# TEMPLETON'S WORK SHOP COMPANION

# APPLICATIONS OF MECHANIC POWERS.

Fig. 1.

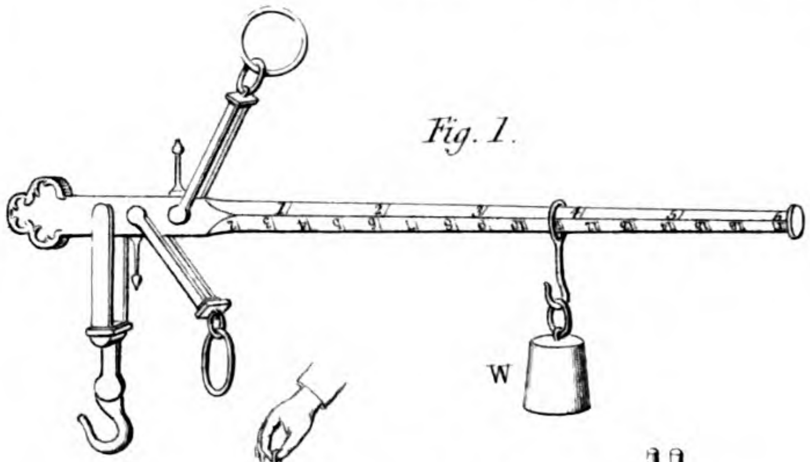
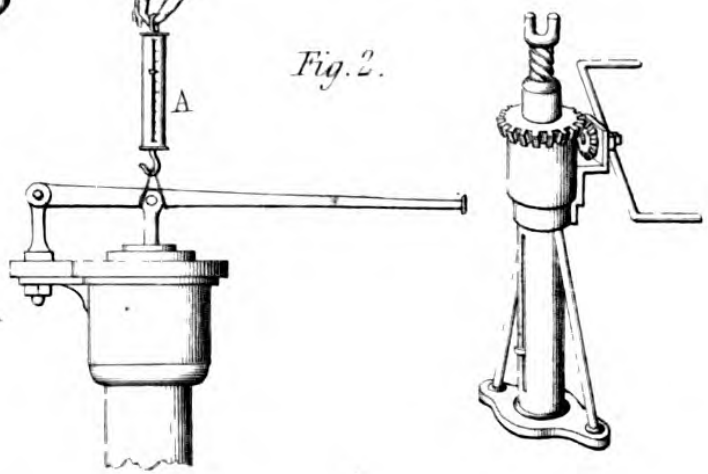
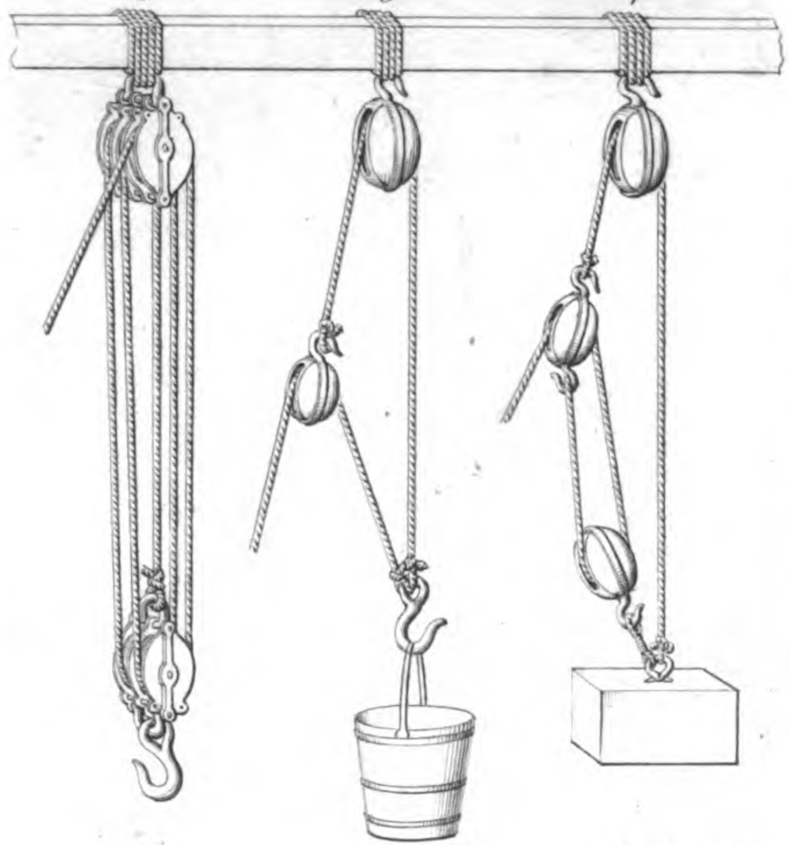



Fig. 2.




J. W. Lowry fc.

John Weale 59 High Holborn 1845.

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,

DIVESTED OF MATHEMATICAL COMPLEXITY;

WITH NUMEROUS TABLES OF PRACTICAL DATA AND CALCULATED RESULTS,

For Facilitating Mechanical and Commercial Transactions.

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BY W. TEMPLETON,

AUTHOR OF THE ENGINEER'S POCKET-BOOK (PUBLISHED ANNUALLY), &c., &c., &c.

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London:

JOHN WEALE, HIGH HOLBORN.

1845.

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# 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, simple, and aptly adapted; also the practical rules much abbreviated through 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 several engravings, are annexed, which add much to its value in regard to practical utility; and it only remains for me to add a hope, that the Operative, the Man of Science, and an interested Public, may give due appreciation to the work, in proportion to its merits.

W. T.

*London, 1st January*, 1845.

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## LIST OF PLATES.

# THE WORKSHOP COMPANION.

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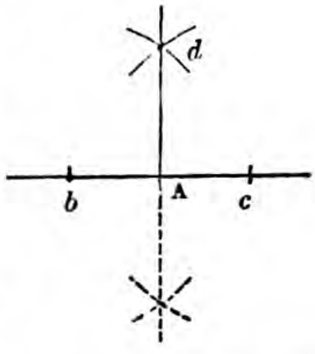
## PRACTICAL GEOMETRY.

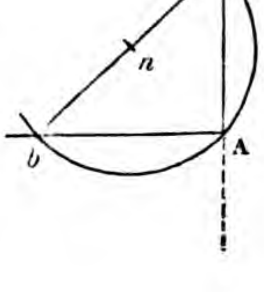
GEOMETRY is the science which investigates and demonstrates the properties of lines on surfaces and solids; hence, PRACTICAL GEOMETRY is the method of applying the rules of the science to practical purposes.

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 made, 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*; then will the line A *d* be the perpendicular required.

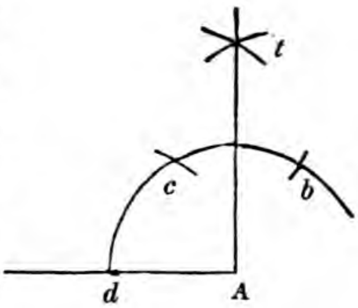
2. *When a perpendicular is to be made at or near the end of a given line.*




With any convenient radius, and with any distance from the given line A *b*, describe a portion of a circle, as *b* A *c*, cutting the given point in A; draw, through the centre of the circle *n*, the line *b n c*, and a line from the point A, cutting the intersections at *c*, is the perpendicular required.

3. *To do the same otherwise.*

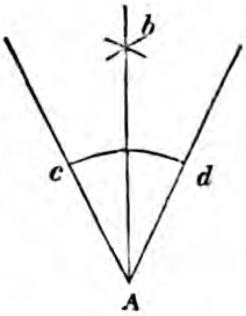
From the given point A, with any convenient radius, describe the arc *d c b*; from *d*, cut the arc in *c*, and from *c*, cut the arc in *b*; also from *c* and *b* as centres, describe arcs cutting each other in *t*; then will the line A *t* be the perpendicular as required.




*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 these or the preceding problems, the perpendiculars may be continued below the given lines, if necessarily required.

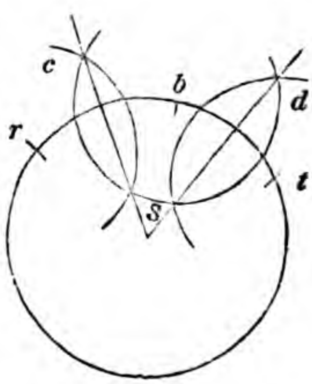
4. *To bisect any given angle.*

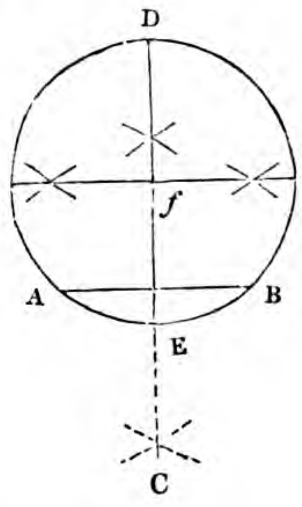
From the point A as a centre, with any radius less than the extent of the angle, describe an arc, as *c d*; and from *c* and *d* as centres, describe arcs cutting each other at *b*; then will the line A *b* bisect the angle as required.




5. *To find the centre of a circle, or radius, 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 s*; draw lines through where the arcs cut each other, and the intersection of the lines at *s* is the centre of the circle as required.

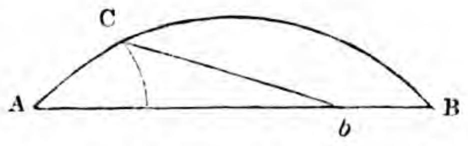





6. *To find the centre of a given circle.*

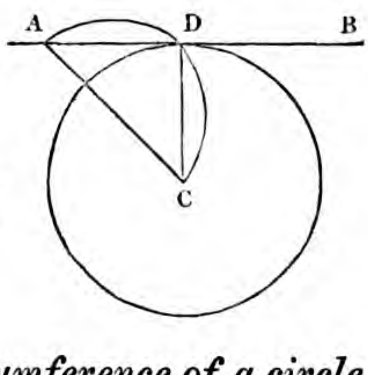
Bisect any chord in the circle, as A B, by a perpendicular C D; bisect also the diameter E D in *f*, and the intersection of the lines at *f* is the centre of the circle required.

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.*

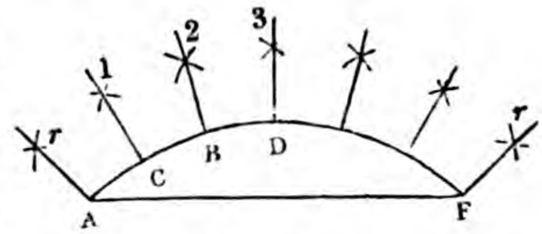



Let the given point be at A; draw the line A C, on which describe the semicircle A D C; draw the line A D B, cutting the circumference in D, which is the tangent as required.

9. *To draw from, or to the circumference of a circle, lines tending towards the centre, when the centre is inacessible.*

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.

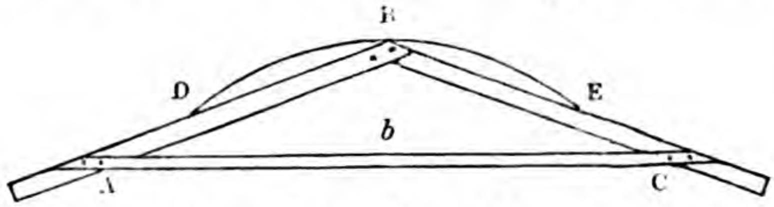



*To draw the end lines,*

As A *r*, F *r*, from C 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. *To describe an arc, or segment of a circle, of large radii.*

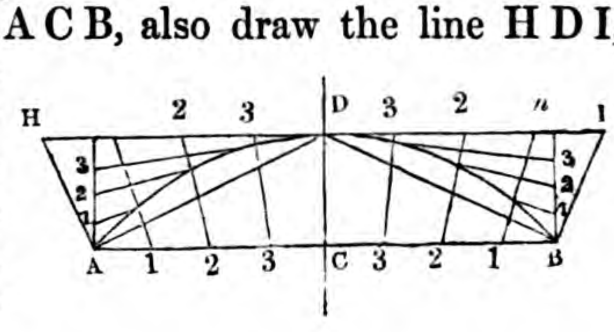
Of any suitable material, construct a triangle, as A B C; make A B, B C, each equal in length to the chord of the arc D E, and height, twice that of




the arc B *b*. At each end of the chord D E fix a pin, and at B, in the triangle, fix a tracer (as a pencil), move the triangle along the pins as guides, and the tracer will describe the arc required.

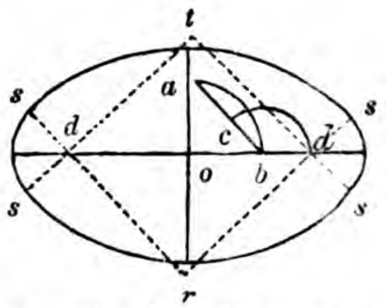
11. *Or otherwise,*

Draw the chord A C B, also draw the line H D I, parallel with the chord and equal to the height of the segment; bisect the chord in C, and erect the perpendi-



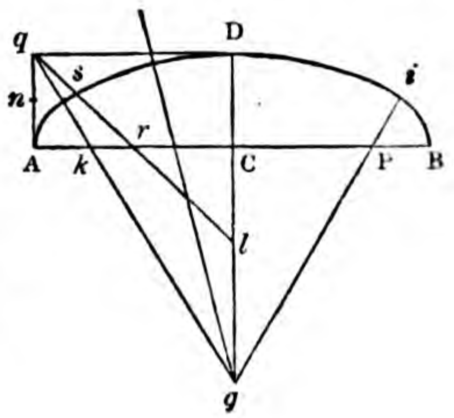
cular C D; join A D, D B; draw A H perpendicular to A D, and B I perpendicular to B D; erect also the perpendiculars A *n*, B *n*, divide A B and H I into any number of equal parts; draw the lines 1 1, 2 2, 3 3, &c., likewise divide the lines A *n*, B *n*, each into half the number of equal parts; draw lines to D from each division in the lines A *n*, B *n*, and through where they intersect the former lines, describe a curve, which will be the arc or segment required.

12. *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*, *s* and *t*, *s*, *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.

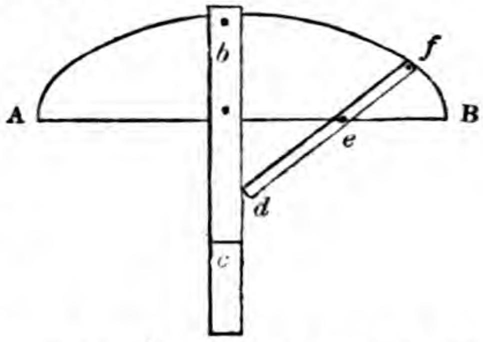
13. *To describe an elliptic arch, the width and rise of span being given.*




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*, make C *l* equal to C D, and draw the line *l r q*;

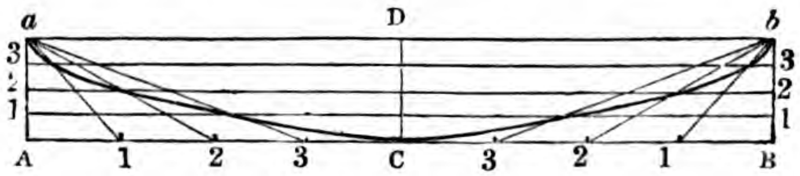
draw also the line *n s* D; bisect *s* D with a line at right angles, and meeting the line C D in *g*; draw the line *g q*, make C P equal to C *k*, and draw the line *g* P *i*; then from *g* as a centre with the radius *g* D, describe the arc *s* D *i*, and from *k* and P as centres, with the radius A *k*, describe the arcs A *s* and B *i*, which completes the arch as required. *Or,*

14. 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 arc required.



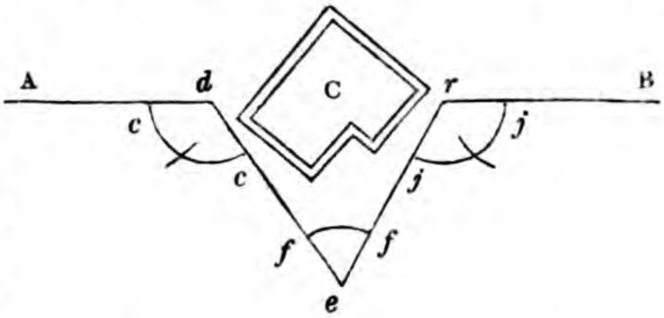

15. *To describe a parabola, the dimensions being given.*

Let A B equal the length, and C D the breadth of the required parabola; divide C A, C B into any



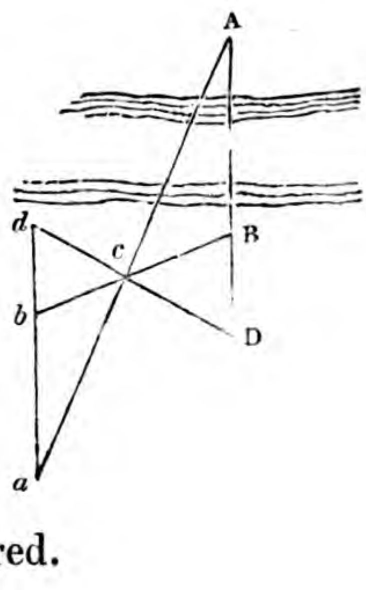

number of equal parts, also divide the perpendiculars A *a* and B *b* into the same number of equal parts; then from *a* and *b* draw lines meeting each division on the line A C B, and a curve line drawn through each intersection will form the parabola required.

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



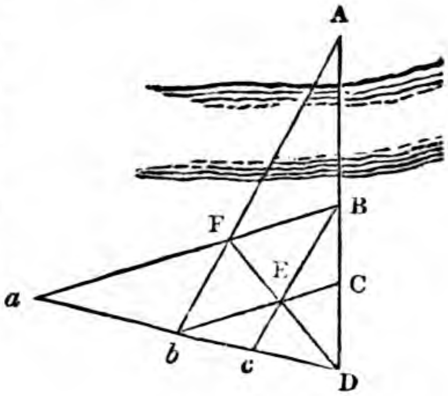

Suppose the distance between A and B is required, but the right line is intercepted by the object C. On the point *d*, with any convenient radius, describe the arc *c c*, make the arc twice the radius in length, through which draw the line *d c e*, and on *e* describe another arc equal in length to once the radius, as *e 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*, equal the distance between *d r*, by which the distance between A and B is obtained as required.

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

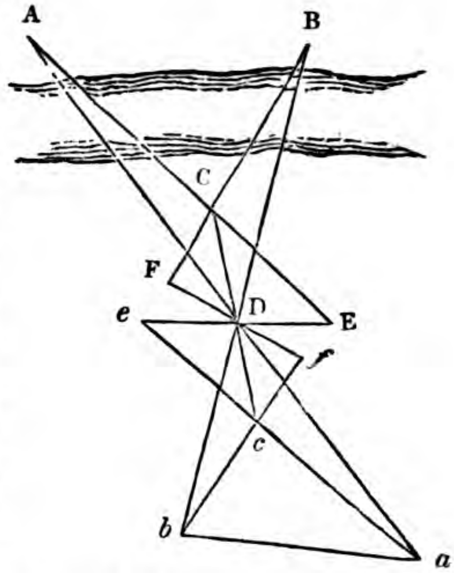



Let it be required to find the distance between A and B A, being inaccessible; produce the line in the direction of A B to any point, as D; draw the line D *d* at any angle to the line A B; bisect the line D *d*, through which draw the line B *b*, making *c b* equal to B *c*; draw the line *d b a*; also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

18. *Otherwise.* Prolong A B to any point D, making B C equal to C D; draw the line D *a* at any angle with D A, and the line C *b* similar to B *c*; draw also the line D E F, which intersects the line D *a*, then *a b* equal B A, or the distance required.

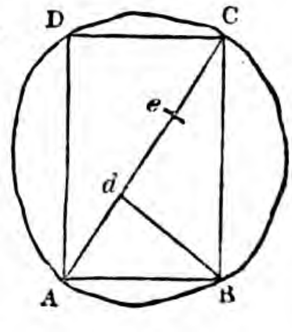



19. *To measure the distance between two objects, both being inaccessible.*



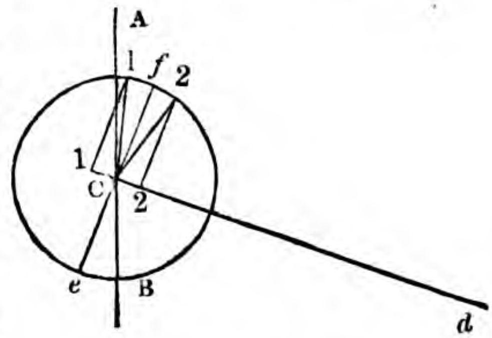

From any point C draw any line C *c*, and bisect it in D; take any point E in the prolongation of A C, and draw the line E *e*, making D *e* equal to D E; in like manner take any point F in the prolongation of B C, and make D *f* equal to F D. Produce A D and *e c* till they meet in *a*, and also B D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

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



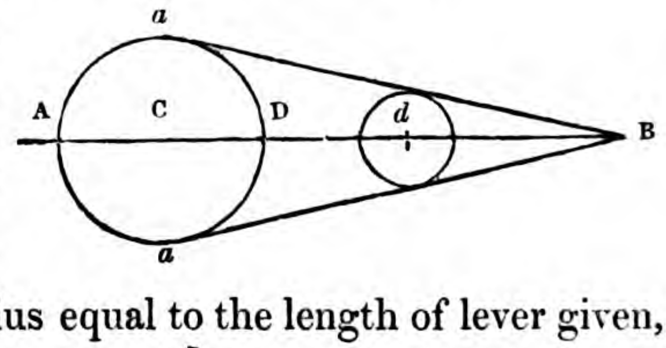

Divide into three equal parts any diameter in the circle, as A *d*, *e* C; from *d* or *e*, erect a perpendicular meeting the circumference of the circle, as *d* B; draw A B and B C, also A D equal to B C, and D C equal to A B, and the rectangle will be a section of the beam as required.

21. *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.*



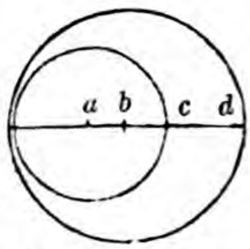

Draw the right line A B, as the situation of the crank at commencement of the stroke; draw also the line C *d*, as the proper given angle of eccentric rod with the crank; then from C as centre, describe a circle equal to the travel of the valve; draw the line *e f* at right angles to the line C *d*,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

22. *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 & 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.

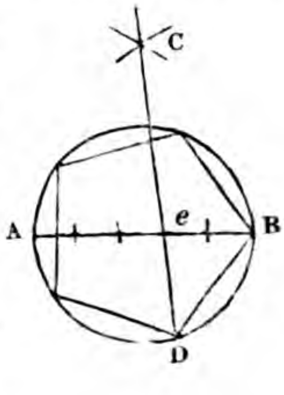
*Note.*—The throw of an eccentric is equal to the sum of twice the distance between the centres of formation and revolution, as *a b*, or to the degree of eccentricity it is made to describe, as *c d*. And




The travel of a valve is equal 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.

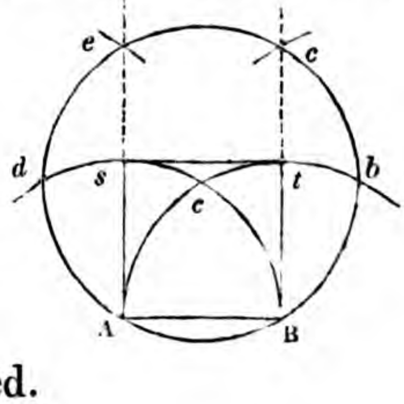
23. *To inscribe any regular polygon in a given circle.*

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 the second point of division on the diameter *e*, and the line D B is one side of the polygon required.

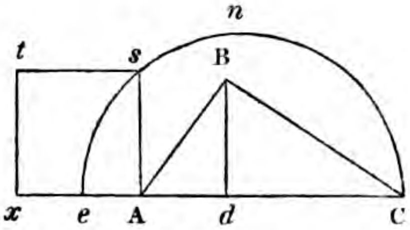



24. *To construct a square upon a given right line.*

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.

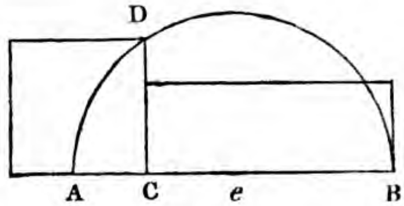


25. *To form a square equal in area to a given triangle.*



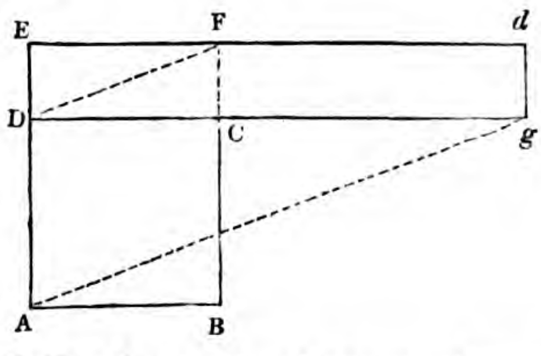

Let A B C be the given triangle; let fall the perpendicular B *d*, and make A *e* half the height *d* B; bisect *e* C, and describe the semicircle *e n* C; erect the perpendicular A *s*, or side of the square, then A *s t x* is the square of equal area as required.

26. *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 equal a side of the square required.

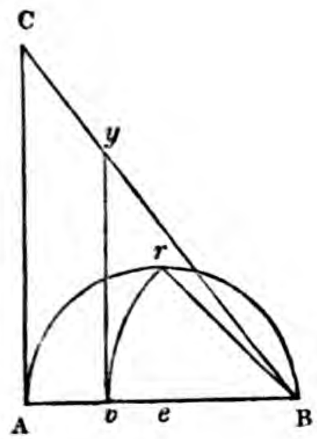
27. *To find the length for a rectangle whose area shall be equal to that of a given square, the breadth of the rectangle being also given.*




Let ABCD be the given square, and D E the given breadth of rectangle; continue the line BC to F, and draw the line D F; also, continue the line D C to *g*, and draw the line A *g* parallel to D F; from the intersection of the lines at *g*, draw the line *g d* parallel to D E, and E *d* parallel to D *g*; then E D *d g* is the rectangle as required.

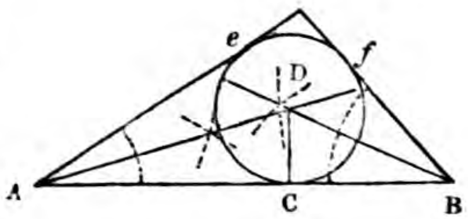
28. *To bisect any given triangle.*

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.



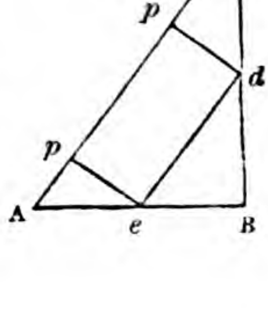

29. *To describe a circle of greatest diameter in a given triangle.*

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 or radii D C, describe the circle C *e f*, as required.

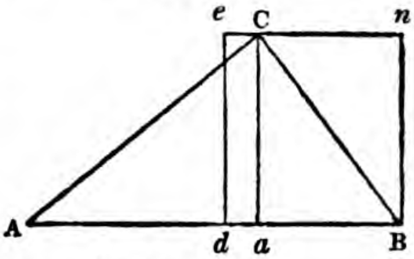



30. *To form a rectangle of greatest surface, in a given triangle.*

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.

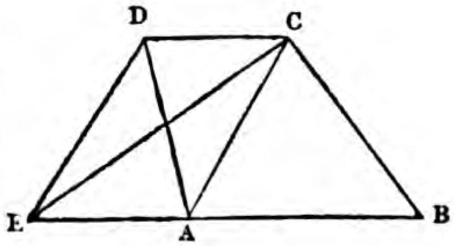


31. *To make a rectangle equal to a given triangle.*



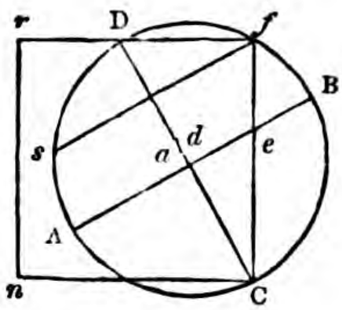

Suppose A B C the given triangle; bisect A B in *d*, and erect the perpendicular *d e*; erect also the perpendicular B *n*, draw the line *e n* parallel to A B, and equal to *a* C; then *d e* B *n* is the rectangle as required.

32. *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.

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

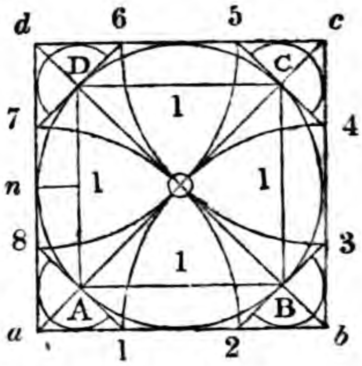



Let A C B D be the given circle; draw the diameters A B and C D, bisect the radius *d* B in *e*, and draw the line C *e f*; draw also at right angles the lines C *n* and *f r*, making each equal to C *f*; join *n r*, and *n* C *f r* is the square as required.

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

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

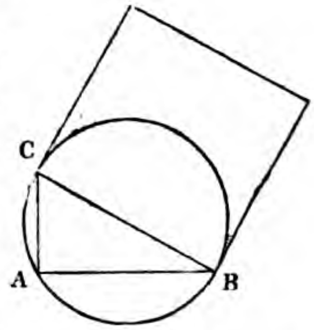
Describe a circle, as A B C D, in diameter equal to the extremity of the angles, or breadth of square required; draw at right angles the diameters A C B D, and within the circle draw the lines A 1 B, B 1 C, C 1 D, and D 1 A, meeting the diameters A B C and D, which completes the inscribed square;—again, with the distance 1 *n* from A B C and D, as centres, describe small arcs; draw lines from each as tangents, meeting the diameters at A B C and D; which will complete the square, equal in breadth to the circle's diameter.




Then from the extremity of the angles *a b c* and *d*, as centres with the distance *a o*, *b o*, &c., cut the sides of the square in 1, 2, 3, &c.; draw the lines 2 3, 4 5, 6 7, 8 1; which completes the octagon as required.

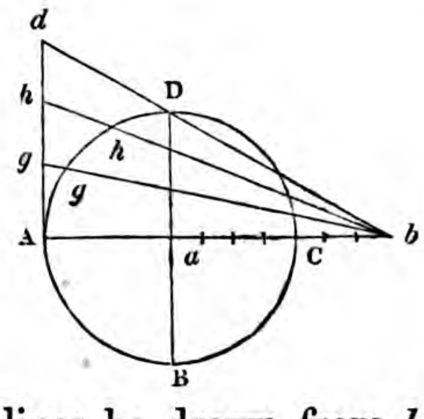
35. *To form a square equal to two given squares, or, a circle equal to two given circles.*

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, and it is equal to the two given circles as required.



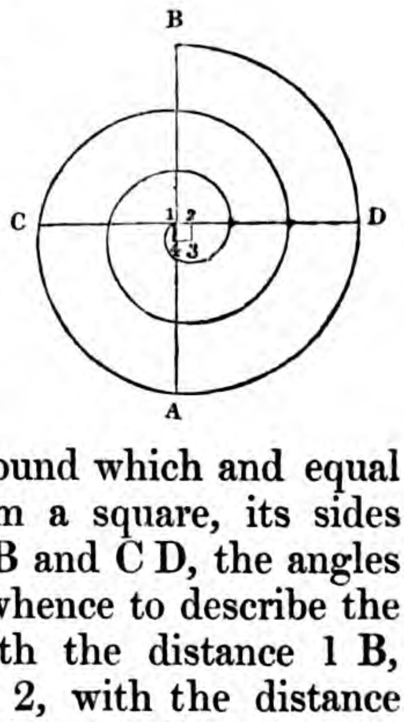

36. *To draw a right line equal to any given portion of the circumference of a circle.*

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* equal one-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.

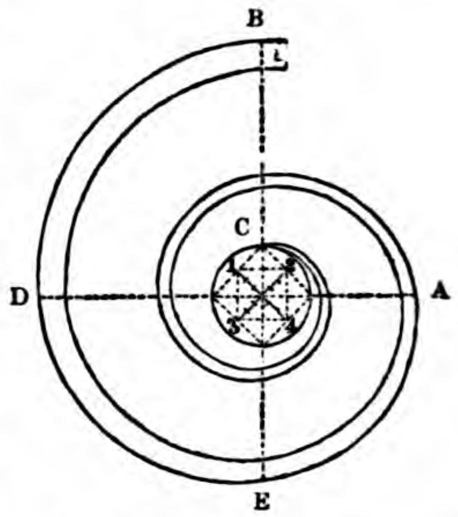



37. *To draw a spiral with spaces of uniform distance.*

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 which draw the line 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.

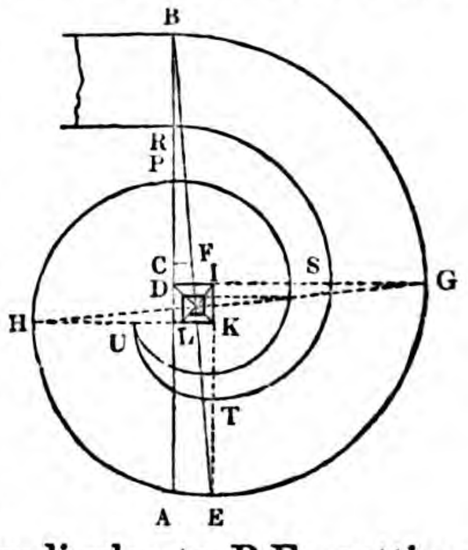


38. *To draw a volute for the capital of the Ionic column.*




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.

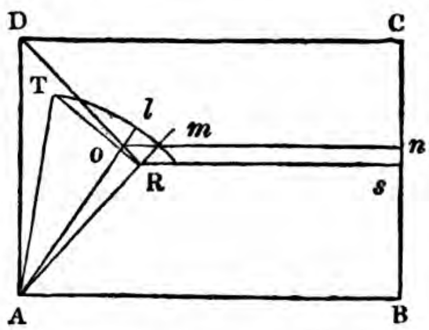
39. *To draw a scroll for the termination of a hand rail, &c.*




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

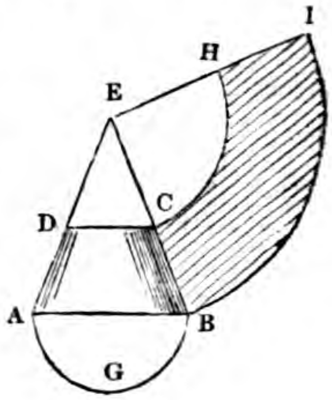
D O K, I O L, perpendicular to D O K; draw I K parallel to B A, K L parallel to I D, &c., meeting the diagonals; from D as a centre, with the distance D B, describe the arc B G; from I as a centre, with the distance I G, describe G E; from K, with the distance K E, describe K H, &c., proceeding in the 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.

40. *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.*

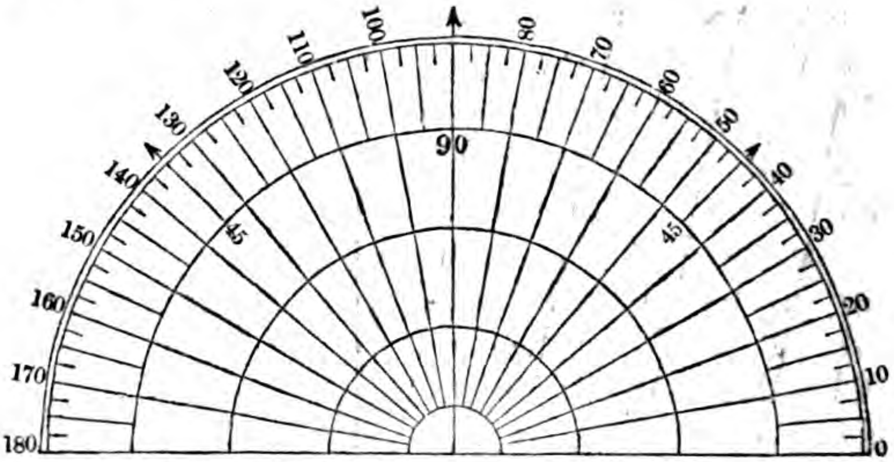



Let A B C D be the given dimensions of plan for a roof, the height R T also being given; draw the diagonal A R, meeting the top or ridge R *s* on plan; from R, at right angles with A R and equal to the required height, draw the line R T, then T A, equal the length of the struts or corners of the roof; 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.

41. *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.

42. *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 the lesser diameter, or diameter at the

SCREWS DELINEATED. *Plate A.*

*Fig. 2.*

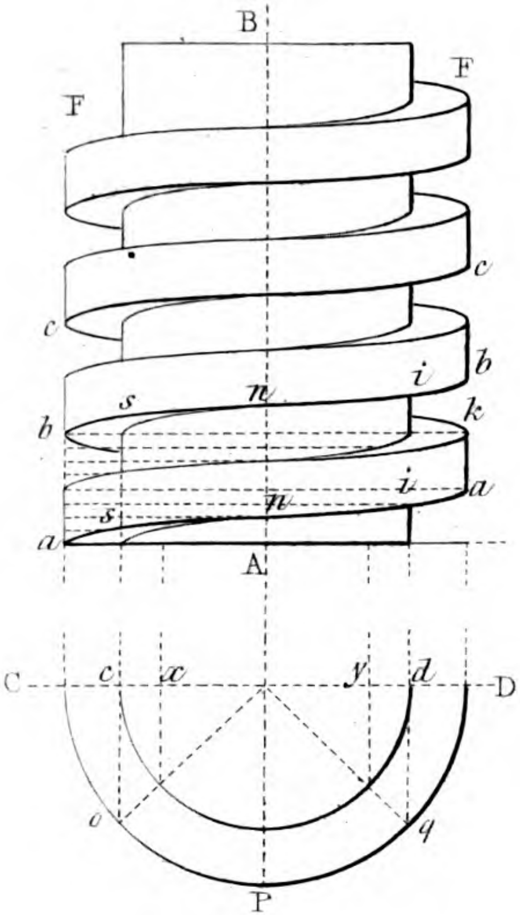



*Fig. 3.*

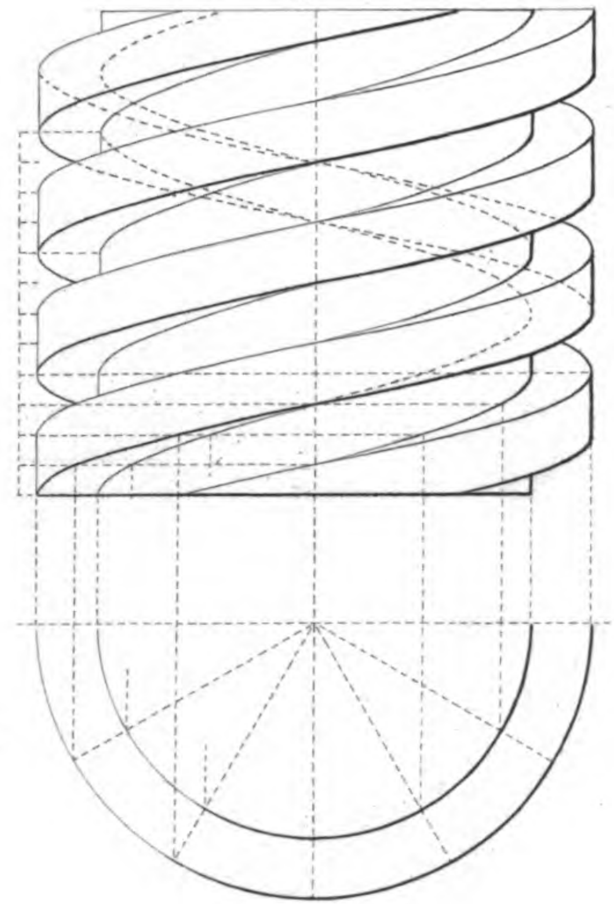
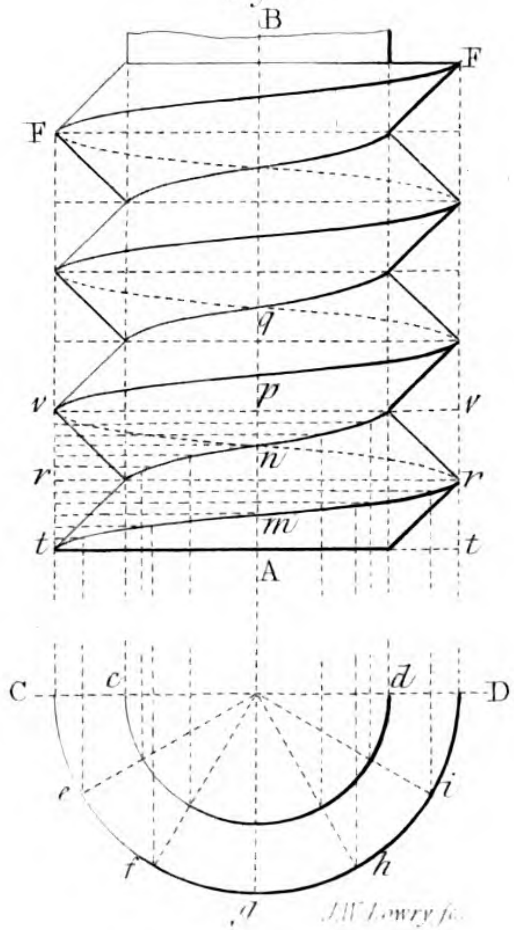


*Fig. 1.*

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bottom of the threads; divide each semi-circumference 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.

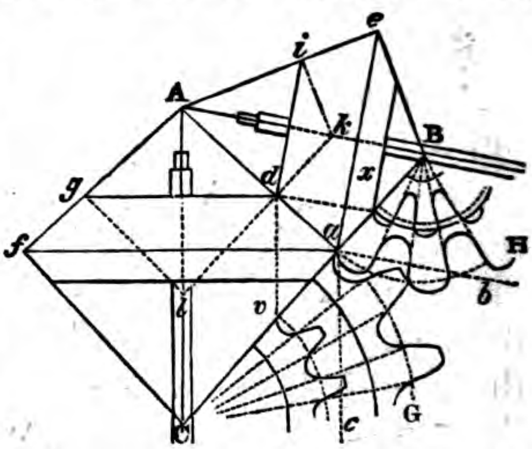
43. *To delineate a square-threaded screw, the pitch and diameter of screw being given.* (See Plate A, fig. 2.)

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.

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

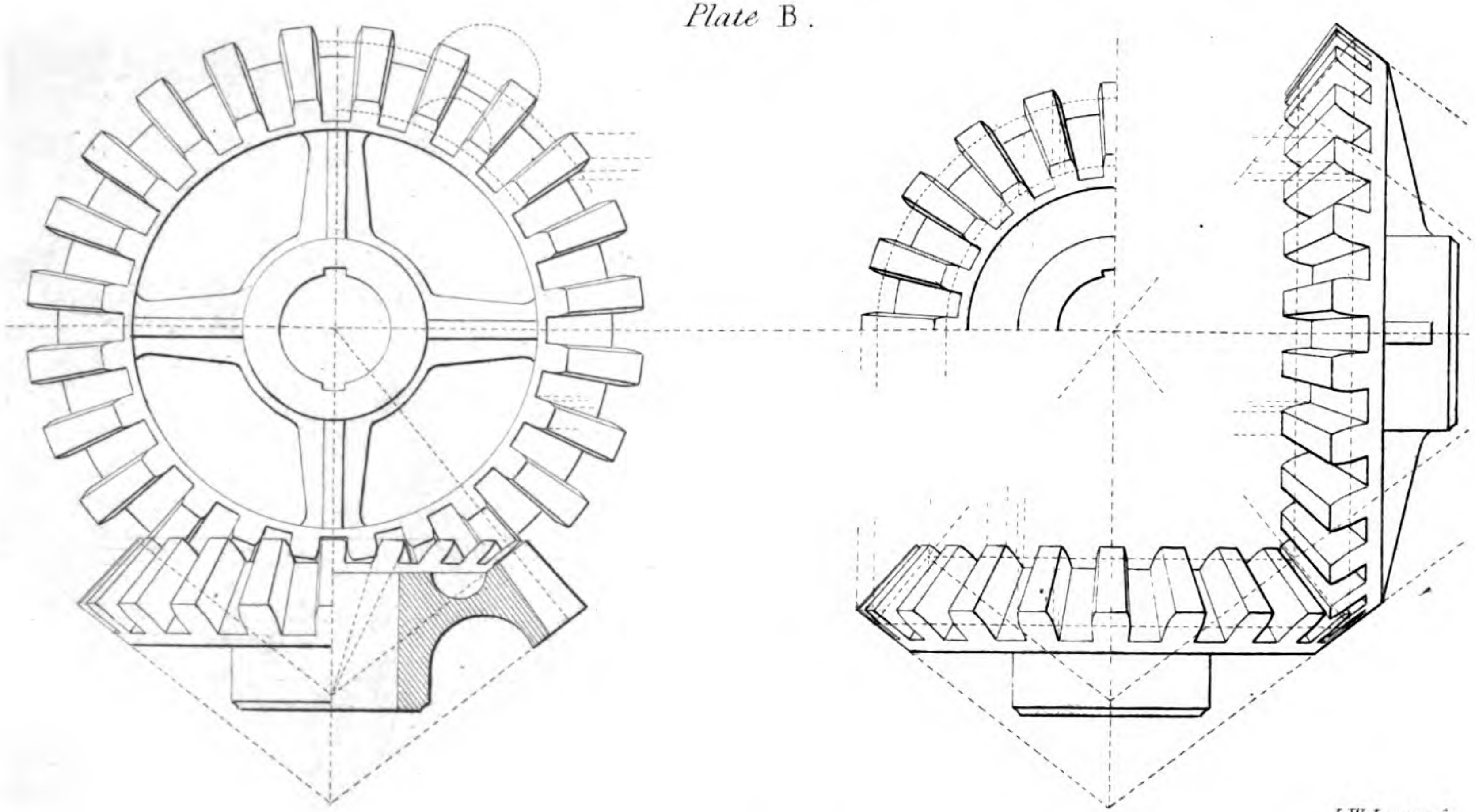
Draw at the given angles lines representing the shafts on which the wheels are to be fixed, as A B, A C; make the lines *a b*, *a c*, parallel with and at a distance from A B, A C, equal to the radius of each respective wheel at the greatest pitch circle; draw the line A *a* through the intersection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



J. W. Lowry fc.

Published by John Weale 59 High Holborn, 1844.

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., Thickness of flat arms — each $\frac{4}{9}$ of the pitch.
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.*

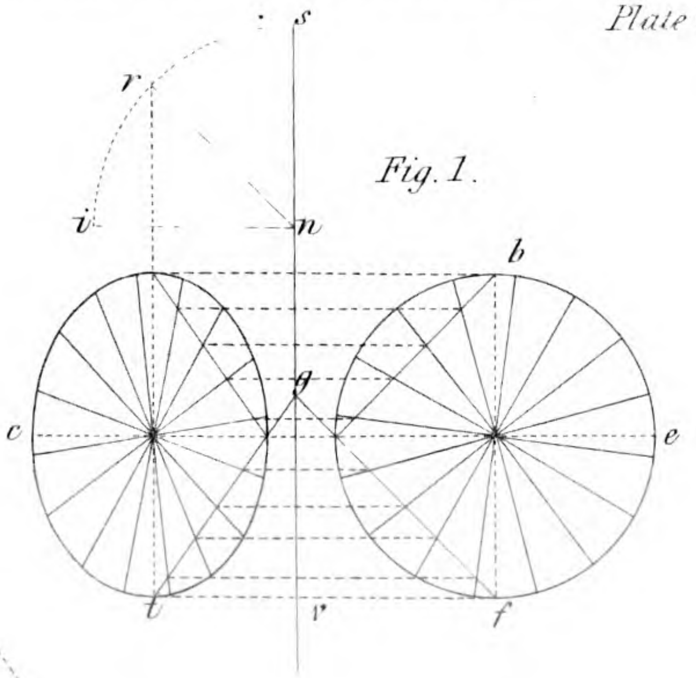



*Fig. 1.*

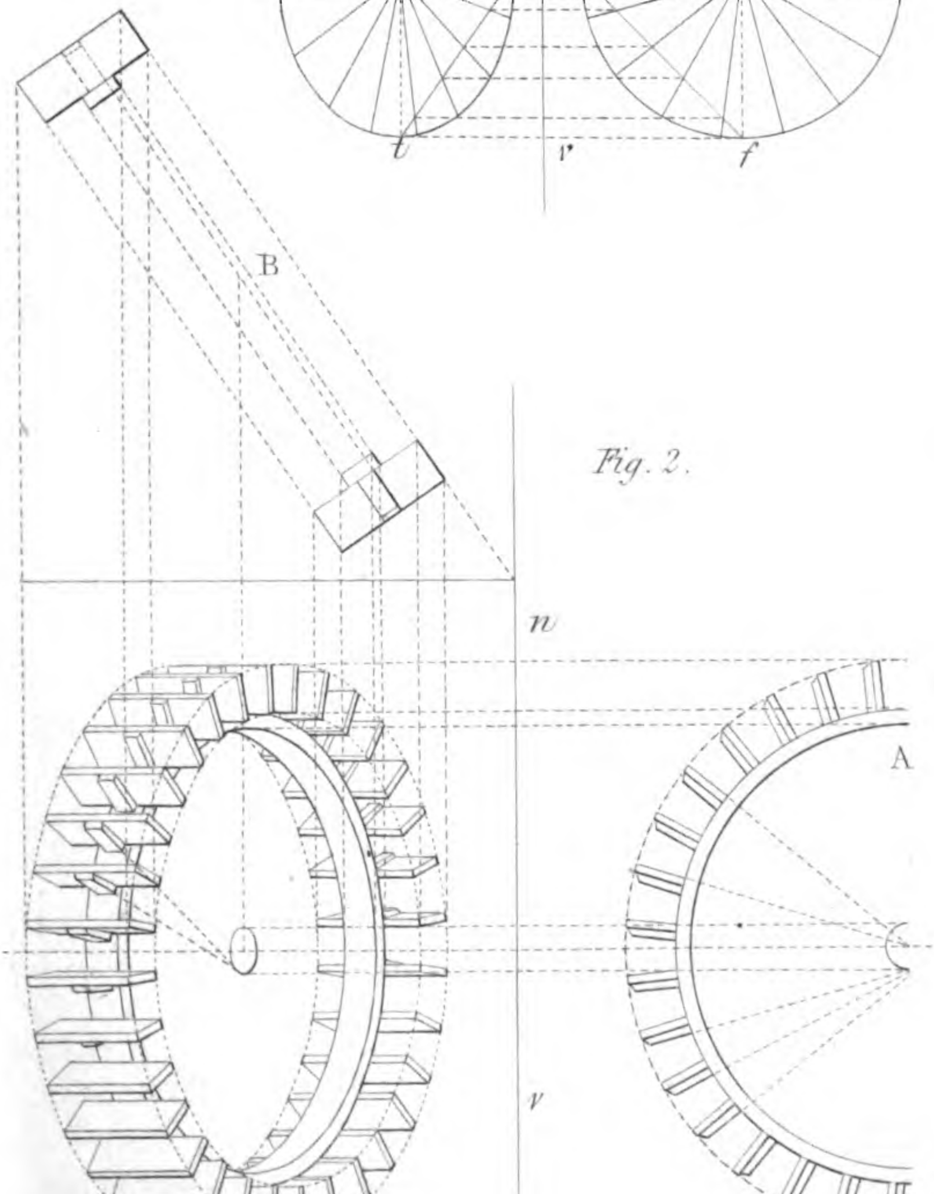



*Fig. 2.*

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*Published by John Weale, 59, High Holborn, 1841.*

# 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 signify 6 tenths; ·06 signify 6 hundredths; and ·006 signify 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 ciphers at pleasure, divide the sum by the denominator, and the quotient is the decimal of equivalent value.

*Rule* 2. Multiply the given decimal by the various fractional denominations of the integer or whole number, cutting off from the right hand of each product for decimals a number of figures equal to the given number of decimals, and thus proceed until the lowest degree, or required value, is obtained.

*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 fractional value of the decimal ·40625 of an inch.

| | |
|---|---|
| | ·40625 |
| Multiply by $\frac{1}{8}$ | 8 |
| | 3·25000 |
| $\times \frac{2}{16} = \frac{1}{8}$ | 2 |
| | ·50000 |
| $\times \frac{2}{32} = \frac{1}{16}$ | 2 |
| | 1·00000 $\frac{3}{8}$ and $\frac{1}{32}$ of an inch, the value required. |

*Ex.* 5. What is the fractional 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 fractional 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 fractional 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.
     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 multiplied by $4=32$. |

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

$\dfrac{\sqrt[3]{20\times 12}}{30}=2$, 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. |
| 5½ 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. |
| 30¼ 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 277¼ 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.*

| | |
|---|---|
| 1 nautical mile | = 6082·66 feet. |
| 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<br>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 | = | ℔s. 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 ℔s. | ,, | ·009 | = | cwts. |
| ,, | ,, | ·00045 | = | tons. |

## 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 | $\frac{3}{8}$ & $\frac{1}{32}$ |
| ·9375 | $\frac{7}{8}$ & $\frac{1}{16}$ | ·59375 | $\frac{5}{8}$ & $\frac{3}{32}$ | ·25 | $\frac{1}{4}$ |
| ·90625 | $\frac{7}{8}$ & $\frac{1}{32}$ | ·5625 | $\frac{5}{8}$ & $\frac{1}{16}$ | ·21875 | $\frac{1}{4}$ & $\frac{3}{32}$ |
| ·875 | $\frac{7}{8}$ | ·53125 | $\frac{5}{8}$ & $\frac{1}{32}$ | ·1875 | $\frac{1}{4}$ & $\frac{1}{16}$ |
| ·84375 | $\frac{3}{4}$ & $\frac{3}{32}$ | ·5 | $\frac{1}{2}$ | ·15625 | $\frac{1}{4}$ & $\frac{1}{32}$ |
| ·8125 | $\frac{3}{4}$ & $\frac{1}{16}$ | ·46875 | $\frac{1}{2}$ & $\frac{3}{32}$ | ·125 | $\frac{1}{8}$ |
| ·78125 | $\frac{3}{4}$ & $\frac{1}{32}$ | ·4375 | $\frac{1}{2}$ & $\frac{1}{16}$ | ·09375 | $\frac{3}{32}$ |
| ·75 | $\frac{3}{4}$ | ·40625 | $\frac{1}{2}$ & $\frac{1}{32}$ | ·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 | $\frac{3}{8}$ & $\frac{1}{32}$ | | |
| ·65625 | $\frac{5}{8}$ & $\frac{1}{32}$ | ·3125 | $\frac{3}{8}$ & $\frac{1}{16}$ | | |

**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. |
| ·6333 | 10 „ | ·3333 | 4 „ | ·0528 | $\frac{5}{8}$ „ |
| ·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. |
| ·9445 | 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 „ | ·1666 | 6 „ |
| ·8056 | 29 „ | ·4722 | 17 „ | ·1389 | 5 „ |
| ·7778 | 28 „ | ·4445 | 16 „ | ·1111 | 4 „ |
| ·75 | 27 „ | ·4166 | 15 „ | ·0833 | 3 „ |
| ·7222 | 26 „ | ·3889 | 14 „ | ·0555 | 2 „ |
| ·6944 | 25 „ | ·3611 | 13 „ | ·0277 | 1 „ |
| ·6667 | 24 „ | ·3333 | 12 „ | | |

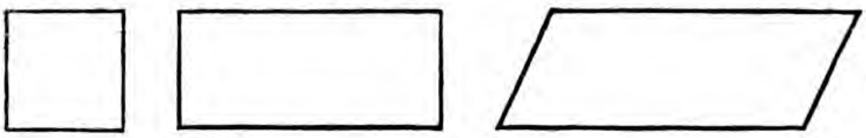
# MENSURATION.

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 $\frac{3}{16} = \cdot 1875$ (see page 31); and $8\cdot 1875 \times 8\cdot 1875 = 67\cdot 03515625$ 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. $= \cdot 5833$ and 6 in. $= \cdot 5$ (see Table of Equivalents, p. 31): hence $4\cdot 5833 \times 3\cdot 5 = 16\cdot 04155$ 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.

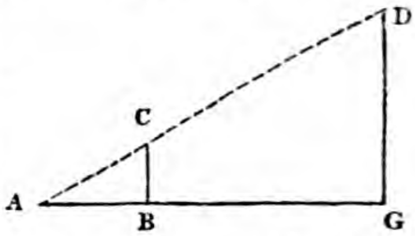
2. From the top of a wall 18 feet in height, a line was stretched across a canal for the purpose of ascer-

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 $\sqrt{\overline{40+18}\times 22}=\sqrt{1276}=35{\cdot}72$, or 35 feet 9 inches nearly, the width of the canal.

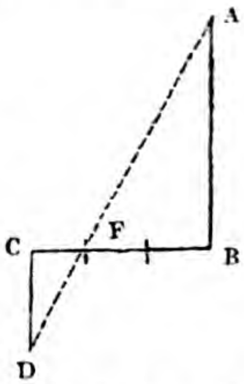
Triangles similar to each other are proportional to each other; hence their utility in ascertaining the heights and distances of inaccessible objects.

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 A be required, make the line B A, B C, a right angle, 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

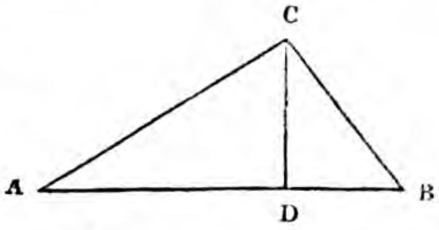



C F : C D :: B F : B A. Let C F = 10 yards, C D = 53, and B F = 30, 10 : 53 :: 30 : 159 yards, the distance from B.

*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 ADB is $11\frac{3}{32}$ inches in length, and the height D C, $3\frac{3}{8}$ inches; required the area.




$\frac{3}{32} = \cdot09375$ and $\frac{3}{8} = \cdot375$ (see page 31):

hence $\frac{11\cdot09375 \times 3\cdot375}{2} = 18\cdot72075$ 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.

$$\frac{53\cdot25 \times 7\cdot75}{2} = 206\cdot34375 \text{ square feet, the area.}$$

*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 the area required.

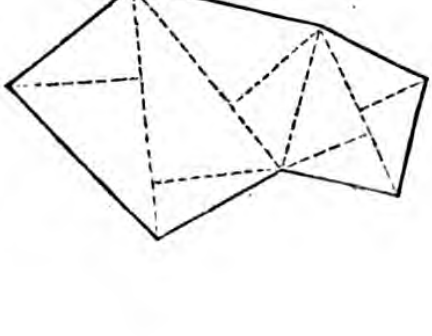
Required the area of a triangle, whose three sides are respectively 50, 40, and 30 feet.

$\frac{50+40+30}{2} = 60$, 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.

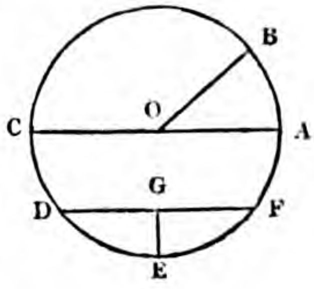
$4\frac{1}{2}^2 \times 2\cdot 598 = 52\cdot 6095$ square yards.

## 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 straight line joining 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.

$7{\cdot}1875 \times 3{\cdot}1416 = 22{\cdot}58025$ inches, the circumference.

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

$3{\cdot}1416 \times 30{\cdot}5 = 95{\cdot}8188$ feet, the circumference.

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

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

$274{\cdot}89 \times {\cdot}31831 = 87{\cdot}5$ 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?

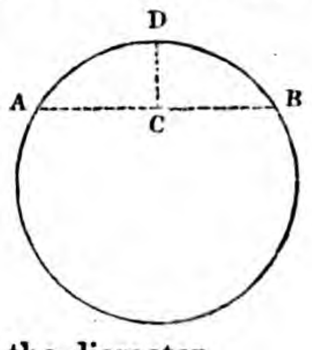
$\sqrt{706{\cdot}86} = 26{\cdot}586 \times 1{\cdot}12837 = 29{\cdot}998$ or 30 inches, the diameter required.

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.

*Any chord and versed sine of a circle being given, to find the diameter.*

*Rule.*—Divide the sum of the squares of the chord and versed sine by the versed sine, the quotient is the diameter of corresponding circle.




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.

$\overline{6{\cdot}5^2 + 2^2} = 46{\cdot}25 \div 2 = 23{\cdot}125$ feet, the diameter.

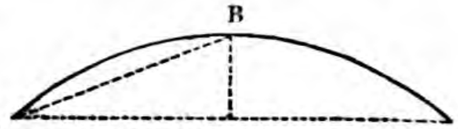
2. In a curve of a railway, I stretched a line 72 feet in length, and the distance from the line to the curve I found to be $1\frac{1}{4}$ ft.; required the radius of the curve.

$$\overline{72^2 + 1{\cdot}25^2} = 5185{\cdot}5625, \text{ and } \frac{5185{\cdot}5625}{1{\cdot}25 \times 2} = 2074{\cdot}225 \text{ ft. the radius.}$$

*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.

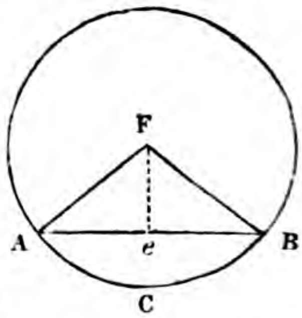



$$4{\cdot}25 \times 8 = 34, \text{ and } 34 - 8{\cdot}333 = \frac{25{\cdot}667}{3} = 8{\cdot}555 \text{ feet, the length of the arc.}$$

*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.




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

*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 $e$ 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.

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

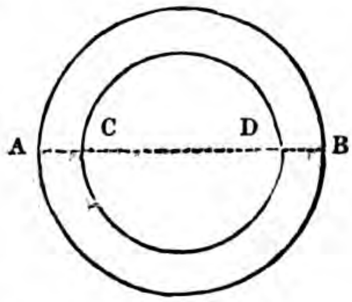
$$\frac{8{\cdot}333 \times 3{\cdot}75}{2} = 15{\cdot}624 \text{ feet, area of the triangle.}$$

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.




$32 + 28 = 60$, 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.

$20 + 18{\cdot}5 = 38{\cdot}5$, 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 ellipsis, 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 ellipsis.

*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 diameter by 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 $9^2 \times \cdot 7854 \times 40 = 2544 \cdot 696$ cubic inches; then $2544 \cdot 696 \times \cdot 00058 = 1 \cdot 4759$ 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?

$$4 \cdot 75^2 \times 16 \cdot 5 \times 4 \cdot 895 = 1822 \cdot 162 \text{ gallons.}$$

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.

$$4 \cdot 75^2 \times 35 \times \cdot 02909 = 22 \cdot 973 \text{ cubic yards.}$$

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?

$4 \cdot 895 \times 10 = 48 \cdot 95$, and $\frac{12500}{48 \cdot 95} = \sqrt{255 \cdot 3} = 15 \cdot 9687$ feet, or 15 feet $11\frac{5}{8}$ inches.

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

$$7 \cdot 5^2 \times \cdot 3223 = 18, \text{ and } \frac{168}{18} = 9 \cdot 3 \text{ inches.}$$

*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 = 15·7 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 equal $18\frac{3}{4}$ inches, and diameter at the base $6\frac{1}{4}$ inches.

$6{\cdot}25 \times 3{\cdot}1416 = 19{\cdot}635$ 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?

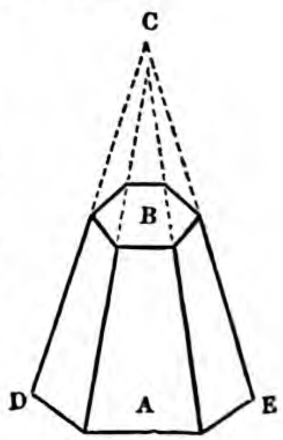
$$\frac{16 \cdot 5 \times 16 \cdot 5 \times 67}{3} = 6080 \cdot 25 \text{ cubic feet.}$$

*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.*



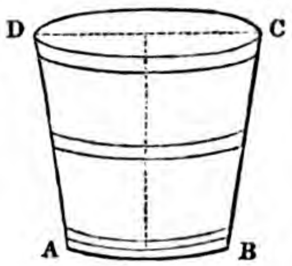

1. The perpendicular height A B of the frustum of a hexagonal pyramid C D E, is $7\frac{1}{2}$ feet, and the breadth of each side at top and base equal $3\frac{3}{4}$ and $2\frac{1}{2}$ feet; required the solid contents of the frustum in cubic feet.

$3{\cdot}75 + 2{\cdot}5 = 6{\cdot}25$, and $6{\cdot}25 \times 6{\cdot}25 = 39{\cdot}0625$, then $3{\cdot}75 \times 2{\cdot}5 = 9{\cdot}375$, and $39{\cdot}0625 - 9{\cdot}375 = 29{\cdot}6875 \times 2{\cdot}598$ (tabular area, p. 36) $= 77{\cdot}138 \times 2{\cdot}5$ 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.

$\overline{7 + 9{\cdot}5}^2 = 272{\cdot}25$, and $7 \times 9{\cdot}5 = 66{\cdot}5$, then $272{\cdot}25 - 66{\cdot}5 = 205{\cdot}75 \times {\cdot}7854 = 161{\cdot}576 \times 4$ or $\frac{1}{3}$ of the height $= 646{\cdot}3$ cubic inches.

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



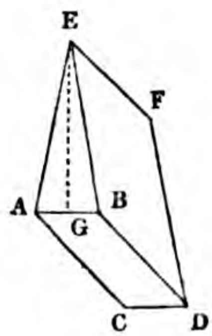

$\overline{5 + 4} = 9^2 = 81$, and $5 \times 4 = 20$, hence $81 - 20 = 61 \times {\cdot}7854$, and by 2 or $\frac{1}{3}$ of the depth $= 95{\cdot}8188$ cubic feet, and $\times\ 6{\cdot}232 = 597{\cdot}1427$ gallons.

*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.




$$\frac{\overline{18{\cdot} + 7} \times 3{\cdot}5 \times 15}{6} = 218{\cdot}75 \text{ cubic inches.}$$

*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 3·263, 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.

$10{\cdot}5^2 \times 3{\cdot}1416 = 346{\cdot}3614$ square inches.

$10{\cdot}5^3 \times {\cdot}5236 = 606{\cdot}132$, &c. cubic inches; and

$606{\cdot}132 \times {\cdot}263$ (see Table of Approximations, p. 30) $= 159{\cdot}4$ 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 $= {\cdot}03617$ lbs. } see p. 63.
" " copper $= {\cdot}3225$ "

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

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

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

${\cdot}0747 \times 16 = \frac{1}{16}$ 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 72 lbs.?

${\cdot}5236 \times {\cdot}4103 = {\cdot}21483308$, and $\dfrac{72}{{\cdot}21483308} = \sqrt[3]{340} = 6{\cdot}97$ 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.

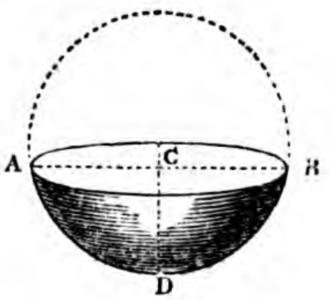
*Rule* 2.—To three times the square of the segment's radius, add the square of its height, multiply the sum by the height, and by ·5236, the product is the solid contents.

*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.

$70·5 \times 9·5 = 669·75$ 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 $\overline{6912 + 144} \times 12 \times ·5236 = 44334·75$ cubic inches.

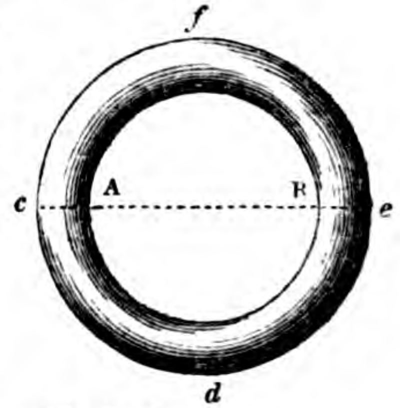
*To find the convex surface and solidity of a cylindrical ring.*

*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 *cdef* 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, in equal terms of unity.

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?

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

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

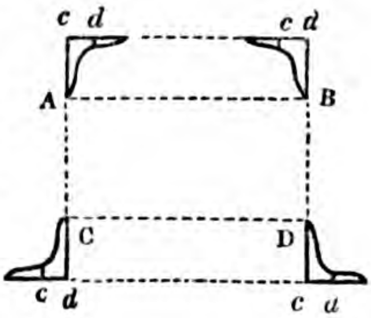
Thus, 33·25 = 2 feet $9\frac{1}{4}$ in., opposite to which is 8 feet $8\frac{1}{2}$ inches.

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.

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

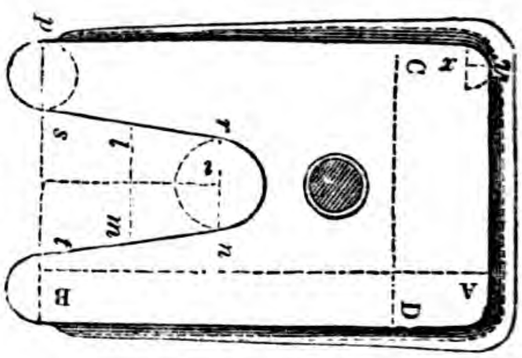
opposite to which, in the Table of Circumferences, is 4 feet 1 inch, independent of any allowance for shutting.

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 strength 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 CD; 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 AB.

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 | $l\,m$ ,, | = 3 ,, | $1\frac{1}{4}$ | ,, | 37·25 ,, |
| Diameter of circle | $r\,n$ ,, | = 2 ,, | $8\frac{1}{4}$ | ,, | 32·25 ,, |
| ,, ,, | $p\,s$ ,, | = 1 ,, | $6\frac{1}{2}$ | ,, | 18·5 ,, |
| Radius of back corners | $v\,x$ ,, | = | 4 | ,, | 4 ,, |

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

Total 10027·325 ,, ,, 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 $46·75 \times 37·25 = 1731·4375$ area of $r$, $n$, $s$, $t$, in sq. ins.

$\frac{32·25^2 \times ·7854}{2} = 408·4$ area of half the circle $r\,n$.

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

Hence, $1731·4375 + 408·4 + 6·87 = 2146·707$, and
$10027·325 - 2146·707 = 7880·618$ square inches, or whole area in plan,
$7880·618 \times 32$ the depth $= 252179·776$ cubic inches, and $252179·776 \times ·003607$ (see Table of Approximations, page 30) $= 909·61245$ 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. | Comparative Strength. | Comparative 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$^{t}$. 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 |
| Carbureted hydrogen gas | 972 |
| Prussic acid „ | 937 |
| Ammoniacal „ | 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 „ feet = 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, equal 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 |

***Proportional breadths for hexagonal or six-sided nuts for wrought iron bolts.***

| Dia. of bolts. | Breadth of nuts. | Dia. of bolts. | Breadth of nuts. |
|---|---|---|---|
| ⅜ | ¾ inch. | 1⅛ | 1 15/16 inch. |
| ½ | ⅞ " | 1¼ | 2 3/16 " |
| ⅝ | 1⅛ " | 1⅜ | 2⅜ " |
| ¾ | 1 5/16 " | 1½ | 2 9/16 " |
| ⅞ | 1½ " | 1⅝ | 2¾ " |
| 1 | 1¾ " | 1¾ | 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 | 10·1 | 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, cause 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 ℔s., thus:

| | | | |
|---|---|---|---|
| A 70 ℔. plate | is | $\frac{3}{16}$ths | of an inch in thickness. |
| 46½ | „ | $\frac{1}{8}$ | „ |
| 23 | „ | $\frac{1}{16}$ | „ |
| 11½ | „ | $\frac{1}{32}$ | „ |
| 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 ℔. lead | is | $\frac{1}{16}$th | of an inch in thickness. |
| 6 | „ | $\frac{1}{10}$ | „ |
| 7½ | „ | $\frac{1}{8}$ | „ |
| 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 728 ℔s., but want the same of copper, and of similar dimensions, what will be its weight?

$728 \times 1{\cdot}16 = 844{\cdot}48$ ℔s.

2. A model of dry pine weighing 32½ ℔s., 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?

$32{\cdot}5 \times 11 = 357{\cdot}5$ ℔s.

*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 | 11½ lbs. plate | | ·38 | 2 lbs. lead | | ·483 |
| $\frac{1}{16}$ | ·653 | 23½ | „ | ·76 | 4 | „ | ·967 |
| $\frac{3}{32}$ | ·976 | 35 | „ | 1·14 | 5½ | „ | 1·45 |
| $\frac{1}{8}$ | 1·3 | 46½ | „ | 1·52 | 8 | „ | 1·933 |
| $\frac{5}{32}$ | 1·627 | 58 | „ | 1·9 | 9¼ | „ | 2·417 |
| $\frac{3}{16}$ | 1·95 | 70 | „ | 2·28 | 11 | „ | 2·9 |
| $\frac{7}{32}$ | 2·277 | 80½ | „ | 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 $7\frac{1}{2}$ inches, its length $6\frac{1}{4}$ feet, and the metal $\frac{1}{8}$ of an inch in thickness.

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

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?

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

*Note.*—Weight of a cubic inch of

| | | | |
|---|---|---|---|
| Lead | equal | ·4103 | lbs. |
| 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 lbs. | Diameter in inches. | Weight in lbs. | Diameter in inches. | Weight in lbs. |
|---|---|---|---|---|---|
| 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 lbs., weight required.

2. Requiring to remove a cast iron ball 37·8 lbs. 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 61).

Then $\frac{6{\cdot}5^3}{1{\cdot}56} = \sqrt[3]{176} = 5{\cdot}6$ 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. |
|---|---|---|---|---|---|
| ¼ | ·0208 | 4 | ·3334 | 8 | ·6667 |
| ½ | ·0417 | 4¼ | ·3542 | 8¼ | ·6875 |
| ¾ | ·0625 | 4½ | ·375 | 8½ | ·7084 |
| 1 | ·0834 | 4¾ | ·3958 | 8¾ | ·7292 |
| 1¼ | ·1042 | 5 | ·4167 | 9 | ·75 |
| 1½ | ·125 | 5¼ | ·4375 | 9¼ | ·7708 |
| 1¾ | ·1459 | 5½ | ·4583 | 9½ | ·7917 |
| 2 | ·1667 | 5¾ | ·4792 | 9¾ | ·8125 |
| 2¼ | ·1875 | 6 | ·5 | 10 | ·8334 |
| 2½ | ·2084 | 6¼ | ·5208 | 10¼ | ·8542 |
| 2¾ | ·2292 | 6½ | ·5416 | 10½ | ·875 |
| 3 | ·25 | 6¾ | ·5625 | 10¾ | ·8959 |
| 3¼ | ·2708 | 7 | ·5833 | 11 | ·9167 |
| 3½ | ·2916 | 7¼ | ·6042 | 11¼ | ·9375 |
| 3¾ | ·3125 | 7½ | ·625 | 11½ | ·9583 |
| | | 7¾ | ·6458 | 11¾ | ·9792 |

### *Application and use of the Table.*

1. Required the number of square feet in a board or plank 16½ feet in length, and 9¾ inches in breadth.

Opposite 9¾ is ·8125 × 16·5 = 13·4 square feet.

2. A board 1 foot 2¾ inches in breadth, and 21 feet in length; what is its superficial content in square feet?

Opposite 2¾ is ·2292, to which add the 1 foot; then 1·2292 × 21 = 25·8 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 1·0208 × 14·5 = 14·8 sq. ft.

## 2. *Cubic or Solid Measure.*

| Mean ¼ girth in inches. | Cubic feet in each lineal foot. | Mean ¼ girth in inches. | Cubic feet in each lineal foot. | Mean ¼ girth 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 girth 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 $\frac{1}{4}$ girth, and the product is the solidity of the given dimensions in cubic feet.

Suppose the mean $\frac{1}{4}$ girth 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 principle 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 4 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 3 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 8¾ yards of cloth, 1½ yards in width, be a sufficient quantity, how much will be required of that which is only ⅞ths 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 ℔s. on C.

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

Set 20 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 ℔s. 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. Pt.) upon A; and against $5\frac{1}{2}$ upon D is 66·65 ℔s. 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. Pt.) upon A; and against 4 on D is 53·16 ℔s. 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. Pt.) upon A; and against 6 on D is 129·5 ℔s. 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.Pr. | 3½ | 4 | 5 | 6 | 8 | 10 | 12 | 16 | 20 | 25 | 30 | 40 | 50 on C. |
| C.D. | 10in. | 10¾ | 12 | 13¼ | 15½ | 17 | 18¾ | 21½ | 24 | 26¾ | 29½ | 33¾ | 37¾ 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 ℔s. 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 ℔s. 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.

## TABLE BY WHICH TO FACILITATE THE CALCULATION OF BRITISH MONEY.

| No. | at ¼d. | | | at ½d. | | | at ¾d. | | | at 1d. | | | at 1¼d. | | | at 1½d. | | | at 1¾d. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. |
| 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 | 5 | 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 | 0½ |
| 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 | 4 | 9½ | 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 | 10 | 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 | 4 |
| 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 | 6 | 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 | 13 | 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 2d. | | | at 2¼d. | | | at 2½d. | | | at 2¾d. | | | at 3d. | | | at 3¼d. | | | at 3½d. | | |
| 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 | 0 | 11½ | 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 | 5¾ | 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 | 1¾ | 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 | 2¾ | 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 | 7 | 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 | 3 | 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.

| | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | at 3¾*d.* | | | at 4*d.* | | | at 4¼*d.* | | | at 4½*d.* | | | at 4¾*d.* | | | at 5*d.* | | | at 5¼*d.* | | |
| 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 |
| 000 | 15 | 12 | 6 | 16 | 13 | 4 | 17 | 14 | 2 | 18 | 15 | 0 | 19 | 15 | 10 | 20 | 16 | 8 | 21 | 17 | 6 |
| 000 | 31 | 5 | 0 | 33 | 6 | 8 | 35 | 8 | 4 | 37 | 10 | 0 | 39 | 11 | 8 | 41 | 13 | 4 | 43 | 15 | 0 |
| 000 | 46 | 17 | 6 | 50 | 0 | 0 | 53 | 2 | 6 | 56 | 5 | 0 | 59 | 7 | 6 | 62 | 10 | 0 | 65 | 12 | 6 |
| 000 | 62 | 10 | 0 | 66 | 13 | 4 | 70 | 16 | 8 | 75 | 0 | 0 | 79 | 3 | 4 | 83 | 6 | 8 | 87 | 10 | 0 |
| 000 | 78 | 2 | 6 | 83 | 6 | 8 | 88 | 10 | 10 | 93 | 15 | 0 | 98 | 19 | 8 | 104 | 3 | 4 | 109 | 7 | 6 |
| 000 | 93 | 15 | 0 | 100 | 0 | 0 | 106 | 5 | 0 | 112 | 10 | 0 | 118 | 15 | 0 | 125 | 0 | 0 | 131 | 5 | 0 |
| 000 | 109 | 7 | 6 | 116 | 13 | 4 | 123 | 19 | 2 | 131 | 5 | 0 | 138 | 10 | 10 | 145 | 16 | 8 | 153 | 2 | 6 |
| 000 | 125 | 0 | 0 | 133 | 6 | 8 | 141 | 13 | 4 | 150 | 0 | 0 | 158 | 6 | 8 | 166 | 13 | 4 | 175 | 0 | 0 |
| 000 | 140 | 12 | 6 | 150 | 0 | 0 | 159 | 7 | 6 | 168 | 15 | 0 | 178 | 2 | 6 | 187 | 10 | 0 | 196 | 17 | 6 |

## MONEY TABLE—CONTINUED.

| | L. S. D. | L. S. D. | L. S. D. | L. S. D. | L. S. D. | L. S. D. | L. S. D |
|---|---|---|---|---|---|---|---|
| No. | at 5½d. | at 5¾d. | at 6d. | at 6¼d. | at 6½d. | at 6¾d. | at 7d. |
| 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 3½ | 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 19 0 | 23 6 8 |
| 900 | 20 12 6 | 21 11 3 | 22 10 0 | 23 18 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 7¼*d.* | | | at 7½*d.* | | | at 7¾*d.* | | | at 8*d.* | | | at 8¼*d.* | | | at 8½*d.* | | | at 8¾*d.* | | |
| 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 | 10½ |
| 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 | 3 | 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 |
| 000 | 30 | 4 | 2 | 31 | 5 | 0 | 32 | 5 | 10 | 33 | 6 | 8 | 34 | 7 | 6 | 35 | 8 | 4 | 36 | 9 | 2 |
| 000 | 60 | 8 | 4 | 62 | 10 | 0 | 64 | 11 | 8 | 66 | 13 | 4 | 68 | 15 | 0 | 70 | 16 | 8 | 72 | 18 | 4 |
| 000 | 90 | 12 | 6 | 93 | 15 | 0 | 96 | 17 | 6 | 100 | 0 | 0 | 103 | 2 | 6 | 106 | 5 | 0 | 109 | 7 | 6 |
| 000 | 120 | 16 | 8 | 125 | 0 | 0 | 129 | 3 | 4 | 133 | 6 | 8 | 137 | 10 | 0 | 141 | 13 | 4 | 145 | 16 | 8 |
| 000 | 151 | 0 | 10 | 156 | 5 | 0 | 161 | 9 | 2 | 166 | 13 | 4 | 171 | 17 | 6 | 177 | 1 | 8 | 182 | 5 | 10 |
| 000 | 181 | 5 | 0 | 187 | 10 | 0 | 193 | 15 | 0 | 200 | 0 | 0 | 206 | 5 | 0 | 212 | 10 | 0 | 218 | 15 | 0 |
| 000 | 211 | 9 | 2 | 218 | 15 | 0 | 236 | 0 | 10 | 233 | 6 | 8 | 240 | 12 | 6 | 247 | 18 | 4 | 255 | 4 | 2 |
| 000 | 241 | 13 | 4 | 250 | 0 | 0 | 258 | 6 | 8 | 266 | 13 | 4 | 275 | 0 | 0 | 283 | 6 | 8 | 291 | 13 | 4 |
| 000 | 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. | at 9d. L. | S. | D. | at 9¼d. L. | S. | D. | at 9½d. L. | S. | D. | at 9¾d. L. | S. | D. | at 10d. L. | S. | D. | at 10¼d. L. | S. | D. | at 10½d. L. | S. | 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 | 7 | 0½ | 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. | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. | L. | S. | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | at 10¾d. | | | at 11d. | | | at 11¼d. | | | at 11½d. | | | at 11¾d. | | | at 1s. | | |
| 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 | 8 | 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 | 6 | 3 | 33 | 10 | 10 | 34 | 5 | 5 | 35 | 0 | 0 |
| 800 | 35 | 16 | 8 | 36 | 13 | 4 | 37 | 0 | 0 | 38 | 6 | 8 | 39 | 3 | 4 | 40 | 0 | 0 |
| 900 | 40 | 6 | 3 | 41 | 5 | 0 | 41 | 13 | 0 | 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 | 320 | 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 | 1*d.* | 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 | 3½ | 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 | 13 | 4 | 0 | 15 | 2 | 0 | 3 | 9½ | 1 | 10¾ | 1⅝ | 1 | 7½ | 2 | 8½ | 0 | 13 | 6 | 0 | 16 | 3 | 0 | 19 | 6 | 6 | 15 | 2 |
| 16 | 16 | 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 | 2*d.* | 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 | 6½ | 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 | 3*d.* | 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 | 7¾ | 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 | 4*d.* | 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 5 | 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 14 6 | 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 8 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. 3 qrs. 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. 81) | = | £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.

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## 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 | $11\frac{1}{2}$ | $30\frac{1}{2}$ | 1 in. | 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 extension 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 | square 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 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 do. | 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?

$$\frac{16 \times 8000}{90 \times 32 \times \cdot 75} = 15175 \div 8 = \sqrt[3]{1897} = 12\cdot 35 \text{ in. the depth.}$$

*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

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

$$\text{Tabular value of S, red pine} = \frac{1341 \times 4 \times 10 \times 60}{204} = 15776 \text{ lbs.}$$

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 $\frac{1}{2}$ of 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 ℔s.

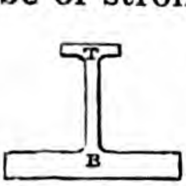
*Ex.* A beam of Riga fir, 12 inches by $4\frac{1}{2}$, and projecting $6\frac{1}{2}$ feet from the wall; what is the greatest weight it will support at the extremity of its length?

Tabular value of S = 1100

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

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

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. 87), 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 ℔s. | Defl. in in. | Wt. in ℔s. | Defl. in in. | Wt. in ℔s. | Defl. in in. | Wt. in ℔s. | Defl. in in. | Wt. in ℔s. | 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 ℔s.

*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.

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

*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 recently 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 ℔s. 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 cylinder, 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 ℔s. without sensible flexure, its breadth being 3 inches, and its length 5 feet?

Tabular value of $E = 105$,

$$\text{and } \frac{2240 \times 5^2}{20 \times 105 \times 3} = \sqrt[3]{8 \cdot 888} = 2 \cdot 05 \text{ inches.}$$

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

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 feet 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 |

*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 |

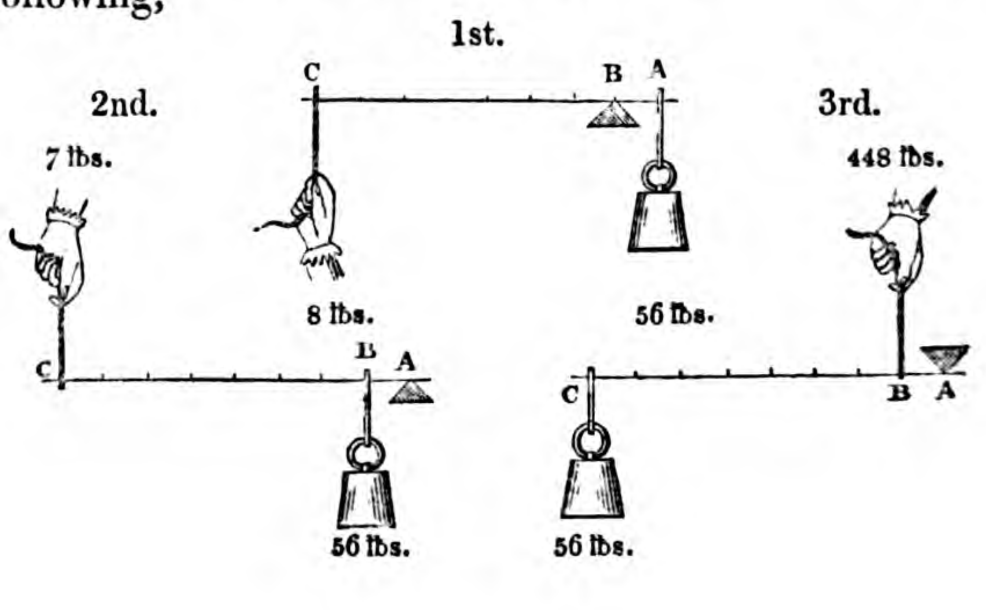
## PRINCIPLES & PRACTICAL APPLICATIONS OF MECHANIC POWERS.

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 to 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 applied 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.

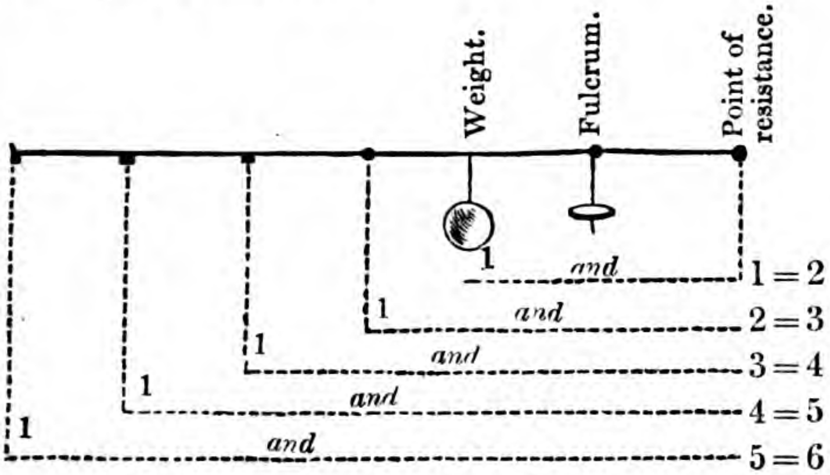
*Ex.* Required the amount of effect or force produced by a power of 50 ℔s. on the ram of a Bramah's pump, the length of the lever being 3 feet, and distance from ram to fulcrum $4\frac{1}{2}$ inches.

3 feet = 36 inches, and $\frac{36}{4\cdot5} = 8$, or the power and resistance are to each other as 8 to 1; hence $50 \times 8 = 400$ ℔s. 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-*

*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 36 lbs. would raise, friction not being taken into account.

$$\frac{30 \times 8}{11} = 21{\cdot}8 \text{ to 1 of exertive force; and } 21{\cdot}8 \times 36 = 784{\cdot}8 \text{ lbs.}$$

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 described by the 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 or angle of inclination: 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 in. | 1 inch. | 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 in principle.

*Ex.* 1. Required the effective power obtained by a screw of $\frac{7}{8}$ inch pitch, and moved by a force equal to 50 lbs. at the extremity of a lever 30 inches in length.

$$\frac{30 \times 2 \times 3{\cdot}1416 \times 50}{{\cdot}875} = 10760 \text{ lbs.}$$

*Ex.* 2. Required the power necessary to overcome a resistance equal to 7000 lbs. by a screw of $1\frac{1}{4}$ inch pitch, and moved by a lever 25 inches in length.

$$\frac{7000 \times 1{\cdot}25}{25 \times 2 \times 3{\cdot}1416} = 55{\cdot}73 \text{ lbs. power.}$$

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 lbs. 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.

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## 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 1 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 2 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 | 3¾ | 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.

$16 \times 10 = 160$ 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 | 0⅝ | 2 | 2⅝ | 2 | 4½ | 2 | 6½ | 2 | 8½ | 2 | 10½ | 3 | 0½ | 3 | 4½ | 3 | 8⅜ | 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 | 8 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 until lately respecting the laws of friction; but those doubts are now 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 ℔s.; hence $\overline{18 \times 9 \times 2} + \overline{13 \times 9 \times 2} = 558 \times 4{\cdot}5 \times 62{\cdot}5 = 156937{\cdot}5$ ℔s.

Weight of water on bottom $= 18 \times 13 \times 9 \times 62{\cdot}5 = 131625$ ℔s.

*Ex.* 2. Required the pressure on a sluice 3 feet square, and its centre 30 feet from the surface of the water.

$3 \times 3 \times 30 \times 62{\cdot}5 = 16875$ ℔s. 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 ℔s. (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 ℔s.; hence $\cdot7854 \times 72 \times \cdot03617 = 2$ ℔s. + 500 = 502 ℔s. total weight of the water.

Again, the whole height of the column = 96 inches; then $\cdot7854 \times 96 \times \cdot03617 = 2{\cdot}33$ ℔s. pressure of column on an equal area. 144 square inches = 1 square foot, and

$$\frac{144 \times 4 \times 6 \text{ sides}}{\cdot7854} = 4400{\cdot}4$$ times the area of the pipe's diameter in the whole surface; therefore $4400{\cdot}4 \times 2{\cdot}33 = 10253$ ℔s., 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.

$$\begin{array}{l} \text{Area of ram} \;\;= \\ \text{Area of pump} = \end{array} \frac{28{\cdot}2744}{{\cdot}6013} = 47;$$

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 $\frac{156 \cdot 254}{1112 \cdot 7} = \cdot 14$ in., the thickness of iron required.

The resistance by which a moving body is opposed in passing through water, is as the square of the body's velocity; hence, if a body be propelled at a certain velocity by a known power, to double that velocity will require four times the power; to triple it, nine times the power, &c.

Water in flowing through an orifice or 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, or falling from an equal height; 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 the orifice or 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.

$\sqrt{11} = 3·3166 \times 8·1 = 26·864$ 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

$\frac{2}{3}$rds 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 $\frac{2}{3}$rds 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 $6\frac{1}{2}$ feet, and depth 9 inches, or ·75 of a foot.

Square root of $\cdot 75 = \cdot 866$.

Then $\frac{6{\cdot}5 \times \cdot 75 \times \cdot 866 \times 5{\cdot}1 \times 2}{3} = 14{\cdot}3839$ 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 $2 \times 5{\cdot}1 = 10{\cdot}2$ feet velocity of the water per second.

And $6{\cdot}5 \times \cdot 75 \times 2 \times 5{\cdot}1 = 49{\cdot}725$ 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.

$$\frac{\overline{9{\cdot}387^2 \times 180} + \overline{50 \times 2 \times 9{\cdot}387^2}}{1542{\cdot}133 \times 2^5} = \frac{15860{\cdot}8}{49348} = {\cdot}5 \text{ of a foot head.}$$

*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 | $4\frac{3}{4}$ | 160 | $12\frac{1}{8}$ |
| 2 | $1\frac{3}{8}$ | 30 | $5\frac{1}{4}$ | 170 | $12\frac{1}{2}$ |
| 3 | $1\frac{5}{8}$ | 35 | $5\frac{5}{8}$ | 180 | $12\frac{3}{4}$ |
| 4 | $1\frac{7}{8}$ | 40 | 6 | 190 | $13\frac{1}{4}$ |
| 5 | $2\frac{1}{8}$ | 45 | $6\frac{1}{2}$ | 200 | $13\frac{5}{8}$ |
| 6 | $2\frac{3}{8}$ | 50 | $6\frac{3}{4}$ | 225 | $14\frac{3}{8}$ |
| 7 | $2\frac{5}{8}$ | 55 | $7\frac{1}{8}$ | 250 | $15\frac{1}{8}$ |
| 8 | $2\frac{3}{4}$ | 60 | $7\frac{1}{2}$ | 275 | 16 |
| 9 | $2\frac{7}{8}$ | 65 | $7\frac{3}{4}$ | 300 | $16\frac{5}{8}$ |
| 10 | 3 | 70 | 8 | 350 | 18 |
| 11 | $3\frac{1}{8}$ | 80 | $8\frac{5}{8}$ | 400 | $19\frac{1}{4}$ |
| 12 | $3\frac{1}{4}$ | 90 | $9\frac{1}{8}$ | 441 | $20\frac{1}{8}$ |
| 13 | $3\frac{1}{2}$ | 100 | $9\frac{5}{8}$ | 529 | 22 |
| 14 | $3\frac{5}{8}$ | 110 | 10 | 625 | 24 |
| 15 | $3\frac{3}{4}$ | 120 | $10\frac{1}{2}$ | 729 | 26 |
| 16 | $3\frac{7}{8}$ | 130 | 11 | 841 | 28 |
| 18 | 4 | 140 | $11\frac{3}{8}$ | 900 | 29 |
| 20 | $4\frac{1}{4}$ | 150 | $11\frac{3}{4}$ | 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 through 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, much discrepancy of opinion has until lately 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 feet 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 an 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.

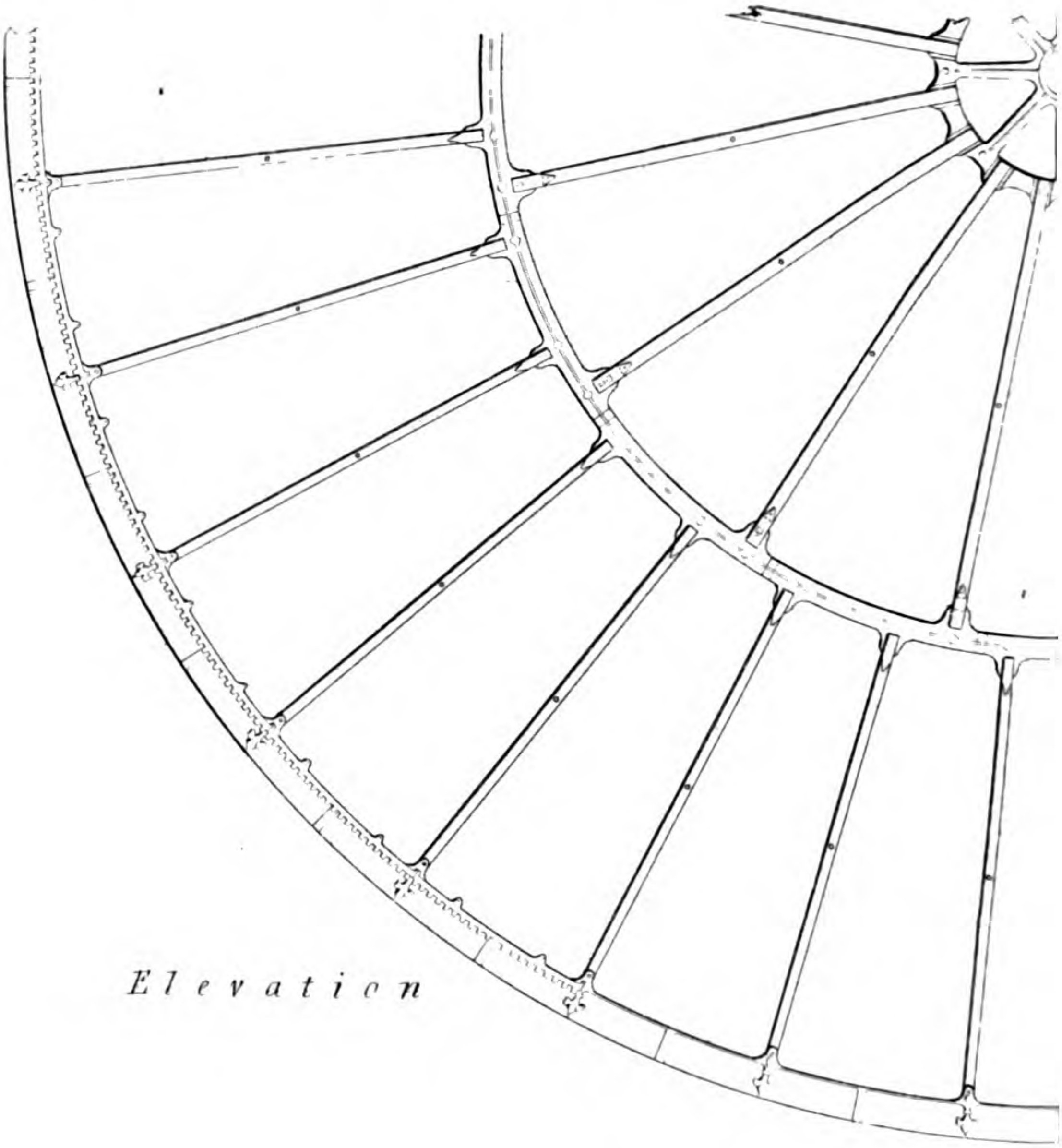
4. That they will work nearly as effectually when drowned to the depth of 5 or 6 feet as when free, and consequently, they will make use of the whole of the fall when placed below the level of extreme low water.

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.

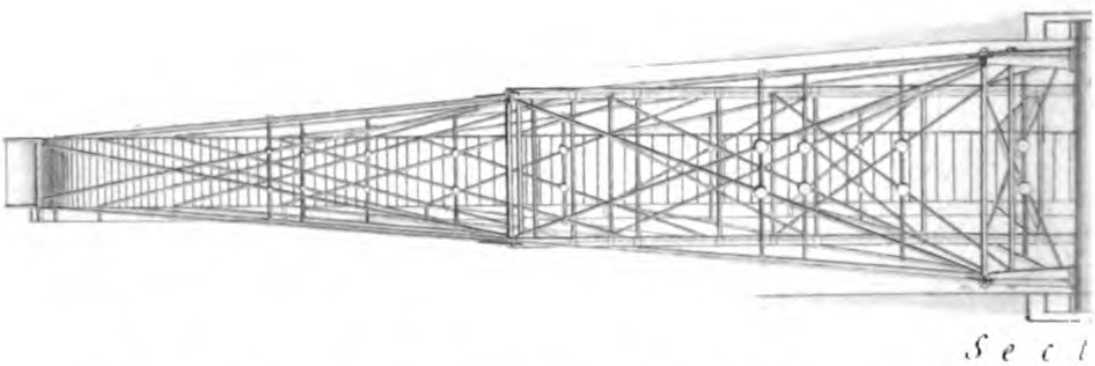
*General Rule by Mr. Whitelaw, whereby to compute the power of their Turbine, or Water-Mill.*

*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 OVRSHOT WATER WHEEL, CONSTRUCTED



*Elevation*

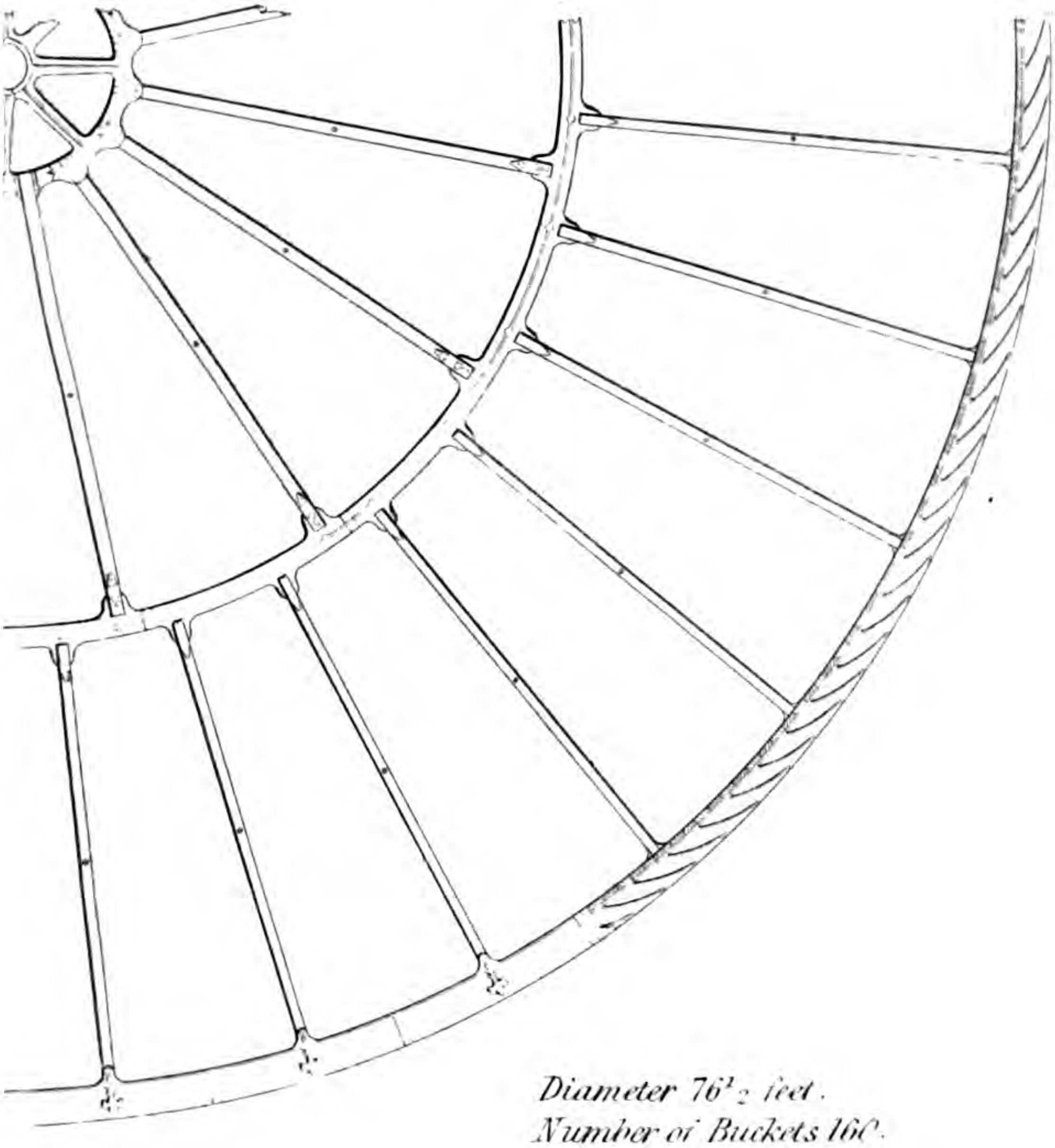


*Sect*

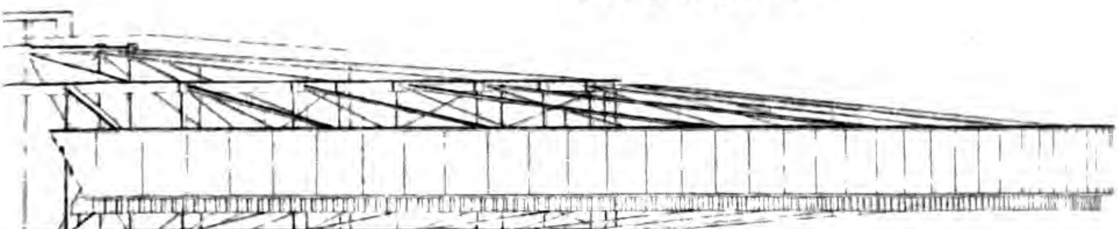
*Published by John Weale 59 High Holborn 1841.*

BY MESS^RS DONKIN & C^O ENGINEERS, LONDON.

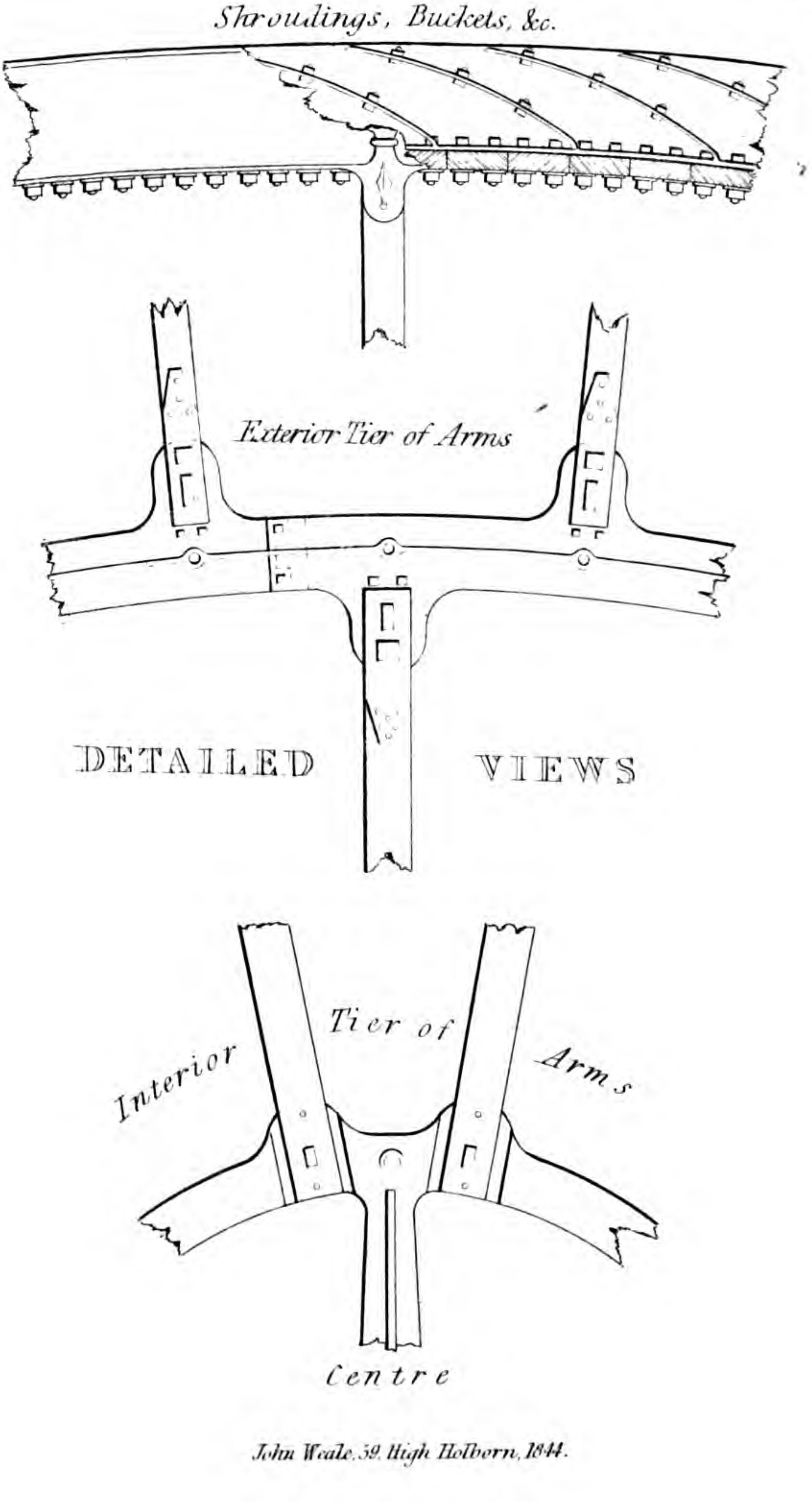
*Plate 6*



*Diameter 76½ feet.*
*Number of Buckets 160.*
*Width of Wheel 2 feet.*
*Horses Power 30.*



*J. W. Lowry, sc*




John Weale, 59, High Holborn, 1844.

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.

2. *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 or fluid principle of which the fire is the immediate cause, and sooner or later, according to the intensity of the heat, attains a temperature of 212° Fahrenheit. If at this point of temperature the water be not enclosed, but exposed to atmospheric pressure, ebullition will take place, and steam or vapour will ascend through the water, carrying with it the superabundant heat, or that which the water cannot under such circumstances of pressure absorb, to be retained and to indicate a higher temperature.

Water, in attaining the aëriform state, is thus uniformly confined to the same laws under every degree of pressure; but as the pressure is augmented, so is the indicated temperature proportionately elevated: hence the various densities of steam, and corresponding 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 incontestible 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°.

$$\frac{312+100}{177} = 2\cdot3277^6 = 159 \text{ inches of mercury.}$$

But the Table, page 138, 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 of at $\frac{1}{3} = 2{\cdot}0986$.

Again, let the greatest elastic force of steam in the cylinder of an engine equal 48 lbs. 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. | Logarithm. | No. | Logarithm. | No. | Logarithm. | No. | Logarithm. |
|---|---|---|---|---|---|---|---|
| 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 | 220 „ | „ 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 ℔s. 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.*

| Deg. of Fahr. | Bulk. | Deg. of Fahr. | Bulk. | Deg. 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 arise 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 per lineal ft. | Number of cubic feet per lineal ft. | Diameter of pump in inches. | Number of gallons per lineal ft. | Number of cubic feet per 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.

$$3{\cdot}068 \times 2{\cdot}25 = 6{\cdot}903 \text{ gallons each stroke.}$$

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 | 12½ | 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 138), 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:

$$295 \times {\cdot}12 = 35{\cdot}4 \text{ square feet of furnace bar.}$$

*Note.*—By effective heating surface is meant horizontal surfaces over fire, flame, or heated air; vertical or side surfaces requiring about $1\frac{3}{4}$ feet 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.

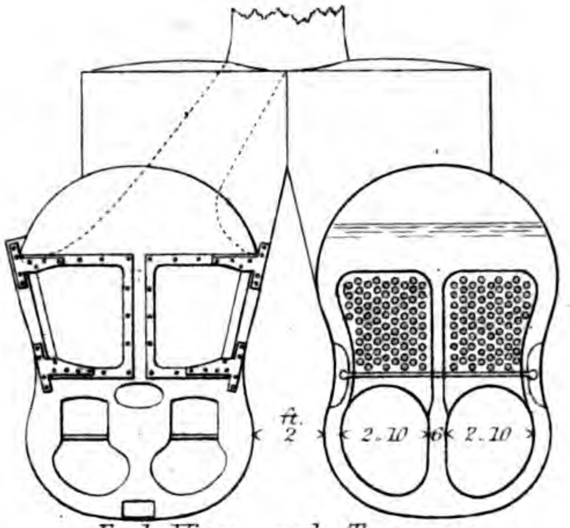
*Ex.* Required the dimensions for a boiler of the waggon form that may present an effective heating surface of 295 square feet.

Bottom surface $= 295 \div 2$, or $147{\cdot}5$ square feet.
Length . . . $= \sqrt{147{\cdot}5} \times 2$, or $24{\cdot}26$ feet.
Width . . . $= 24{\cdot}26 \div 4$, or $6{\cdot}06$ feet.
Height . . . $= 24{\cdot}26 \div 3$, or $8{\cdot}08$ feet.

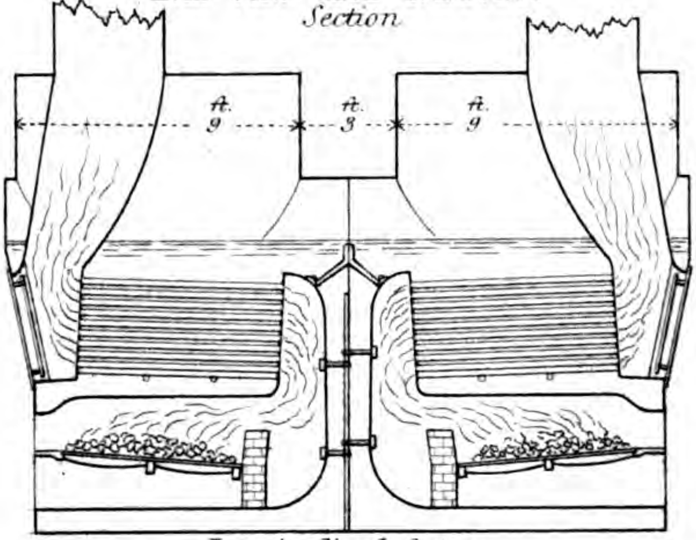
*Note.*—The amount of side or vertical surface equal twice

Plate K

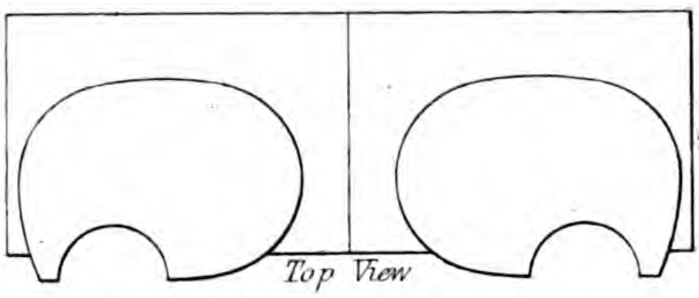
Plans of the Boilers on board the Peninsular Co.s Steam Ship Braganza
By Mess.rs Bury, Curtis and Kennedy, Liverpool.



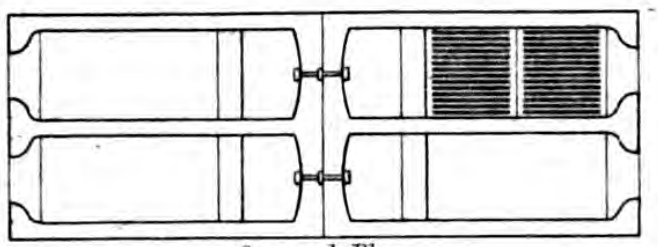

End View and Transverse Section




Longitudinal Section



Top View



Ground Plan

W. T., del.

G. Gladwin, sc

London: J. Weale, 1845

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 are now 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 favored by Messrs. Bury, Curtis, and Kennedy, with particulars of boilers lately constructed by them for the 'Braganza' steam vessel, and which are now giving the highest degree of satisfaction in every respect, I give the annexed designs and data, in preference to any others. (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 14·1 × 140 = 1974 square feet to each engine.

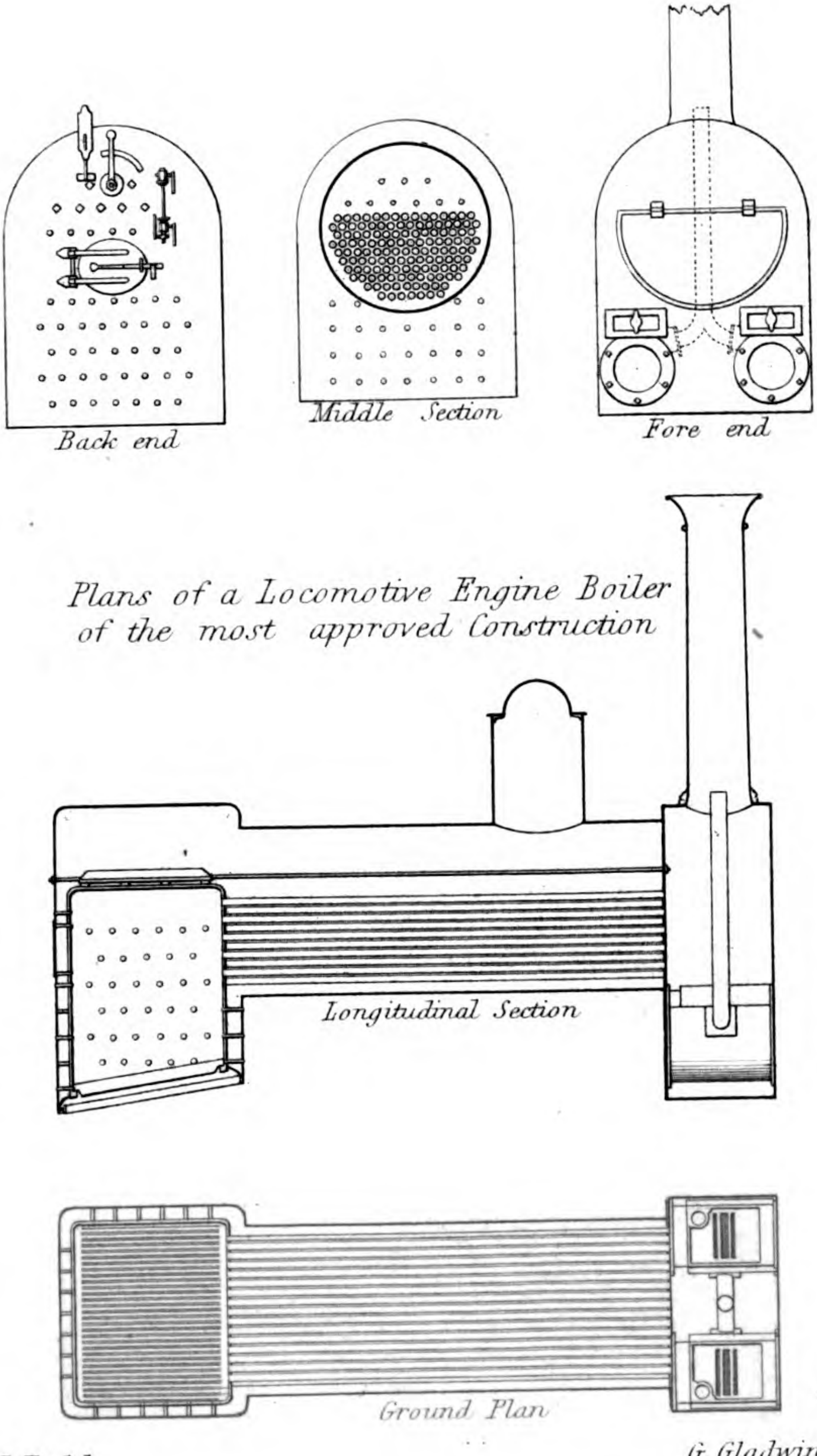
Then as per rule (page 149), 375 multiplied by the area of cylinder or 21 feet, and by the velocity per minute or 231 feet, and divided by 1044 (see Table, page 139) or volume of steam to 1 of water, at 10 lbs. per square inch, equal 1742·4 square feet; to which add about $\frac{1}{8}$th of the quotient, 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.




Plans of a Locomotive Engine Boiler of the most approved Construction

W. T., del.

G. Gladwin, sc.

London: J. Weale, 1845

*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 do. . . . . . . . . . . . | 3 „ 5 „ |
| Length of cylindrical part of boiler | 8 „ 8 „ |
| Diameter of do. . . . . . . . . . . | 3 „ 4½ „ |
| Length of tubes . . . . . . . . . . | 8 „ 11½ „ |
| Number of tubes . . . . . . . . | 133, of brass. |
| Interior diameter of do. . . . . . . . | 1¾ inches. |
| Diameter of blast-pipe . . . . . . . . | 4 „ |

About 112 lbs. of coke consumed in this boiler evaporate 84 gallons of water; and from 20 to 25 lbs. of coke are consumed per mile.

*Heating Powers of Combustible Substances.*

| Species of combustible. | lbs. of water heated from 32° to 212°. | lbs. of boiling water evaporated by 1 lb. of fuel. | lbs. of atmospheric air to each lb. 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 a required number of horses' power, it has lately 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 Maudsley, 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 | 6½ |
| 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 connexion, and by its properties renders the action of alternate circular motion, and reciprocating vertical motion, mutually agreeable, thereby properly ensuring 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.*

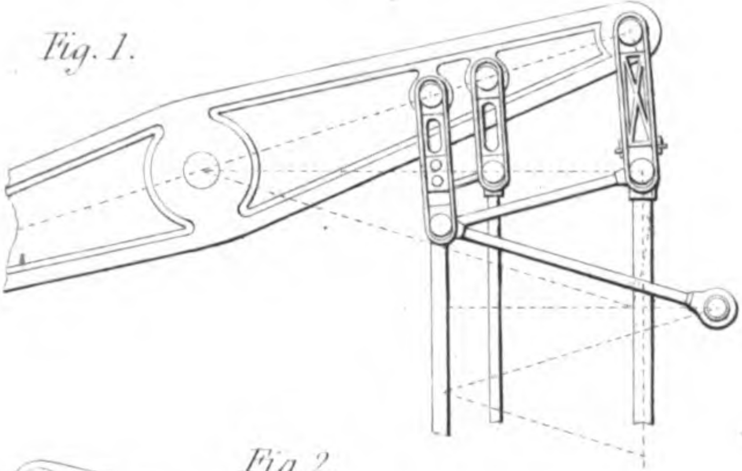


*Fig. 2.*

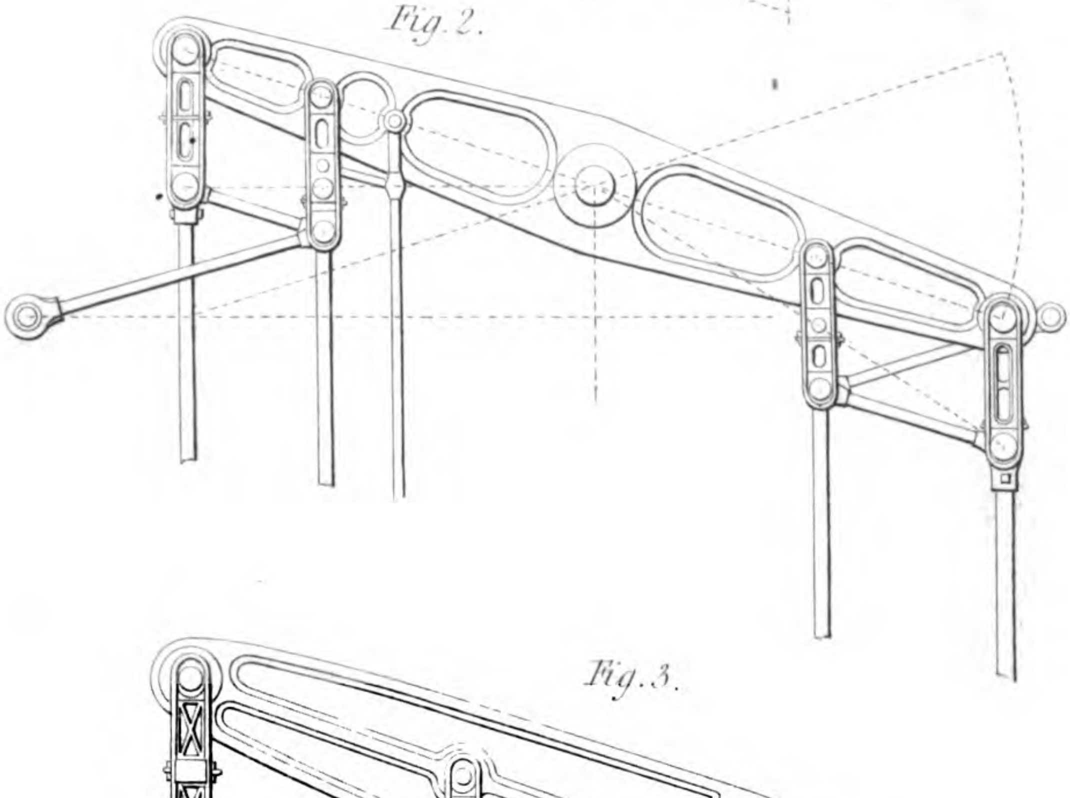
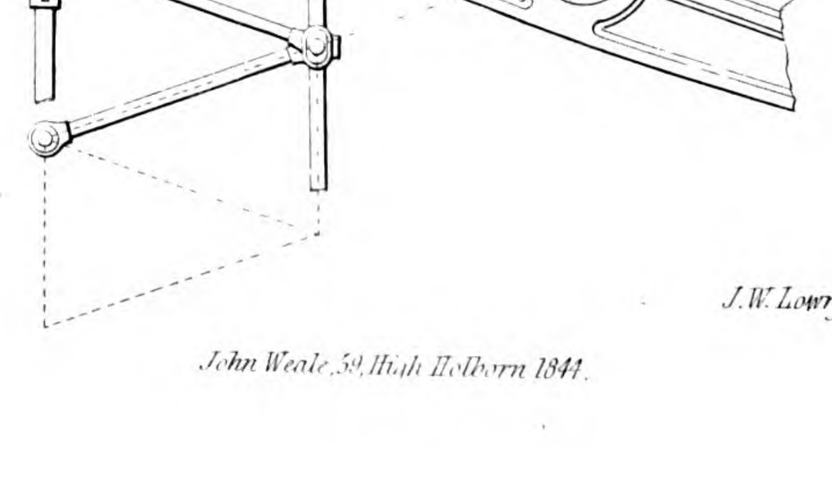


*Fig. 3.*



*J. W. Lowry fc.*

*John Weale, 59, High Holborn 1844.*

# PARALLEL MOTIONS.

Plate F

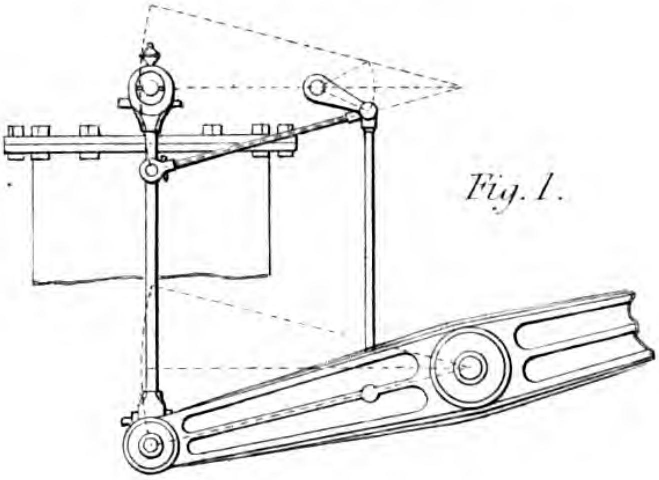


Fig. 1.

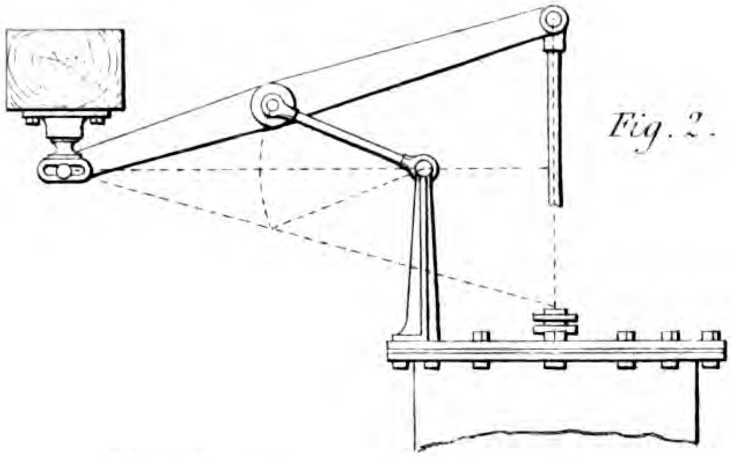
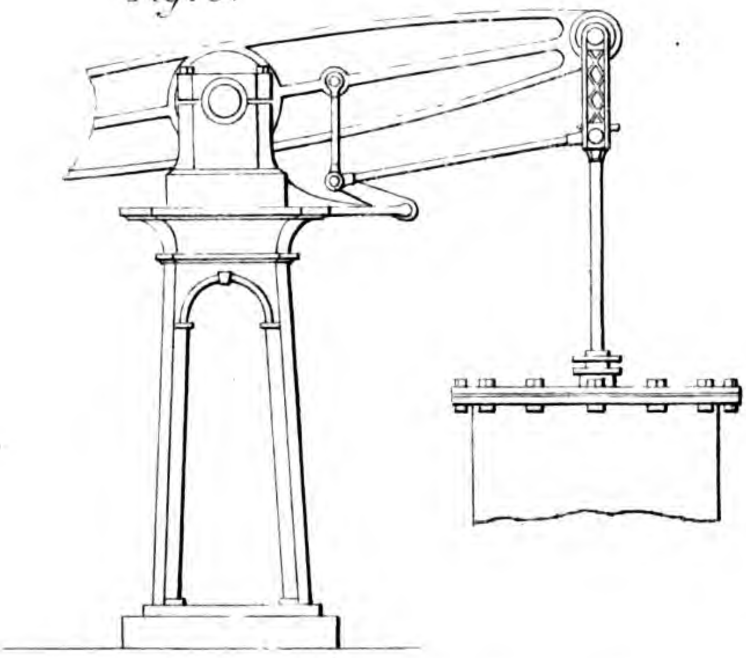


Fig. 2.

Fig. 3.



J.W. Lowry fc.

John Weale, 59, High Holborn, 1844.

*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 |

| Radius of beams in ft. | Parallel bars in ft. | Length of radius rods in ft. & in. | |
|---|---|---|---|
| 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 |

| Radius of beams in ft. | Parallel bars in ft. | Length of radius rods in ft. & in. | |
|---|---|---|---|
| 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 |

| Radius of beams in ft. | Parallel bars in ft. | Length of radius rods in ft. & in. | |
|---|---|---|---|
| 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 | 8½ |
| | 7¾ | 2 | 4 |

# 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, &c. 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 $\frac{64}{253} = \cdot 25$

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. $= \frac{2·562293}{2} =$ 1·281146 indicated number or root = 19·105.

*Ex.* 4. Find the cube root of 12345.

Log. $= \frac{4·091491}{3} =$ 1·363830 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.*—The best Tables of Logarithms are those by Taylor, Gardiner, Hutton, Babbage, and Caillet. The smaller works are those by Lalande, Hassler, Renaud, Christison, and Wallace, and those published in the 'Library of Useful Knowledge.'

*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. |
|---|---|---|---|
| 1/16 | ·196 | ·0030 | ·0554 |
| 1/8 | ·392 | ·0122 | ·1107 |
| 3/16 | ·589 | ·0276 | ·1661 |
| 1/4 | ·785 | ·0490 | ·2115 |
| 5/16 | ·981 | ·0767 | ·2669 |
| 3/8 | 1·178 | ·1104 | ·3223 |
| 7/16 | 1·374 | ·1503 | ·3771 |
| 1/2 | 1·570 | ·1963 | ·4331 |
| 9/16 | 1·767 | ·2485 | ·4995 |
| 5/8 | 1·963 | ·3068 | ·5438 |
| 11/16 | 2·159 | ·3712 | ·6093 |
| 3/4 | 2·356 | ·4417 | ·6646 |
| 13/16 | 2·552 | ·5185 | ·7200 |
| 7/8 | 2·748 | ·6013 | ·7754 |
| 15/16 | 2·945 | ·6903 | ·8308 |
| 1 in. | 3 1/8 | ·7854 | 7/8 |
| 1 1/8 | 3 1/2 | ·9940 | 7/8 & 3/32 |
| 1 1/4 | 3 7/8 | 1·227 | 1 in. |
| 1 3/8 | 4 1/4 | 1·484 | 1 3/16 |
| 1 1/2 | 4 5/8 | 1·767 | 1 5/16 |
| 1 5/8 | 5 1/8 | 2·074 | 1 7/16 |
| 1 3/4 | 5 1/2 | 2·405 | 1 9/16 |
| 1 7/8 | 5 7/8 | 2·761 | 1 11/16 |
| 2 in. | 6 1/4 | 3·141 | 1 3/4 |
| 2 1/8 | 6 5/8 | 3·546 | 1 7/8 |
| 2 1/4 | 7 | 3·976 | 2 in. |
| 2 3/8 | 7 3/8 | 4·430 | 2 1/8 |
| 2 1/2 | 7 3/4 | 4·908 | 2 3/16 |
| 2 5/8 | 8 1/4 | 5·412 | 2 5/16 |
| 2 3/4 | 8 5/8 | 5·939 | 2 7/16 |
| 2 7/8 | 9 | 6·491 | 2 9/16 |
| 3 in. | 9 3/8 | 7·068 | 2 5/8 |
| 3 1/8 | 9 3/4 | 7·669 | 2 3/4 |
| 3 1/4 | 10 1/4 | 8·295 | 2 7/8 |
| 3 3/8 | 10 5/8 | 8·946 | 3 in. |
| 3 1/2 | 11 | 9·621 | 3 1/8 |
| 3 5/8 | 11 3/8 | 10·320 | 3 1/4 |
| 3 3/4 | 11 3/4 | 11·044 | 3 3/8 |
| 3 7/8 | 12 1/8 | 11·793 | 3 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 | 7⅞ | 153·938 | 1·0775 | 19 | 4 | 11⅝ | 283·529 | 1·9847 |
| 14⅛ | 3 | 8⅜ | 156·699 | 1·0968 | 19⅛ | 5 | 0 | 287·272 | 1·9941 |
| 14¼ | 3 | 8¾ | 159·485 | 1·1193 | 19¼ | 5 | 0½ | 291·039 | 2·0371 |
| 14⅜ | 3 | 9⅛ | 162·295 | 1·1360 | 19⅜ | 5 | 0⅞ | 294·831 | 2·0637 |
| 14½ | 3 | 9½ | 165·130 | 1·1569 | 19½ | 5 | 1¼ | 298·648 | 2·0904 |
| 14⅝ | 3 | 9⅞ | 167·989 | 1·1749 | 19⅝ | 5 | 1⅝ | 302·489 | 2·1172 |
| 14¾ | 3 | 10¼ | 170·873 | 1·1961 | 19¾ | 5 | 2 | 306·355 | 2·1443 |
| 14⅞ | 3 | 10¾ | 173·782 | 1·2164 | 19⅞ | 5 | 2⅜ | 310·245 | 2·1716 |
| 15 | 3 | 11⅛ | 176·715 | 1·2370 | 20 | 5 | 2⅞ | 314·160 | 2·1990 |
| 15⅛ | 3 | 11½ | 179·672 | 1·2577 | 20⅛ | 5 | 3¼ | 318·099 | 2·2265 |
| 15¼ | 3 | 11⅞ | 182·654 | 1·2785 | 20¼ | 5 | 3⅝ | 322·063 | 2·2543 |
| 15⅜ | 4 | 0¼ | 185·661 | 1·2996 | 20⅜ | 5 | 4 | 326·051 | 2·2822 |
| 15½ | 4 | 0⅝ | 188·692 | 1·3208 | 20½ | 5 | 4⅜ | 330·064 | 2·3103 |
| 15⅝ | 4 | 1 | 191·748 | 1·3422 | 20⅝ | 5 | 4¾ | 334·101 | 2·3386 |
| 15¾ | 4 | 1½ | 194·828 | 1·3637 | 20¾ | 5 | 5⅛ | 338·163 | 2·3670 |
| 15⅞ | 4 | 1⅞ | 197·933 | 1·3855 | 20⅞ | 5 | 5½ | 342·250 | 2·3956 |
| 16 | 4 | 2¼ | 201·062 | 1·4074 | 21 | 5 | 5⅞ | 346·361 | 2·4244 |
| 16⅛ | 4 | 2⅝ | 204·216 | 1·4295 | 21⅛ | 5 | 6⅜ | 350·497 | 2·4533 |
| 16¼ | 4 | 3 | 207·394 | 1·4517 | 21¼ | 5 | 6¾ | 354·657 | 2·4824 |
| 16⅜ | 4 | 3⅜ | 210·597 | 1·4741 | 21⅜ | 5 | 7⅛ | 358·841 | 2·5117 |
| 16½ | 4 | 3¾ | 213·825 | 1·4967 | 21½ | 5 | 7½ | 363·051 | 2·5412 |
| 16⅝ | 4 | 4¼ | 217·077 | 1·5195 | 21⅝ | 5 | 7⅞ | 367·284 | 2·5708 |
| 16¾ | 4 | 4⅝ | 220·353 | 1·5424 | 21¾ | 5 | 8¼ | 371·543 | 2·6007 |
| 16⅞ | 4 | 5 | 223·654 | 1·5655 | 21⅞ | 5 | 8¾ | 375·826 | 2·6306 |
| 17 | 4 | 5⅜ | 226·980 | 1·5888 | 22 | 5 | 9⅛ | 380·133 | 2·6608 |
| 17⅛ | 4 | 5¾ | 230·330 | 1·6123 | 22⅛ | 5 | 9½ | 384·465 | 2·6691 |
| 17¼ | 4 | 6⅛ | 233·705 | 1·6359 | 22¼ | 5 | 9⅞ | 388·822 | 2·7016 |
| 17⅜ | 4 | 6½ | 237·104 | 1·6597 | 22⅜ | 5 | 10¼ | 393·203 | 2·7224 |
| 17½ | 4 | 6⅞ | 240·528 | 1·6836 | 22½ | 5 | 10⅝ | 397·608 | 2·7632 |
| 17⅝ | 4 | 7⅜ | 243·977 | 1·7078 | 22⅝ | 5 | 11 | 402·038 | 2·7980 |
| 17¾ | 4 | 7¾ | 247·450 | 1·7321 | 22¾ | 5 | 11½ | 406·493 | 2·8054 |
| 17⅞ | 4 | 8⅛ | 250·947 | 1·7566 | 22⅞ | 5 | 11⅞ | 410·972 | 2·8658 |
| 18 | 4 | 8½ | 254·469 | 1·7812 | 23 | 6 | 0¼ | 415·476 | 2·8903 |
| 18⅛ | 4 | 8⅞ | 258·016 | 1·8061 | 23⅛ | 6 | 0⅝ | 420·004 | 2·9100 |
| 18¼ | 4 | 9¼ | 261·587 | 1·8311 | 23¼ | 6 | 1 | 424·557 | 2·9518 |
| 18⅜ | 4 | 9¾ | 265·182 | 1·8562 | 23⅜ | 6 | 1⅜ | 429·135 | 2·9937 |
| 18½ | 4 | 10⅛ | 268·803 | 1·8816 | 23½ | 6 | 1¾ | 433·737 | 3·0129 |
| 18⅝ | 4 | 10½ | 272·447 | 1·9071 | 23⅝ | 6 | 2¼ | 438·363 | 3·0261 |
| 18¾ | 4 | 10⅞ | 276·117 | 1·9328 | 23¾ | 6 | 2⅝ | 443·014 | 3·0722 |
| 18⅞ | 4 | 11¼ | 279·811 | 1·9586 | 23⅞ | 6 | 3 | 447·690 | 3·1081 |

| 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 | 0¼ | 6 | 4⅛ | 461·864 | 3·2075 |
| 2 | 0½ | 6 | 4⅞ | 471·436 | 3·2731 |
| 2 | 0¾ | 6 | 5¾ | 481·106 | 3·3410 |
| 2 | 1 | 6 | 6½ | 490·875 | 3·4081 |
| 2 | 1¼ | 6 | 7¼ | 500·741 | 3·4775 |
| 2 | 1½ | 6 | 8⅛ | 510·706 | 3·5468 |
| 2 | 1¾ | 6 | 8⅞ | 520·769 | 3·6101 |
| 2 | 2 | 6 | 9⅝ | 530·930 | 3·6870 |
| 2 | 2¼ | 6 | 10½ | 541·189 | 3·7583 |
| 2 | 2½ | 6 | 11¼ | 551·547 | 3·8302 |
| 2 | 2¾ | 7 | 0 | 562·002 | 3·9042 |
| 2 | 3 | 7 | 0¾ | 572·556 | 3·9761 |
| 2 | 3¼ | 7 | 1⅝ | 583·208 | 4·0500 |
| 2 | 3½ | 7 | 2⅜ | 593·958 | 4·1241 |
| 2 | 3¾ | 7 | 3⅛ | 604·807 | 4·2000 |
| 2 | 4 | 7 | 3⅞ | 615·753 | 4·2760 |
| 2 | 4¼ | 7 | 4¾ | 626·798 | 4·3521 |
| 2 | 4½ | 7 | 5½ | 637·941 | 4·4302 |
| 2 | 4¾ | 7 | 6¼ | 649·182 | 4·5083 |
| 2 | 5 | 7 | 7 | 660·521 | 4·5861 |
| 2 | 5¼ | 7 | 7⅞ | 671·958 | 4·6665 |
| 2 | 5½ | 7 | 8⅝ | 683·494 | 4·7467 |
| 2 | 5¾ | 7 | 9½ | 695·128 | 4·8274 |
| 2 | 6 | 7 | 10¼ | 706·860 | 4·9081 |
| 2 | 6¼ | 7 | 11 | 718·690 | 4·9901 |
| 2 | 6½ | 7 | 11¾ | 730·618 | 5·0731 |
| 2 | 6¾ | 8 | 0⅝ | 742·644 | 5·1573 |
| 2 | 7 | 8 | 1⅜ | 754·769 | 5·2278 |
| 2 | 7¼ | 8 | 2⅛ | 766·992 | 5·3264 |
| 2 | 7½ | 8 | 2⅞ | 779·313 | 5·4112 |
| 2 | 7¾ | 8 | 3¾ | 791·732 | 5·4982 |
| 2 | 8 | 8 | 4½ | 804·249 | 5·5850 |
| 2 | 8¼ | 8 | 5⅜ | 816·865 | 5·6729 |
| 2 | 8½ | 8 | 6⅛ | 829·578 | 5·7601 |
| 2 | 8¾ | 8 | 6⅞ | 842·390 | 5·8491 |
| 2 | 9 | 8 | 7⅝ | 855·300 | 5·9398 |
| 2 | 9¼ | 8 | 8½ | 868·308 | 6·0291 |
| 2 | 9½ | 8 | 9¼ | 881·415 | 6·1201 |
| 2 | 9¾ | 8 | 10 | 894·619 | 6·2129 |
| 2 | 10 | 8 | 10¾ | 907·922 | 6·3051 |
| 2 | 10¼ | 8 | 11½ | 921·323 | 6·3981 |
| 2 | 10½ | 9 | 0⅜ | 934·822 | 6·4911 |
| 2 | 10¾ | 9 | 1⅛ | 948·419 | 6·5863 |
| 2 | 11 | 9 | 1⅞ | 962·115 | 6·6815 |
| 2 | 11¼ | 9 | 2¾ | 975·908 | 6·7772 |
| 2 | 11½ | 9 | 3½ | 989·800 | 6·8738 |
| 2 | 11¾ | 9 | 4¼ | 1003·79 | 6·9701 |
| 3 | 0 | 9 | 5 | 1017·87 | 7·0688 |
| 3 | 0¼ | 9 | 5⅞ | 1032·06 | 7·1671 |
| 3 | 0½ | 9 | 6⅝ | 1046·35 | 7·2664 |
| 3 | 0¾ | 9 | 7½ | 1060·73 | 7·3662 |
| 3 | 1 | 9 | 8¼ | 1075·21 | 7·4661 |
| 3 | 1¼ | 9 | 9 | 1089·79 | 7·5671 |
| 3 | 1½ | 9 | 9⅞ | 1104·46 | 7·6691 |
| 3 | 1¾ | 9 | 10½ | 1119·24 | 7·7791 |
| 3 | 2 | 9 | 11⅜ | 1134·12 | 7·8681 |
| 3 | 2¼ | 10 | 0⅛ | 1149·09 | 7·9791 |
| 3 | 2½ | 10 | 0⅞ | 1164·16 | 8·0846 |
| 3 | 2¾ | 10 | 1¾ | 1179·32 | 8·1891 |
| 3 | 3 | 10 | 2½ | 1194·59 | 8·2951 |
| 3 | 3¼ | 10 | 3¼ | 1209·95 | 8·4026 |
| 3 | 3½ | 10 | 4 | 1225·42 | 8·5091 |
| 3 | 3¾ | 10 | 4⅞ | 1240·98 | 8·6171 |
| 3 | 4 | 10 | 5⅝ | 1256·64 | 8·7269 |
| 3 | 4¼ | 10 | 6⅜ | 1272·39 | 8·8361 |
| 3 | 4½ | 10 | 7¼ | 1288 25 | 8·9462 |
| 3 | 4¾ | 10 | 8 | 1304·20 | 9·0561 |
| 3 | 5 | 10 | 8¾ | 1320·25 | 9·1686 |
| 3 | 5¼ | 10 | 9½ | 1336·40 | 9·2112 |
| 3 | 5½ | 10 | 10⅜ | 1352·65 | 9·3936 |
| 3 | 5¾ | 10 | 11⅛ | 1369·00 | 9·5061 |
| 3 | 6 | 10 | 11⅞ | 1385·44 | 9·621 |
| 3 | 6¼ | 11 | 0¾ | 1401·98 | 9·736 |
| 3 | 6½ | 11 | 1½ | 1418·62 | 9·851 |
| 3 | 6¾ | 11 | 2¼ | 1435·36 | 9·967 |
| 3 | 7 | 11 | 3 | 1452·20 | 10·084 |
| 3 | 7¼ | 11 | 3⅞ | 1469·14 | 10·202 |
| 3 | 7½ | 11 | 4⅝ | 1486·17 | 10·320 |
| 3 | 7¾ | 11 | 5⅜ | 1503·30 | 10·439 |

| 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. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| 4 | 5¼ | 13 | 11¼ | 2227·05 | 15·465 | 5 | 3¼ | 16 | 6¼ | 3142·04 | 21·819 |
| 4 | 5½ | 14 | 0 | 2248·01 | 15·611 | 5 | 3½ | 16 | 7½ | 3166·92 | 21·992 |
| 4 | 5¾ | 14 | 0⅞ | 2269·06 | 15·757 | 5 | 3¾ | 16 | 8¼ | 3191·91 | 22·166 |

| 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. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 2½ | 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 |

| No. | S. R. | C. R. | No. | S. R. | C. R. | No. | S. R. | C. R. | No. | S. R. | C. R. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1·0000 | 1·0000 | 55 | 7·4161 | 3·8029 | 109 | 10·4403 | 4·7768 | 163 | 12·7671 | 5·4625 |
| 2 | 1·4142 | 1·2599 | 56 | 7·4833 | 3·8258 | 110 | 10·4880 | 4·7914 | 164 | 12·8062 | 5·4737 |
| 3 | 1·7320 | 1·4422 | 57 | 7·5498 | 3·8485 | 111 | 10·5356 | 4·8058 | 165 | 12·8452 | 5·4848 |
| 4 | 2·0000 | 1·5874 | 58 | 7·6157 | 3·8708 | 112 | 10·5830 | 4·8202 | 166 | 12·8840 | 5·4958 |
| 5 | 2·2360 | 1·7099 | 59 | 7·6811 | 3·8929 | 113 | 10·6301 | 4·8345 | 167 | 12·9228 | 5·5068 |
| 6 | 2·4494 | 1·8171 | 60 | 7·7459 | 3·9148 | 114 | 10·6770 | 4·8488 | 168 | 12·9614 | 5·5178 |
| 7 | 2·6457 | 1·9129 | 61 | 7·8102 | 3·9364 | 115 | 10·7238 | 4·8629 | 169 | 13·0000 | 5·5287 |
| 8 | 2·8284 | 2·0000 | 62 | 7·8740 | 3·9578 | 116 | 10·7703 | 4·8769 | 170 | 13·0384 | 5·5396 |
| 9 | 3·0000 | 2·0800 | 63 | 7·9372 | 3·9790 | 117 | 10·8166 | 4·8909 | 171 | 13·0766 | 5·5404 |
| 10 | 3·1622 | 2·1544 | 64 | 8·0000 | 4·0000 | 118 | 10·8627 | 4·9048 | 172 | 13·1148 | 5·5612 |
| 11 | 3·3166 | 2·2239 | 65 | 8·0622 | 4·0207 | 119 | 10·9087 | 4·9186 | 173 | 13·1529 | 5·5720 |
| 12 | 3·4641 | 2·2894 | 66 | 8·1240 | 4·0412 | 120 | 10·9544 | 4·9324 | 174 | 13·1909 | 5·5827 |
| 13 | 3·6055 | 2·3513 | 67 | 8·1853 | 4·0615 | 121 | 11·0000 | 4·9460 | 175 | 13·2287 | 5·5934 |
| 14 | 3·7416 | 2·4101 | 68 | 8·2462 | 4·0816 | 122 | 11·0453 | 4·9596 | 176 | 13·2664 | 5·6040 |
| 15 | 3·8729 | 2·4662 | 69 | 8·3066 | 4·1015 | 123 | 11·0905 | 4·9731 | 177 | 13·3041 | 5·6416 |
| 16 | 4·0000 | 2·5198 | 70 | 8·3666 | 4·1212 | 124 | 11·1355 | 4·9866 | 178 | 13·3416 | 5·6252 |
| 17 | 4·1231 | 2·5712 | 71 | 8·4261 | 4·1408 | 125 | 11·1803 | 5·0000 | 179 | 13·3790 | 5·6357 |
| 18 | 4·2426 | 2·6207 | 72 | 8·4852 | 4·1601 | 126 | 11·2249 | 5·0132 | 180 | 13·4164 | 5·6462 |
| 19 | 4·3588 | 2·6684 | 73 | 8·5440 | 4·1793 | 127 | 11·2694 | 5·0265 | 181 | 13·4536 | 5·6566 |
| 20 | 4·4721 | 2·7144 | 74 | 8·6023 | 4·1983 | 128 | 11·3137 | 5·0396 | 182 | 13·4907 | 5·6670 |
| 21 | 4·5825 | 2·7589 | 75 | 8·6602 | 4·2171 | 129 | 11·3578 | 5·0527 | 183 | 13·5277 | 5·6774 |
| 22 | 4·6904 | 2·8020 | 76 | 8·7177 | 4·2358 | 130 | 11·4017 | 5·0657 | 184 | 13·5646 | 5·6877 |
| 23 | 4·7958 | 2·8438 | 77 | 8·7749 | 4·2543 | 131 | 11·4455 | 5·0787 | 185 | 13·6014 | 5·6980 |
| 24 | 4·8989 | 2·8844 | 78 | 8·8317 | 4·2726 | 132 | 11·4891 | 5·0916 | 186 | 13·6381 | 5·7082 |
| 25 | 5·0000 | 2·9240 | 79 | 8·8881 | 4·2908 | 133 | 11·5325 | 5·1044 | 187 | 13·6747 | 5·7184 |
| 26 | 5·0990 | 2·9624 | 80 | 8·9442 | 4·3088 | 134 | 11·5758 | 5·1172 | 188 | 13·7113 | 5·7286 |
| 27 | 5·1961 | 3·0000 | 81 | 9·0000 | 4·3267 | 135 | 11·6189 | 5·1299 | 189 | 13·7477 | 5·7387 |
| 28 | 5·2915 | 3·0365 | 82 | 9·0553 | 4·3444 | 136 | 11·6619 | 5·1425 | 190 | 13·7840 | 5·7488 |
| 29 | 5·3851 | 3·0723 | 83 | 9·1104 | 4·3620 | 137 | 11·7046 | 5·1551 | 191 | 13·8202 | 5·7589 |
| 30 | 5·4772 | 3·1072 | 84 | 9·1651 | 4·3795 | 138 | 11·7473 | 5·1676 | 192 | 13·8564 | 5·7689 |
| 31 | 5·5677 | 3·1413 | 85 | 9·2195 | 4·3968 | 139 | 11·7898 | 5·1801 | 193 | 13·8924 | 5·7789 |
| 32 | 5·6568 | 3·1748 | 86 | 9·2736 | 4·4140 | 140 | 11·8321 | 5·1924 | 194 | 13·9283 | 5·7889 |
| 33 | 5·7445 | 3·2075 | 87 | 9·3273 | 4·4310 | 141 | 11·8743 | 5·2048 | 195 | 13·9642 | 5·7988 |
| 34 | 5·8309 | 3·2396 | 88 | 9·3808 | 4·4479 | 142 | 11·9163 | 5·2171 | 196 | 14·0000 | 5·8087 |
| 35 | 5·9160 | 3·2710 | 89 | 9·4339 | 4·4647 | 143 | 11·9582 | 5·2293 | 197 | 14·0356 | 5·8186 |
| 36 | 6·0000 | 3·3019 | 90 | 9·4868 | 4·4814 | 144 | 12·0000 | 5·2414 | 198 | 14·0712 | 5·8284 |
| 37 | 6·0827 | 3·3322 | 91 | 9·5393 | 4·4979 | 145 | 12·0415 | 5·2535 | 199 | 14·1067 | 5·8382 |
| 38 | 6·1644 | 3·3619 | 92 | 9·5916 | 4·5143 | 146 | 12·0830 | 5·2656 | 200 | 14·1421 | 5·8480 |
| 39 | 6·2449 | 3·3912 | 93 | 9·6436 | 4·5306 | 147 | 12·1243 | 5·2776 | 201 | 14·1774 | 5·8577 |
| 40 | 6·3245 | 3·4199 | 94 | 9·6953 | 4·5468 | 148 | 12·1655 | 5·2895 | 202 | 14·2126 | 5·8674 |
| 41 | 6·4031 | 3·4482 | 95 | 9·7467 | 4·5629 | 149 | 12·2065 | 5·3014 | 203 | 14·2478 | 5·8771 |
| 42 | 6·4807 | 3·4760 | 96 | 9·7979 | 4·5788 | 150 | 12·2474 | 5·3132 | 204 | 14·2828 | 5·8867 |
| 43 | 6·5574 | 3·5033 | 97 | 9·8488 | 4·5947 | 151 | 12·2882 | 5·3250 | 205 | 14·3178 | 5·8963 |
| 44 | 6·6332 | 3·5303 | 98 | 9·8994 | 4·6104 | 152 | 12·3288 | 5·3368 | 206 | 14·3527 | 5·9059 |
| 45 | 6·7082 | 3·5568 | 99 | 9·9498 | 4·6260 | 153 | 12·3693 | 5·3484 | 207 | 14·3874 | 5·9154 |
| 46 | 6·7823 | 3·5830 | 100 | 10·0000 | 4·6415 | 154 | 12·4096 | 5·3601 | 208 | 14·4222 | 5·9249 |
| 47 | 6·8556 | 3·6088 | 101 | 10·0498 | 4·6570 | 155 | 12·4498 | 5·3716 | 209 | 14·4568 | 5·9344 |
| 48 | 6·9282 | 3·6342 | 102 | 10·0995 | 4·6723 | 156 | 12·4899 | 5·3832 | 210 | 14·4913 | 5·9439 |
| 49 | 7·0000 | 3·6593 | 103 | 10·1488 | 4·6875 | 157 | 12·5299 | 5·3946 | 211 | 14·5258 | 5·9533 |
| 50 | 7·0710 | 3·6840 | 104 | 10·1980 | 4·7026 | 158 | 12·5698 | 5·4061 | 212 | 14·5602 | 5·9627 |
| 51 | 7·1414 | 3·7084 | 105 | 10·2469 | 4·7176 | 159 | 12·6095 | 5·4175 | 213 | 14·5945 | 5·9720 |
| 52 | 7·2111 | 3·7325 | 106 | 10·2956 | 4·7326 | 160 | 12·6491 | 5·4288 | 214 | 14·6287 | 5·9814 |
| 53 | 7·2801 | 3·7562 | 107 | 10·3440 | 4·7474 | 161 | 12·6885 | 5·4401 | 215 | 14·6628 | 5·9907 |
| 54 | 7·3484 | 3·7797 | 108 | 10·3923 | 4·7622 | 162 | 12·7279 | 5·4513 | 216 | 14·6969 | 6·0000 |

***To find the square or cube root of a number consisting of integers and decimals.—Rule.*** Multiply the difference between the root of the integer part of the given number, and the root of the next higher number, by the decimal part of the given number, and add the product to the root of the given integer number; the sum is the root required.

*Ex.* Required the square root of 20·321.

Square root of 21=4·5825
Do. 20=4·4721
Diff. = ·1104×·321+4·4721=4·507, &c., the root required.

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## PER CENTAGE AND DISCOUNT TABLE.

| Rate per cent. | Rate per £. in shillings. | Rate per s. in pence. | Rate per cent. | Rate per £. in shillings. | Rate per s. in pence. |
|---|---|---|---|---|---|
| ⅛ | ·025 | ·015 | 5½ | 1·1 | ·66 |
| ¼ | ·05 | ·03 | 6 | 1·2 | ·72 |
| ½ | ·1 | ·06 | 6¼ | 1·25 | ·75 |
| ¾ | ·15 | ·09 | 7½ | 1·5 | ·9 |
| 1 | ·2 | ·12 | 8¾ | 1·75 | 1·05 |
| 2 | ·4 | ·24 | 10 | 2 | 1·2 |
| 2½ | ·5 | ·3 | 12½ | 2·5 | 1·5 |
| 3 | ·6 | ·36 | 15 | 3 | 1·8 |
| 3½ | ·7 | ·42 | 20 | 4 | 2·4 |
| 4 | ·8 | ·48 | 25 | 5 | 3 |
| 4½ | ·9 | ·54 | 30 | 6 | 3·6 |
| 5 | 1 | ·6 | 40 | 8 | 4·8 |
| To cover a discount of | Mult. the net price by | Divide the product by | To cover a discount of | Mult. the net price by | Divide the product by |
| 5 p. ct. | 20 | 19 | 27½ p.ct. | 40 | 29 |
| 7½ | 40 | 37 | 30 | 10 | 7 |
| 10 | 10 | 9 | 32½ | 40 | 27 |
| 12½ | 8 | 7 | 35 | 20 | 13 |
| 15 | 20 | 17 | 37½ | 8 | 5 |
| 17½ | 40 | 33 | 40 | 5 | 3 |
| 20 | 5 | 4 | 42½ | 40 | 23 |
| 22½ | 40 | 31 | 45 | 20 | 11 |
| 25 | 4 | 3 | 47½ | 40 | 21 |
| For 50 per cent., double the sum. | | | | | |

*Ex.* 1. Required the per centage on £127 at 3½ per cent.

127×·7=88·9 shillings, or £4. 8*s*. 10¾*d*.

*Ex.* 2. What is the per centage on 36 shillings at 2½ per cent.?

36×·3=10·8 pence, or 10 pence and 3 farthings nearly.

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