	293·	347·	402·
19	··	··	95·5	144·8	195·	247·	300·	354·	412·
19½	··	··	97·8	148·5	200·	253·	307·	363·	422·
20	··	··	100·0	152·	205·	259·	315·	372·	432·
20½	··	··	102·5	156·	210·	265·	323·	381·	442·
21	··	··	105·0	159·5	215·	271·	330·	390·	452·
21½	··	··	107·5	163·	220·	277·	337·	398·	461·
22	··	··	110·0	166·5	226·	283·	344·	408·	471·

Millwright's Work,		£	s.	d.
Pipe, cast iron,				
for rain water	per yard	0	5	0
fountain heads for ditto	each	0	5	0
copper	per lb.	0	1	9
small or crooked	do.	0	2	2
tinned inside and out, 1¼ inch	per foot	0	2	0
do. 1½ do.	do.	0	2	6
do. 2 do.	do.	0	3	0
do. 2½ do.	do.	0	4	0
elm, 2 inches diameter	per yard	0	3	0
3 do.	do.	0	3	8
4 do.	do.	0	4	10
5 do.	do.	0	6	0
6 do.	do.	0	8	6
7 do.	do.	0	9	6
8 do.	do.	0	13	3
9 do.	do.	0	17	0
lead, ½ inch, cast	per foot	0	0	7
¾ do.	do.	0	0	10
1 do.	do.	0	1	6
1¼ do.	do.	0	1	10
1½ do.	do.	0	2	3
2 do.	do.	0	3	0
3 inch, milled	do.	0	2	6
3½ do.	do.	0	3	0
4 do.	do.	0	4	0
4½ do.	do.	0	5	0
5 do.	do.	0	6	0
5½ do.	do.	0	7	0
1¼ inch, soldered	do.	0	1	6
1½ do.	do.	0	2	0
2 do.	do.	0	3	0

Patent lead pipe,

Bore.	Common.	Middling.	Strong.
Inch.	s. d.	s. d.	s. d.
½	0 4	0 0	0 0
⅝	0 5½	0 0	0 0
¾	0 6½	0 7½	0 8½
1	0 9½	0 11½	1 0
1¼	1 0	1 2	1 3
1½	1 3	1 5	1 6
1¾	1 6	1 8	1 10
2	2 0	2 3	2 6
2½	2 6	2 10	3 2
3	3 2	3 6	4 0

Steam pipe. The steam pipe of an engine generally consists of the twenty-fourth part of the cylinder; for instance, the cylinder 26 inches diameter, thus: $26 \times 26 = 676 \times \cdot 7854 = 530 \cdot 9304$; area of the cylinder,

Millwright's Work, £ s. d.

Steam pipe, &c.,

530 inches. The pipe 5 inches diameter, then $5 \times 5 = 25 \times \cdot 7854 = 19\cdot 6350$, $19\cdot 5 \times 24 = 468$.

from this it will appear, that a cylinder of 26 inches diameter, will require the steam pipe to be 5 inches diameter, or thereabouts.

Plummer blocks of cast iron, with ditto caps, two bolts to each, fitted to the bearings turned on the shafts, pattern included.

					£	s.	d.
diameter of bearing,	1½	inches	....	per inch in width	1	1	0
do.	2	do.	....	do.	1	1	0
do.	2½	do.	....	do.	1	1	0
do.	3	do.	....	do.	1	1	0
do.	3½	do.	....	do.	1	1	0
do.	4	do.	....	do.	1	5	0
do.	4½	do.	....	do.	1	5	0
do.	5	do.	....	do.	1	5	0
do.	5½	do.	....	do.	1	5	0
do.	6	do.	....	do.	1	7	0
do.	6½	do.	....	do.	1	7	0
do.	7	do.	....	do.	1	10	0
do.	7½	do.	....	do.	1	10	0
do.	8	do.	....	do.	1	10	0
do.	8½	do.	....	do.	1	10	0
do.	9	do.	....	do.	1	10	0
do.	9½	do	....	do.	1	10	0
do.	10	do.	....	do.	1	15	0
do.	10½	do.	....	do.	1	15	0
do.	11	do.	....	do.	2	0	0
do.	11½	do.	....	do.	2	0	0
do.	12	do.	....	do.	2	2	0

Shafts of cast iron,

Diameter of bearing.	Per inch superficial, collars included.	Per inch in length between collars, the collars included.	Per bearing, the length equal to the diameter.
Inches.	s. d.	s. d.	£ s. d.
2	0 3½	4 6	0 9 0
3	0 3	4 6	0 13 6
4	0 2½	4 10½	0 17 6
5	0 2¼	5 3	1 6 3
6	0 2¼	5 8	1 14 0
7	0 2¼	6 1	2 2 4
8	0 2¼	6 9	2 14 3
9	0 2¼	7 4	3 5 7
10	0 2¼	7 11	3 19 3
11	0 2¼	8 6	4 3 9
12	0 2¼	9 2	4 8 3

MILLWRIGHT'S WORK, £ s. d.

Shafts, weight of, &c., square and round in cast iron, per foot run:

	SQUARE.	ROUND.		SQUARE.	ROUND.
2 ins.	13 lbs.	10½ lbs.	7¼ ins.	165 lbs.	133 lbs.
2¼	16	13	7½	177	142
2½	20	15½	7¾	188	151
2¾	24	18½	8	200	160
3	28	22½	8¼	213	170
3¼	33	26½	8½	226	180
3½	38	31½	8¾	239	190
3¾	44	35½	9	252	200
4	50	40	9¼	267	212
4¼	57	45½	9½	282	224
4½	64	51	9¾	297	237
4¾	71	56½	10	312	250
5	78	62	10¼	331	265
5¼	86	69	10½	350	280
5½	94	76	10¾	369	295
5¾	103	83	11	388	310
6	112	90	11¼	407	325
6¼	122	98	11½	426	340
6½	132	107	11¾	445	356
6¾	142	115	12	464	372
7	153	124			

		£	s.	d.
shafts, up to 2 inches, square or round, with two bearings, turned	per lb.	0	0	6
2 inches to 2½ inches	do.	0	0	5½
2½ do. 4 do.	do.	0	0	5
4 do. 6 do.	do.	0	0	4½
6 do. 9 do.	do.	0	0	4
9 do. 12 do.	do.	0	0	3½

Where shafts are turned extra, or in addition to the bearing at each end, for the plummer blocks, such additional turned part must be measured and charged at 1¾*d.* per inch, in addition to the price of the shaft.

Shafts, of wood,

		£	s.	d.
elm, of all sizes	per foot cube	0	8	6
fir do.	do.	0	7	0
oak, up to 18 inches	do.	0	9	0
ditto 2 feet	do.	0	11	0

the above includes mortising and letting in the gudgeons.

measure the largest part of the wood shaft for the charging dimension.

		£	s.	d.
staves, turned	per foot run	0	1	6
wallowers, with staves	per foot diameter	3	17	0
wash wheels, the rings, arms, and sides of elm, ribs of fir, 6 ft. diam., and 4 ft. wide	per foot diam.	5	5	0
ditto ditto 7 feet diam.	do.	5	10	0
wood horse yokes, of 4-inch elm	per pair	1	10	0

Water wheel work,

		£	s.	d.
elm rings, from 4½ to 5 inches thick, with oak griped arms to ditto	per foot diam.	2	0	0
oak rings from 4½ to 5 in. thick, &c.	do.	2	10	0

Millwright's Work, — £ *s.* *d.*

Water wheel work, &c.,

		£	*s.*	*d.*
oak starts, 3½ by 2	per foot run	0	1	6
floats and back boards of elm, prepared to size	per foot super.	0	0	10
over shot wheels, rings, and arms ready made, the rings 8 in. wide and 3 in. thick ..	per foot diam.	2	7	0
elm sole boards, risers, and buckets,	per foot super.	0	0	10
wrought iron floats bent to order.....	per lb.	0	0	10
Wheels, bevel, of wood, for the bevel, charge additional	per foot	0	5	0
windmill brakes, 9 inches wide......	per foot diam.	1	15	0
maltmill heads, with staves	do.	3	0	0
wallowers, with ditto	do.	3	17	0
spur nuts of elm, of 2 to 4 inch plank	do.	3	10	0

the cogs, in all cases, to be charged extra.

Wheels, of cast iron, both tooth and mortis, geared, pitched, chipped and filed, the pattern included in the price.

width of cog,	pr. ft. diam. £	*s.*	*d.*	width of cog,	per ft. diam. £	*s.*	*d.*
1 inch	£3	3	0	8¾ inches......	11	12	6
1¼	3	5	0	9	12	0	0
1½	3	10	0	9¼	12	5	0
1¾	3	15	0	9½	12	10	0
2	4	0	0	9¾	12	15	0
2¼	4	5	0	10	13	0	0
2½	4	10	0	10¼	13	5	0
2¾	4	15	0	10½	13	10	0
3	5	0	0	10¾	13	15	0
3¼	5	5	0	11	14	0	0
3½	5	10	0	11¼	14	10	0
3¾	5	15	0	11½	15	0	0
4	6	0	0	11¾	15	10	0
4¼	6	7	6	12	16	0	0
4½	6	15	0	12¼	17	0	0
4¾	7	2	6	12½	18	0	0
5	7	10	0	12¾	19	0	0
5¼	7	12	6	13	20	0	0
5½	7	15	0	13¼	20	10	0
5¾	7	17	6	13½	21	0	0
6	8	0	0	13¾	21	10	0
6¼	8	5	0	14	22	0	0
6½	8	10	0	14¼	22	10	0
6¾	8	15	0	14½	23	0	0
7	9	0	0	14¾	23	10	0
7¼	9	7	6	15	24	0	0
7½	9	15	0	15¼	24	10	0
7¾	10	2	6	15½	25	0	0
8	10	10	0	15¾	25	10	0
8¼	10	17	6	16	26	0	0
8½	11	5	0				

Wheels, lantern, made solid, and fitted together in two pieces, or halves, with wrought iron hoops and copper screws, &c.

		£	*s.*	*d.*
7 inches deep over all	per foot diam.	7	0	0
8 do.	do.	8	0	0
9 do.	do.	9	0	0

Millwright's Work,			£	s.	d.
Wheels, &c.,					
10 inches deep over all		per foot diam.	10	0	0
11 do.		do.	11	0	0
12 do.		do.	12	0	0
13 do.		do.	13	0	0
14 do.		do.	14	0	0
Wheels, overshot water, all of iron.					
a wheel 20 feet diameter, and 2 feet wide		each	350	0	0
24 do. do.		do.	420	0	0
28 do. do.		do.	470	0	0
32 do. do.		do.	535	0	
36 do. do.		do.	585	0	
for a wheel 2 feet wide		per foot diam.	16	16	0
do. 2 feet 3 inches wide		do.	18	18	0
do. 2 6 do.		do.	21	0	0
do. 2 9 do.		do.	23	2	0
do. 3 0 do.		do.	25	4	0
do. 3 3 do.		do.	27	6	0
do. 3 6 do.		do.	29	8	0
do. 3 9 do.		do.	31	10	0
do. 4 0 do.		do.	33	12	0
do. 4 3 do.		do.	35	14	0
do. 4 6 do.		do.	37	16	0
do. 4 9 do.		do.	40	0	0
do. 5 0 do.		do.	42	0	0
do. 5 3 do.		do.	44	2	0
do. 5 6 do.		do.	46	4	0
do. 5 9 do.		do.	48	6	0
do. 6 0 do.		do.	50	8	0

The millwright's table for water wheels,

Height of the fall of Water.	Velocity of the fall of Water per second.	Velocity of the Wheel per second.	Revolution of the Wheel per minute.
Feet.	ft. dec.	ft. dec.	rev. dec.
1	8 02	2·67	2·83
2	11·34	3·78	4·00
3	13·89	4·63	4·91
4	16·04	5·35	5·67
5	17·93	5·98	6 34
6	19·64	6·55	6·94
7	21·21	7·07	7·50
8	22·68	7·56	8·02
9	24·05	8·02	8·51
10	25·35	8·45	8 97
11	26·59	8·86	9·40
12	27·27	9·26	9·82
13	28·91	9·64	10·22
14	30·00	10 00	10·60
15	31·05	10·35	10·99
16	32·07	10 79	11·34
17	33·06	11·02	11·70
18	34·02	11·34	12·02
19	34·95	11·65	12·37
20	35·86	11·95	12·68

MILLWRIGHT'S WORK,		£	s.	d.
Wheels, tread 4 feet 6 inches diameter	per foot	2	10	0
do. 5 feet do.	do.	3	3	0
Wheels, wood,				
a horse wheel of any diameter, 4 in. thick	do.	2	14	0
do. 5 do.	do.	3	0	0
do. 6 do.	do.	3	6	0
do. 7 do.	do.	3	12	0
do. 8 do.	do.	3	18	0
the cogs, truss, arms, and braces, to be charged for extra.				
a horse wheel, including shaft, ground frame, yokes, cogs, braces, the iron and brass work, together with the labour of fixing and gearing, will amount to (according to the degree of strength) from 8*l*. 18*s*. to per foot, for good wheels		10	10	0
a framed wood wheel, exclusive of cogs of elm, from 7 to 9 inches thick, with through arms..	per foot	3	18	0
do. griped arms ..	do.	4	6	0
do. 10 to 12 in. thick, with through arms	do.	4	16	0
do. do. griped arms..	do.	5	10	0
Master's charges, &c.				
in attending workmen, giving instructions, exclusive of all reasonable expenses	per day	0	15	0
attending upon arbitrations, exclusive of expenses	per day	2	2	0

upon tradesmen's bills charge 20 per cent. profit upon cast iron as per founder's account; 25 per cent. upon brass ditto; 20 per cent. upon smith's ditto; 10 per cent. to be charged upon all timber provided by the employer.

all land and water carriage to be charged.

but the most regular, approved, and convenient method for ascertaining the price of any single article of work is in the manner following, viz. :—

	£	s.	d.
timber cost	£2	10	0
cast iron	5	0	0
brass	3	15	0
wrought iron	4	0	0
files......................	0	12	0
sundries	0	7	8
	£16	4	8

	£	s.	d.
The above being the actual cost of the materials used, add, therefore, to	£16	4	8
workmen's time, 12 days, at 7*s*. per day	4	4	0
for the use of tools, 2*s*. per day..........	1	4	0
for the profit, to this amount add one-fourth, viz.	5	8	2
Amount to Charge	£ 27	0	10

Labour prices only,		£	s.	d.
cogs, apple tree, for gearing wheels, up to 3 inches wide	each	0	0	2

MILLWRIGHT'S WORK,	£	s.	d.
Labour prices only,			
cogs, apple tree, above 3 inches wide, extra per inch in width .... each	0	0	0¾
beech, shanked to 3 inches wide, &c. .. do.	0	0	1½
ditto, above 3 inches wide, extra per inch in width .... each	0	0	0¾
hornbeam, shanked to 3 inches wide, &c. do.	0	0	2¼
ditto, above 3 inches wide, extra per inch in width .... each	0	0	1
oak, shanked as before .... do.	0	0	2¼
ditto, above 3 inches wide, extra per inch in width .... each	0	0	1
foreign live oak, shanked as before .... do.	0	0	4½
ditto, above 3 inches wide, extra per inch in width .... each	0	0	2
for wood wheels, not exceeding 12 in. long, in addition to the foregoing prices .. per inch	0	0	0½
labour, shanking .... each	0	0	3½
patterns for wheels, all above 18 in. diam.,			

width of cog,	pr. ft. diam.			width of cog,	per ft. diam.		
1 inch	£0	9	6	7¾	0	19	6
1¼	0	9	9	8	1	0	0
1½	0	10	0	8¼	1	0	6
1¾	0	10	3	8½	1	1	4
2	0	10	6	8¾	1	2	2
2¼	0	10	9	9	1	3	0
2½	0	11	0	9¼	1	4	0
2¾	0	11	3	9½	1	5	0
3	0	11	6	9¾	1	6	0
3¼	0	11	9	10	1	7	0
3½	0	12	0	10¼	1	8	0
3¾	0	12	3	10½	1	9	0
4	0	12	6	10¾	1	10	0
4¼	0	12	9	11	1	11	0
4½	0	13	0	11¼	1	12	0
4¾	0	13	6	11½	1	13	0
5	0	14	0	11¾	1	14	0
5¼	0	14	6	12	1	15	0
5½	0	15	0	12¼	1	16	0
5¾	0	15	6	12½	1	17	0
6	0	16	0	12¾	1	18	0
6¼	0	16	6	13	1	19	0
6½	0	17	0	13¼	2	0	0
6¾	0	17	6	13½	2	2	0
7	0	18	0	13¾	2	4	0
7¼	0	18	6	14	2	6	0
7½	0	19	0				

	£	s.	d.
riggers of wood,			
above 20 inches diameter, single grooved, and made of 4-inch elm .... per foot diam.	0	4	6
double ditto .... do.	0	4	0
under 18 inches................ do.	0	4	0
double ditto .... do.	0	4	0
under 12 inches................ do.	0	4	0
iron, covered with wood, for straps or ropes per foot diam	0	10	6

Millwright's Work, £ s. d.

Labour prices only,

shafts, of cast iron, collars included, per in. sup.,

	£	s.	d.		£	s.	d.
2 inches....	£0	0	1	5¼ inches....	£0	0	0¾
2¼	0	0	1	5½	0	0	0¾
2½	0	0	1	5¾	0	0	0¾
2¾	0	0	1	6	0	0	0¾
3	0	0	0¾	6¼	0	0	0¾
3¼	0	0	0¾	6½	0	0	0¾
3½	0	0	0¾	6¾	0	0	0¾
3¾	0	0	0¾	7	0	0	0½
4	0	0	0¾	7¼	0	0	0½
4¼	0	0	0¾	7½	0	0	0½
4½	0	0	0¾	7¾	0	0	0½
4¾	0	0	0¾	8	0	0	0½
5	0	0	0¾				

	£	s.	d.
shafts of wood, elm, any size .... per foot cube	0	2	0
do. fir .... do.	0	1	6
do. oak .... do.	0	2	6
staves of beech or hornbeam, turned.. per foot run	0	0	3
wallowers, with staves .... per foot diam.	0	15	0
wash wheels, the rings, arms, and sides of elm, &c.,			
6 feet diameter, and 4 feet wide.. per foot diam.	1	5	0
7 feet ditto ditto .. do.	1	7	0
wood horse yokes, of 4-inch elm.......... per pair	0	7	6
water wheel work, elm rings, from 4½ to 5 inches thick, with oak griped arms to ditto, per ft. diam.	0	10	0
oak rings, from 4½ to 5 inches thick do.	0	12	6
ditto starts.................... per foot run	0	0	4
floats and back boards of elm, prepared to size per foot sup.	0	0	2½
overshot wheels, rings and arms, &c., per ft. dia.	0	12	0
sole boards, risers, buckets, &c., to ditto per foot sup.	0	0	2
wheels, bevel of wood,			
for the bevel charge, in addition...... per foot	0	1	6
windmill breaks, 9 inches wide .... per foot diam.	0	9	0
maltmill heads with staves .... do.	0	15	0
wallowers, with staves .... do.	0	18	0
spur nuts, with ditto .... do.	0	16	0

wheels of cast iron, tooth and mortis geared, pitched, chipped, and filed, including pattern:—

width of cog,	pr. ft. diam.			width of cog,	pr. ft. diam.		
2 inches....	£1	0	0	5¼ inches......	1	18	0
2¼	1	1	0	5½	1	18	6
2½	1	2	0	5¾	1	19	0
2¾	1	3	6	6	2	0	0
3	1	5	0	6¼	2	1	0
3¼	1	6	6	6½	2	2	0
3½	1	8	0	6¾	2	3	0
3¾	1	9	0	7	2	4	0
4	1	10	0	7¼	2	5	0
4¼	1	11	6	7½	2	6	6
4½	1	13	0	7¾	2	8	0
4¾	1	15	0	8	2	10	0
5	1	17	6	8¼	2	12	0

Millwright's Work, £ s. d.

Labour prices only,

width of cog,	pr. ft. diam.	width of cog,	pr. ft. diam.
8½ inches....	£2 14 0	11½ inches......	3 15 0
8¾	2 17 0	11¾	3 17 6
9	3 0 0	12	4 0 0
9¼	3 1 6	12¼	4 5 0
9½	3 3 0	12½	4 10 0
9¾	3 4 6	12¾	4 15 0
10	3 6 0	13	5 0 0
10¼	3 7 0	13¼	5 5 0
10½	3 8 0	13½	5 10 0
10¾	3 9 0	13¾	5 15 0
11	3 10 0	14	6 0 0
11¼	3 12 6		

pitching and trimming, including filing, p. in. sup. 0 0 1
measurement to be taken from the pattern, and not from the wheel.

wheels of wood,

a horse wheel, of any diam.,	4 in. thick,	per foot	0 12 0
do.	5 do.	do.	0 13 6
do.	6 do.	do.	0 15 0
do.	7 do.	do.	0 16 6
do.	8 do.	do.	0 18 0

The cogs to be charged extra.

PRICES OF PORTABLE STEAM-ENGINES, WITH TUBULAR BOILERS COMPLETE.

Horse-power.	Diameter of Cylinder.	Length of stroke.	Price.
1	3 inches.	6½ inches.	£45
2	4½ "	9 "	65
3	5½ "	11 "	85
4	6½ "	13 "	105
5	7½ "	14 "	125
7	8½ "	14 "	150
9	9½ "	16 "	180
11	10¾ "	18 "	210
13	11¾ "	20 "	240
16	13 "	22 "	275
20	14½ "	24 "	310
25	11½ Pr.	20 "	370

The following formulæ, with some modification and improvement, are extracted from Nystrom's Mechanics, an American publication designed for the use of engineers. To render them more generally available to the practical workman, they are reduced, at page 268, &c., to the form of verbal rules, each of which is to be employed in connection with the figure to which the number prefixed to the rule refers.

HYDRAULICS.

Let the vessel A, Fig I., be kept constantly full of water up to the water line w. In two horizontal faces lower than the water line w, are made orifices a and a', through which the water will pass up vertical nearly to the water line w. Omitting the resistance of air, &c., the jet should theoretically reach the water line w; practically it reaches $0{\cdot}967h$.

It is evident that the velocity of the *jet* through the orifices, must be the velocity due to a body falling the height h, according to the law of force of gravity.

Letters denote.

Q = actual quantity of water discharged per second or in the time t, in cubic feet.

h = head, or height of water over the orifice.

t = operating time in seconds.

a = area of the orifice in square feet.

m = the coefficient for contraction. (See Table, p. 261).

G = gallons of 277 cubic inches discharged in the time t.

V = velocity through the orifice in feet per second.

Example 1. Fig. I. How many gallons of water will be discharged in five minutes, through an orifice of 0·025 square feet, applied at 8 feet under the level of the water?

$$G = 31{\cdot}5 a t \sqrt{h} = 31{\cdot}5 \times 0{\cdot}025 \times 5 \times 60 \sqrt{8} = 667 \text{ gallons.}$$

Fig. II. The weight P can represent the weight of a column of water whose height $= \frac{P}{62{\cdot}5A} = \frac{h'}{0{\cdot}967}$, acting on the area A.

Fig. III. n = number of down strokes per minute, s=stroke of piston; the air vessel $C = 6\,A\,s$ at the pressure of the atmosphere.

Example 2. Fig. III. How many double strokes must be made per minute by the lever of a hand pump, to throw up 22 cubic feet of water 18 feet high, in the time of 8 minutes and 15 seconds; the lever $l = 30$ inches, $e = 8$ inches, $s = 0{\cdot}6$ feet, $F = 20$ pounds? $8 \times 60 + 15 = 495$ seconds.

$$n = \frac{3630\,Q\,h'\,e}{t\,s\,F\,l} = \frac{3630 \times 22 \times 18 \times 8}{495 \times 0{\cdot}6 \times 20 \times 30} = 64{\cdot}5 \text{ strokes per min.}$$

Example 3. Fig. XI. A vessel of rectangular form is of dimensions $A = 6$ square feet, the height $h = 5$ feet. What time will it take the water level to sink 2 feet, when the orifice $a = 0{\cdot}212$ square feet?

$$t = \frac{A\,(\sqrt{h} - \sqrt{h'})}{4 \times {\cdot}64\,a} = \frac{6\,(\sqrt{5} - \sqrt{3})}{2{\cdot}56 \times {\cdot}212} = 5{\cdot}6.$$

MOTION OF WATER IN PIPES.

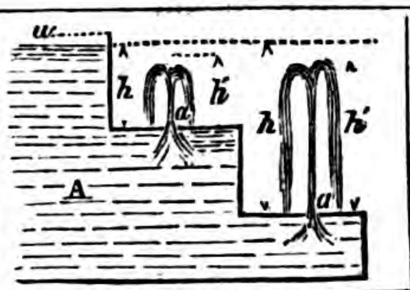
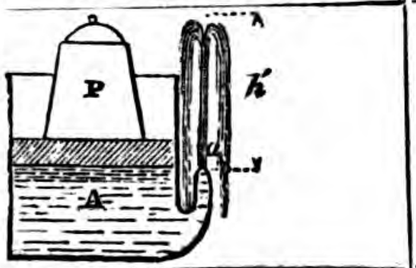
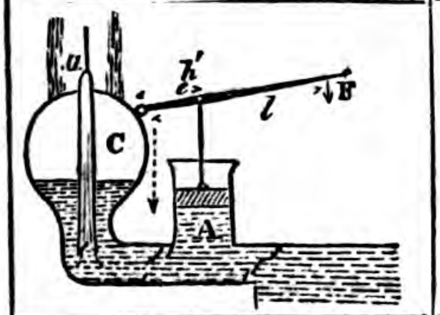
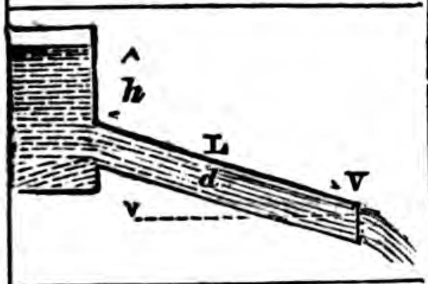
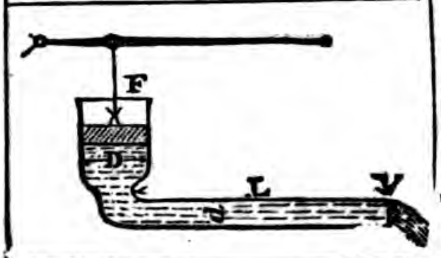
Letters denote.

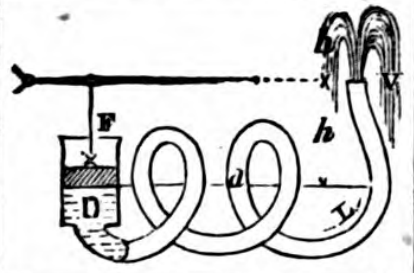
L = extreme length of the pipe in feet.

d = inside diameter in feet, and uniform throughout the length L.

Example 4. Fig. IV. What will be the velocity of the water through a pipe of 0·45 feet inside diameter, and L=68 feet long, the head pressure of water being h=8 feet?

$$V=48\sqrt{\frac{0{\cdot}45\times 8}{68+50\times 0{\cdot}45}}=9{\cdot}6 \text{ feet per second.}$$

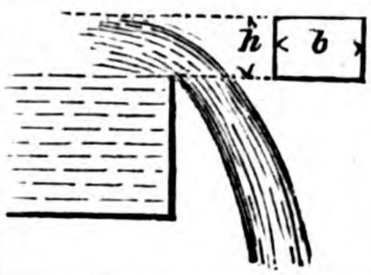
	I. $V=8{\cdot}02\sqrt{h}$ $Q=m\,a\,t\,8{\cdot}02\sqrt{h}=5{\cdot}05\,a\,t\sqrt{h}$ $G=31{\cdot}5\,a\,t\sqrt{h}$, $m=0{\cdot}63$, $jet=0{\cdot}967h$, $h=\dfrac{Q^2}{25{\cdot}5\,a^2\,t^2}$, $=h'$.
	II. $V=1{\cdot}015\sqrt{\dfrac{P}{A}}$, $Q=a\,t\sqrt{\dfrac{P}{A}}$, $G=6{\cdot}2\,a\,t\sqrt{\dfrac{P}{A}}$, $h'=\dfrac{P}{64{\cdot}6A}$.
	III. $Q=a\,t\sqrt{\dfrac{F\,l}{A\,e}}$, $n=\dfrac{3630\,Q\,h'\,e}{t\,s\,F\,l}$, $G=6{\cdot}2\,a\,t\sqrt{\dfrac{F\,l}{A\,e}}$, $h'=\dfrac{F\,l}{64{\cdot}6\,A\,e}$.
	IV. *Motion of Water in Pipes.* $V=48\sqrt{\dfrac{d\,h}{L+50d}}$, $Q=37{\cdot}7\,d^2\sqrt{\dfrac{d\,h}{L+50d}}$, $d=0{\cdot}24\sqrt[5]{\dfrac{L\,Q^2}{h}}$, $h=\dfrac{Q^2\,(L+50d)}{1421\,d^5}$.
	V. *Motion of Water in Pipes.* $V=6.86\sqrt{\dfrac{d\,F}{D(L+50d)}}$, $Q=5{\cdot}38\,d^2\sqrt{\dfrac{d\,F}{D(L+50d)}}$ $d=1{\cdot}68\sqrt[5]{\dfrac{L\,D\,Q'}{F}}$, $F=\dfrac{Q^2\,D(L+50d)}{29d^5}$.



VI.

$$V = 6{\cdot}86\sqrt{\frac{d\,(F-49\,D^2h)}{D\,(L+50d)}},\quad Q = 5{\cdot}38\;Vd^2t$$

$$h = \frac{V^2}{66{\cdot}5},\quad h' = \frac{D\sqrt{s\,n}}{57{\cdot}65d}.$$

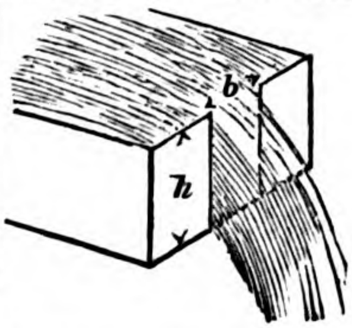


VII.

Weirs.

$Q = k\,b\,t$. See Table for *Weirs, p.* 262.

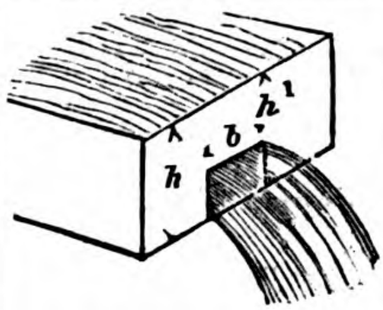
$$t = \frac{Q}{k\,b},\qquad b = \frac{Q}{k\,t}.$$



VIII.

$$Q = 5{\cdot}35m\,b\,h\,t\sqrt{h},$$
$$G = 33m\,b\,h\,t\sqrt{h},$$

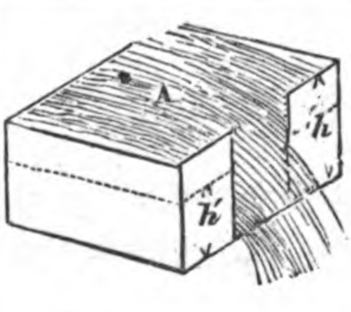
$$t = \frac{Q}{5{\cdot}35\,m\,b\,h\,\sqrt{h}}.$$



IX.

$$Q = 5{\cdot}35m\,b\,t\,(h\sqrt{h} - h'\sqrt{h'}),$$
$$G = 33m\,b\,t\,(h\sqrt{h} - h'\sqrt{h'}),$$

$$t = \frac{Q}{5{\cdot}35m\,b\,(h\sqrt{h} - h'\sqrt{h'})}.$$

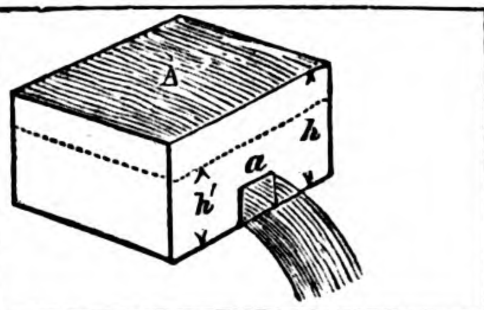


X.

$$t = \frac{0{\cdot}95m\,A\,(\sqrt{h} - \sqrt{h'})}{b\sqrt{h\,h'}},$$

A = area of the vessel in square feet.

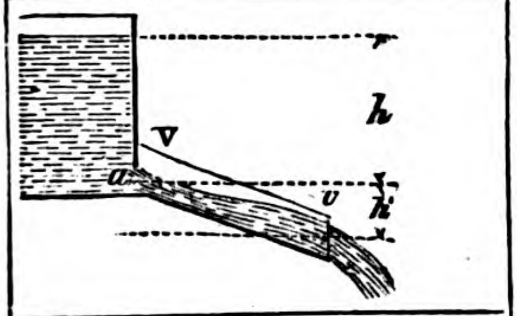
t = time in seconds, in which the water level will sink the space $h - h'$.



XI.

$$t = \frac{A(\sqrt{h} - \sqrt{h'})}{4ma},$$

$$Q = 4mat(\sqrt{h} + \sqrt{h'}).$$



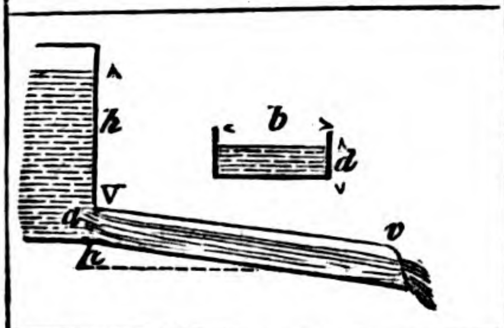
XII.

Short Drain.

$$V = \frac{8\cdot02\sqrt{h}}{\sqrt{1 + \left(\frac{1}{m} - 1\right)^2}}$$

$$v = \sqrt{V^2 + 32\cdot1\, h'},$$

$Q = a\, m V t$. *From V to v about* $6\sqrt{a}$.



XIII.

Long Drain.

$$V = \frac{8\cdot02\sqrt{h}}{\sqrt{1 + \left(\frac{1}{m} - 1\right)^2}},$$

$$v = \sqrt{\left(V^2 + 64\cdot32h' - 0\cdot007\,\frac{s\,l\,V^2}{a}\right)}$$

$s = b + 2d$ $\qquad$ $l = V$ *to* v, *feet.*

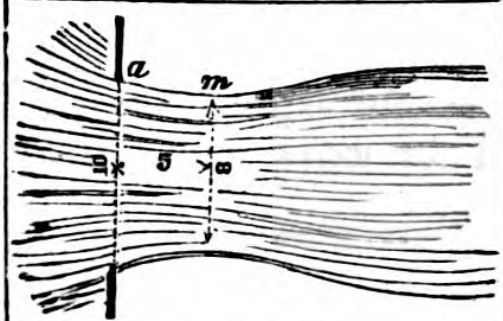
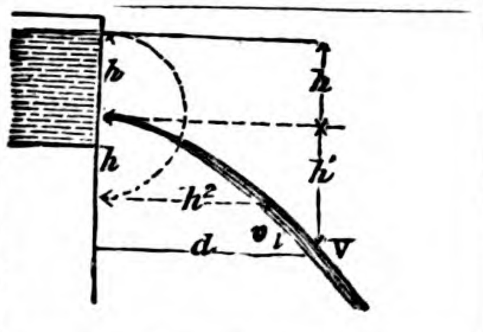


Table for the Contracted Vein.

$a : m = 10^2 : 8^2$. $\qquad m = 0\cdot64\, a$.

$m = 0\cdot64$	*when*	*contracted on*	4 *sides.*
$m = 0\cdot72$	,,	,,	3 *sides.*
$m = 0\cdot8$	,,	,,	2 *sides.*
$m = 0\cdot9$	,,	,,	1 *side.*



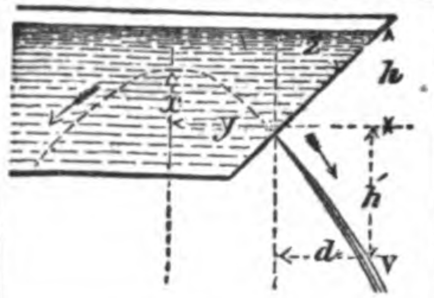
XIV.

The form of the Vein is a Parabola.

$d = 2\sqrt{hh'}$, $\qquad V = 8\sqrt{h + h'}$

$Q = 8\, m\, a\, t\, \sqrt{h}$,

$\tan. v = \frac{2h'}{d}$, $\qquad h = \frac{d^2}{4h'}$.



XV.

$x = h \sin.^2 z \qquad y = h \sin. z \cos. z.$

$$d = 2\sqrt{(h' + x)(h - x)} - y$$

$$Q = 8\, m\, a\, t \sqrt{h} \qquad V = 8\sqrt{(h + h'.)}$$

Example 5. Fig. VI. Required the velocity and quantity of water discharged in a long pipe or hose of $L = 135$ feet long, and $d = 0{\cdot}17$ feet, attached to a hand-pump of $D = 0{\cdot}2$ feet in diameter $P = 44$ pounds, and the end of the pipe elevated $h = 20$ feet above the piston D?

$$V = 6{\cdot}86\sqrt{\frac{0{\cdot}17(44 - 49 \times 0{\cdot}2^2 \times 20)}{0{\cdot}2(135 + 50 \times 0{\cdot}17)}} = 1{\cdot}95 \text{ feet per second.}$$

$Q = 1{\cdot}95 \times 5{\cdot}38 \times 0{\cdot}2^2 = 0{\cdot}042$ per second $\times 60 = 2{\cdot}52$ cubic feet per minute.

$s = 0{\cdot}8$ feet the stroke of piston, we shall have

$$n = \frac{2{\cdot}52}{0{\cdot}8 \times 0{\cdot}785 \times 0{\cdot}2^2} = 100 \text{ strokes per minute.}$$

TABLE FOR WATER FLOWING OVER WEIRS.

This Table is set up from careful experiments on a large scale, and is suited for *weirs* only. See Fig. VII.

h. inches.	*h. feet.*	*m.*	*k.*
0·4	0·033	0·424	0·01365
0·8	0·066	0·417	0·05452
1·2	0·100	0·412	0·10592
1·6	0·133	0·407	0·16616
2·4	0·200	0·401	0·29171
3·2	0·266	0·397	0·44480
4·	0·333	0·395	0·63111
6·	0·500	0·393	1·1295
8·	0·666	0·390	1·7464
9·	0·750	0·385	2·0331
12·	1·000	0·376	3·1350

Rule. Multiply the width b in feet, of the *weir*, by the coefficient k, and the product is the quantity of water discharged per second, in cubic feet. h is the height as represented by Fig. VII. The width b should be $b > h$.

Example 6. How much water will flow over a weir of $b=5$ feet, $h=0·5$ feet in one minute?

$$Q = k\,b\,t = 1·1295 \times 5 \times 60 = 338·35 \text{ cubic feet.}$$

HYDRODYNAMICS.—WATER POWER.

The natural effect concentrated in a fall of water, is equal to the weight of the quantity of water passed through per second multiplied by the vertical space it falls.

Fig. XII. Let Q be the quantity of water which passes through the orifice a in the time $t = 1$ second, in cubic feet of 62·5 pounds each.

h = the vertical space the water falls; then the value or natural effect of the fall is at the orifice a,

$$P = 62·5\;Q\,h, \text{ effects.}$$

But, $Q = 5·06 a \sqrt{h}$, then we have

$$P = 315·5\;a\,h\sqrt{h}.$$

This will be in horse-power,

$$H = 0·573\;a\,h\sqrt{h}, \quad h = \frac{1}{1·07}\sqrt[3]{\frac{H^2}{a^2}},$$

$$H = 0·1134 Q\,h, \qquad h = \frac{H}{0·1134\;Q}.$$

Example 1. In a creek passes 18 cubic feet of water per second. How high must that creek be dammed up to produce an effect of 10 horses?

$$h = \frac{10}{0·1134 \times 18} = 4·9 \text{ feet, the answer.}$$

WATER-WHEELS.

Water-wheels are of two essential kinds, namely, *Vertical* and *Horizontal.*

The *Vertical* are subdivided into

Overshot-wheels, Undershot-wheels, ***Breast-wheels,*** and *High-breast* and *Low-breast wheels.*

The *Horizontal* are *with Floats, Screw-wheels, Turbin, Reaction-wheels, &c.*

Water-wheels do not transmit in full the natural effect concentrated in a fall of water; under most favourable circumstances 80 per cent. has been utilised, but under poor arrangements only 20 per cent. may be expected.

Example 1. Fig. XVI. The vertical section of the immersed floats of an undershot-wheel in a mid-stream is $\mathbf{a} = 27$ square feet, velocity of the stream $V = 8{\cdot}6$, and $v = 4$ feet per second. Required the horse-power of the wheel, $H = ?$

$$H = \frac{\mathbf{a}\,v}{200}(V - v)^2 = \frac{27 \times 4}{200}(8{\cdot}6 - 4)^2 = 11{\cdot}4 \text{ horses.}$$

Example 2. Fig. XXI. On a breast-wheel is acting $Q = 88$ cubic feet of water per second, the head $h = 8$ feet, velocity of the wheel at the centre of the buckets $v = 5$ feet per second; the water strikes the buckets at an angle $u = 8°$ and velocity $V = 7$ feet per second. Required the horse-power of the wheel, $H = ?$

$$H = \frac{88}{11{\cdot}4}\left(8 + \frac{5}{25}(7 \times \cos.\ 8° - 5)\right) = 65 \text{ horses.}$$

Example 3. Required the effect of Poncelet's wheel, the head $h = 4$ feet, and the orifice $a = 5$

square feet, the velocity of the wheel at the centre of pressure of the floats is $v = 6{\cdot}78$ feet per second.

$$V = 6{\cdot}91\sqrt{4} = 13{\cdot}82 \text{ feet per second.}$$

$$Q = 6{\cdot}5 \times 5 \times \sqrt{4} = 65 \text{ cubic feet per second.}$$

$$H = \frac{65 \times 6{\cdot}78}{197}(13{\cdot}82 - 6{\cdot}78) = 15{\cdot}8 \text{ horses.}$$

Example 4. Fig. XXIII. A saw-mill wheel is to be built under a fall of $h = 18$ feet, and to make $n = 110$ revolutions per minute. Required the proper diameter of the wheel.

$$D = \frac{100}{110}\sqrt{18} = 3{\cdot}857 \text{ feet,}$$

at the centre of pressure of the buckets.

$$\text{Velocity } V = 8\sqrt{18} = 33{\cdot}94 \text{ feet per second.}$$

$$\text{Velocity } \quad v = \frac{3{\cdot}14 \times 3{\cdot}857 \times 110}{60} = 22{\cdot}2 \text{ feet per second.}$$

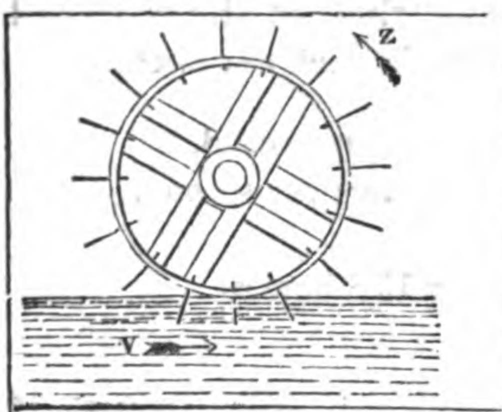
The fall discharged 30 cubic feet of water per second. Required the horse-power of the wheel $H = ?$

$$H = \frac{30 \times 22{\cdot}2}{200}(33{\cdot}94 - 22{\cdot}2) = 39 \text{ horses.}$$

How many square feet of dry Pine can it saw per hour?

$$30 \times 39 = 1170 \text{ square feet.}$$

The saw is meant to be applied direct on the wheel shaft.



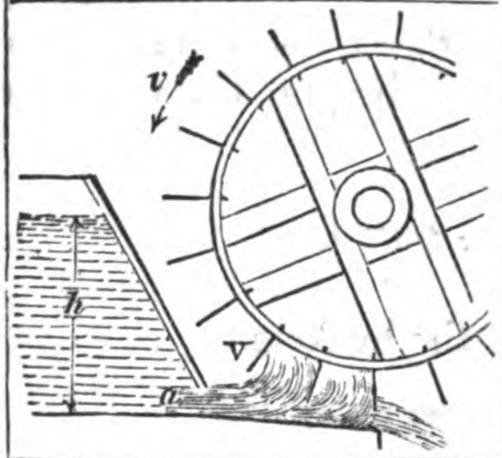
XVI.

Undershot Wheel in a mid-stream.

$$H = \frac{\mathbf{a}\, v}{200}(V - v)^2,$$

When $V = 2v$ about, the effect will be,

$$H = \frac{\mathbf{a}\, V^3}{1600},\ \mathbf{a} = \text{area of float.}$$



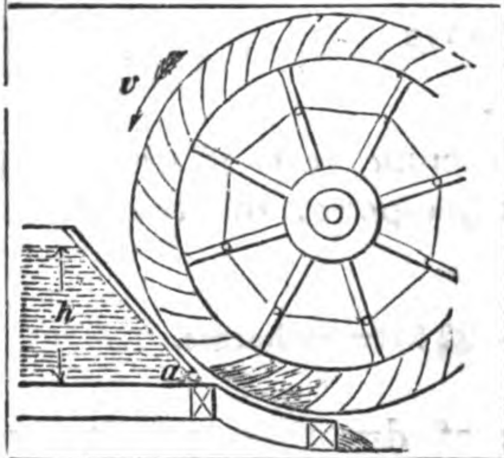
XVII.

Undershot Wheel.

$$H = \frac{Q\, v}{454}(V - v),$$

$$H = \frac{m\, a\, v}{86\cdot8}(V - v)\sqrt{h}$$

When $V = 2v$, about, $H = \dfrac{a\, h \sqrt{h}}{0\cdot47}$.



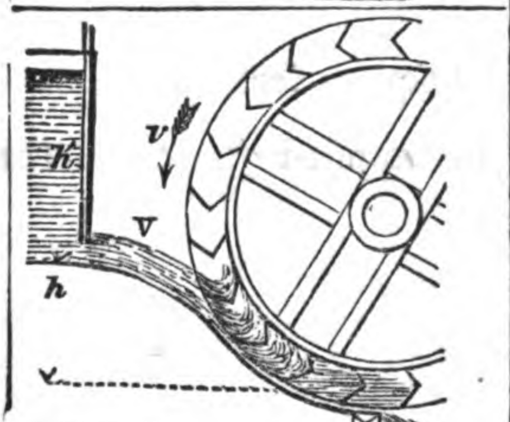
XVIII.

Poncelet's Wheel.

$$H = \frac{Q\, v}{228}(V - v), \text{ when } h > 5 \text{ feet},$$

$$H = \frac{Q\, v}{197}(V - v), \text{ when } h < 5 \text{ feet},$$

$Q = 8ma\sqrt{h}$, $\quad V = 6\cdot91\sqrt{h}$.

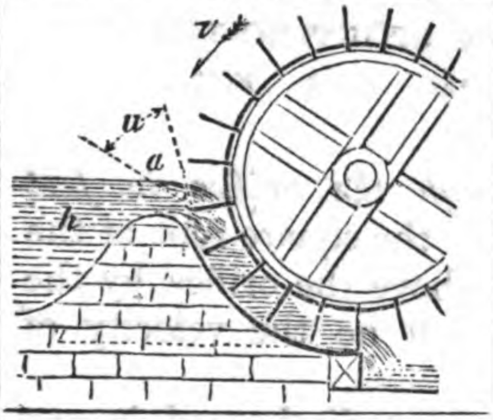


XIX.

Breast-Wheel with Parabolic drain.

$$H = \frac{Q}{12}\left[h + \frac{v}{28}(V - v)\right],$$

$Q = 6\cdot5a\sqrt{h}$.

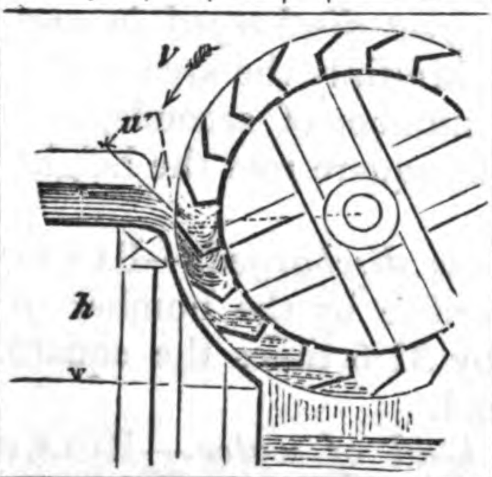


XX.

Low-breast Wheel.

$$H = \frac{Q}{11 \cdot 2}\left[h + \frac{v}{32}(V \cos u - v)\right]$$

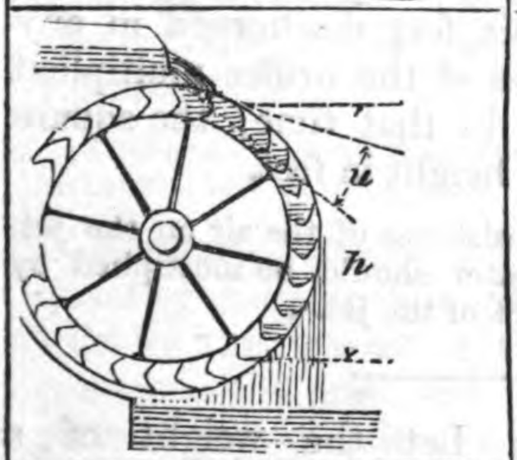
$Q = kb$, $V = \frac{Q}{a}$. See table for weirs.



XXI.

Breast Wheel.

$$H = \frac{Q}{11 \cdot 4}\left[h + \frac{v}{25}(V \cos u - v)\right]$$



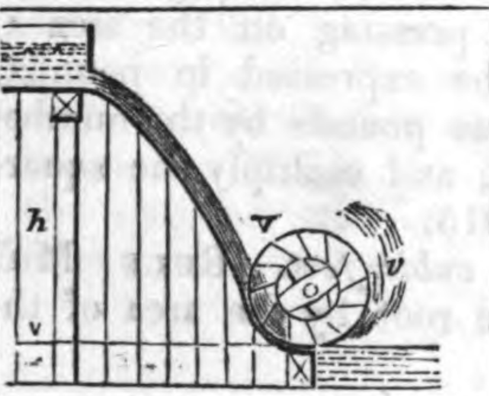
XXII.

Overshot Wheel.

$$H = \frac{Q}{13 \cdot 7}\left[h + \frac{v}{21 \cdot 5}(V \cos u - v)\right]$$

Proper velocity about $n = \frac{35D + 100}{D}$

revolutions per minute.



XXIII.

Saw-Mill Wheel.

$$H = \frac{Qv}{200}(V - v)$$

Proper diameter of the Wheel,

$D = \frac{100}{n}\sqrt{h}$, *in feet,*

n = *revolutions per min.*

RULES FOR JETS, OR FLUIDS SPOUTING THROUGH ORIFICES DERIVED FROM THE FOREGOING FORMULÆ.

I. *For the velocity through the orifice in feet per second.*—Rule: Multiply the square root of the height of the head of water above the orifice by the number 8·02, the product will be the velocity of issue.

For the number of cubic feet discharged in any number of seconds.—Rule: Multiply the area of the orifice in square feet by the number of seconds, and the product by 5·05 times the square root the height of the head of water.

For the number of gallons discharged.—Rule: Multiply the area of the orifice by the number of seconds, and the product by 31·5 times the square root of the height of the head.

For the height of the head of water.—Rule: Divide the number of cubic feet discharged in any time by 5·05 times the area of the orifice multiplied by the number of seconds in that time; the square of the quotient will be the height in feet.

Note.—To allow for the resistance of the air on the jet, the height of the head of water should be multiplied by ·967; the product is the height of the jet.

II. *Velocity.*—Rule: Let the weight of a column of water which, pressing on the area A, would produce the jet, be expressed in pounds; divide the number of these pounds by the number of square feet in the area, and multiply the square root of the quotient by 1·015.

Quantity discharged in cubic feet.—Rule: Multiply the preceding square root by the area of the orifice, and by the number of seconds in the time, the product will be the quantity in cubic feet.

Quantity discharged in gallons.—RULE: Multiply the quantity discharged in cubic feet by 6·2; the product will be the number of gallons.

Height of the jet allowing for the resistance of the air.—RULE: Divide the weight of the column of water capable of producing the jet by the area A, on which it presses, and also by the number 64·6; the quotient will be the height of the jet.

III. *Quantity discharged in cubic feet.*—RULE: Multiply the entire length of the lever by the number of pounds (the force) applied to its extremity. Multiply also the area of the piston by the length of that part of the lever between the piston-rod and the fulcrum. Divide the former product by the latter, take the square root of the quotient, and then multiply this square root, the area of the orifice, and the number of seconds together.

NOTE.—It is matter of indifference whether the lever be measured in feet or inches.

Number of strokes per minute.—RULE: Find the quantity discharged in cubic feet as above. Multiply this by the height of the jet in feet, due to the pressure on A, and also by the distance between the piston-rod and fulcrum, and then multiply the product by 3630. Again, multiply together the applied force in pounds, the length of the lever, the length of the stroke in feet, and the number of seconds in the time. Divide the former product by the latter: the quotient will be the number of strokes per minute.

Number of gallons discharged in any time.—RULE: Multiply the quantity discharged in cubic feet by 6·2; the product will be the number of gallons.

Height of the jet due to the pressure on A.—RULE: Multiply the applied force in pounds by the length of the lever. Also multiply together the area of the piston in square feet, the distance between the piston-rod and fulcrum, and the number 64·6. Divide the former product by the latter, and the quotient will be the height of the jet due to the pressure on A.

RULES FOR THE MOTION OF WATER IN PIPES.

IV. *For the velocity of delivery.*—RULE: Multiply the inner diameter of the pipe in feet by the height in feet of the head of water above the point of delivery. Add the entire length of the pipe in feet to 50 times the inner diameter. Divide the former product by the sum. Extract the square root of the quotient, and multiply that root by 48.

For the cubic feet delivered in a second.—RULE: Take the square root found above, and multiply it by 37·7 times the square of the diameter of the pipe; the product will be the number of cubic feet discharged in a second.

For the diameter of the pipe.—RULE: Multiply the square of the number of cubic feet delivered, found as above, by the length of the pipe, divide the product by the height of the head above the point of delivery; take the *fifth* root of the quotient, and multiply it by ·24; the product will be the inside diameter in feet.

For the height of the head of water.—RULE: Add the length of the pipe to 50 times the inner diameter, and multiply the sum by the square of the number of cubic feet discharged in a second. Divide the product by 1421 times the fifth power of the diameter; and the quotient will be the height of the head.

V. *For the velocity of the discharge.*—RULE: Multiply the force in pounds acting on the piston by the inner diameter of the pipe. Multiply the length of the pipe increased by 50 times its diameter by the diameter of the piston—all the measures being taken in feet. Divide the former product by the latter, and multiply the square root of the quotient by 6·86; the product will be the velocity per second in feet.

For the cubic feet delivered per second.—RULE: Multiply the square root, found as above, by 5·38 times the square of the inner diameter of the pipe in feet; the product will be the number of cubic feet delivered.

For the diameter of the pipe.—RULE: Multiply together the length of the pipe, the diameter of the piston, and the square of the number of cubic feet discharged per second. Divide the product by the force in pounds acting on the piston, and multiply the *fifth* root of the quotient by 1·68; the product will be the diameter in feet.

For the force applied to the piston.—RULE: Multiply the length of the pipe increased by 50 times its diameter by the diameter of the piston, and by the square of the number of cubic feet delivered in a second. Multiply the fifth power of the diameter of the pipe by 29. Divide the former product by the latter; the quotient will be the force in pounds acting on the piston.

VI. *For the velocity of discharge.*—RULE: Multiply 49 times the elevation of the point of discharge above the piston by the square of the piston's diameter: subtract the product from the number of pounds acting on the piston, and multiply the remainder by the inner diameter of the pipe. Multiply the diameter of the piston by the length of the pipe increased by 50 times its diameter. Divide the last product by this, and multiply the square root of the quotient by 6·86; the result will be the velocity per second of the issuing water.

For the cubic feet delivered.—RULE: Multiply together the velocity determined as above, the square of the inner diameter of the pipe, the number of seconds in the time, and the number 5·38; the product will be the number of cubic feet delivered in that time.

For the height above the end of the pipe to which the water spouts.—RULE: Divide the square of the issuing velocity by 66·5, the quotient will be the height in feet, allowing for the resistance of the air.

Or, multiply the number of strokes per minute by the length of the stroke, and the square root of the product by the diameter of the piston: then divide the result by 57·65 times the inner diameter of the pipe.

For the number of strokes of the piston per minute (see ex. 5).—RULE: Multiply together the length of the stroke, the square of the diameter of the piston, and the number ·785, and divide the number of cubic feet discharged per *minute* by the product.

RULES FOR WEIRS (See the Table, p. 262).

VII. *For the cubic feet discharged in any number of seconds.*—RULE: Multiply together the number of seconds, the width of the weir in feet, and the coefficient k taken out of the table : the product will be the number of cubic feet discharged in the time.

For the time of discharging any number of cubic feet.—RULE ; Divide the number of cubic feet by k times the width of the weir: the quotient will be the number of seconds.

For the width necessary for a given discharge in a given time.—RULE: Divide the number of cubic feet in the quantity to be discharged in the time by k times the number of seconds in that time.

VIII. *For the cubic feet discharged in any time.*—RULE: Multiply together the height, the square-root of the height, the number of seconds, the width of the aperture, the number m, taken out of the table for the contracted vein, and the number 5·35: the product of these six numbers will give the number of cubic feet discharged in the given time.

For the number of gallons discharged.—RULE: Multiply together the height, the square root of the height, the number of seconds, the width of the aperture, the number m, from the table for contraction, and the number 33; the product of these six numbers will be the number of gallons discharged.

For the time of discharging a given number of cubic feet.—RULE: Multiply together the height, the square root of the height, the width of the aperture, the number m from the table, and the number 5·35. Divide the given number of cubic feet by the product, and the quotient will the number of seconds required.

IX. *For the cubic feet discharged in any given time.*—RULE: Multiply the height of the level of the water above the bottom of the issuing stream by the square root of that height. Multiply the height of the water-level above the top of the issuing stream by the square root of that height. Subtract this product from the former, and multiply the difference by the width of the aperture, the number of seconds in the time, the number *m* from the table, and the number 5·35. The product of these five numbers will be the number of cubic feet discharged.

For the number of gallons discharged.—RULE: Take the product of the first *four* of the numbers multiplied together in the preceding rule, and instead of the fifth multiplier there used, employ the multiplier 33; the product of the five numbers will be the number of gallons discharged in the time.

For the time of discharging a given number of cubic feet.—RULE: Multiply the height of the water-level above the bottom of the issuing stream by the square root of that height. Multiply the height of the water-level above the top of the issuing stream by the square root of that height. Subtract this product from the former. Multiply the difference by the width of the aperture, the number *m* from the table, and the number 5·35. Divide the number of cubic feet discharged by this product, and the quotient will be the number of seconds in the time.

X. *For the time in which the water-level will sink through a given space.*—RULE: Take the square root of the entire height of the water-level from the bottom of the issuing stream, as also the square root of the height of the level to which it is to sink, above the bottom. Subtract the latter from the former, and multiply the remainder by the area of the surface of the inclosed water in square feet, by the number *m* from the table, and by the number ·95. Multiply the square root of the product of the two heights by the width of the aperture. Divide the former product by the latter, and the quotient will be the number of seconds in the time.

XI. *For the time in which the water level will sink through a given space.*—RULE: From the square root of the height of the vessel subtract the square root of the height of the water level after sinking the proposed space. Multiply the remainder by the area of the water surface, and divide the product by four times the area of the orifice multiplied by *m* taken from the table.

For the number of cubic feet discharged in this time.—RULE: Add the two square roots instead of subtracting them as above, and multiply the sum by four times the area of the orifice, by the number of seconds, and by the number *m* from the table.

Or, multiply the difference of the two heights by the area of the water surface, or of the bottom of the vessel; the product will be the number of cubic feet discharged.

RULES FOR THE SHORT DRAIN.

XII. *For the velocity at the orifice or entrance of the drain.*—RULE: Multiply the square root of the height of the water-level above the orifice by 8·02. Divide 1 by *m*, taken from the table, subtract 1 from the quotient, and take the square of the remainder; increase this square by 1, and then take the square root of the sum. The before-found product, divided by this square root, will give the velocity required.

For the velocity with which the water issues from the drain.—RULE: Find, as above, the velocity with which the water enters the drain, and take the square of it. Add to this square 32·1 times the height of the orifice above the mouth of the drain, and take the square root of the sum.

For the number of cubic feet discharged in any time.—RULE: Multiply together the velocity at the orifice, the area of the orifice, the number of seconds in the time, and the number *m* taken from the table.

NOTE.—The length of this drain is about 6 times the square root of the area of the orifice.

RULES FOR THE LONG DRAIN.

XIII. *For the velocity at the orifice or entrance of the drain.*—RULE; As the length of the drain has nothing to do with the velocity with which the water enters it, the RULE will obviously be the same as that given above for the short drain.

For the velocity with which the water issues out.—RULE: To the square of the velocity with which the water enters the drain, add 64·32 times the height of the point of entrance above that of discharge, and note the sum. Add the width of the drain to twice the depth of water flowing along it; multiply the sum by the length of the drain, by the square of the velocity at entrance, and by the number ·007, and divide the product by the area of the orifice. Subtract the quotient from the above-found sum, and take the square root of the remainder for the velocity of issue required.

RULES FOR THE PARABOLIC VEIN.

XIV. *For the horizontal distance spouted on any plane.*—RULE: Multiply together the height of the water-level above the orifice, and the height of the orifice above the horizontal plane, and take twice the square root of the product.

For the velocity with which the water strikes the horizontal plane.—RULE: Add together the two heights mentioned above, and take eight times the square root of the sum.

For the number of cubic feet discharged in any time.—RULE: Multiply together the area of the orifice, the seconds in the time, the square root of the height of the orifice above the water level, and eight times the number *m* taken from the table for the contracted vein.

For the height of the head of water above the orifice necessary to cause the water to spout a given distance on a given horizontal plane.—RULE: Divide the square of the given distance by four times the height of the orifice above the given plane; the quotient will be the height of the head.

XV. The rules for the velocity and number of cubic feet discharged are the same as in the former case.

RULES FOR WATER WHEELS, FROM THE FORMULÆ.

XVI. *For the horse-power of the under-shot wheel in mid stream.*—RULE: Subtract the velocity of the wheel from the velocity of the stream. Multiply the square of the remainder by the area of the float and the velocity of the wheel. Divide the product by 200; the quotient will be the horse-power.

For the horse-power when the wheel moves with *half the velocity of the stream.*—RULE: Multiply the cube of the velocity of the stream by the area of the float and divide the product by 1600.

XVII. *For the horse-power of the wheel.*—RULE 1: Multiply the difference between the velocity of the issuing stream and that of the wheel by the latter velocity, and also by the number of cubic feet of water acting on the wheel per second. Divide the product by 454, the quotient will be the horse-power. RULE 2: Multiply the difference of the velocities by the velocity of the wheel, the area of the aperture, the square root of the height of the head of water, and the number *m* taken from the table for the vein, and divide the product by 86·8.

For the horse-power when the velocity of the issuing stream is double that of the wheel.—RULE: Multiply together the area of the aperture, the height of the head, and the square root of that height. Divide the product by ·47; the quotient will be the horse-power.

XVIII. *For the horse-power when the height of the head of water exceeds five feet.*—RULE: Multiply the difference of the velocities by the velocity of the wheel and the number of cubic feet of water acting upon it per second; and divide the product by 228.

When the height of the head is less than five feet.—RULE: Proceed as above, using, however, the number 197 for the divisor instead of 228.

For the number of cubic feet of water per second.—RULE: Multiply together the area of the aperture, the square root of the height of the head of water, and 8 times the number *m* taken from the table for the contracted vein.

For the velocity of the issuing stream.—RULE: Multiply the square root of the height of the head by 6·91; the product will be the velocity of the stream.

For the horse-power when the head of water is less than five feet in height.—RULE: Multiply the difference of the velocities by the velocity of the wheel and the number of cubic feet of water acting upon it per second, and divide the product by 197.

NOTE.—The number of cubic feet of water per second, and the velocity of the stream are computed as in the former case.

RULES FOR THE BREAST-WHEEL WITH PARABOLIC DRAIN.

XIX. *For the horse-power.*—RULE: Multiply the difference of the velocities of the wheel and stream by the velocity of the wheel, divide the product by 28, and add the height of the head of water above the lower part of the drain to the quotient. Multiply the sum by the number of cubic feet of water per second, and divide the product by 12: the result will be the horse-power.

For the number of cubic feet per second.—RULE: Multiply the square root of the height of the head of water above the orifice by the area of the orifice, and by the number 6·5: the product will be the number of cubic feet per second flowing through the orifice.

RULES FOR THE LOW-BREAST WHEEL.

XX. *For the horse-power.*—RULE: Multiply the velocity of the stream by the natural cosine of the angle at which the water strikes the floats, and subtract the velocity of the wheel from the product. Multiply the remainder by the velocity of the wheel, and divide the product by 32. Add the height of the head of water above the lowermost float to the quotient, multiply the sum by the number of cubic feet acting on the floats, and divide the product by 11·2.

For the number of cubic feet of water acting per second.—RULE: Multiply together the breadth of the fall and the number *k*, taken from the table for weirs, the product will be the number of cubic feet per second.

For the velocity of the stream.—RULE: Divide the number of cubic feet acting per second by the area of a section of the stream; the quotient will be the velocity per second.

RULE FOR THE BREAST-WHEEL.

XXI. *For the horse-power.*—RULE: Multiply the velocity of the stream by the natural cosine of the angle at which the water strikes the buckets, and subtract the velocity of the wheel from the product. Multiply the remainder by the velocity of the wheel, and divide the product by 25. Add the height of the head of water above the lowermost bucket to the quotient, multiply the sum by the number of cubic feet acting on the buckets in a second, and divide the product by 11·4.

RULES FOR THE OVER-SHOT WHEEL.

XXII. *For the horse-power.*—RULE: Multiply the velocity of the falling stream by the natural cosine of the angle at which it strikes the buckets, and subtract the velocity of the wheelfrom the product. Multiply the remainder by the velocity of the wheel, and divide the product by 21·5. Add the height of the head above the lowest bucket to the result, multiply the sum by the number of cubic feet acting on the buckets in a sec., and divide the result by 13·7.

For the number of revolutions per minute.—Rule: Divide 100 by the diameter of the wheel, or distance between the centres of pressure of opposite buckets. Add 35 to the quotient, and the sum will express the number of revolutions per minute.

RULES FOR THE SAW-MILL WHEEL.

XXIII. *For the horse-power.*—Rule: Multiply the difference between the velocity of the water acting on the wheel and the velocity of the wheel itself by the latter velocity, and by the number of cubic feet acting on the buckets in a sec. Divide the result by 200; the quotient will be the horse-power.

For the proper diameter of the wheel.—Rule: Multiply the square root of the height of the head of water above the lowest bucket by 100, and divide the product by the number of revolutions per minute.

Effects produced by water in an aëriform state.

When water in a vessel is subjected to the action of fire, it readily imbibes the heat of which the fire is the cause, and sooner or later attains a temperature of 212° Fahrenheit. If at this temperature the water be not enclosed, but exposed to atmospheric pressure, ebullition will take place, and steam will ascend through the water, carrying with it the superabundant heat. Water, in attaining the aëriform state, thus obeys the same laws under every degree of pressure; but as the pressure is augmented, so is the indicated temperature proportionately raised; hence the various densities of steam, and degrees of elastic force.

Table of the Elastic Force of Steam, and corresponding Temperature of the Water with which it is in contact.

Pressure per square inch, atmospheric pressure included.		Elastic Force in		Temperature in Degrees of			Volume of Steam compared with vol. of Water.
		Inches of Mercury.	Metres of Mercury.	Fahr.	Reaum.	Cent.	
lbs.	kilog.						
14·7	6·668	30·00	·762	212·0	80·0	100·0	1711
15	6·80	30·60	·778	212·8	80·4	100·4	1670
16	7·26	32·64	·829	216·3	81·9	102·4	1573
17	7·71	34·68	·880	219·6	83·3	104·2	1488
18	8·16	36·72	·932	222·7	84·7	105·9	1411
19	8·62	38·76	·984	225·6	86·0	107·6	1343
20	9·07	40·80	1·037	228·5	87·3	109·2	1281
21	9·52	42·84	1·089	231·2	88·5	110·7	1225
22	9·98	44·88	1·140	233·8	89·7	112·1	1174
23	10·43	46·92	1·192	236·3	90·8	113·5	1127
24	10·88	48·96	1·244	238·7	91·9	114·8	1084
25	11·34	51·00	1·296	241·0	93·0	116·1	1044
26	11·79	53·04	1·348	243·3	93·9	117·4	1007
27	12·25	55·08	1·400	245·5	94·9	118·6	973
28	12·70	57·12	1·452	247·6	95·8	119·8	941
29	13·15	59·16	1·503	249·6	96·7	120·9	911
30	13·61	61·21	1·555	251·6	97·6	122·0	883
31	14·06	63·24	1·607	253·6	98·5	123·1	857
32	14·51	65·28	1·659	255·5	99·3	124·2	833
33	14·97	67·32	1·711	257·3	100·1	125·2	810
34	15·42	69·36	1·763	259·1	100·9	126·2	788
35	15·87	71·40	1·814	260·9	101·7	127·2	767
36	16·33	73·44	1·866	262·6	102·5	128·1	748
37	16·78	75·48	1·918	264·3	103·2	129·1	729
38	17·23	77·52	1·970	265·9	104·0	129·9	712
39	17·69	79·56	2·022	267·5	104·7	130·8	695
40	18·14	81·60	2·074	269·1	105·4	131·7	679
41	18·59	83·64	2·126	270·6	106·0	132·6	664
42	19·05	85·68	2·178	272·1	106·7	133·4	649
43	19·50	87·72	2·229	273·6	107·4	134·2	635
44	19·96	89·76	2·281	275·0	108·0	135·0	622
45	20·41	91·80	2·333	276·4	108·6	135·8	610
46	20·86	93·84	2·385	277·8	109·2	136·6	598
47	21·32	95·88	2·437	279·2	109·9	137·3	586
48	21·77	97·92	2·489	280·5	110·4	138·1	575
49	22·22	99·96	2·541	281·9	111·1	138·8	564
50	22·68	102·00	2·592	283·2	111·6	139·6	554

The preceding Table is peculiarly adapted for estimating the power of steam engines on the condensing principle, because in such the effective force of the steam is the difference between the total force and the resisting vapour retained in the condenser. The following Table is more adapted for estimating the effects of non-condensing engines, as, in such, the atmospheric pressure is not generally taken into account, engines of this principle being supposed to work in a medium; or, the atmospheric pressure on the boiler, to cause a greater density of steam, is equal to the resisting atmosphere which the effluent steam has to contend with on leaving the cylinder.

Table of the Elastic Force of Steam, the Pressure of the Atmosphere not being included.

Elastic Force in			Temperature in degrees of Fahr.	Volume of Steam Water being 1.	Cubic in. of Water in a cubic foot of Steam.
Atmosphere.	lbs. ℔ sq. in.	in. of Merc.			
1·19	2·5	5·15	220	1496	1·14
1·22	3	6·18	222	1453	1·18
1·29	4	8·24	225	1366	1·25
1·36	5	10·3	228	1282	1·33
1·70	10	20·6	240	1044	1·64
2·04	15	30·9	251	883	1·93
2·38	20	41·2	260	767	2·23
2·72	25	51·5	268	678	2·52
3·06	30	61·8	275	609	2·81
3·40	35	72·1	282	553	3·09
3·74	40	82·4	288	506	3·38
4·08	45	92·7	294	468	3·66
4·42	50	103·0	299	435	3·93
4·76	55	113·3	304	407	4·20
5·10	60	123·6	309	382	4·48

Steam, independent of the heat indicated by an immersed thermometer, also contains heat that cannot be measured by any instrument at present known, and, in consequence of which, is termed latent or concealed heat; the only positive proof we have of its existence being that of incontestable results or effects produced on various bodies. Thus, if one part by weight of steam at 212°, be mixed with nine parts of water at 62°, the result is water at 178·6°; therefore, each of the nine parts of water has received from the steam 116·6° of heat, and consequently the steam has diffused or given out $116 \cdot 6 \times 9 = 1049 \cdot 4 - 33 \cdot 4 =$ 1016° of heat which it must have contained. Again, it is ascertained by experiment, that if one gallon of water be transformed into steam at 212°, and that steam allowed to mix with water at 52°, the whole will be raised to the boiling point, or 212°. From these and other experiments, it is ascertained that the latent heat in steam varies from 940° to 1044°, the ratio of accumulation advancing from 212°, as the steam becomes more dense and of greater elastic force: hence the severity of a scald by steam to that by boiling water.

It is because of the latent heat in steam, or water in an aëriform state, that it becomes of such essential service in *heating*, *boiling*, *drying*, &c. In the heating of buildings, its *economy*, *efficiency*, and *simplicity* of *application*, are alike acknowledged;—the steam being simply conducted through all the departments by pipes, by extent of circulation condenses, the latent heat being thus given to the pipes and diffused by radiation. In boiling, its efficiency is considerably increased if advantage be taken of sufficiently enclosing the fluid and reducing the pressure on its surface by means of an air-pump; thus, water in a vacuum boils at about a temperature of 98°, and in sugar-refining, where such means are employed, the syrup is boiled at 150°.

Steam is also of great utility as a productive source of motive power; and in this respect its properties are *elastic force*, *expansive force*, and *reduction* by *condensation*. Elastic force signifies the whole urgency or power the steam is capable of exerting with undiminished effect. By expansive force is generally understood the amount of diminishing effect of the steam on the piston of a steam engine, reckoning from that point of the stroke where the steam of uniform elastic force is cut off; but it is more properly the force which steam is capable of exerting when expanded to a known number of times its original bulk. And

Condensation, here understood, is the abstraction or reduction of heat by another body, and consequently not properly a contained property of the steam, but an effect produced by combined agency, in which steam is the principal; because any colder body will extract the heat and produce condensation, but steam cannot be so beneficially replaced by any other fluid capable of maintaining equal results.

The rules formed by experimenters as corresponding with the results of their experiments on the elastic force of steam at given temperatures vary, but approximate so closely that the following rule, because of being simple, may in practice be taken in preference to any other.

Rule.—To the temperature of the steam in degrees of Fahrenheit, add 100, divide the sum by 177, and the 6th power of the quotient equal the force in inches of mercury.

Ex. Required the force of steam corresponding to a temperature of 312°.

$$\frac{312+100}{177}=2{\cdot}3277^6=159 \text{ inches of mercury.}$$

But the Table, page 282, is much better adapted to practical purposes, as the various results or effects are obtained simply by inspection.

To estimate the amount of advantage gained by using steam expansively in a steam engine.

When steam of a uniform elastic force is employed throughout the whole ascent or descent of the piston, the amount of effect produced is as the quantity of steam expended. But let the steam be shut off at any portion of the stroke, say, for instance, at one half, it expands by degrees until the termination of the stroke, and then exerts half its original force; hence an accumulation of effect in proportion to the quantity of steam.

Rule.—Divide the length of the stroke by the distance or space into which the dense steam is admitted, and find the hyperbolic logarithm of the quotient, to which add 1, and the sum is the ratio of the gain.

Ex. Suppose an engine with a stroke of 6 feet, and the steam cut off when the piston has moved through 2; required the ratio of gain by uniform and expansive force.

$6 \div 2 = 3$; hyperbolic logarithm of $3 = 1{\cdot}0986 + 1 = 2{\cdot}0986$ ratio of effect; that is, supposing the whole effect of the steam to be 3, the effect by the steam being cut off at $\frac{1}{3} = 2{\cdot}0986$.

Again, let the greatest elastic force of steam in the cylinder of an engine equal 48lbs. per square inch, and let it be cut off from entering the cylinder when the piston has moved $4\frac{1}{2}$ inches, the whole stroke being 18; required an equivalent force of the steam throughout the whole stroke.

$18 \div 4{\cdot}5 = 4$, and $48 \div 4 = 12$.
Logarithm of $4 + 1 = 2{\cdot}38629$.
Then $2{\cdot}38629 \times 12 = 28{\cdot}635$ lbs. per square inch.

Table of Hyperbolic Logarithms.

No.	Logrthm.	No.	Logrthm.	No.	Logrthm.	No.	Logrthm.
1¼	·22314	3½	1·25276	5¾	1·74919	8	2·07944
1½	·40546	3¾	1·32175	6	1·79175	8½	2·14006
1¾	·55961	4	1·38629	6¼	1·83258	9	2·19722
2	·69314	4¼	1·44691	6½	1·87180	9½	2·25129
2¼	·81093	4½	1·50507	6¾	1·90954	10	2·30258
2½	·91629	4¾	1·55814	7	1·94591	12	2·48490
2¾	1·01160	5	1·60943	7¼	1·98100	14	2·63905
3	1·09861	5¼	1·65822	7½	2·01490	16	2·77258
3¼	1·17865	5½	1·70474	7¾	2·04769	18	2·89037

In regard to the other case of expansion: When the temperature is constant the bulk is inversely as the pressure: thus, Suppose steam at 30 ℔s. per square inch, required its bulk to that of original bulk, when expanded so as to retain a pressure equal to that of the atmosphere, or 15 ℔s.

$$\frac{15+30}{15}=3 \text{ times its original bulk.}$$

Condensation of steam for motive purposes, generally, is effected by cold water, the quantity of which may be estimated by the following rule. From 1000 plus the temperature of the steam, subtract the required temperature of the condensed water, divide the remainder by the temperature of the condensed water minus the temperature of the cold or condensing water, and the quotient equal the number of times that the quantity, for condensation, must exceed that by which the steam is formed.

Ex. Required the ratio or quantity of water for condensation to 1 of water for the formation of steam, the temperature of the steam being 220°, and the required temperature of condensed water 180°.

$$\frac{1000+220-180}{180-52}=8 \text{ times the quantity.}$$

Water holding impurities in solution tends to retard its attaining the aëriform state, and so impairs the amount of its elastic force at an equal temperature, as exhibited in the following Tables. Thus, common water boils at 212° Fahrenheit.

Name of Substance.		Proportionate quantity in 100 parts by weight of water.	Boiling points.
Salts in sea water.		3·03	213·2° F.
Sulphate of soda	In common water.	31·5	213
Sulphate of iron		64	216
Alum		52	220
Sulphate of lime		45	220
Sulphate of magnesia ...		57·5	222
Muriate of soda		30	224
Nitrate of soda............		60	246
Acetate of soda............		60	256

Elastic Force of Steam in Inches of Mercury.

Common water	boiling point,	212° F.	elastic force	30 in.
Sea water	at	212 „	„	23·05 „
Common water	boiling point,	216° F.	elastic force	32·5 in.
Sea water	at	216 „	„	24·6 „
Common water	boiling point,	220° F.	elastic force	35·1 in.
Sea water	at	200 „	„	26·5 „

Hence the propriety of procuring, for steam, water in its purest state.

3. *Effects produced by air in its natural and also in a rarefied state.*

The weight or pressure of the atmosphere is equal to the weight of a column of water 34 feet in height, or to a column of mercury 30 inches in height, or to 14·7 lbs. av. per square inch at a mean temperature. But air, like all other gases, is rendered lighter by the application of heat, for then the particles of the mass are repelled from each other, or rarefied, and occupy a greater space. Rarefied air being specifically lightest, mounts above that of common density; hence change of temperature, and the principal cause of winds.

Table of the Expansion of Atmospheric Air by Heat.

Degrees of Fahr.	Bulk.	Degrees of Fahr.	Bulk.	Degrees of Fahr.	Bulk.
32°	1000	65°	1077	100°	1152
35	1007	70	1089	120	1194
40	1021	75	1099	140	1235
45	1032	80	1110	160	1275
50	1043	85	1121	180	1315
55	1055	90	1132	200	1364
60	1066	95	1142	212	1376

The pressure or gravity of the atmosphere being equal to a column of water 34 feet in height, is the means or principle on which rests the utility of the common pump, also of the syphon and all other such hydraulic applications. In a pump the internal pressure on the surface of the liquid is removed by the action of the bucket, and as by degrees the density becomes lessened, so the water rises by the external pressure to the above-named height; and at such height it will remain, unless by some derangement of construction taking place, the atmospheric fluid is allowed to enter and displace the liquid column. But observe if the temperature of the water or other liquid be so elevated that steam or vapour arises through it, then, according to the vapour's accumulation of density, may the action of the pump be partially or wholly destroyed; and the only means of evasion in such cases is to place the working bucket beneath the surface of the liquid which is required to be raised.

Table showing the quantity of Water per lineal foot in Pumps or Vertical Pipes of different diameters.

Diameter of pump in inches.	Number of gallons pr. lineal ft.	Number of cubic feet pr. lineal ft.	Diameter of pump in inches.	Number of gallons pr. lineal ft.	Number of cubic feet pr. lineal ft.
2	·136	·0218	8	2·176	·3490
2¼	·172	·0276	8¼	2·314	·3712
2½	·212	·0340	8½	2·456	·3940
2¾	·257	·0412	8¾	2·603	·4175
3	·306	·0490	9	2·754	·4417
3¼	·359	·0576	9¼	2·909	·4666
3½	·416	·0668	9½	3·068	·4923
3¾	·478	·0766	9¾	3·232	·5184
4	·544	·0872	10	3·400	·5454
4¼	·614	·0985	10¼	3·572	·5730
4½	·688	·1104	10½	3·748	·6013
4¾	·767	·1230	10¾	3·929	·6302
5	·850	·1363	11	4·114	·6599
5¼	·937	·1503	11¼	4·303	·6902
5½	1·028	·1649	11½	4·496	·7212
5¾	1·124	·1803	11¾	4·694	·7529
6	1·224	·1963	12	4·896	·7853
6¼	1·328	·2130	12½	5·312	·8521
6½	1·436	·2304	13	5·746	·9217
6¾	1·549	·2489	13½	6·196	·9939
7	1·666	·2672	14	6·664	1·0689
7¼	1·787	·2866	15	7·650	1·2271
7½	1·912	·3067	16	8·704	1·3962
7¾	2·042	·3275	18	11·016	1·7670

Examples illustrative of the Utility of the Table.

1. Required the quantity of water lifted by each stroke of the bucket of a 9½-inch pump, the length of the stroke being 2¼ feet.

$3·068 \times 2·25 = 6·903$ gallons each stroke.

2. What length of stroke with a 6-inch pump will be necessary to discharge 44 gallons of water per

minute, the number of strokes being 18 in the given time?

$$\frac{44}{1\cdot224 \times 18} = 2 \text{ feet, the length of stroke.}$$

3. What must be the diameter capable of raising 25 cubic feet of water per minute, the length of the stroke being $2\frac{1}{2}$ feet, and making 16 effective strokes per minute?

$$\frac{25}{2\cdot5 \times 16} = \cdot625, \text{ or } 10\tfrac{3}{4} \text{ inches nearly.}$$

It is by the oxygen of the atmosphere that combustion is supported. The common combustibles of nature are chiefly compounds of carbon and hydrogen, which, during combustion, combine with the oxygen of the atmosphere, and are converted into carbonic acid and watery vapour, different species of fuel requiring different quantities of oxygen. The quantity required for the combustion of a pound of coal varies from 2 to 3 lbs., according to the quality of the coal: 60 cubic feet of atmospheric air is necessary to produce 1 lb. of oxygen.

The pressure or fluid properties of the atmosphere oppose bodies in passing through it, the opposing resistance increasing as the square of the velocity of the body, and the resistance per square foot in lbs. as its velocity in feet per second, multiplied into ·002288. Thus, suppose a locomotive engine in a still atmosphere, at a velocity of 25 miles per hour, presents a resisting frontage of 20 feet; required the amount of opposing resistance at that velocity.

25 miles per hour equal 36·67 feet per second.

Then $36\cdot67^2 \times \cdot002288 \times 20 = 61\cdot5$ lbs. constant opposing force.

Table of the force and common Appellations given to Winds at different velocities.

Velocity of the wind in		Force in lbs. avoirdupois per square foot.	Common Appellations given to the Wind.
Miles per hour.	Feet per second.		
1	1·47	·005	Hardly perceptible.
2	2·93	·020	Just perceptible.
3	4·40	·044	
4	5·87	·079	Gentle pleasant wind.
5	7·33	·123	
10	14·67	·492	Pleasant brisk gale.
15	22·00	1·107	
20	29·34	1·968	Very brisk.
25	36·67	3·075	
30	44·01	4·429	High winds.
35	51·34	6·027	
40	58·68	7·873	Very high.
45	66·01	9·963	
50	73·35	12·300	A storm or tempest.
60	88·02	17·715	A great storm.
80	117·36	31·490	A hurricane.

In order to gain the greatest amount of the wind's impulsive effect to produce rotary or circular motion by the sails of a wind-mill, the total surface of the sails presented to the wind ought to be about $\frac{7}{8}$ths of the circle's surface which is formed by their motion, and each sail angled to the plane of motion as follows, the whip or back being divided into six equal parts.

Distance from centre of motion	1	2	3	4	5	6	Smeaton's rule.
Angle with plane of motion...	18°	19	18	16	$12\frac{1}{2}$	7	
By G. Forrester, Liverpool	24°	21	18	14	9	3	

RULES, TABLES, &c., RELATIVE TO BOILERS AND THE STEAM ENGINE.

THE Boiler of a Steam Engine may be explained as that portion of the structure in which the vital principle of the engine is generated; consequently its construction is of the utmost importance, for upon the proper efficiency of the boiler depends in a great measure the efficiency of the engine.

Boilers not unfrequently, because of unavoidable peculiarities, are necessarily constructed of various forms; but for land or stationary engine boilers, if no thwarting circumstances intervene, either the waggon or cylindrical forms are commonly resorted to; the former for those of condensing engines, and the latter for those of the high pressure principle.

In the construction of boilers, much attention ought to be paid in avoiding thin films of water where the action of the fire is great, because it is neither consistent with safety, nor can there be the proper quantities of steam generated according to the surface exposed, unless under some extraordinary degree of pressure. Also convex surfaces, exposed to the action of the steam, unless properly supported, ought strenuously to be avoided. Large water spaces, concave surfaces, or straight plates securely stayed, with ample steam room, are the chief requisites to be attended to.

1. *To determine the proper quantity of heating surface in a boiler for an engine with a cylinder of a given capacity, and steam at any density required.*

Rule.—Multiply 375 times the area of the cylinder in feet by the velocity of the piston in feet per minute, and divide the product by the volume of steam to 1 of water at the density required (see Table, page 242), and the quotient is the amount of effective heating surface in square feet.

Ex. Required the amount of effective heating surface in a boiler for an engine whose cylinder is $4\frac{1}{2}$ square feet in area, and the piston's velocity 224 feet per minute, the pressure of the steam to equal 5 lbs. per square inch above the pressure of the atmosphere.

$\frac{375 \times 4{\cdot}5 \times 224}{1282} = 295$ square feet nearly; the fire-grate being in accordance with the following rule.

Multiply the number of square feet of heating surface by ·12, the product equal the area of fire-grate in square feet, thus:

$295 \times {\cdot}12 = 35{\cdot}4$ square feet of furnace-bar.

Note.—By effective heating surface is meant horizontal surfaces over fire, flame, or heated air; vertical or side surfaces requiring about $1\frac{3}{4}$ ft. to equal in effect 1 of horizontal surface.

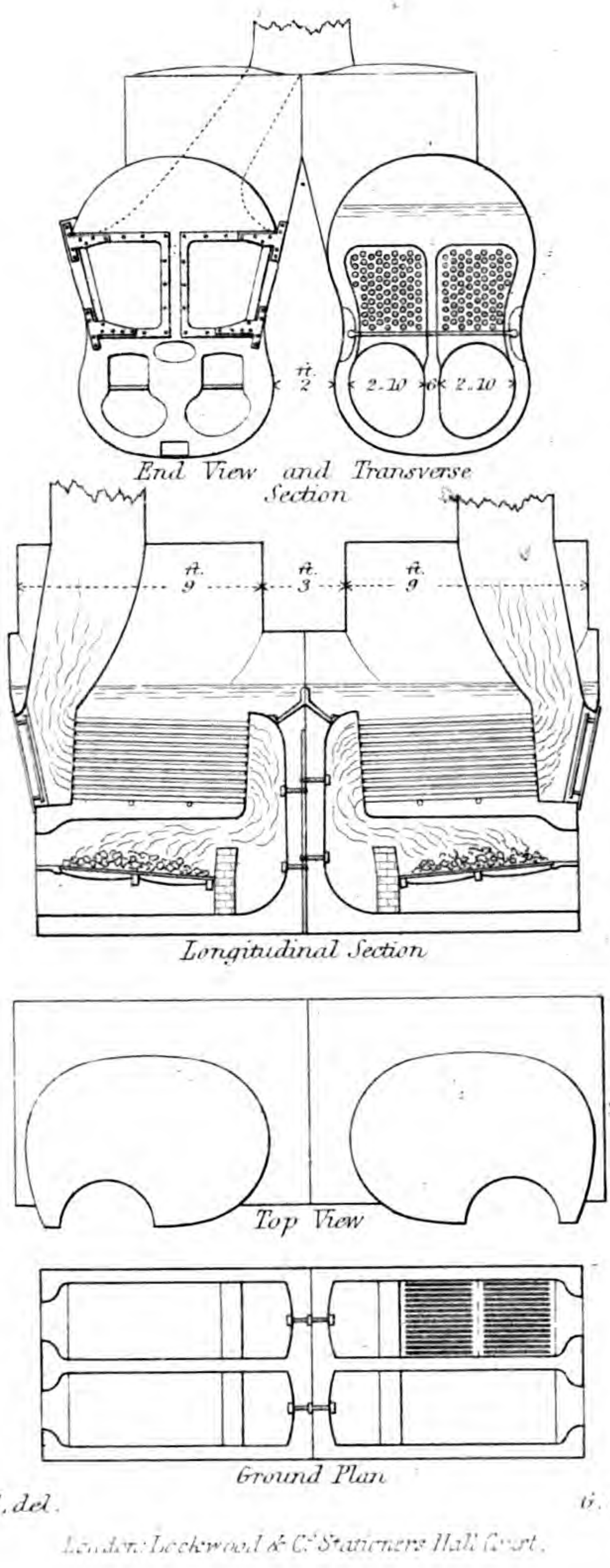
2. *To determine the proper dimensions for a waggon-shaped boiler, when the amount of effective heating surface in square feet is obtained by the preceding rule.*

1. The bottom surface equal half the whole surface.
2. The length of the boiler equal twice the square root of bottom surface.
3. The width equal one-fourth the length; and
4. The height equal one-third the length.

Ex. Required the dimensions for a boiler of the waggon form that may present an effective heating surface of 295 square feet.

Bottom surface $= 295 \div 2$, or 147·5 square feet.
Length . . . $= \sqrt{147{\cdot}5} \times 2$, or 24·26 feet.
Width . . . $= 24{\cdot}26 \div 4$, or 6·06 feet.
Height . . . $= 24{\cdot}26 \div 3$, or 8·08 feet.

Note.—The amount of side or vertical surface equal twice



Plans of the Boilers on board the Peninsular Co.s Steam Ship Braganza
By Mess.rs Bury, Curtis and Kennedy, Liverpool.

W. T., del.

G. Gladwin, sc.

London: Lockwood & Co. Stationers Hall Court.

the length of the boiler, added to the width, and multiplied by 1·75 to obtain that of effective surface; hence,

$$\frac{147{\cdot}5 \times 1{\cdot}75}{24{\cdot}26 \times 2 + 6{\cdot}06} = 4{\cdot}7 \text{ feet, depth of side flue.}$$

3. *To determine the dimensions for a cylindrical boiler.*

Rule.—Extract the square root of 1·34 times the effective heating surface in square feet, and twice the root equal the boiler's circumference in feet; also, the circumference equal the length.

Ex. Let a cylindrical boiler be required with an effective heating surface of 86 square feet; what must be its length and diameter in feet?

$\sqrt{86 \times 1{\cdot}34} = 10{\cdot}74 \times 2 = 21{\cdot}48$ feet circumference, or 6 feet 10 inches diameter, and 21·48 feet in length.

Note.—When an internal flue is to be inserted in a boiler, the external surface of the boiler may be diminished in length equal to half the exposed surface of the flue. Observe, also, that the height of the contained water in boilers generally ought to be about ⅔rds the whole height of the boiler.

Marine Engine Boilers have become so varied in their designs, that any attempt at enumerating—by ever so slight a description—those that may be considered worthy of record, would much exceed the limits of my present purpose; but having been favoured by Messrs. Bury, Curtis, and Kennedy, with particulars of the boilers constructed by them for the 'Braganza' steam vessel, and which have given the highest degree of satisfaction in every respect, I annex designs and data, in preference to those of any other description. (See Plate K.)

These boilers are constructed so as to work at 10 lbs. per square inch if required; they are four in number; the diameter of each cylinder is 62⅛ inches, length of stroke 5½ feet, or calculated velocity about 231 feet per minute: the nominal power of each engine is 140 horses, and the heating surface per horse-power is 14·1 square feet.

Now $14{\cdot}1 \times 140 = 1974$ square feet to each engine.

Then as per rule (page 268), 375 multiplied by the area of cylinder or 21 feet, and by the velocity per minute or 231 feet, and divided by 1044 (see Table, page 258) or volume of steam to 1 of water, at 10 lbs. per square inch, equal 1742·4 square feet; to which add about $\frac{1}{8}$th of the quotient, or 217·8, for side or vertical surface, equal 1960·2 square feet to each engine,—thus nearly corresponding with *their* given quantity of heating surface.

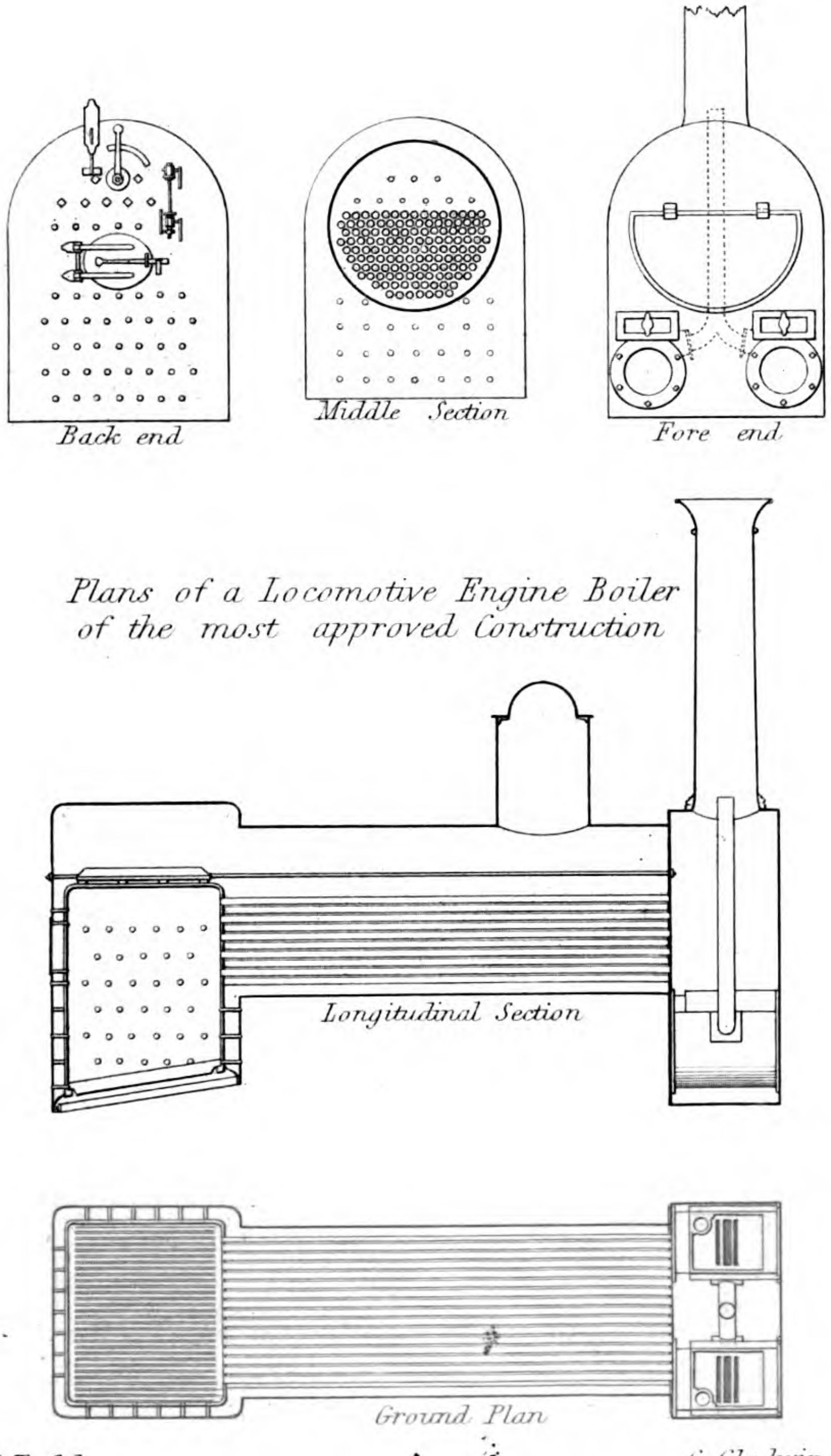
Note.—In the four boilers there are 608 brass tubes, $6\frac{1}{2}$ feet in length and 3 inches in diameter. The length of each fire-place is 5 feet 10 inches, and breadth 2 feet 10; there are, ·56 of a square foot of fire-bar to each cubic foot of cylinder capacity, and ·16 of a square foot of tube aperture to each square foot of fire-bar, the openings of the tubes being reduced by the thickness of the tube hoops. The diameter of each chimney, of which there are two, is 3 feet 5 inches.

Locomotive Boilers, in the manner of their construction, are a class which, of necessity, demand the utmost degree of qualified attention, because of the great pressures they are required to sustain, and the unavoidably narrow limits in which such vast volumes of steam are required to be generated.

In boilers of this description, it is of the most essential consequence that the water spaces in the fire-box be of a sufficient width, say, on the back and sides, not less than $2\frac{3}{4}$ to 3 inches, and in the front, where the tendency of the fire is urged by the action of the blast-pipe, at least $3\frac{1}{2}$ inches.

The boiler which I have selected for illustration (see Plate L) is of the most modern description; and from an intimate knowledge of its performances, I am enabled to assert, with full confidence, that it possesses efficient and economical properties to the production of steam.

Plate I.



Plans of a Locomotive Engine Boiler of the most approved Construction

W. T., del. *G. Gladwin, sc.*

London: Lockwood & C.o Stationers' Hall Court.

Specified particulars relative to the Boiler and Engine.

Diameter of cylinders		14 inches.
Length of stroke		18 „
Lap of the valve		1 „
Diameter of driving wheels		5½ feet.
Length of internal fire-box	2 feet	11½ inches.
Width of ditto	3 „	5 „
Length of cylindrical part of boiler	8 „	8 „
Diameter of ditto	3 „	4½ „
Length of tubes	8 „	11½ „
Number of tubes	133, of brass.	
Interior diameter of ditto		1¾ inches.
Diameter of blast-pipe		4 „

About 112 ℔s. of coke consumed in this boiler evaporate 84 gallons of water; and from 20 to 25 ℔s. of coke are consumed per mile.

Heating Powers of Combustible Substances.

Species of combustible.	℔s. of water heated from 32° to 212°.	℔s. of boiling water evaporated by 1 ℔. of fuel.	℔s. of atmospheric air to each ℔. of fuel.
Wood in its ordinary state	26	4·72	4·47
Wood charcoal	73	13·37	11·46
Coal	60	10·90	9·26
Coke	65	11·81	11·46
Turf	30	5·45	4·60
Turf charcoal	64	11·63	9·86

In regard to the giving of an order for a steam engine of any required number of horses' power, it has been argued and ultimately decided, that in a commercial point of view the order is not sufficiently completed by the dimensions of cylinder, boiler, &c. being of ample magnitude to produce the specified dynamical effect in horses' power; and not unless corresponding with the established custom by Boulton and Watt, or that of other manufacturers of equally well known respectability: hence, generally, the following Tables may be better adapted to practice than even the most simple rule.

Table of Dimensions for Steam Engine Cylinders by celebrated makers.

Stationary Condensing Engines, by Boulton & Watt.			Marine Engines, by Maudslay, Napier, &c.			High-Pressure, or Non-Condensing Engines, by various makers.				
Nominal horses' power.	Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horses' power.	Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horses' power.	Diameters of cylinders, the force of the steam being, per square inch,			
							25 lbs.	30 lbs.	40 lbs.	50 lbs.
6	14½	3	10	20	2	1	3¾	3½	3	2¾
8	16¼	3	15	24	2¼	2	5¼	4¾	4¼	3¾
10	18	3½	20	27	2½	3	6½	6	5	4½
12	19½	4	25	29½	2¾	4	7½	6¾	6	5¼
14	21	4½	30	32	3	5	8¼	7½	6½	5⅞
16	22½	4½	40	36	3½	6	9	8¼	7¼	6⅛
18	23½	5	50	40	4	7	9¾	9	7¾	6⅞
20	24½	5	60	43	4	8	10½	9¾	8½	7½
22	26	5	70	46½	4½	9	11⅛	10¼	8¾	7⅞
24	27	5½	80	47½	4½	10	11¾	11	9½	8½
25	27½	5½	90	50	4¾	11	12¼	11⅜	9¾	8¾
26	28	5¾	100	53	5	12	13	12	10½	9¼
28	29	6	110	55½	5½	14	14	12¾	11¼	10
30	30	6	120	57	5½	16	15	13¾	12	10½
35	32½	6½	130	60¾	5¾	18	15¾	14½	12¾	11¼
40	34½	6½	150	65	6	20	16¾	15¼	13½	11¾
50	38½	7	200	74½	6	25	18½	17¼	15	13¼
60	42¼	7	250	84	6	30	20¼	19¾	16¼	14½

The *unit* of nominal power for steam engines, or the usual estimate of dynamical effect per minute of a horse, called by engineers a horse-power, is 33,000 lbs. at a velocity of 1 foot per minute; or, the effect of a load of 200 lbs. raised by a horse for 8 hours a day, at the rate of 2½ miles per hour, or 150 lbs. at the rate of 220 feet per minute.

To estimate by means of an indicator the amount of effective power produced by a steam engine.

Rule.—Multiply the area of the piston in square inches by the average force of the steam in lbs. and by the velocity of the piston in feet per minute; divide the product by 33,000, and $\frac{7}{10}$ths of the quotient equal the effective power.

Ex. Suppose an engine with a cylinder of $37\frac{1}{2}$ inches diameter, a stroke of 7 feet, and making 17 revolutions per minute, or 238 feet velocity, and the average indicated pressure of the steam 16·73 lbs. per square inch; required the effective power.

$$\frac{\text{Area}=1104{\cdot}4687\text{ inches}\times 16{\cdot}73\text{ lbs}\times 238\text{ feet}}{33000}$$

$$=\frac{133{\cdot}26\times 7}{10}=93{\cdot}282\text{ horses' power.}$$

To determine the proper velocity for the piston of a steam engine.

Rule.—Multiply the logarithm of the *n*th part of the stroke at which the steam is cut off by 2·3, and to the product of which add ·7. Multiply the sum by the distance in feet the piston has travelled when the steam is cut off, and 120 times the square root of the product equal the proper velocity for the piston in feet per minute.

Ex. Let the steam be cut off in an 8-feet stroke when the piston has travelled $\frac{1}{4}$th of the length; required its proper velocity.

Logarithm of 4	=0·60206
Multiplied by	2·3
	1·384738
To which add	·7
	2·084738
	2

$\sqrt{4{\cdot}169476}=2{\cdot}04\times 120=245$ feet, velocity per minute.

Table of Approximate Velocities for the Pistons of Steam Engines.

CONDENSING ENGINES.			NON-CONDENSING ENGINES.		
Length of stroke in feet.	Velocity in feet per minute.	Number of revolutions per minute.	Length of stroke in feet.	Velocity in feet per minute.	Number of revolutions per minute.
2	160	40	1½	186	62
2½	177½	35½	2	200	50
3	192	32	2½	212½	42½
3½	203	29	2¾	217¼	39½
4	214	26¾	3	222	37
4½	220½	24½	3½	231	33
5	230	23	4	236	29½
5½	236½	21½	4½	243	27
6	240	20	5	247½	24¾
7	245	17½	5½	253	23
8	256	16	6	264	22

Of the Parallel Motion in a Steam Engine.

When the power from the piston is communicated by means of a beam or lever moving upon an axis, the parallel motion becomes a very important portion of the machine, for then it forms the link of connection, and by its properties renders the action of alternate circular motion and reciprocating vertical motion mutually agreeable, thereby properly insuring to the piston-rod a truly direct line to that of the cylinder: but to effect this, the greatest degree of exactitude of the various parts is required, otherwise extra friction is created, and the effective power of the engine proportionately diminished. (See Plates E. and F.)

Fig. 1, Plate E, is a motion for a double-cylinder engine.
„ 2, „ a motion for a pumping engine.
„ 3, „ the common condensing engine.

Fig. 1, Plate F, is for a marine engine.
„ 2, „ also for a marine engine.
„ 3, „ for a non-condensing or high-pressure engine.

PARALLEL MOTIONS.

Plate E

Fig. 1.

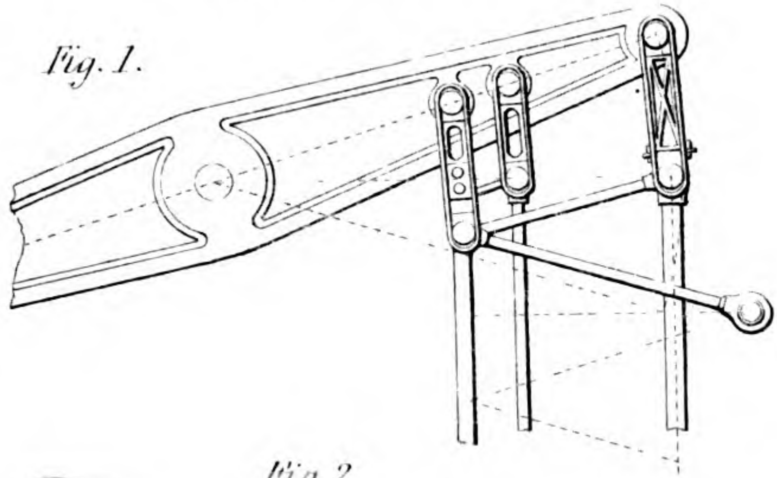


Fig. 2.

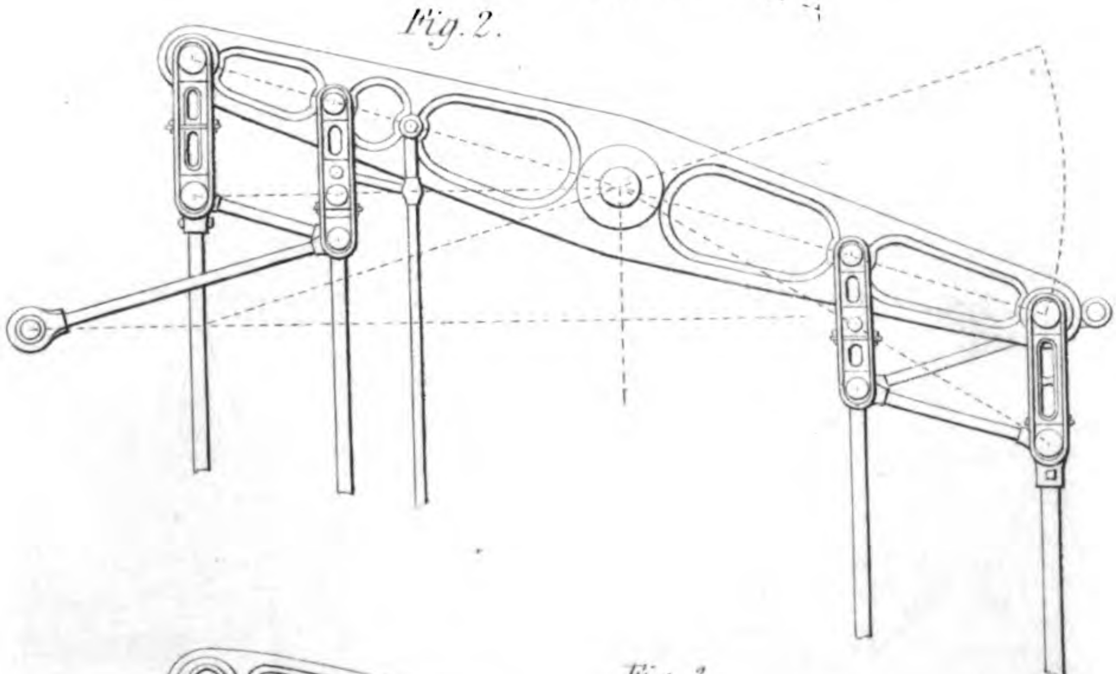
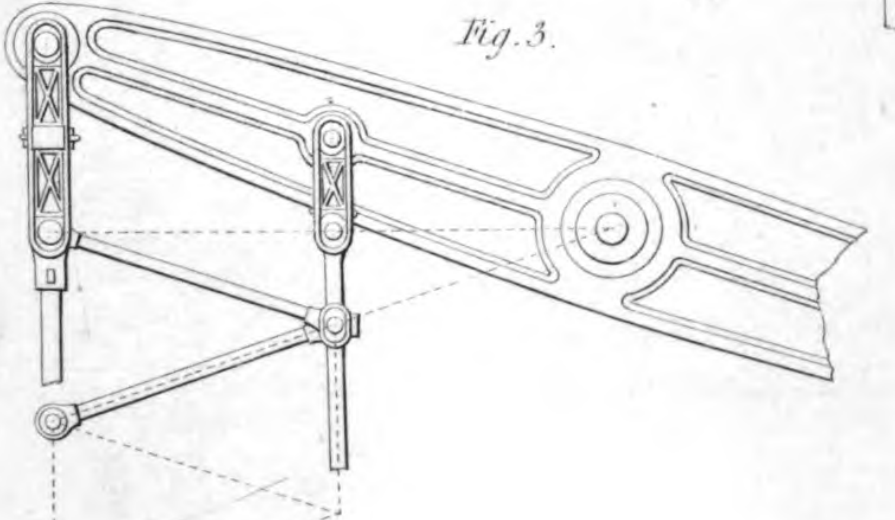


Fig. 3.



J.W. Lowry fc.

London: Lockwood & C°. Stationers Hall Court

PARALLEL MOTIONS.

Plate F

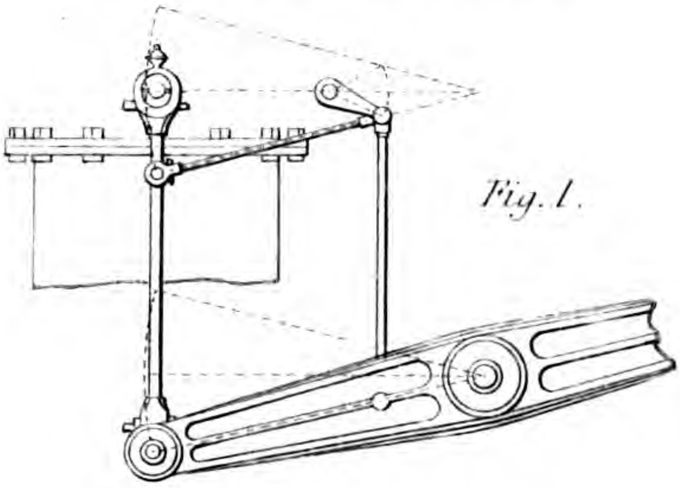


Fig. 1.

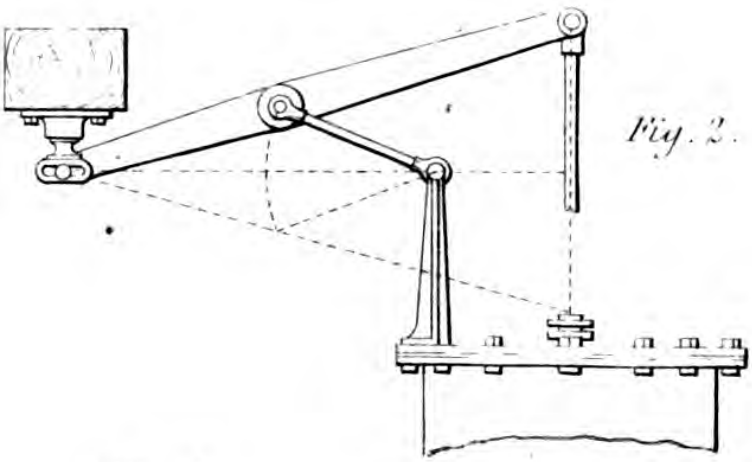
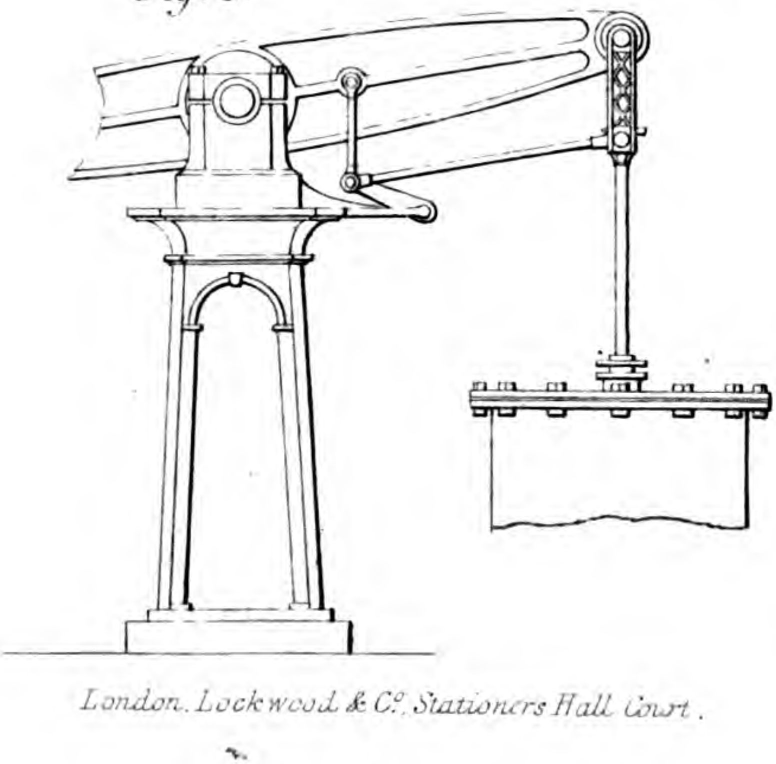


Fig. 2.

Fig. 3.



J.W.

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Table by which to determine the various Distances of the Moveable Points in a Parallel Motion.

Radius of beams in ft.	Parallel bars in ft.	Length of radius rods in ft. & in.	
4 feet	2	2	0
	2¼	1	4⅜
	2½	0	10⅞
	2¾	0	6⅞
	3	0	4
4½ feet	2	3	1½
	2¼	2	3
	2½	1	7¼
	2¾	1	1⅜
	3	0	9
	3¼	0	5¾
5 feet	2	4	6
	2¼	3	4⅜
	2½	2	6
	2¾	1	10⅛
	3	1	4
	3¼	0	11¼
	3½	0	7¾
5½ feet	2¼	4	8⅜
	2½	3	7¼
	2¾	2	9
	3	2	1
	3¼	1	6⅜
	3½	1	1¾
	3¾	0	9⅞
6 feet	2¾	3	10
	3	3	0
	3¼	2	3⅞
	3½	1	9½
	3¾	1	4¼
	4	1	0
	4¼	0	8½
6½ feet	3	4	1⅛
	3¼	3	3
	3½	2	6⅞
	3¾	2	0¼
	4	1	6¾
	4¼	1	2¼
	4½	0	10½
7 feet	3	5	4
	3¼	4	4
	3½	3	6
	3¾	3	2⅞
	4	2	3
	4¼	1	9
	4½	1	4⅝
	4¾	1	0⅞
	5	0	9⅝
7½ feet	3½	4	6⅞
	3¾	3	9
	4	3	0¾
	4¼	2	6
	4½	2	0
	4¾	1	7
	5	1	3
	5¼	0	11½
8 feet	3½	5	9½
	3¾	4	9¾
	4	4	0
	4¼	3	3¾
	4½	2	8⅝
	4¾	2	2¾
	5	1	9⅝
	5¼	1	5¼
8½ feet	3¾	6	0¼
	4	5	6¾
	4¼	4	3
	4½	3	6⅝
	4¾	2	11½
	5	2	5⅜
	5¼	2	0⅛
	5½	1	7⅝
9 feet	4	6	3
	4¼	5	3¾
	4½	4	6
	4¾	3	9⅝
	5	3	2½
	5¼	2	8⅛
	5½	2	2¾
	5¾	1	10
	6	1	6
9½ feet	4½	5	6⅝
	4¾	4	9
	5	4	0⅝
	5¼	3	5⅜
	5½	2	10⅞
	5¾	2	5¼
	6	2	0½
10 feet	4¾	5	9½
	5	5	0
	5¼	4	3½
	5½	3	8⅛
	5¾	3	1¾
	6	2	8
	6¼	2	3
	6½	1	10½
10½ feet	5	6	0½
	5¼	5	3
	5½	4	6½
	5¾	3	11
	6	3	3¼
	6¼	2	10¾
	6½	2	5⅜
	6¾	2	1
11 feet	5¼	6	3½
	5½	5	6
	5¾	4	9½
	6	4	2
	6¼	3	7⅜
	6½	3	1⅜
	6¾	2	8⅛
11½ feet	5½	6	6½
	5¾	5	9
	6	5	0½
	6¼	4	5
	6½	3	10⅛
	6¾	3	4
	7	2	10⅝
	7¼	2	6
12 feet	5¾	6	8¼
	6	6	0
	6¼	5	3½
	6½	4	7⅞
	6¾	4	1
	7	3	6⅞
	7¼	3	1⅜
	7½	2	8¼
	7¾	2	4

DUNDAS'S STEAM HAMMER.

THE Improved Steam Hammer, of which our frontispiece is an accurate engraving, manufactured at Paragon Works, near South Queensferry, Scotland. I have much pleasure, by the aid of a friend, of thus describing:

These Hammers are made of all sizes from 7 cwt. upwards, and are self-acting or can be wrought by hand; and the great advantages of these hammers are their substantiality, simplicity, and almost impossibility of getting deranged in any of their parts, combined with great moderation in price. The Slide Valve is of a peculiar description, for besides being a balance valve, thereby reducing the friction on its face to the lowest possible point, it is so arranged that after the steam has been admitted to the under side of the piston to raise the hammer, the same steam (before it is allowed to exhaust to the atmosphere) is led to the upper side of the piston, and thereby an addition to the blow or impetus is given to the hammer, from one-third to one-fifth more than its actual weight or gravity: this is achieved by using a very thick piston rod, the area of which piston rod is deducted from the under area of the piston, thereby showing the area of the upper side of the piston to be more by the area of the piston rod than the under side; for instance, in a hammer of 8 cwt. we have a cylinder of 10 inches, and a piston rod of 5 inches. The area of the under side of the piston exposed to steam is in round numbers 58½ inches, whereas the area of the upper side is 78 inches, and if you are working with 30 ℔ steam, you have 585℔ minus expansion in favour of the upper side of your piston to bring down the hammer. The Piston is solid (*no packing*): the Piston Rod is of unusual thickness, of malleable iron, as is also the cross head, and these with the hammer and hammer-face make up the weight required. As mentioned, the Hammer is self-acting, and this is arranged as follows: upon the cross head there is a conical roller (case-hardened), which roller acts upon a spiral incline, also case-hardened, and bolted to a socket which is moved up and down by a hand wheel having attached to it a double-threaded screw working in the socket: this socket has a feather, and is moved up and down by the hand wheel upon a wiper shaft; thus the spiral incline is lowered or raised: the roller on the cross head acting upon the incline causes the wiper shaft to oscillate, and the shaft having a link connecting it to the valve spindle, shuts off the steam from the hammer. Then upon the hammer coming in contact with the work upon the anvil, be it thick and thin alternately; there is a plumper rod, as we term it, working vertically between two guides fixed to cross head or hammer: this plumper rod has a head somewhat larger in diameter than the diameter of the rod; betwixt this head and the upper guide there is a spiral spring which is sufficiently strong to support the weight of this plumper rod and to raise and retain it at its usual position: in this plumper rod there is a slot cut, into which one end of a bell crank is introduced; the other end of this bell crank, whose axis or centre is upon the cross head, plays up and down ½ inch clear of what we term the kicker bar; but so soon as the hammer strikes any substance on the anvil and comes to rest, this plumper rod continues its course to fall and carries with it the end of the bell crank in the slot hole, throwing out the other arm of the bell crank, which hits the kicker bar and relieves a detent which allows a steam spring to pull the valve open to steam under the hammer, which instantly raises it, the incline shutting it off and throwing in the detent, and thus the hammer rises and falls, increasing or diminishing the number of strokes per minute according to the fall you wish to give your hammer.

LOGARITHMS.

LOGARITHMS literally signify *ratios of numbers;* hence Logarithmic Tables may be various, but those in common use for the facilitating of arithmetical operations generally are of the following corresponding progressions, viz.

Arithmetical, 0, 1, 2, 3, &c., or series of logarithms.
Geometrical, 1, 10, 100, 1000, &c., or ratio of numbers.

And thus it may be perceived, that if the log. of 10 be 1, the log. of any number less than 10 must consist wholly of decimals, because increasing by a decimal ratio. Again, if the log. of 100 be 2, the log. of any intermediate number between 10 and 100 must be 1, with so many decimals annexed; and in like manner, the log. of any intermediate number between 100 and 1000 must be 2, with decimals annexed proportionally, as before.

APPLICATION AND UTILITY OF COMMON LOGARITHMIC TABLES.

The whole numbers of the series of logarithms, as 1, 2, 3, &c., are called the indices, or characteristics of the logarithm, and which must be added to the logarithm obtained by the Table, in proportion to the number of figures contained in the given sum. Thus, suppose the logarithm be required for a sum of only two figures, the index is 1; if of three figures, the index is 2; and if of four figures, the index is 3, &c., being always a number less by unity than the number of figures the given sum contains.

Ex. The index of 8 is 0, because it is less than 10.
The index of 80 is 1, because it is less than 100.
The index of 800 is 2, because it is less than 1000.
The index of 8000 is 3, because it is less than 10,000, &c.

The index of a decimal is always the number which denotes the significant figure from the decimal point, and is marked with the sign thus —, to distinguish it from a whole number.

Ex. The index of ·32549 is —1, because the first significant figure is the first decimal.

The index of ·032549 is —2, because the first significant figure is the second decimal.

The index of ·0032549 is —3, because the first significant figure is the third decimal, and so on, of any other sum.

If the given sum for which the logarithm is required contains or consists of both integers and decimals, the index is determined by the integer part, without having any regard to the other.

1. *To find the logarithm of any whole number under* 100.

Look for the number under N in the first page of any Logarithmic Table; then immediately on the right of it is the logarithm required, with its proper index. Thus, the log. of 64 is 1·806180, and the log. of 72 is 1·857332.

2. *To find the logarithm of any number between* 100 *and* 1000, *or any sum not exceeding* 4 *figures.*

Find the first three figures in the left-hand column of the page under N, in which the number is situated, and the fourth figure, at the top or bottom of the page; then the logarithm directly under the fourth figure, and in a line with the three figures in the column on the left, with its proper index, is the logarithm required. Thus, the log. of 450 is 2·653213, and the log. of 7464 is 3·872972. Or, the log. of 378·5 is 2·578066, and that of ·7854 is —1·895091.

3. *To find the number indicated by a given logarithm.*

Look for the decimal part of the given logarithm in the different columns, and if it cannot be found exactly, take the next less. Then under N in the left-hand column, and in a line with the logarithm found, are three figures of the number required, and on the top of the column in which the found logarithm stands is one figure more; place the decimal point as indicated by the logarithmic index, which determines the sum, properly valued, as required.

If the logarithm cannot be found exactly in the Tables, subtract from it the next less that can be found, and divide the remainder by the tabular difference; the quotient will be the rest of the figures of the given number, which, being annexed to the tabular number already found, is the proper number required.

Ex. Required the number answering to the logarithm 3·233568.

Given logarithm ....=3·233568
Next less is the log. of 1712 ...=3·233504
Remainder 64

Tab. Diff.=253, and $\frac{64}{253}$=·25

Hence the number required=1712·25.

For practical purposes in mechanics, logarithms are seldom resorted to, unless for the raising of the powers of numbers or extraction of their roots: these operations, when Tables are at hand, they very much facilitate; involution, or the raising of powers, being performed simply by multiplication; and evolution, or the extraction of roots, by division, as in simple arithmetic.

Ex. 1. Required the square or second power of 25·791.

Log. of 25·791 =1·411468
Multiplied by 2, the power required.
Logarithm 2·822936, indicated number or square required=665·175.

Ex. 2. What is the cube of 30·7146?

Logarithm =1·487345
Multiplied by 3, the power required.
Logarithm 4·462035, indicated number or cube required=28975·7.

Ex. 3. Required the square root of 365.

Log.$=\frac{2\cdot562293}{2}=1\cdot281146$, indicated number or root= 19·105.

Ex. 4. Find the cube root of 12345.

Log.$=\frac{4\cdot091491}{3}=1\cdot363830$, indicated number or root= 23·1116.

Table of Logarithms from 1 *to* 100.

N.	Log.	N.	Log.	N.	Log.	N.	Log.
1	0·000000	26	1·414973	51	1·707570	76	1·880814
2	0·301030	27	1·431364	52	1·716003	77	1·886491
3	0·477121	28	1·447158	53	1·724276	78	1·892095
4	0·602060	29	1·462398	54	1·732394	79	1·897627
5	0·698970	30	1·477121	55	1·740363	80	1·903090
6	0·778151	31	1·491362	56	1·748188	81	1·908485
7	0·845098	32	1·505150	57	1·755875	82	1·913814
8	0·903090	33	1·518514	58	1·763428	83	1·919078
9	0·954243	34	1·531479	59	1·770852	84	1·924279
10	1·000000	35	1·544068	60	1·778151	85	1·929419
11	1·041393	36	1·556303	61	1·785330	86	1·934498
12	1·079181	37	1·568202	62	1·792392	87	1·939519
13	1·113943	38	1·579784	63	1·799341	88	1·944483
14	1·146128	39	1·591065	64	1·806180	89	1·949390
15	1·176091	40	1·602060	65	1·812913	90	1·954243
16	1·204120	41	1·612784	66	1·819544	91	1·959041
17	1·230449	42	1·623249	67	1·826075	92	1·963788
18	1·255273	43	1·633468	68	1·832509	93	1·968483
19	1·278754	44	1·643453	69	1·838849	94	1·973128
20	1·301030	45	1·653213	70	1·845098	95	1·977724
21	1·322219	46	1·662758	71	1·851258	96	1·982271
22	1·342423	47	1·672098	72	1·857332	97	1·986772
23	1·361728	48	1·681241	73	1·863323	98	1·991226
24	1·380211	49	1·690196	74	1·869232	99	1·995635
25	1·397940	50	1·698970	75	1·875061	100	2·000000

Note.—For accurate Tables of Logarithms of a convenient size, see Tables of Logarithms in Mr. Weale's Rudimentary Series, being Vols. 94 and 95 of that series.

Tables of the Circumferences of Circles to the nearest fraction of practical measurement; also the Areas of Circles in inches and decimal parts, likewise of feet and decimal parts, as may be required.

Rules that may render the following Tables more generally useful.

1. Any of the areas in inches multiplied by ·04328, or the areas in feet multiplied by 6·232, the product is the number of imperial gallons at 1 foot in depth.

2. Any of the areas in feet multiplied by ·03704, the product equal the number of cubic yards at 1 foot in depth.

3. The area of a circle in inches multiplied by the length or thickness in inches, and by ·263, the product equal the weight in lbs. of cast iron.

Note.—The French cubic metre, or unit of solid measure, equal 35·31716 English cubic feet. Also the litre, or unit for measures of capacity, equal 61·028 English cubic inches, or about ·453 of an imperial gallon.

Dia. in inch.	Circum. in inch.	Area in sq. inch.	Side of = squ.
$\frac{1}{16}$	·196	·0030	·0554
$\frac{1}{8}$	·392	·0122	·1107
$\frac{3}{16}$	·589	·0276	·1661
$\frac{1}{4}$	·785	·0490	·2115
$\frac{5}{16}$	·981	·0767	·2669
$\frac{3}{8}$	1·178	·1104	·3223
$\frac{7}{16}$	1·374	·1503	·3771
$\frac{1}{2}$	1·570	·1963	·4331
$\frac{9}{16}$	1·767	·2485	·4995
$\frac{5}{8}$	1·963	·3068	·5438
$\frac{11}{16}$	2·159	·3712	·6093
$\frac{3}{4}$	2·356	·4417	·6646
$\frac{13}{16}$	2·552	·5185	·7200
$\frac{7}{8}$	2·748	·6013	·7754
$\frac{15}{16}$	2·945	·6903	·8308
1 in.	$3\frac{1}{8}$	·7854	$\frac{7}{8}$
$1\frac{1}{8}$	$3\frac{1}{2}$	·9940	$\frac{7}{8}$ & $\frac{3}{32}$
$1\frac{1}{4}$	$3\frac{7}{8}$	1·227	1 in.
$1\frac{3}{8}$	$4\frac{1}{4}$	1·484	$1\frac{3}{16}$
$1\frac{1}{2}$	$4\frac{5}{8}$	1·767	$1\frac{5}{16}$
$1\frac{5}{8}$	$5\frac{1}{8}$	2·074	$1\frac{7}{16}$
$1\frac{3}{4}$	$5\frac{1}{2}$	2·405	$1\frac{9}{16}$
$1\frac{7}{8}$	$5\frac{7}{8}$	2·761	$1\frac{11}{16}$
2 in.	$6\frac{1}{4}$	3·141	$1\frac{3}{4}$
$2\frac{1}{8}$	$6\frac{5}{8}$	3·546	$1\frac{7}{8}$
$2\frac{1}{4}$	7	3·976	2 in.
$2\frac{3}{8}$	$7\frac{3}{8}$	4·430	$2\frac{1}{8}$
$2\frac{1}{2}$	$7\frac{3}{4}$	4·908	$2\frac{3}{16}$
$2\frac{5}{8}$	$8\frac{1}{4}$	5·412	$2\frac{5}{16}$
$2\frac{3}{4}$	$8\frac{5}{8}$	5·939	$2\frac{7}{16}$
$2\frac{7}{8}$	9	6·491	$2\frac{9}{16}$
3 in.	$9\frac{3}{8}$	7·068	$2\frac{5}{8}$
$3\frac{1}{8}$	$9\frac{3}{4}$	7·669	$2\frac{3}{4}$
$3\frac{1}{4}$	$10\frac{1}{4}$	8·295	$2\frac{7}{8}$
$3\frac{3}{8}$	$10\frac{5}{8}$	8·946	3 in.
$3\frac{1}{2}$	11	9·621	$3\frac{1}{8}$
$3\frac{5}{8}$	$11\frac{3}{8}$	10·320	$3\frac{1}{4}$
$3\frac{3}{4}$	$11\frac{3}{4}$	11·044	$3\frac{3}{8}$
$3\frac{7}{8}$	$12\frac{1}{8}$	11·793	$3\frac{7}{16}$

Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
4 in.	1	0½	12·566	·0879	9 in.	2	4¼	63·617	·4453
4⅛	1	0⅞	13·364	·0935	9⅛	2	4⅝	65·396	·4577
4¼	1	1⅜	14·186	·0993	9¼	2	5	67·200	·4704
4⅜	1	1¾	15·033	·1052	9⅜	2	5⅜	69·029	·4832
4½	1	2⅛	15·904	·1113	9½	2	5¾	70·882	·4961
4⅝	1	2½	16·800	·1176	9⅝	2	6¼	72·759	·5093
4¾	1	2⅞	17·720	·1240	9¾	2	6⅝	74·662	·5226
4⅞	1	3¼	18·665	·1306	9⅞	2	7	76·588	·5361
5 in.	1	3⅝	19·635	·1374	10 in.	2	7⅜	78·540	·5497
5⅛	1	4⅛	20·629	·1444	10⅛	2	7¾	80·515	·5636
5¼	1	4½	21·647	·1515	10¼	2	8⅛	82·516	·5776
5⅜	1	4⅞	22·690	·1588	10⅜	2	8½	84·540	·5917
5½	1	5¼	23·758	·1663	10½	2	8⅞	86·590	·6061
5⅝	1	5⅝	24·850	·1739	10⅝	2	9⅜	88·664	·6206
5¾	1	6	25·967	·1817	10¾	2	9¾	90·762	·6353
5⅞	1	6⅜	27·108	·1897	10⅞	2	10⅛	92·855	·6499
6 in.	1	6¾	28·274	·1979	11 in.	2	10½	95·033	·6652
6⅛	1	7¼	29·464	·2062	11⅛	2	10⅞	97·205	·6804
6¼	1	7⅝	30·679	·2147	11¼	2	11¼	99·402	·6958
6⅜	1	8	31·919	·2234	11⅜	2	11¾	101·623	·7143
6½	1	8⅜	33·183	·2322	11½	3	0⅛	103·869	·7270
6⅝	1	8¾	34·471	·2412	11⅝	3	0½	106·139	·7429
6¾	1	9⅛	35·784	·2504	11¾	3	0⅞	108·434	·7590
6⅞	1	9½	37·122	·2598	11⅞	3	1¼	110·753	·7752
7 in.	1	10	38·484	·2693	12 in.	3	1⅝	113·097	·7916
7⅛	1	10⅜	39·871	·2791	12⅛	3	2	115·466	·8082
7¼	1	10¾	41·282	·2889	12¼	3	2½	117·859	·8250
7⅜	1	11⅛	42·718	·2990	12⅜	3	2⅞	120·276	·8419
7½	1	11½	44·178	·3092	12½	3	3¼	122·718	·8590
7⅝	1	11⅞	45·663	·3196	12⅝	3	3⅝	125·185	·8762
7¾	2	0⅜	47·173	·3299	12¾	3	4	127·676	·8937
7⅞	2	0¾	48·707	·3409	12⅞	3	4⅜	130·192	·9113
8 in.	2	1⅛	50·265	·3518	13 in.	3	4¾	132·732	·9291
8⅛	2	1½	51·848	·3629	13⅛	3	5¼	135·297	·9470
8¼	2	1⅞	53·456	·3741	13¼	3	5⅝	137·886	·9642
8⅜	2	2¼	55·088	·3856	13⅜	3	6	140·500	·9835
8½	2	2⅝	56·745	·3972	13½	3	6⅜	143·139	1·0019
8⅝	2	3	58·426	·4089	13⅝	3	6¾	145·802	1·0206
8¾	2	3⅜	60·132	·4209	13¾	3	7⅛	148·489	1·0294
8⅞	2	3⅞	61·862	·4330	13⅞	3	7½	151·201	1·0584

Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
14	3	7 7/8	153·938	1·0775	19	4	11 5/8	283·529	1·9847
14 1/8	3	8 3/8	156·699	1·0968	19 1/8	5	0	287·272	1·9941
14 1/4	3	8 3/4	159·485	1·1193	19 1/4	5	0 1/2	291·039	2·0371
14 3/8	3	9 1/8	162·295	1·1360	19 3/8	5	0 7/8	294·831	2·0637
14 1/2	3	9 1/2	165·130	1·1569	19 1/2	5	1 1/4	298·648	2·0904
14 5/8	3	9 7/8	167·989	1·1749	19 5/8	5	1 5/8	302·489	2·1172
14 3/4	3	10 1/4	170·873	1·1961	19 3/4	5	2	306·355	2·1443
14 7/8	3	10 3/4	173·782	1·2164	19 7/8	5	2 3/8	310·245	2·1716
15	3	11 1/8	176·715	1·2370	20	5	2 7/8	314·160	2·1990
15 1/8	3	11 1/2	179·672	1·2577	20 1/8	5	3 1/4	318·099	2·2265
15 1/4	3	11 7/8	182·654	1·2785	20 1/4	5	3 5/8	322·063	2·2543
15 3/8	4	0 1/4	185·661	1·2996	20 3/8	5	4	326·051	2·2822
15 1/2	4	0 5/8	188·692	1·3208	20 1/2	5	4 3/8	330·064	2·3103
15 5/8	4	1	191·748	1·3422	20 5/8	5	4 3/4	334·101	2·3386
15 3/4	4	1 1/2	194·828	1·3637	20 3/4	5	5 1/8	338·163	2·3670
15 7/8	4	1 7/8	197·933	1·3855	20 7/8	5	5 1/2	342·250	2·3956
16	4	2 1/4	201·062	1·4074	21	5	5 7/8	346·361	2·4244
16 1/8	4	2 5/8	204·216	1·4295	21 1/8	5	6 3/8	350·497	2·4533
16 1/4	4	3	207·394	1·4517	21 1/4	5	6 3/4	354·657	2·4824
16 3/8	4	3 3/8	210·597	1·4741	21 3/8	5	7 1/8	358·841	2·5117
16 1/2	4	3 3/4	213·825	1·4967	21 1/2	5	7 1/2	363·051	2·5412
16 5/8	4	4 1/4	217·077	1·5195	21 5/8	5	7 7/8	367·284	2·5708
16 3/4	4	4 5/8	220·353	1·5424	21 3/4	5	8 1/4	371·543	2·6007
16 7/8	4	5	223·654	1·5655	21 7/8	5	8 3/4	375·826	2·6306
17	4	5 3/8	226·980	1·5888	22	5	9 1/8	380·133	2·6608
17 1/8	4	5 3/4	230·330	1·6123	22 1/8	5	9 1/2	384·465	2·6691
17 1/4	4	6 1/8	233·705	1·6359	22 1/4	5	9 7/8	388·822	2·7016
17 3/8	4	6 1/2	237·104	1·6597	22 3/8	5	10 1/4	393·203	2·7224
17 1/2	4	6 7/8	240·528	1·6836	22 1/2	5	10 5/8	397·608	2·7632
17 5/8	4	7 3/8	243·977	1·7078	22 5/8	5	11	402·038	2·7980
17 3/4	4	7 3/4	247·450	1·7321	22 3/4	5	11 1/2	406·493	2·8054
17 7/8	4	8 1/8	250·947	1·7566	22 7/8	5	11 7/8	410·972	2·8658
18	4	8 1/2	254·469	1·7812	23	6	0 1/4	415·476	2·8903
18 1/8	4	8 7/8	258·016	1·8061	23 1/8	6	0 5/8	420·004	2·9100
18 1/4	4	9 1/4	261·587	1·8311	23 1/4	6	1	424·557	2·9518
18 3/8	4	9 3/4	265·182	1·8562	23 3/8	6	1 3/8	429·135	2·9937
18 1/2	4	10 1/8	268·803	1·8816	23 1/2	6	1 3/4	433·737	3·0129
18 5/8	4	10 1/2	272·447	1·9071	23 5/8	6	2 1/4	438·363	3·0261
18 3/4	4	10 7/8	276·117	1·9328	23 3/4	6	2 5/8	443·014	3·0722
18 7/8	4	11 1/4	279·811	1·9586	23 7/8	6	3	447·690	3·1081

Dia. in ft. in.	Circum. in ft. in.	Area in sq. inch.	Area in sq. feet.	Dia. in ft. in.	Circum. in ft. in.	Area in sq. inch.	Area in sq. feet.
2 0	6 3⅜	452·390	3·1418	2 10	8 10¾	907·922	6·3051
2 0¼	6 4⅛	461·864	3·2075	2 10¼	8 11½	921·323	6·3981
2 0½	6 4⅞	471·436	3·2731	2 10½	9 0⅜	934·822	6·4911
2 0¾	6 5¾	481·106	3·3410	2 10¾	9 1⅛	948·419	6·5863
2 1	6 6½	490·875	3·4081	2 11	9 1⅞	962·115	6·6815
2 1¼	6 7¼	500·741	3·4775	2 11¼	9 2¾	975·908	6·7772
2 1½	6 8⅛	510·706	3·5468	2 11½	9 3½	989·800	6·8738
2 1¾	6 8⅞	520·769	3·6101	2 11¾	9 4¼	1003·79	6·9701
2 2	6 9⅝	530·930	3·6870	3 0	9 5	1017·87	7·0688
2 2¼	6 10½	541·189	3·7583	3 0¼	9 5⅞	1032·06	7·1671
2 2½	6 11¼	551·547	3·8302	3 0½	9 6⅝	1046·35	7·2664
2 2¾	7 0	562·002	3·9042	3 0¾	9 7½	1060·73	7·3662
2 3	7 0¾	572·556	3·9761	3 1	9 8¼	1075·21	7·4661
2 3¼	7 1⅝	583·208	4·0500	3 1¼	9 9	1089·79	7·5671
2 3½	7 2⅜	593·958	4·1241	3 1½	9 9⅞	1104·46	7·6691
2 3¾	7 3⅛	604·807	4·2000	3 1¾	9 10½	1119·24	7·7791
2 4	7 3⅞	615·753	4·2760	3 2	9 11⅜	1134·12	7·8681
2 4¼	7 4¾	626·798	4·3521	3 2¼	10 0⅛	1149·09	7·9791
2 4½	7 5½	637·941	4·4302	3 2½	10 0⅞	1164·16	8·0846
2 4¾	7 6¼	649·182	4·5083	3 2¾	10 1¾	1179·32	8·1891
2 5	7 7	660·521	4·5861	3 3	10 2½	1194·59	8·2951
2 5¼	7 7⅞	671·958	4·6665	3 3¼	10 3¼	1209·95	8·4026
2 5½	7 8⅝	683·494	4·7467	3 3½	10 4	1225·42	8·5091
2 5¾	7 9½	695·128	4·8274	3 3¾	10 4⅞	1240·98	8·6171
2 6	7 10¼	706·860	4·9081	3 4	10 5⅝	1256·64	8·7269
2 6¼	7 11	718·690	4·9901	3 4¼	10 6⅜	1272·39	8·8361
2 6½	7 11¾	730·618	5·0731	3 4½	10 7¼	1288·25	8·9462
2 6¾	8 0⅝	742·644	5·1573	3 4¾	10 8	1304·20	9·0561
2 7	8 1⅜	754·769	5·2278	3 5	10 8¾	1320·25	9·1686
2 7¼	8 2⅛	766·992	5·3264	3 5¼	10 9½	1336·40	9·2112
2 7½	8 2⅞	779·313	5·4112	3 5½	10 10⅜	1352·65	9·3936
2 7¾	8 3¾	791·732	5·4982	3 5¾	10 11⅛	1369·00	9·5061
2 8	8 4½	804·249	5·5850	3 6	10 11⅞	1385·44	9·6212
2 8¼	8 5⅜	816·865	5·6729	3 6¼	11 0¾	1401·98	9·7364
2 8½	8 6⅛	829·578	5·7601	3 6½	11 1½	1418·62	9·8518
2 8¾	8 6⅞	842·390	5·8491	3 6¾	11 2¼	1435·36	9·9671
2 9	8 7⅝	855·300	5·9398	3 7	11 3	1452·20	10·084
2 9¼	8 8½	868·308	6·0291	3 7¼	11 3⅞	1469·14	10·202
2 9½	8 9¼	881·415	6·1201	3 7½	11 4⅝	1486·17	10·320
2 9¾	8 10	894·619	6·2129	3 7¾	11 5⅜	1503·30	10·439

Dia. in ft.	Dia. in in.	Circum. in ft.	Circum. in in.	Area in sq. inch.	Area in sq. feet.	Dia. in ft.	Dia. in in.	Circum. in ft.	Circum. in in.	Area in sq. inch.	Area in sq. feet.
3	8	11	6¼	1520·53	10·559	4	6	14	1⅝	2290·22	15·904
3	8¼	11	7	1537·86	10·679	4	6¼	14	2⅜	2311·48	16·051
3	8½	11	7¾	1555·28	10·800	4	6½	14	3¼	2332·83	16·200
3	8¾	11	8½	1572·81	10·922	4	6¾	14	4	2354·28	16·349
3	9	11	9⅜	1590·43	11·044	4	7	14	4¾	2375·83	16·498
3	9¼	11	10⅛	1608·15	11·167	4	7¼	14	5½	2397·48	16·649
3	9½	11	10⅞	1625·97	11·291	4	7½	14	6⅜	2419·22	16·800
3	9¾	11	11¾	1643·89	11·415	4	7¾	14	7⅛	2441·07	16·951
3	10	12	0½	1661·90	11·534	4	8	14	7⅞	2463·01	17·104
3	10¼	12	1¼	1680·02	11·666	4	8¼	14	8⅝	2485·05	17·257
3	10½	12	2	1698·23	11·793	4	8½	14	9½	2507·19	17·411
3	10¾	12	2⅞	1716·54	11·920	4	8¾	14	10¼	2529·42	17·565
3	11	12	3⅝	1734·94	12·048	4	9	14	11	2551·76	17·720
3	11¼	12	4⅜	1753·45	12·176	4	9¼	14	11⅞	2574·19	17·876
3	11½	12	5¼	1772·05	12·305	4	9½	15	0⅝	2596·72	18·033
3	11¾	12	6	1790·76	12·435	4	9¾	15	1⅜	2619·35	18·189
4	0	12	6¾	1809·56	12·566	4	10	15	2¼	2642·08	18·347
4	0¼	12	7½	1828·46	12·697	4	10¼	15	2⅞	2664·91	18·506
4	0½	12	8⅜	1847·45	12·829	4	10½	15	3¾	2687·83	18·665
4	0¾	12	9⅛	1866·55	12·962	4	10¾	15	4½	2710·85	18·825
4	1	12	9⅞	1885·74	13·095	4	11	15	5¼	2733·97	18·985
4	1¼	12	10¾	1905·03	13·229	4	11¼	15	6⅛	2757·19	19·147
4	1½	12	11½	1924·42	13·364	4	11½	15	6⅞	2780·51	19·309
4	1¾	13	0¼	1943·91	13·499	4	11¾	15	7¾	2803·92	19·471
4	2	13	1	1963·50	13·635	5	0	15	8½	2827·44	19·635
4	2¼	13	1⅞	1983·18	13·772	5	0¼	15	9¼	2851·05	19·798
4	2½	13	2⅝	2002·96	13·909	5	0½	15	10	2874·76	19·963
4	2¾	13	3⅜	2022·84	14·047	5	0¾	15	10¾	2898·56	20·128
4	3	13	4¼	2042·82	14·186	5	1	15	11⅝	2922·47	20·294
4	3¼	13	5	2062·90	14·325	5	1¼	16	0⅜	2946·47	20·461
4	3½	13	5¾	2083·07	14·465	5	1½	16	1¼	2970·57	20·629
4	3¾	13	6½	2103·35	14·606	5	1¾	16	1⅞	2994·77	20·797
4	4	13	7⅜	2123·72	14·748	5	2	16	2¾	3019·07	20·965
4	4¼	13	8⅛	2144·19	14·890	5	2¼	16	3½	3043·47	21·135
4	4½	13	8⅞	2164·75	15·033	5	2½	16	4¼	3067·96	21·305
4	4¾	13	9¾	2185·42	15·176	5	2¾	16	5⅛	3092·56	21·476
4	5	13	10½	2206·18	15·320	5	3	16	5⅞	3117·25	21·647
	5¼	13	11¼	2227·05	15·465	5	3¼	16	6¼	3142·04	21·819
	5½	14	0	2248·01	15·611	5	3½	16	7½	3166·92	21·992
	5¾	14	0⅞	2269·06	15·757	5	3¾	16	8¼	3191·91	22·166

Dia. in ft.	Dia. in in.	Circum. in ft.	Circum. in in.	Area in sq. inch.	Area in sq. feet.	Dia. in ft.	Dia. in in.	Circum. in ft.	Circum. in in.	Area in sq. inch.	Area in sq. feet.
5	4	16	9	3216·99	22·333	6	2	19	4½	4300·85	29·867
5	4¼	16	9¾	3242·17	22·515	6	2¼	19	5¼	4329·95	30·069
5	4½	16	10⅝	3267·46	22·621	6	2½	19	6	4359·16	30·271
5	4¾	16	11⅜	3292·83	22·866	6	2¾	19	6¾	4388·47	30·475
5	5	17	0⅛	3318·31	23·043	6	3	19	7⅝	4417·87	30·679
5	5¼	17	0⅞	3343·88	23·221	6	3¼	19	8⅜	4447·37	30·884
5	5½	17	1¾	3369·56	23·330	6	3½	19	9⅛	4476·97	31·090
5	5¾	17	2½	3395·33	23·578	6	3¾	19	9⅞	4506·67	31·296
5	6	17	3⅜	3421·20	23·758	6	4	19	10¾	4536·47	31·503
5	6¼	17	4⅛	3447·16	23·938	6	4¼	19	11½	4566·36	31·710
5	6½	17	4⅞	3473·23	24·119	6	4½	20	0¼	4596·35	31·919
5	6¾	17	5⅝	3499·39	24·301	6	4¾	20	1⅛	4626·44	32·114
5	7	17	6½	3525·66	24·483	6	5	20	1⅞	4656·63	32·337
5	7¼	17	7¼	3552·01	24·666	6	5¼	20	2⅝	4686·92	32·548
5	7½	17	8	3578·47	24·850	6	5½	20	3½	4717·30	32·759
5	7¾	17	8¾	3605·03	25·034	6	5¾	20	4¼	4747·79	32·970
5	8	17	9⅝	3631·68	25·220	6	6	20	5	4778·37	33·183
5	8¼	17	10⅜	3658·44	25·405	6	6¼	20	5¾	4809·05	33·396
5	8½	17	11⅛	3685·29	25·592	6	6½	20	6½	4839·83	33·619
5	8¾	17	11⅞	3712·24	25·779	6	6¾	20	7⅜	4870·70	33·824
5	9	18	0¾	3739·28	25·964	6	7	20	8⅛	4901·68	34·039
5	9¼	18	1½	3766·43	26·155	6	7¼	20	8⅞	4932·75	34·255
5	9½	18	2¼	3793·67	26·344	6	7½	20	9¾	4963·92	34·471
5	9¾	18	3⅛	3821·02	26·534	6	7¾	20	10½	4995·19	34·688
5	10	18	3⅞	3848·46	26·725	6	8	20	11¼	5026·26	34·906
5	10¼	18	4⅝	3875·99	26·916	6	8¼	21	0⅛	5058·02	35·125
5	10½	18	5½	3903·63	27·108	6	8½	21	0⅞	5089·58	35·344
5	10¾	18	6¼	3931·36	27·301	6	8¾	21	1⅝	5121·24	35·564
5	11	18	7	3959·20	27·494	6	9	21	2⅜	5153·00	35·784
5	11¼	18	7¾	3987·13	27·688	6	9¼	21	3¼	5184·86	36·006
5	11½	18	8⅝	4015·16	27·883	6	9½	21	4	5216·82	36·227
5	11¾	18	9⅜	4043·28	28·078	6	9¾	21	4¾	5248·87	36·450
6	0	18	10⅛	4071·51	28·274	6	10	21	5½	5281·02	36·674
6	0¼	18	10⅞	4099·83	28·471	6	10¼	21	6⅜	5313·27	36·897
6	0½	18	11¾	4128·25	28·668	6	10½	21	7⅛	5345·62	37·122
6	0¾	19	0½	4156·77	28·866	6	10¾	21	7⅞	5378·07	37·347
6	1	19	1¼	4185·39	29·065	6	11	21	8¾	5410·62	37·573
6	1¼	19	2⅛	4214·11	29·264	6	11¼	21	9½	5443·26	37·700
6	1½	19	2⅞	4242·92	29·466	6	11½	21	10¼	5476·00	38·027
6	1¾	19	3⅝	4271·83	29·665	6	11¾	21	11	5508·84	38·256

Dia. in ft. & in.	Circum. in ft. and in.	Area in feet.	Dia. in ft. & in.	Circum. in ft. and in.	Area in feet.
7 0	21 11⅞	38·4846	10 0	31 5	78·5400
1	22 3	39·4060	1	31 8⅛	79·8540
2	22 6⅛	40·3388	2	31 11¼	81·1795
3	22 9¼	41·2825	3	32 2⅜	82·5160
4	23 0⅜	42·2367	4	32 5½	83·8627
5	23 2⅛	43·2022	5	32 8⅝	85·2211
6	23 6¾	44·1787	6	32 11¾	86·5903
7	23 11	45·1656	7	33 2⅞	87·9697
8	24 1⅛	46·1638	8	33 6⅛	89·3608
9	24 4⅛	47·1730	9	33 9¼	90·7627
10	24 7¼	48·1926	10	34 0⅜	92·1749
11	24 10⅜	49·2236	11	34 3½	93·5986
8 0	25 1½	50·2656	11 0	34 6⅝	95·0334
1	25 4⅝	51·3178	1	34 9¾	96·4783
2	25 7⅞	52·3816	2	35 0⅞	97·9347
3	25 11	53·4562	3	35 4⅛	99·4021
4	26 2⅛	54·5412	4	35 7¼	100·8797
5	26 5¼	55·6377	5	35 10⅝	102·3689
6	26 8⅜	56·7451	6	36 1½	103·8691
7	26 11½	57·8628	7	36 4½	105·3794
8	27 2¾	58·9920	8	36 7¾	106·9013
9	27 5¾	60·1321	9	36 10⅞	108·4342
10	27 9	61·2826	10	37 2¾	109·9772
11	28 0⅛	62·4445	11	37 5¼	111·5319
9 0	28 3¼	63·6174	12 0	37 8⅜	113·0976
1	28 6⅜	64·8006	1	37 11½	114·6732
2	28 9½	65·9951	2	38 2⅝	116·2607
3	29 0⅝	67·2007	3	38 5¾	117·8590
4	29 3¾	68·4166	4	38 8⅞	119·4674
5	29 7	69·6440	5	39 0	121·0876
6	29 10⅛	70·8823	6	39 3¼	122·7187
7	30 1¼	72·1309	7	39 6⅜	124·3598
8	30 4⅜	73·3910	8	39 9½	126·0127
9	30 7½	74·6620	9	40 0⅝	127·6765
10	30 11⅝	75·9433	10	40 3¾	129·3504
11	31 1¾	77·2362	11	40 6⅞	131·0360

Dia. in ft. & in.	Circum. in ft. and in.	Area in feet.	Dia. in ft. & in.	Circum. in ft. and in.	Area in feet.
13 0	40 10	132·7326	16 0	50 3⅛	201·0624
1	41 1⅛	134·4391	1	50 6¼	203·1615
2	41 4⅜	136·1574	2	50 9⅝	205·2726
3	41 7½	137·8867	3	51 0½	207·3946
4	41 10⅝	139·6260	4	51 3¾	209·5264
5	42 1⅝	141·3771	5	51 6½	211·6703
6	42 4⅞	143·1391	6	51 10	213·8251
7	42 8	144·9111	7	52 1⅛	215·9896
8	42 11⅛	146·6949	8	52 4¼	218·1662
9	43 2¼	148·4896	9	52 7⅜	220·3537
10	43 5½	150·2943	10	52 10½	222·5510
11	43 8⅝	152·1109	11	53 1⅝	224·7603
14 0	43 11¾	153·9384	17 0	53 4⅞	226·9806
1	44 2⅞	155·7758	1	53 8	229·2105
2	44 6	157·6250	2	53 11⅛	231·4625
3	44 9⅛	159·4852	3	54 2⅛	233·7055
4	45 0¼	161·3553	4	54 5⅜	235·9682
5	45 3½	163·2373	5	54 8½	238·2430
6	45 6⅝	165·1303	6	54 11⅝	240·5287
7	45 9¾	167·0331	7	55 2⅞	242·8241
8	46 0⅞	168·9479	8	55 6	245·1316
9	46 4	170·8735	9	55 9⅛	247·4500
10	46 7⅛	172·8091	10	56 0¼	249·7781
11	46 11¼	174·7565	11	56 3½	252·1184
15 0	47 1½	176·7150	18 0	56 6½	254·4696
1	47 4⅝	178·6832	1	56 9⅝	256·8303
2	47 7¾	180·6634	2	57 0⅞	259·2033
3	47 10⅞	182·6545	3	57 4	261·5872
4	48 2⅛	184·6555	4	57 7⅛	263·9807
5	48 5⅛	186·6684	5	57 10¼	266·3864
6	48 8¼	188·6923	6	58 1⅜	268·8031
7	48 11⅜	190·7260	7	58 4½	271·2293
8	49 2⅝	192·7716	8	58 7⅝	273·6678
9	49 5¾	194·8282	9	58 10¾	276·1171
10	49 8⅞	196·8946	10	59 2	278·5761
11	50 0	198·9730	11	59 5⅛	281·0472

COMPARATIVE DEGREES OF TEMPERATURE, AS INDICATED BY THE DIFFERENT THERMOMETERS, VIZ., FAHRENHEIT, CENTIGRADE, AND REAUMUR.

Degrees of			Degrees of			Degrees of		
Fah.	Cent.	Reau.	Fah.	Cent.	Reau.	Fah.	Cent.	Reau.
212	100	80	176	80	64	140	60	48
211	99·4	79·5	175	79·4	63·5	139	59·4	47·5
210	98·8	79·1	174	78·8	63·1	138	58·8	47·1
209	98·3	78·6	173	78·3	62·6	137	58·3	46·6
208	97·7	78·2	172	77·7	62·2	136	57·7	46·2
207	97·2	77·7	171	77·2	61·7	135	57·2	45·7
206	96·6	77·3	170	76·6	61·3	134	56·6	45·3
205	96·1	76·8	169	76·1	60·8	133	56·1	44·9
204	95·5	76·4	168	75·5	60·4	132	55·5	44·4
203	95	76	167	75	60	131	55	44
202	94·4	75·5	166	74·4	59·5	130	54·4	43·5
201	93·8	75·1	165	73·8	59·1	129	53·8	43·1
200	93·3	74·6	164	73·3	58·6	128	53·3	42·6
199	92·7	74·2	163	72·7	58·2	127	52·7	42·2
198	92·2	73·7	162	72·2	57·7	126	52·2	41·7
197	91·6	73·3	161	71·6	57·3	125	51·6	41·3
196	91·1	72·8	160	71·1	56·8	124	51·1	40·8
195	90·5	72·4	159	70·5	56·4	123	50·5	40·4
194	90	72	158	70	56	122	50	40
193	89·4	71·5	157	69·4	55·5	121	49·4	39·5
192	88·8	71·1	156	68·8	55·1	120	48·8	39·1
191	88·3	70·6	155	68·3	54·6	119	48·3	38·6
190	87·7	70·2	154	67·7	54·2	118	47·7	38·2
189	87·2	69·7	153	67·2	53·7	117	47·2	37·7
188	86·6	69·3	152	66·6	53·3	116	46·6	37·3
187	86·1	68·8	151	66·1	52·8	115	46·1	36·8
186	85·5	68·4	150	65·5	52·4	114	45·5	36·4
185	85	68	149	65	52	113	45	36
184	84·4	67·5	148	64·4	51·5	112	44·4	35·5
183	83·8	67·1	147	63·8	51·1	111	43·8	35·1
182	83·3	66·6	146	63·3	50·6	110	43·3	34·6
181	82·7	66·2	145	62·7	50·2	109	42·7	34·2
180	82·2	65·7	144	62·2	49·7	108	42·2	33·7
179	81·6	65·3	143	61·6	49·3	107	41·6	33·3
178	81·1	64·8	142	61·1	48·8	106	41·1	32·8
177	80·5	64·4	141	60·5	48·4	105	40·5	32·4

Degrees of			Degrees of			Degrees of		
Fah.	Cent.	Reau.	Fah.	Cent.	Reau.	Fah.	Cent.	Reau.
104	40	32	65	18·3	14·6	26	— 3·3	— 2·6
103	39·4	31·5	64	17·7	14·2	25	— 3·8	— 3·1
102	38·8	31·1	63	17·2	13·7	24	— 4·4	— 3·5
101	38·3	30·6	62	16·6	13·3	23	— 5	— 4
100	37·7	30·2	61	16·1	12·8	22	— 5·5	— 4·4
99	37·2	29·7	60	15·5	12·4	21	— 6·1	— 4·8
98	36·6	29·3	59	15	12	20	— 6·6	— 5·3
97	36·1	28·8	58	14·4	11·5	19	— 7·2	— 5·7
96	35·5	28·4	57	13·8	11·1	18	— 7·7	— 6·2
95	35	28	56	13·3	10·6	17	— 8·3	— 6·6
94	34·4	27·5	55	12·7	10·2	16	— 8·8	— 7·1
93	33·8	27·1	54	12·2	9·7	15	— 9·4	— 7·5
92	33·3	26·6	53	11·6	9·3	14	—10	— 8
91	32·7	26·2	52	11·1	8·8	13	—10·5	— 8·4
90	32·2	25·7	51	10·5	8·4	12	—11·1	— 8·8
89	31·6	25·3	50	10	8	11	—11·6	— 9·3
88	31·1	24·8	49	9·4	7·5	10	—12·2	— 9·7
87	30·5	24·4	48	8·8	7·1	9	—12·7	—10·2
86	30	24	47	8·3	6·6	8	—13·3	—10·6
85	29·4	23·5	46	7·7	6·2	7	—13·8	—11·1
84	28·8	23·1	45	7·2	5·7	6	—14·4	—11·5
83	28·3	22·6	44	6·6	5·3	5	—15	—12
82	27·7	22·2	43	6·1	4·8	4	—15·5	—12·4
81	27·2	21·7	42	5·5	4·4	3	—16·1	—12·8
80	26·6	21·3	41	5	4	2	—16·6	—13·3
79	26·1	20·8	40	4·4	3·5	1	—17·2	—13·7
78	25·5	20·4	39	3·8	3·1	zero.	—17·7	—14·2
77	25	20	38	3·3	2·6	— 1	—18·3	—14·6
76	24·4	19·5	37	2·7	2·2	— 2	—18·8	—15·1
75	23·8	19·1	36	2·2	1·7	— 3	—19·4	—15·5
74	23·3	18·6	35	1·6	1·3	— 4	—20	—16
73	22·7	18·2	34	1·1	0·8	— 5	—20·5	—16·4
72	22·2	17·7	33	0·5	0·4	— 6	—21·1	—16·8
71	21·6	17·3	32	zero.	zero.	— 7	—21·6	—17·3
70	21·1	16·8	31	—0·5	—0·4	— 8	—22·2	—17·7
69	20·5	16·4	30	—1·1	—0·8	— 9	—22·7	—18·2
68	20	16	29	—1·6	—1·3	—10	—23·3	—18·6
67	19·4	15·5	28	—2·2	—1·7	—11	—23·8	—19·1
66	18·8	15·1	27	—2·7	—2·2	—12	—24·4	—19·5

Degrees of Fah.	Cent.	Reau.	Degrees of Fah.	Cent.	Reau.	Degrees of Fah.	Cent.	Reau.
—13	—25	—20	—21	—29·4	—23·5	—29	—33·8	—27·1
—14	—25·5	—20·4	—22	—30	—24	—30	—34·4	—27·5
—15	—26·1	—20·8	—23	—30·5	—24·4	—31	—35	—28
—16	—26·6	—21·3	—24	—31·1	—24·8	—32	—35·5	—28·4
—17	—27·2	—21·7	—25	—31·6	—25·3	—33	—36·1	—28·8
—18	—27·7	—22·2	—26	—32·2	—25·7	—34	—36·6	—29·3
—19	—28·3	—22·6	—27	—32·7	—26·2	—35	—37·2	—29·7
—20	—28·8	—23·1	—28	—33·3	—26·6			

Relative Indications of Temperature by Fahrenheit, Centigrade, and Reaumur's Thermometers, practically tabulated.

Degrees of Fah.	Cent.	Reau.	METALS, ETC.
2786	1530	1224	Cast Iron melts.
2500	1371	1097	Cast Steel „
2016	1102	882	Gold „
1996	1091	873	Copper, Cast „
1900	1038	830	Gun Metal „
1873	1023	818	Silver „
1869	1020	816	Brass „
810	432	345	Antimony „
700	371	297	Zinc „
594	312	250	Lead „
476	247	197	Bismuth „
442	228	182	Tin „
226	108	86	Sulphur „
151	67	53	Bees-wax „
142	61	49	Spermaceti „
120	48·8	39·1	Stearine „
100	37·7	30·2	Phosphorus „
98	36·6	29·3	Tallow „
			ALLOYS.
212	100	80	Bismuth 5, tin 3, lead 2, melts.

Degrees of Fah.	Cent.	Reau.	
			ALLOYS.
210	98·8	79·1	Bismuth 8, tin 3, lead 5, melts.
138	58·8	47·1	Bismuth 15, tin 4, lead 8, and cadmium 3, „
			LIQUIDS.
662	350	280	Mercury boils.
600	315·5	252·4	Linseed oil „
590	310	248	Sulphuric acid „
560	293	235	Oil, turpentine „
98	36·6	29·3	Ether and water in a vacuum „
212	100	80	Fresh water boils, barometer 30 inches at sea level.
213·2	100·6	80·5	Common sea-water containing $\frac{1}{33}$ salt, boils under atmospheric pressure.
214·4	101·3	81	Sea-water containing $\frac{2}{33}$ boils.
215·5	102	81·6	„ „ $\frac{3}{33}$ „
216·7	102·6	82	„ „ $\frac{4}{33}$ „
217·9	103·2	82·6	„ „ $\frac{5}{33}$ „
219·1	104	83·2	„ „ $\frac{6}{33}$ „
220·3	104·5	83·6	„ „ $\frac{7}{33}$ „
			NOTE.—Relative to steam-boilers at sea, as a general rule no deposit of salt takes place up to 216·7 degrees of atmospheric boiling.
			FREEZING.
32	0	0	Freezing-point of Fah., and zero of Cent. and Reau.
28	— 2·2	— 1·7	Vinegar freezes.
27½	— 2·5	— 2	Sea-water „
20	— 6·6	— 5·3	Strong Wines „
14	—10	— 8	Turpentine „
1	—17·2	—13·7	Sulphuric acid „
0	—17·7	—14·2	Zero of Fahrenheit

SIMPLE PRACTICAL QUESTIONS NOT UNFREQUENTLY PUT TO YOUNG MEN ON THEIR EXAMINATION AS QUALIFIED ENGINEERS:—

1. Subtract ·002 from 100.

$$\begin{array}{r} 100 \\ \cdot002 \\ \hline 99\cdot998 \end{array}$$ Answer.

2. Find the value of 24·004—·987516.

$$\begin{array}{r} 24\cdot004 \\ \cdot987516 \\ \hline 23\cdot016484 \end{array}$$ Answer.

3. Multiply ·0001 by ·001. As there must always be as many decimals in the product as there are in the factors, the product here must be ·0000001.

4. Multiply ·03 by 2, by ·001 and by 6.

$\cdot03 \times 2 \times \cdot001 \times 6 = \cdot00036$, the product consisting of fiv decimal places, because those in the factors make up that number.

Express as decimals,

$$\frac{7}{10} = \cdot7, \frac{3}{100} = \cdot03, \frac{37}{100000} = \cdot00037.$$

5. A bar of iron is in length 8 feet, a hole is required to be drilled in it so that it may be worked as a lever upon a pin or stud, one end of the lever must move through a space of 3 feet, the other end through 2·5 feet, at what distance from either end must the hole be made.

$$2\cdot5 + 3 = \frac{5\cdot5}{2} = 2\cdot75 \text{ and } \frac{8}{2} = 4, \text{ then } 3 \times 4 = 12 \div 2\cdot75 = 4\cdot3636 \text{ feet from one end.}$$

and $2\cdot5 \times 4 = 10 \div 2\cdot75 = 3\cdot6363$ feet from the other.

6. What weight on the end of a lever 8 feet in length, will exert a force equal to 100 lbs. on the other end, 6 inches being the distance of the fulcrum from the 100 lbs?

The arm of the power is 96 in. — 6 in. = 90 in. therefore $100 \times 6 \div 90 = 6{\cdot}667$ lbs. the weight required.

7. What are the solid contents and superficial surface of a cylindrical boiler with spherical ends, the boiler being 4 feet in diameter and the cylindrical part 10 feet in length?

$4 \times 4 \times {\cdot}7854 \times 10 = 125{\cdot}664$ contents of cylindrical part.

$4 \times 4 \times 4 \times {\cdot}5236 = 33{\cdot}5104 + 125{\cdot}664 = 159{\cdot}1744$ total amount of cubic feet.

then, $4 \times 3{\cdot}1416 \times 10 = 125{\cdot}664$ surface of cylinder.

$4 \times 3{\cdot}1416 \times 4 = 50{\cdot}2656 + 125{\cdot}664 = 175{\cdot}9296$ total surface in square feet.

8. What quantity of coals will a bunker contain that is 16 feet long, 6·5 feet wide, and 18 feet in height, allowing 45 cubic feet capacity per ton?

$$16 \times 6{\cdot}5 \times 18 = 1872 \div 45 = 41{\cdot}6 \text{ tons.}$$

9. Required the necessary weight to be attached on the end of a lever for an overflow valve of 5 inches diameter, the pressure of steam in the boiler being 10 lbs. per square inch, the length of the lever 42 inches, and the fulcrum 6 inches from the centre of the valve.

$$5^2 \times {\cdot}7854 \times 10 \times 6 = 1178{\cdot}1000 \div 42 = 28{\cdot}05 \text{ lbs.}$$

10. The diameter of the screw shaft of a 100 horse-power engine is 6 inches, what should be the diameter when the power is 400 horses?

$$6 \times 6 = 36 \times 4, \text{ and } \sqrt{144} = 12 \text{ inches diameter.}$$

11. How much copper and tin will be required to cast a screw propeller weighing 16 cwts. 3 qrs. 11 lbs., gun-metal being of 100 parts copper and 11 of tin?

16 cwt. 3 qrs. 11 lbs. $= 1887$ lbs. $\times 100 \div 111 = 1700$ lbs. of copper.
and 1887 lbs. $\times 11 \div 111 = 187$ lbs. of tin.

12. The consumption of coal is 60 cwts. per hour, and the rate of the ship 10 knots full speed, what will be the consumption at 8 knots, and what distance will 400 tons of coals carry a vessel so circumstanced?

$10^3 = 1000$ and $8^3 = 512$. $512 \times 60 \div 1000 = 30{\cdot}72$ cwts. per hour at 8 knots.
Then if 30·72 gives 8 knots, what will 400×20 give? *Ans.* 8000 cwts.
Then $8000 \times 8 \div 30{\cdot}72 = 2083{\cdot}3$ knots the distance.

13. A safety valve is 6 inches diameter, what weight must be placed upon it to equal 12 lbs. per square inch?

$$6^2 \times {\cdot}7854 \times 12 = 339{\cdot}2928 \text{ lbs.}$$

14. The pitch of a screw propeller is 16 feet, the number of revolutions 80 per minute; find the rate of the screw in knots per hour, supposing the knot or nautical mile equal 6080 English lineal feet.

$$16 \times 80 \times 60 = 76{,}800 \div 6080 = 12{\cdot}631 \text{ knots.}$$

15. The area of a brine valve is one fourth that of the feed, if the diameter of the latter be $4\frac{1}{2}$ inches, what should be the diameter of the former?

$$4{\cdot}5^2 \times {\cdot}7854 = \frac{15{\cdot}904350}{{\cdot}7854 \times 4} = \frac{15{\cdot}904350}{3{\cdot}1416} = \sqrt{5{\cdot}06} = 2{\cdot}25$$
inches nearly.

16. What should be the diameter of the piston of an indicator, the area of which is one fourth of a square inch?

$$\frac{\cdot 25000000}{\cdot 7854} = \sqrt{\cdot 3183} = \cdot 561 \text{ of an inch.}$$

17. A piece of boiler-plate (iron) is 7 feet long, 6 feet broad, and $\frac{5}{8}$ inch in thickness, how many cubic feet does it contain, and what is its weight at 25 lbs. per square foot?

$$84 \times 72 \times \cdot 625 = 3780\cdot 000 \div 1728 = 2\cdot 187 \text{ cubic feet.}$$
or, $7 \times 6 \times \cdot 052 = 2\cdot 184$ cubic feet.
$$7 \times 6 \times 25 = 1050 \div 112 = 9 \text{ cwts. 1 qr. 14 lbs.}$$

18. What weight on the end of a lever 12 feet in length will equipoise 2 tons on the other end, the fulcrum being distant 6 inches from the weight to be equipoised, and the weight of the lever not taken into account?

$$4480 \times 6 = 26880 \div 138 = 194\cdot 7 \text{ lbs.}$$

19. A boiler has 1800 tubes, $2\frac{1}{2}$ inches diameter and 6 feet 6 inches long, what is the total amount of heating surface, and what the horse power at 15 square feet of heating surface per horse power; also, what is the amount of smoke draught through the boiler by tubes, the metal of the tubes being $\frac{1}{8}$ of an inch in thickness.

$$2\cdot 5 \times 3\cdot 1416 \times 78 \times 1800 = \frac{1102701\cdot 6}{144} \times \frac{7657\cdot 65}{15} = 510$$
horses power.

and $2\cdot 25^2 \times \cdot 7854 \times 1800 = 7056\cdot 8 \div 144 = 49$ sq. feet.

Relative proportions of plates and rivets for the construction of steam boilers.

Dimensions in inches.

Thickness of plates in parts of an inch.	Multipliers.	Diameters of Rivets.	Lengths of rivets from heads.	Distance of rivets from centre to centre.	Breadth of lap for single joints.	Breadth of lap for double row of rivets.
$\frac{3}{16}$	·19	·38	·88	1·25	1·25	Add to single lap two-thirds of it.
$\frac{1}{4}$	·25	·5	1·13	1·5 6	1·5 6	
$\frac{5}{16}$	·31	·63	1·38	1 63	1·88	
$\frac{3}{8}$	·38	·75 2	1·63 4·5	1·75 5	2 5·5	
$\frac{1}{2}$	·5	·81	2·25	2	2·25	
$\frac{5}{8}$	·63	·94 1·5	2·75	2·5 4	2·75 4·5	
$\frac{3}{4}$	·75	1·13	3·25	3	3·25	

The numbers on the right, in the several columns after the first two, namely, the numbers 2, 1·5, 4·5, 6, 5, 4, 6, 5·5, and 4·5, are used as multipliers, as in the following example.

Let the thickness of plate equal $\frac{3}{8}$ or ·375.

·375 {
× 2 = ·75 or $\frac{3}{4}$ the diameter of rivets.
× 4·5 = 1·688 or $1\frac{3}{4}$ length of rivets.
× 5 = 1·875 or $1\frac{7}{8}$ distance from centre to centre of rivets.
× 5·5 = 2·063 or 2 inches breadth of lap for single rivets.
× 5·5 = 2·063 + $\frac{2}{3}$rds or 1·375 = 3·448 or $3\frac{1}{2}$ inches lap for a double row of rivets.

Suppose a $\frac{5}{8}$ plate or ·625.

·625 {
× 1·5 = ·9375 or $\frac{15}{16}$ diameter of rivets.
× 4·5 = 2·8125 or $2\frac{13}{16}$ length of rivets.
× 4 = 2·5 or $2\frac{1}{2}$ from centre to centre of rivets.
× 4·5 = 2·8125 or $2\frac{13}{16}$ breadth of lap.
× 4·5 = 2·8125 + $\frac{2}{3}$rds or 1·875 = 4·6875 or $4\frac{11}{16}$ for breadth of lap for a double row of rivets.

Conversion of cwts., qrs., and lbs. into lbs.

We terminate this work with the following compendious method of converting cwts., qrs., and lbs. into lbs.

RULE.—If there are cwts. only, repeat the number under itself. Below the first figure on the right put a 0, and then the figures of the same number, thus pushing those figures one place to the left. Again, commencing with two 0's, repeat the number a third time, the figures being one more place to the left, and then add up. If there be also qrs. and lbs. write the equivalent to them in lbs. under the whole before adding up, thus :—

234 cwt.	234 cwt. 3 qrs. 25 lbs.
234	234
2340	2340
23400	23400
	109 = 3 qrs. 25 lbs.
26208 lbs.	26317 lbs.

Should there be tons as well, add 20 times the number of tons to the cwts. and then proceed with the result as above.

*** *The foregoing method is selected out of a great variety of similar short processes, from a work entitled, "Intuitive Calculations," by Daniel O'Gorman. 23rd Edition.*

NOTE (A), *Page* 79.

THE circumference of a circle of 1 inch in diameter is 3·1416 inches. In the calculation at p. 79, the decimal part of this latter number, namely ·1416, is converted into *eighths* by multiplying it by 8, the product being 1·1328 eighths. The integral portion of these eighths, namely 1, is alone retained, and the decimals rejected, as of no practical moment. But the several successive eighths may be deduced, one after another, from the first result, more readily by continually adding the number 3·1416, thus :

Diameter.	Circumference.			
1 in.	3 in.	and	1·1328	eighths.
			3·1416	
1⅛	3	,,	4·2744	,,
			3·1416	
1¼	3	,,	7·4160	,,
			3·1416	
1⅜	4	,,	2·5576	,,
			3·1416	
1½	4	,,	5·6992	,,
			3·1416	

Note (A) continued.

Diameter.		Circumference.	
$1\frac{5}{8}$	.... 5 in. and	·8408	eighths.
		3·1416	
$1\frac{3}{4}$	.... 5 „	3·9824	„
		3·1416	
$1\frac{7}{8}$	.... 5 „	7·1240	„
		3·1416	
2	.... 6 „	2·2656	„

And so on. The integers of the several results are alone retained and tabulated. Of course the results against the diameters $1\frac{1}{8}$, $1\frac{3}{8}$, 2, being 4 eighths, 2 eighths, 2 eighths, are tabulated $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{4}$. It is proper to add that any individual number in the Table may be found independently of the other numbers by multiplying 3·1416 by the diameter. Thus (p. 62), taking the diameter at 2 ft. $10\frac{3}{4}$ in., and multiplying by the feet and inches separately, we have

	3·1416	$\frac{1}{4}$ of 3·1416 =	·7854
	2	10	3
For 2 ft.	= 6.2832 ft.	31·416	2.3562 = three-fourths
For $10\frac{3}{4}$ in.	= 2·814	2·356	
	9·097 ft.	12)33·772 in.	
	12		
		2·814 ft., for $10\frac{3}{4}$ in.	
	1·164 in.		
	8		
	1·312 eighths.	Hence 9 ft. $1\frac{1}{8}$ in. = circumference.	

The practical man may readily infer the value of the Table from this calculation.

NOTE (B), *Page* 107.

The successive numbers in the Table may be obtained in a way similar to that exhibited in the preceding Note; thus:

Diameter.	Circumference.		
3 ft. 0 in.	8 ft. 9 in., and	4·1856	eighths.
		2·9312	
3 ft. $0\frac{1}{8}$ in.	„	7·1168	„
		2 9312	
3 ft. $0\frac{1}{4}$ in.	10 in.	2·0480	„
		2,9312	
3 ft. $0\frac{3}{8}$ in.	„	4·9792 =	five-eighths, very nearly.

Hence the circumferences for these diameters (the flange outside) are respectively 8 ft. $9\frac{4}{8}$ in., 8 ft. $9\frac{7}{8}$ in., 8 ft. $10\frac{2}{8}$ in., 8 ft. $10\frac{5}{8}$ in. The fractions $\frac{4}{8}$, $\frac{2}{8}$, are, of course, replaced in the Table by their equivalents $\frac{1}{2}$, $\frac{1}{4}$.

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