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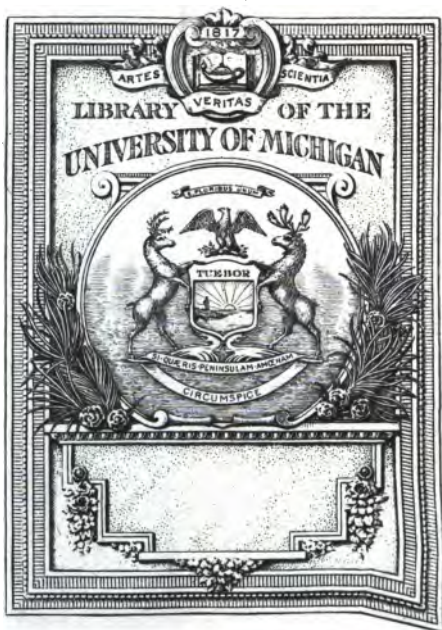
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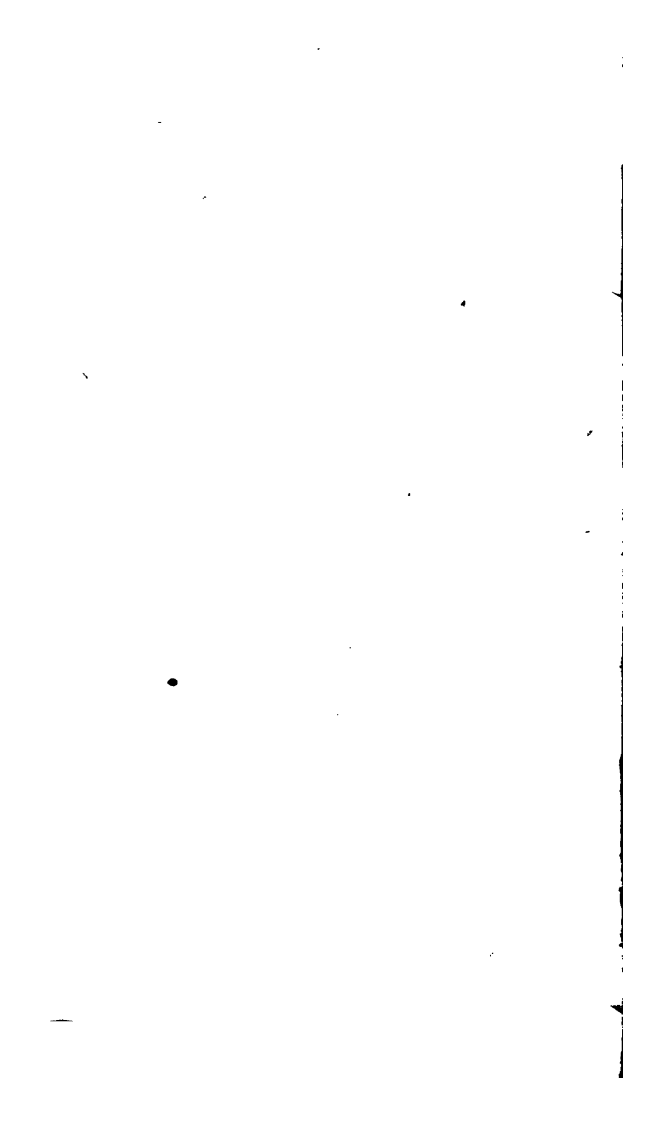
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*A. W. Longfellow.*

THE

PRACTICAL

ENGINEER'S POCKET GUIDE:

CONTAINING

A CONCISE TREATISE

ON THE NATURE AND APPLICATION OF MECHANICAL FORCES; ACTION OF GRAVITY; THE ELEMENTS OF MACHINERY; RULES AND TABLES FOR CALCULATING THE WORKING EFFECTS OF MACHINERY; OF THE STRENGTH, RESISTANCE, AND PRESSURE OF MATERIALS; WITH TABLES OF THE WEIGHT AND COHESIVE STRENGTH OF IRON AND OTHER METALS.

COMPILED AND ARRANGED

BY THOMAS KELT,

OF THE "GLOUCESTER CITY MACHINE COMPANY," N. J.

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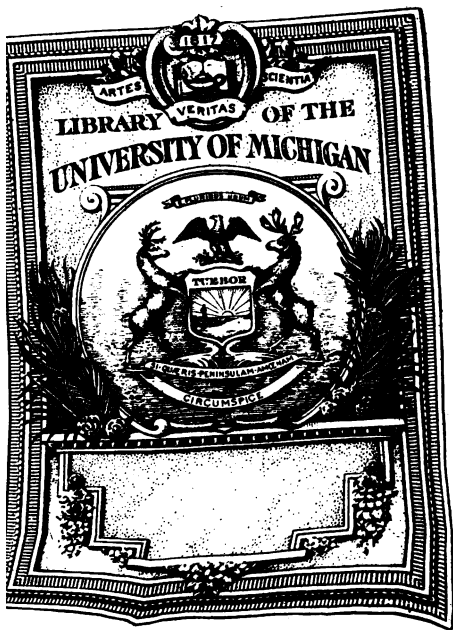
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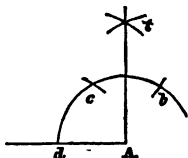
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3. *To do the same otherwise.*

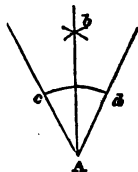
From the given point  $A$ , with any convenient radius, describe the arc  $dcb$ ; from  $d$ , cut the arc in  $c$ , and from  $c$ , cut the arc in  $b$ ; also, from  $c$  and  $b$  as centres, describe arcs cutting each other in  $t$ ; then will the line  $A t$  be the perpendicular as required.



*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.

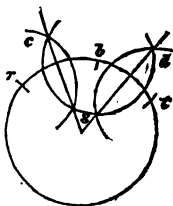
4. *To bisect any given angle.*

From the point  $A$  as a centre, with any radius less than the extent of the angle, describe an arc, as  $cd$ ; 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.



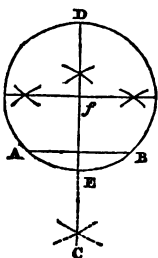
5. *To find the centre of a circle, or radius, that shall cut any three given points, not in a direct line.*

From the middle point  $b$  as a centre, with any radius, as  $bc$ ,  $bd$ , describe a portion of a circle, as  $csd$ ; and from  $r$  and  $t$  as centres, with an equal radius, cut the portion of the circle in  $cs$  and  $ds$ ; 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.



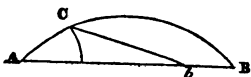
6. *To find the centre of a given circle.*

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.



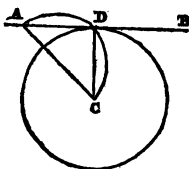
7. *To find the length of any given arc of a circle.*

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.*

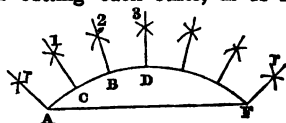
Let the given point be at  $A$ ; draw the line  $A C$ , on which describe the semicircle  $A D C$ ; draw the line  $A D B$ , cutting the circumference in  $D$ , which is the tangent as required.



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

Divide the whole or any given portion of the circumference into the desired number of equal parts; then, with any radius less than the distance of two

divisions, describe arcs cutting each other, as A 1 B 1, C 2, D 2, &c.; draw the lines C 1, B 2, D 3, &c., which lead to the centre as required.

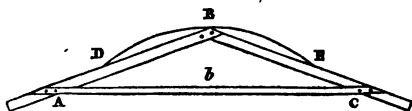


*To draw the end lines.*

As A r, F r, 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.*

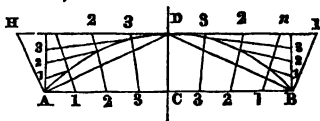
Of any suitable material, construct a triangle, as A B C; make A B, B C, each equal in length to the chord of the arc D E, and height, twice that of the arc



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.*

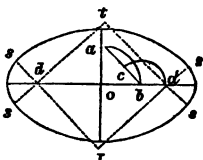
Draw the chord A C B; also draw the line H D I, parallel with the chord, and equal to the height of the segment; bisect the chord in C, and erect the perpendicular C D; join A D, D B; draw A H perpendicular to A D, and B I perpendicular to B D; erect also the perpendiculars A n, B n; divide A B and H 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.

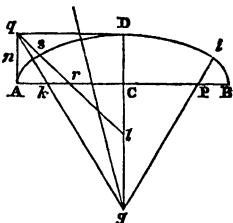
12. *To describe an ellipse, having the two diameters given.*

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.

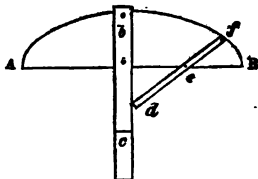


13. *To describe an elliptic arch, the width and rise of span being given.*

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,

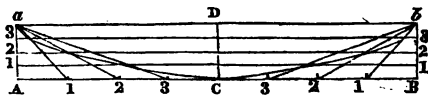


14. Bisect the chord  $AB$ , and fix at right angles any straight guide, as  $bc$ ; prepare, of any suitable material, a rod or staff, equal to half the chord's length, as  $def$ ; from the end of the staff, equal to the height of the arch, fix a pin  $e$ , and at the extremity a tracer  $f$ ; move the 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.

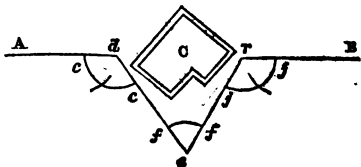
Let  $AB$  equal the length, and  $CD$  the breadth of the required parabola; divide  $CA$ ,  $CB$  into any num-



ber of equal parts; also divide the perpendiculars  $Aa$  and  $Bb$  into the same number of equal parts; then from  $a$  and  $b$  draw lines meeting each division on the line  $ACB$ ; 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.

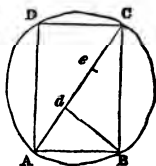
Suppose the distance between  $A$  and  $B$  is required, but the right line is intercepted by the object  $C$ . On the point  $d$ , with any con-



venient radius, describe the arc  $cc$ , make the arc twice the radius in length, through which draw the line  $dc$ , and on  $e$  describe another arc equal in length to once the radius, as  $eff$ ; draw the line  $efr$  equal to  $efd$ ; on  $r$  describe the arc  $jj$ , in length twice the radius; continue the line through  $rj$ , which will be a right line, and  $de$ , or  $er$ , equal the distance between  $d$  and  $r$ , by which the distance between  $A$  and  $B$  is obtained as required.

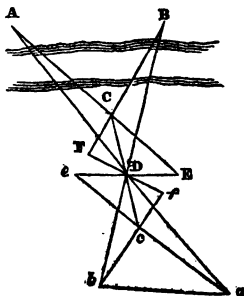
17. *A round piece of timber being given, out of which to cut a beam of strongest section.*

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.



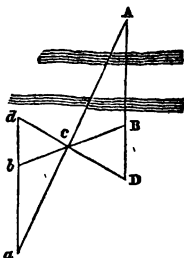
18. *To measure the distance between two objects, both being inaccessible.*

From any point  $C$  draw any line  $Cc$ , and bisect it in  $D$ ; take any point  $E$  in the prolongation of  $A C$ , and draw the line  $Ee$ , making  $De$  equal to  $DE$ ; in like manner take any point  $F$  in the prolongation of  $B C$ , and make  $Df$  equal to  $F D$ . Produce  $A D$  and  $ec$  till they meet in  $a$ , and also  $B D$  and  $fc$  till they meet in  $b$ ; then  $ab$  equal  $A B$ , or the distance between the objects as required.



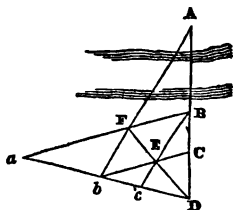
19. To ascertain the distance, geometrically, of any inaccessible object on an equal plane.

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  $cb$  equal to  $Bc$ ; 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.



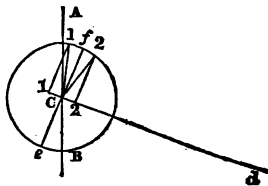
20. Otherwise.

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.



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.

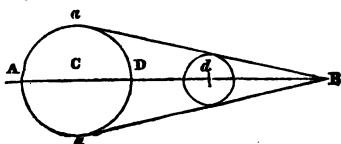
Draw the right line A B, as the situation of the crank at commencement of the stroke; draw also the line C d, as the proper given angle of eccentric rod with the crank; then from C as centre, describe a circle equal to the travel of the valve; draw the line  $e f$  at right angles to the line



C  $\alpha$ , 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.

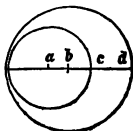
22. *The throw of an eccentric, and the travel of the valve in a steam-engine, also the length of one lever for communicating motion to the valve, being given, to determine the proper length for the other.*

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



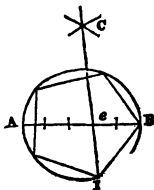
*Note.*— The throw of an eccentric is equal to the sum of twice the distance between the centres of formation and revolution, as  $a b$ , or to the degree of eccentricity it is made to describe, as  $c d$ . And

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.



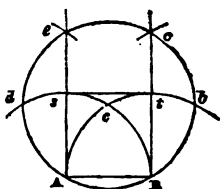
23. *To inscribe any regular polygon in a given circle*

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.



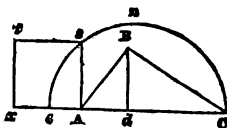
24. *To construct a square upon a given right line.*

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.



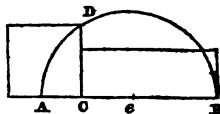
25. *To form a square equal in area to a given triangle.*

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.*

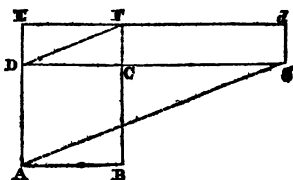
Let the line A B equal the length and breadth of the given rectangle; bisect the line in e, and describe the semicircle A D B; then from A with the breadth, or from B with the length, of the rectangle, cut the line A B at C, and erect the perpendicular C D, meeting the curve at D, and C D equal a side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

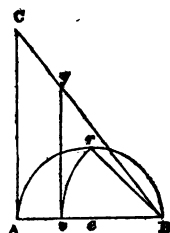
Let A B C D be the given square, and D E the given breadth of rectangle; continue the line B C to F, and

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.



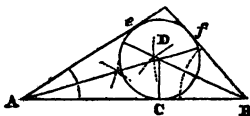
28. To bisect any given triangle.

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.



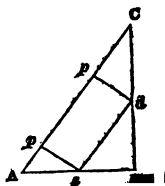
29. To describe a circle of greatest diameter in a given triangle.

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.



## 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.

$$\frac{3.00}{12} = .25, \text{ the decimal required.}$$

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

$$\frac{1.000}{8} = .125, \text{ the decimal required.}$$

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

$$\frac{7.000}{8} = .875, \text{ the decimal equivalent.}$$

**Ex. 4.** Required the fractional value of the decimal .40625 of an inch.

$$\begin{array}{r} .40625 \\ \text{Multiply by } \frac{1}{8} \quad \underline{\quad 8} \end{array}$$

$$\begin{array}{r} 3.25000 \\ \times \frac{2}{16} = \frac{1}{8} \quad \underline{\quad 2} \end{array}$$

$$\begin{array}{r} .50000 \\ \times \frac{2}{16} = \frac{1}{8} \quad \underline{\quad 2} \end{array}$$

$$\frac{1.00000}{\underline{\underline{\quad}}} \frac{3}{8} \text{ and } \frac{1}{32} \text{ of an inch, the value required.}$$

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

$$\begin{array}{r} .625 \\ \text{Multiply by 4 qrs.} \quad \underline{\quad 4} \end{array}$$

$$\begin{array}{r} 2.500 \\ \times 28 \text{ lbs.} \quad \underline{\quad 28} \end{array}$$

$$\frac{14.000}{\underline{\underline{\quad}}} = 2 \text{ quarters and 14 lbs., the value required.}$$

*Ex. 6.* Ascertain the fractional value of  $\cdot 875$  of an imperial gallon.

$$\begin{array}{r}
 \cdot 875 \\
 \text{Multiply by 4 quarts} \quad 4 \\
 \hline
 3\cdot 500 \\
 \times 2 \text{ pints} \quad 2 \\
 \hline
 1\cdot 000 = 3 \text{ quarts and 1 pint the} \\
 \hline \hline
 \text{value required.}
 \end{array}$$

*Ex. 7.* What is the fractional value of  $\cdot 525$  of a £ sterling?

$$\begin{array}{r}
 \cdot 525 \\
 \text{Multiply by 20 sh.} \quad 20 \\
 \hline
 10\cdot 500 \\
 \times 12 \text{ pence} \quad 12 \\
 \hline
 6\cdot 000 = 10 \text{ shillings and 6 pence,} \\
 \hline \hline
 \text{the value required.}
 \end{array}$$

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.

$$\begin{array}{r}
 16\cdot 625 \\
 11\cdot 4 \\
 20\cdot 7831 \\
 12\cdot 125 \\
 8\cdot 04 \\
 7\cdot 002 \\
 \hline
 75\cdot 9751 = \text{the sum required.} \\
 \hline \hline
 \end{array}$$

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

$$\begin{array}{r} 234\cdot98276 \\ 119\cdot80764 \\ \hline \end{array}$$

$$\hline$$

115·17512 = the remainder required.

**Ex. 3.** Multiply 62·10372 by 16·732.

$$\begin{array}{r} 62\cdot10372 \\ 16\cdot732 \\ \hline \end{array}$$

$$\hline$$

$$12420744$$

$$18631116$$

$$43472604$$

$$37262232$$

$$6210372$$

$$\hline$$

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.

$$\begin{array}{r} 3700 \\ \hline \end{array}$$

$$2375$$

$$1850$$

$$\hline$$

$$5250$$

$$4625$$

$$\hline$$

$$6250$$

$$5550$$

$$\hline$$

$$700$$

$$\hline$$

$$\hline$$

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.
X	multiplication, " multiplied by, as 8 X 3 = 24.
÷	division, " divided by, 24 ÷ 4 = 6 or $2\frac{4}{4}$ = 6.
:	proportion, " that 2 is to 3 as 4 is to 6, &c.
√	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 $4^3 = 64$ .
$3 + 5 \times 4 = 32$	" 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.
$\sqrt[2]{20 \times 12} = 2$	20 multiplied by 12, and divided by 30, the cube
<u>30</u>	root of the quotient = 2.

## DECIMAL APPROXIMATIONS.

FOR FACILITATING CALCULATIONS IN MENSURATION.

Lineal feet multiplied by	0.00019	=	miles.
“ yards	“ 0.00568	=	“
Square inches	“ 0.07	=	square feet.
“ yards	“ 0.002067	=	acres.
Circular inches	“ 0.0546	=	square feet.
Cylindrical inches	“ 0.004546	=	cubic feet.
“ feet	“ 0.2969	=	cubic yards.
Cubic inches	“ 0.0058	=	cubic feet.
“ feet	“ 0.3704	=	cubic yards.
“ “	“ 6.232	=	imperial gallons.
“ inches	“ 0.03607	=	“ “
Cylindrical feet	“ 4.895	=	“ “
“ inches	“ 0.02832	=	“ “
Cubic inches	“ .263	=	lbs. avs. of cast iron
“ “	“ .281	=	“ wrought do.
“ “	“ .283	=	“ steel.
“ “	“ .3225	=	“ copper.
“ “	“ .3637	=	“ brass. <i>sheet</i>
“ “	“ .26	=	“ zinc.
“ “	“ .4108	=	“ lead.
“ “	“ .2636	=	“ tin.
“ “	“ .4908	=	“ mercury.
Cylindrical inches	“ .2065	=	“ cast iron.
“ “	“ .2168	=	“ wrought iron.
“ “	“ .2223	=	“ steel.
“ “	“ .2533	=	“ copper.
“ “	“ .2385	=	“ brass.
“ “	“ .2042	=	“ zinc.
“ “	“ .3223	=	“ lead.
“ “	“ .207	=	“ tin.
“ “	“ .3854	=	“ mercury.
Avoirdupois lbs.	“ .009	=	cwts.
“ “	“ 0.045	=	tons.

## DECIMAL EQUIVALENTS TO FRACTIONAL PARTS OF LINEAL MEASURES.

One inch, the integer, or whole number.					
·96875	$\frac{7}{8} \& \frac{3}{32}$	·625	$\frac{5}{8}$	·26125	$\frac{5}{8} \& \frac{1}{32}$
·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	$\frac{7}{8} \& \frac{3}{32}$	·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.					
·9166	11 inches.	·4166	5 inches.	·0625	$\frac{1}{2}$ of inch.
·8333	10 "	·3333	4 "	·0598	"
·75	9 "	·25	3 "	·04166	"
·6666	8 "	·1666	2 "	·03125	"
·5833	7 "	·0833	1 "	·02063	"
·5	6 "	·07291	$\frac{1}{2}$ "	·01041	"
One yard, or 36 inches, the integer.					
·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  $\frac{3}{16} = \cdot1875$ , (see page 26); and  $8\cdot1875 \times 8\cdot1875 = 67\cdot03515625$  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. =  $\cdot5833$  and 6 in. =  $\cdot5$ , (see Table of Equivalents, p. 26); hence  $4\cdot5833 \times 3\cdot5 = 16\cdot04155$  square feet, the area.

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

$$13\cdot5 \times 9\cdot75 = 131\cdot625 \div 9 = 14\cdot625 \text{ square yards.}$$

**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.

v 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.*

16 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?

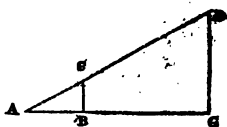
$25^2 + 16^2 = \sqrt{881} = 29.6816$  feet, or  $.6816 \times 12 = 8$  inches; consequently, 29 feet 8 inches nearly.

20 2. From the top of a wall 18 feet in height, a line was stretched across a canal for the purpose of ascertaining 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  $\overline{40 + 18} \times 22 = \sqrt{1276} = 35.72$ , or 35 feet 9 inches nearly, the width of the canal.

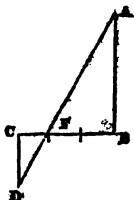
Triangles similar to each other are proportional to each other; hence their utility in ascertaining the heights and distances of inaccessible objects.

Thus, suppose the height of an inaccessible object  $D$  is required; I find by means of two staves, or otherwise, the height of the perpendicular  $BC$  and the length of the base line  $AB$ ; also the distance from  $A$  to the base of the object  $GD$ ;



then  $AB : BC :: AG : GD$ . And suppose  $AB = 6$  feet,  $BC = 2$  feet, and  $AG = 150$   
 $6 : 2 :: 150 : 50$  feet, the height of  $D$  from  $G$ .

Again, suppose the inaccessible distance  $AB$  be required; make the line  $BA$ ,  $BC$ , a right angle, and  $BC$  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  $CDF$ ; then the proportion will be as

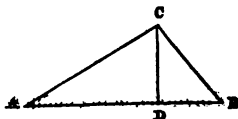


$CF : CD :: BF : BA$ . Let  $CF = 10$  yards,  $CD = 53$ , and  $BF = 30$ ,  $10 : 53 :: 30 : 159$  yards, the distance from  $B$ .

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  $11\frac{3}{4}$  inches in length, and the height  $DC$ ,  $3\frac{1}{2}$  inches; required the area.



$\frac{3}{2} = .09375$  and  $\frac{3}{4} = .375$ , (see page 26 :)

hence  $\frac{11.09375 \times 3.375}{2} = 18.72075$  square inches, the area.

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

$$\frac{53.25 \times 7.75}{2} = 206.34375 \text{ square feet, the area.}$$

*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.

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

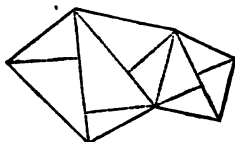
$$60 - 30 = 30 \text{ first difference,}$$

$$60 - 40 = 20 \text{ second difference,}$$

$$60 - 50 = 10 \text{ third difference,}$$

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

Triangles are employed to great advantage in determining the area of any rectilinear 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.



*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.

$$\cdot 867 \times 6.5 = 5.6355, \text{ or } 5 \text{ feet } 7\frac{1}{2} \text{ inches nearly.}$$

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

$$\cdot 852 \times 9 = 7.668, \text{ or } 7 \text{ feet } 8 \text{ inches.}$$

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?

$$1.08 \times 12 = 12.96, \text{ or } 12 \text{ feet } 11\frac{1}{2} \text{ inches.}$$

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

$$4\frac{1}{2}^2 \times 2.598 = 52.6095 \text{ square yards.}$$

## THE CIRCLE AND ITS SECTIONS.

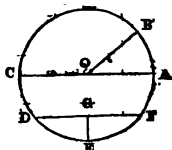
*Observations and Definitions.*

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  $OB$ .

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



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

6. The versed sine is a straight line joining the chord and circumference, as  $EG$ .

7. An arc is a 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  $7\frac{3}{8}$  inches, required its circumference.

$$7\cdot1875 \times 3\cdot1416 = 22\cdot58025 \text{ inches, the circumference.}$$

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

$$3\cdot1416 \times 30\cdot5 = 95\cdot8138 \text{ feet, the circumference.}$$

2. A straight line, or the circumference of a circle, being 274·89 inches, required the circle's diameter corresponding thereto.

$$274\cdot89 \times \cdot31831 = 87\cdot5 \text{ inches diameter.}$$

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

$$\cdot31831 \times 39 = 12\cdot41409 \text{ feet, and } \cdot41409 \times 12 = 4\cdot96908 \text{ inches, or } 12 \text{ feet } 7 \text{ inches, very nearly the diameter.}$$

3. The diameter of a circle is  $3\frac{1}{2}$  inches; what is its area in square inches?

$$3.75^2 = 14.0625 \times .7854 = 11.044, \text{ \&c., inches area.}$$

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

$$25.5^2 = 650.25 \times .7854 = 510.706, \text{ \&c., feet, the area.}$$

4. What must the diameter of a circle be, to contain an area equal to 706.86 square inches?

$$\sqrt{706.86} = 26.586 \times 1.12837 = 29.998 \text{ or } 30 \text{ inches, the diameter required.}$$

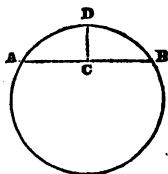
5. The diameter of a circle is  $14\frac{1}{2}$  inches; what must I make each side of a square, to be equal in area to the given circle?

$$14.25 \times .8862 = 12.62835 \text{ inches, length of side required.}$$

*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.



$$\overline{6.5^2 + 2^2} = 46.25 \div 2 = 23.125 \text{ feet, the diameter.}$$

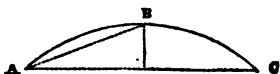
2. In a curve of a railway, I stretched a line 72 feet in length, and the distance from the line to the curve I found to be  $1\frac{1}{2}$  ft.; required the radius of the curve.

$$\overline{72^2 + 1.25^2} = 5185.5625, \text{ and } \frac{5185.5625}{1.25 \times 2} = 2074.225 \text{ ft., the radius.}$$

*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.



$4.25 \times 8 = 34$ , and  $34 - 8.333 = \frac{25.667}{3} = 8.555$  feet, the length of the arc.

*To find the area of the sector of a circle.*

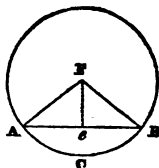
*Rule.* — Multiply the length of the arc by its radius, and half the product is the area.

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

$9.5 \times 7 = 65.5 \div 2 = 32.75$ , the area.

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

Thus, suppose the area of the segment  $A C B e$  is required, and that the length of the arc  $A C B$  equal  $9\frac{1}{2}$  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  $3\frac{1}{4}$  feet.



$\frac{9.75 \times 7}{2} = 34.125$  feet, the area of the sector.

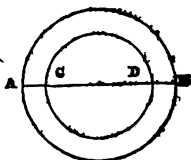
$\frac{8.333 \times 3.75}{2} = 15.624$  feet, area of the triangle.

And  $34.125 - 15.624 = 18.501$  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  $60 \times 4 \times .7854 = 188.496$  in., the area.

2. The exterior diameter of the fly-wheel of a steam engine is 20 feet, and the interior diameter 18½ feet; required the area of the surface or rim of the wheel.

$20 + 18.5 = 38.5$  and  $20 - 18.5 = 1.5$ , hence  $38.5 \times 1.5 \times .7854 = 45.35$ , &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?

$25 \times 16.5 = 412.5 \times .7854 = 323.9775$  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,  $7\frac{1}{2}$  inches broad, and  $3\frac{1}{2}$  inches in thickness.

$$23.5 \times 7.75 \times 3.625 = 660.203 \text{ cubic inches.}$$

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

$$8.5 \times 5.25 \times 4 = 178.5 \text{ cubic feet, and } 178.5 \times 6.232 \text{ (see Table of Decimal Approximations, p. 25)} = 1112.412 \text{ gallons.}$$

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

$$7.25 \times 4.5 \times 6.232 = 203.318, \text{ and } \frac{520.000}{203.318} = 2.557 \text{ feet, or 2 feet } 6\frac{3}{4} \text{ inches nearly.}$$

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?

$$20 \times 6 \times .263 \text{ (see Table of Decimal Approximations, Cast Iron, p. 25)} = 31.96, \text{ and } \frac{150}{31.96} = 4.69 \text{ in., or 4 and } \frac{11}{16} \text{ in., the thickness required.}$$

*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  $54\frac{1}{2}$  inches; required the convex surface in square feet.

$$54.75 \times 37.5 \times .007 \text{ (see Table of Approximations)} = 14.371 \text{ square feet.}$$

2. A cylindrical piece of timber is 9 inches diameter, and 3 feet 4 inches in length; required its solidity in cubic inches, and also in cubic feet.

$$3 \text{ feet } 4 \text{ inches} = 40 \text{ inches, and } 9^2 \times .7854 \times 40 = 2544.696 \text{ cubic inches; then } 2544.696 \times .00058 = 1.4759 \text{ cubic feet.}$$

. 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?

$$4.75^2 \times 16.5 \times 4.895 = 1822.162 \text{ gallons.}$$

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.

$$4.75^2 \times 35 \times .02909 = 22.973 \text{ cubic yards.}$$

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?

$$4.895 \times 10 = 48.95, \text{ and } \frac{12500}{48.95} = \sqrt{255.3} = 15.9687 \text{ feet, or } 15 \text{ feet } 11\frac{1}{2} \text{ inches.}$$

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?

$$7.5^2 \times .3223 = 18, \text{ and } \frac{168}{18} = 9.3 \text{ inches.}$$

*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.

$$22 \times 3.5 = 77^2 = 5929, \text{ and } 16^2 = 256, \text{ then } \sqrt{5929 + 256} = 78.64 \text{ inches.}$$

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.

$$15.7 \times 2.5 = 39.25^2 = 1540.5625, \text{ and } 25^2 = 625, \text{ then } \sqrt{1540 + 625} \doteq 46.5 \text{ feet, the length required.}$$

*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  $18\frac{1}{2}$  inches, and diameter at the base  $6\frac{1}{2}$  inches.

$$6.25 \times 3.1416 = 19.635 \text{ circumference of the base; and } \frac{19.635 \times 18.75}{2} = 184.078125 \text{ square inches.}$$

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.

$$\frac{4.75 \times 42 \times 6 \text{ sides}}{2} = 598.5 \text{ square feet.}$$

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?

$$\frac{15^2 \times .7854 \times 32.5}{3} = 1914.4125 \text{ cubic inches.}$$

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?

$$\frac{16.5 \times 16.5 \times 67}{3} = 6080.25 \text{ cubic feet.}$$

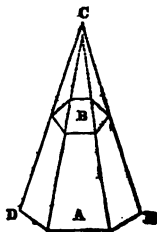
*To find the solidity or capacity of any frustum of a cone or pyramid.*

*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. 31) 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  $3\frac{1}{2}$  and  $2\frac{1}{2}$  feet; required the solid contents of the frustum in cubic feet.



$3.75 + 2.5 = 6.25$ , and  $6.25 \times 6.25 = 39.0625$ , then  $3.75 \times 2.5 = 9.375$ , and  $39.0625 - 9.375 = 29.6875 \times 2.598$  (tabular area, p 31)  $= 77.138 \times 2.5$  or  $\frac{1}{2}$  of the height  $= 192.845$  cubic feet.

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

$7 + 9.5 = 16.5$ , and  $7 \times 9.5 = 66.5$ , then  $16.5^2 - 66.5 = 205.75 \times .7854 = 161.876 \times 4$  or  $\frac{1}{2}$  of the height  $= 646.3$  cubic inches.

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



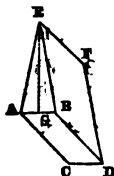
$5 + 4 = 9 = 9^2 = 81$ , and  $5 \times 4 = 20$ , hence  $81 - 20 = 61 \times .7854$ , and by 2 or  $\frac{1}{2}$  of the depth  $= 95.8188$  cubic feet, and  $\times 6.232 = 597.1427$  gallons.

*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.



$$\frac{18 + 7 \times 3.5 \times 15}{6} = 218.75 \text{ cubic inches.}$$

*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 10½ inches in diameter.

$$10.5^2 \times 3.1416 = 346.3614 \text{ square inches.}$$

$$10.5^3 \times .5236 = 606.132, \text{ \&c., cubic inches; and -}$$

$$606.132 \times .263 \text{ (see Table of Approximations, p. 25)} = 159.4 \text{ lbs.}$$

Surface  
Contents

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?

$$\begin{array}{l} \text{Weight of a cubic inch of water} = .03617 \text{ lbs.} \\ \text{" " " copper} = .3225 \text{ " } \end{array} \left. \vphantom{\begin{array}{l} \text{Weight of a cubic inch of water} \\ \text{" " " copper} \end{array}} \right\} \text{ see p. 63.}$$

$$\frac{8^3 \times .5236 \times .03617}{.3225} = 4.84828 \text{ cub. in. of water to be displaced.}$$

$$\text{And } \frac{4.84828}{.3225} = 15.0334 \text{ cubic inches of copper in the ball.}$$

Then  $8^2 \times 3.1416 = 201.0624$ , and  $\frac{15.0334}{201.0624} = .0747$  inches, the thickness of copper required.

$$.0747 \times 16 = \frac{1}{8} \text{ of an inch full, or 3 lbs. copper to a square foot.}$$

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

$$.5236 \times .4103 = .21483308, \text{ and } \frac{72}{.21483308} = \sqrt[3]{340} = 6.97 \text{ inches, diameter.}$$

# 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 31s. 6d. 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  $8\frac{1}{2}$  yards of cloth,  $1\frac{1}{2}$  yards in width, be a sufficient quantity, how much will be required of that which is only  $\frac{1}{2}$ ths in width, to effect the same purpose?

Set 1.5 on C to 8.75 on A; and against .875 upon C is 15 yards upon A.

### SQUARE AND CUBE ROOTS OF NUMBERS.

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

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

*To find the geometrical mean proportion between two numbers.*

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

Required the mean proportion between 20 and 45.

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

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

Required the cube of 4.

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

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

Required the cube root of 64.

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

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

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

MENSURATION OF SURFACE.

1. *Squares, Rectangles, &c.*

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

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

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

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

2. *Circles, Polygons, &c.*

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

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

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

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

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

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

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

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

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

## INSTRUMENTAL MENSURATION.

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 lbs.	16	23	276	293	352	305	528
Gold "	814	1175	141	149	178	155	262
Silver "	15	216	261	276	324	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	491	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	188	119	206
Water in lbs.	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	459
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	124
Freestone "	394	57	69	728	873	755	132

## MENSURATION OF SOLIDITY AND CAPACITY.

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

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

Set 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 lbs. upon C.

*By the common rule.*

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

Set 10 upon B to 283 (G. Pt.) upon A; and against  $5\frac{1}{2}$  upon D is 66.65 lbs. on C.

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

Set 25 upon B to 47 (G. Pt.) upon A; and against 4 on D is 83.16 lbs. on C.

6. What is the weight of a short-linked chain 30 yards in length, and  $\frac{1}{8}$ ths of an inch in diameter?

Set 30 upon B to 52 (G. Pt.) upon A; and against 6 on D is 129.5 lbs. on C.

## LAND SURVEYING.

If the dimensions taken are in chains, the gauge-point is 1 or 10; if in perches, 160; and if in yards, 4840.

*Rule.* — Set the length upon B to the gauge-point on A; and against the breadth upon A is the content in acres upon B.

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

Set 20.5 on B to 1 on A; and against 4.4 on A is 9 acres on B.

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

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

## POWER OF STEAM-ENGINES.

*Condensing Engines.* — *Rule.* Set 3.5 on C to 10 on D; then D is a line of diameters for cylinders, and C the corresponding number of horses' power; thus,

H. Pr. 3½ 4 5 6 8 10 12 16 20 25 30 40 50 on C.  
C.D. 10 in. 10½ 12 13½ 15½ 17 18½ 21½ 24 26½ 29½ 33½ 37½ on D.

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

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

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

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

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

## OF ENGINE BOILERS.

How many superficial feet are contained in a boiler 23 feet in length and  $5\frac{1}{2}$  in width?

Set 1 upon B to 23 upon A; and against  $5\cdot5$  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.

## 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.*

3½	4½	5	5¾	6½	7	8	8½	9½
2½	4¾	5¾	7	9¾	11½	15	19	21
1½	1¾	1¾	2	2½	2½	3	3½	4
5½	8	10½	14	18	22	27	32	37
1	1	2	3	4	5	6	7	8
5½	16¾	10	5½	3½	2	4½	7	13½
10	10¾	11½	12½	13	13¾	14½	15½	16
23	28	30½	36	39	45	48½	56	60
¾	1½	1 in.	1½	1½	1¾	1¾	1¾	1¾
43	49	56	63	71	79	87	96	106
0	11	13	14	16	18	20	22	24
10	11	13	14	16	18	20	22	24
18	8	18	14	14	11	8	13	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 pts., Malacca tin 1;	tenacity per sq. inch	64,000	lbs.
Chili copper 6 parts, Malacca tin 1;	"	60,000	"
Japan copper 5 parts, Banca tin 1;	"	57,000	"
Anglesea copper 6 parts, Cornish tin 1;	"	41,000	"
Common block-tin 4, lead 1, zinc 1;	"	13,000	"
Malacca tin 4, regulus of antimony 1;	"	12,000	"
Block tin 3, lead 1;	"	10,200	"
Block tin 8, zinc 1;	"	10,000	"
Lead 1, zinc 1;	"	4,500	"

#### RESISTANCE TO LATERAL PRESSURE, OR TRANSVERSE ACTION.

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

$$\frac{16 \times 8000}{90 \times 32 \times .75} = 15175 \div 8 = \sqrt[3]{1897} = 12.35 \text{ in., the depth.}$$

*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?

$$\frac{2240 \times 5.5}{2} = 6160 \text{ lbs. to carry at each end.}$$

And 18 feet—7 = 11, double each, or 14 and 22, then  
 $\frac{14 \times 22}{18} = 17 \text{ feet, or } 204 \text{ inches, effective length of beam.}$

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

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 =  $119 \times 4 \times .5 = 238$  the divisor;  
 then  $700 \div 238 = \sqrt[3]{2.94} \times 5 = 7.25$  inches, depth of the beam.

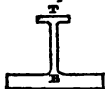
To find the absolute strength of a rectangular beam, when fixed at one end, and loaded at the other.

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

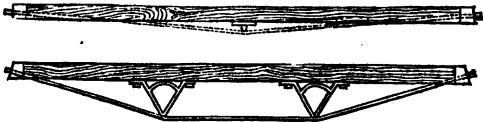
*Ex.* A beam of Riga fir, 12 inches by 4½, and projecting 6½ feet from the wall; what is the greatest weight it will support at the extremity of its length?

$$\begin{aligned} \text{Tabular value of S} &= 1100 \\ 12 \times 4.5 &= 54 \text{ sectional area,} \\ \text{Then, } \frac{1100 \times 12 \times 54}{78} &= 9138.4 \text{ lbs.} \end{aligned}$$

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. 52) 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 6½ 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 6½ 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.	
	Wt. in lbs.	Def. in in.	Wt. in lbs.	Def. in in.	Wt. in lbs.	Def. in in.	Wt. in lbs.	Def. in in.	Wt. in lbs.	Def. 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	2675	·16	2450	·217	2146	·284	1924	·36	1721	·443
5	3560	·144	3050	·196	2650	·256	2375	·32	2125	·4
6	5119	·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	·096	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	3027	·81	2720	1·00
9	5733	·32	4914	·44	4302	·57	3825	·72	3438	·89
10	7083	·28	6071	·39	5312	·51	4722	·64	4250	·8
11	8570	·26	7346	·36	6428	·47	5714	·59	5142	·73
12	10192	·24	8736	·33	7648	·43	6796	·54	6120	·67
13	11971	·22	10260	·31	8978	·39	7980	·49	7182	·61
14	13883	·21	11900	·28	10412	·36	9255	·46	8330	·57
15	15937	·19	13660	·26	11952	·34	10624	·43	9562	·53
16	18128	·18	15536	·24	13584	·32	12080	·40	10880	·5
17	20500	·17	17500	·23	15353	·3	13647	·38	12282	·47
18	22932	·16	19656	·21	17208	·28	15700	·36	13752	·44

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

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

*Rule.* — Multiply the sectional area in inches by the length in feet, and by 3.2, the product equal the weight in lbs.

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

$$11 \times 1.5 \times 16 \times 3.2 = 844.8 \text{ lbs.}$$

*Resistance of Bodies to Flexure by vertical Pressure.*

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

Columns of cast iron and of other bodies are also similarly circumstanced, this law having 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  $\frac{1}{4}$ th than in a solid column containing the same quantity of material.

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

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

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

**2.** If the pillar or column be a 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 lbs. without sensible flexure, its breadth being 3 inches, and its length 5 feet?

$$\begin{aligned} & \text{Tabular value of E} = 105, \\ \text{and } & \frac{2240 \times 5^2}{20 \times 105 \times 3} = \sqrt[3]{8.888} = 2.05 \text{ inches.} \end{aligned}$$

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

$$\begin{aligned} & \text{Tabular value of E} = 96, \\ \text{and } & \frac{6000 \times 9^2}{20 \times 96} = \sqrt[4]{253} = 4 \text{ inches nearly.} \end{aligned}$$

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

**STRENGTH OF MATERIALS.**

Diameter in inches.	Length or height in feet.											
	4	6	8	10	12	14	16	18	20	22	24	
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  
 =  $\overline{657}$  cwt.

*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

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*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.

$$\frac{1245 \times 35 \times 2.5}{55 \times 1} = \sqrt[4]{1981} = 6.67 \text{ inches in diameter.}$$

*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

## MECHANICS.

### PRELIMINARY REMARKS.

**MECHANICS**, regarded as a science, comprehends the sum of our knowledge relative to the sensible motions of bodies either actually existing or expressed by the opposition of forces tending to produce motion. The science is thus resolvable into a code of discovered laws, applying to the causes which occasion and modify the direction and the velocities of motion, and is therefore distinct from those branches of science in which, although presenting phenomena of motion in sensible portions of matter, we do not consider the circumstances and laws of these motions, but only the effects produced.

When motion itself is considered, the reasoning belongs to mechanics, and it is probable that as our knowledge of the laws which govern the phenomena that are

evolved under the hand of the experimental philosopher becomes more extended, a wider meaning will be given to the science of motion. The definition which is here given of mechanics is not coeval with the name. The science, like most other sciences, has gradually expanded to its present extent. It was originally the science of machines—these being the first subjects of its speculation; and, as every material combination employed for producing or preventing motion may be regarded as a machine, and may be resolved into the same elementary principles as those employed in machines,—the mechanical powers,—the name “mechanics” became to be applied to motion, the tendency to motion of any bodies whatever. Mechanics still continues to be defined by some the *science of force*, and there does not appear to be any valid objection to the definition. Force is the cause of motion, and its laws are identical with the laws of motion: and, consequently, the science of force coincides, in all its parts, with the science of motion, which is mechanics.

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## ELEMENTS OF MACHINERY.

### THE LEVER.

To produce mechanical effects, it is rarely convenient to apply directly our available force,—meaning by mechanical effect moving a body of a certain weight through a certain space,—the assistance of machinery is required. In fact, the essential idea of machinery is, that it renders force available for effecting certain practical ends. Machines prepare, as it were, the raw material of force supplied to us from natural sources. It is transmitted and modified by certain combinations of the elements of machinery, and is given off, at last, in a condition suitable for producing the

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desired mechanical effect. We do not create force; the end of machinery is just to transmit it, and diffuse or concentrate it in one or more points of action. The various diffused or concentrated forces, then, being added together, will just amount to the original available force.

All machinery, when analyzed, will be found to consist of a combination of six simple machines, or elements, commonly called *mechanical powers*. This term is not correctly applied to these elements. They are not powers, or, in other words, sources of power or force; they simply transmit and diffuse or concentrate forces. These six elements are, the *lever*, the *pulley*, the *wheel and axle*, the *inclined plane*, the *wedge*, and the *screw*.

To understand, therefore, the nature of any machine, a correct idea of these elements is requisite.

A lever is an inflexible rod, by the application of which one force may balance or overcome another. These forces are termed, respectively, the *power* and the *resistance* or *weight*, not from any difference in the action of the forces, but with reference merely to the intention with which the machine is used; and indeed the same terms are used about all the other mechanical elements. In applying the rod to operate upon any resistance, it must rest upon a centre prop, or fulcrum, somewhere along its length, upon which it turns in the performance of its work. Thus, there are three points in every lever, to be regarded in examining its action, namely, the two points of application of the power and the weight, and the point resting on the fulcrum. There is a certain relation to be observed between the magnitudes of the opposing force, and their distances from the fulcrum, namely, that, in every case, the power, multiplied by its distance from the fulcrum, is equal to the weight, multiplied by its distance from the same point. From this, simple rules may be deduced for calculation.

To know the power to be applied, at a certain distance from the fulcrum, to overcome a resistance acting also at a certain distance, multiply the resistance by its

distance from the fulcrum, which gives its moment, and divide the product by the distance given. Quotient will be the power, it being observed that the distance and the force be each expressed in the same unit of measure. For example, a weight, 1120 lbs., at 3 inches from the fulcrum, is to be balanced by a force at the distance of 10 feet. Now 10 feet are equal to 120 inches; and the moment of 1120 lbs. is  $1120 \times 3 = 3360$ . Divide this by 120, we have 28 lbs. for the power required.

Again; to know the distance at which a given force ought to be applied to balance a given weight at a certain distance, we must, in like manner, multiply the weight by its distance, as before, and divide by the given power. 1120 lbs., for example, at 3 inches distance, are to be balanced by a force of 28 lbs. To find the distance of this weight, 1120 lbs. multiplied by 3, give 3360, which, divided by 28, give 120 inches, or 10 feet.

#### THE WHEEL AND AXLE, 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.

*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 handle and the number of revolutions of the pinion to one 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 handle 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 taken into account.

$$\frac{30 \times 8}{11} = 21.9 \text{ to 1 of exertive force, and } 21.9 \times 36 = 785.5 \text{ lbs.}$$

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*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 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?

$$16 \times 2 = 32 \text{ inches diameter described by the handle.}$$

$$\text{And } \frac{32}{40} \times 11 = 8.8 \text{ inches, the barrel's diameter.}$$

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### 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, 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 lbs. by a four and five sheived block and tackle, the four being the movable or rising block.

Necessarily, there are nine cords leading to and from the rising block ; —

Consequently,  $\frac{3000}{9} = 333$  lbs., the power required.

*Ex. 2.* I require to raise a weight 4256 lbs.; the amount of my power to effect this object being 500 lbs. What kind of block and tackle must I, of necessity, employ ?

$\frac{4256}{500} = 8.51$  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 amount, so may the pulley and tackle be similarly augmented by purchase upon purchase. Two of the most useful are known by the term *runner* and *tackle*, and the second by that of *Spanish burton*.

*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	
10	.01	.005	.00333	.0025	.002	.00167	.00143	.00125	.00111	
20	.00909	.00476	.00322	.00244	.00196	.00164	.00141	.00123	.0011	
30	.00833	.00454	.00312	.00238	.00192	.00161	.00139	.00122	.00109	
40	.00769	.00435	.00303	.00232	.00189	.00159	.00137	.0012	.00107	
50	.00714	.00417	.00294	.00227	.00185	.00156	.00135	.00119	.00106	
60	.00667	.004	.00286	.00222	.00182	.00154	.00133	.00118	.00105	
70	.00625	.00385	.00278	.00217	.00178	.00151	.00131	.00116	.00104	
80	.00588	.0037	.0027	.00213	.00175	.00149	.0013	.00115	.00103	
90	.00555	.00357	.00263	.00208	.00172	.00147	.00128	.00114	.00102	
90	.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  $\frac{150}{00711} = 21097$  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  $\frac{150}{00123} = 121915$  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.

$$\frac{230 \times 75 \times 163}{12 \times 8} = \frac{2811750}{96} = 29288 \text{ lbs., or } 13.25 \text{ tons.}$$

## THE INCLINED PLANE.

The inclined plane is the representative of the second class of mechanical elements. Its fundamental law of action is that of the composition and resolution of forces. The manner in which the advantage is immediately derived from it is, therefore, distinct from that of the first class; there is necessarily a fulcrum, a point round which all the motion takes place, and through which the power acts on the resistance; whereas, in this class, there is no apparent centre of action. 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.

$$\frac{350}{12} = 29.16 \text{ lbs.}, \text{ or } \frac{350 \times 3}{36} = 29.16 \text{ lbs. power, as before}$$

## 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, its inclined sides each 10 inches, re-

quired the power necessary to act upon the wedge so as to separate two substances whose resisting force is equal to 150 lbs.

$$\frac{150 \times 1.5}{10} = 22.5 \text{ lbs.}$$

*Note.* — When only one of the bodies is movable, the whole breadth of the wedge is taken for the multiplier.

### THE SCREW.

The screw is another modification of the inclined plane, and it may be said to remove the same kind of practical inconveniences incidental to the use of the latter, that the pulley does in reference to the simple lever. The lever is very limited in the extent of its action; so is the inclined plane. But the pulley multiplies the extent of the action of the lever, by presenting, in effect, a series of levers acting in regular succession; and just such a purpose is effected by the screw. It multiplies the extent of the action of the inclined plane, by presenting, in effect, a continued series of planes.

The screw, in principle, is that of an inclined plane wound round 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 the two consecutive threads,—the pitch being the height or angle of inclination and the circumference 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.* Required the effective power obtained by a screw of  $\frac{1}{8}$  inch pitch, and moved by a force equal to 50 lbs. at the extremity of a lever 30 inches in length.

$$\frac{30 \times 2 \times 3.1416 \times 50}{875} = 10760 \text{ lbs.}$$

**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.

$$\frac{7000 \times 1.25}{25 \times 2 \times 3.1416} = 55.73 \text{ lbs. power.}$$

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 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  $\frac{1}{8}$  of an inch.

$$\frac{14 \times 24 \times 100 \times 6.2832}{6.25 \times 2 \times 8} = 21111.55 \text{ lbs., the power sustained.}$$

**Note.** — It is estimated that about one third more power must be added, to overcome the friction of the screw when loaded, than is necessary to constitute a balance between power and weight.

## OF CONTINUOUS CIRCULAR MOTION.

In mechanics, circular motion is transmitted by means of wheels, drums, or pulleys; and accordingly as the driving and driven are of equal or unequal diameters, so are equal or unequal velocities produced. Hence the principle on which the following rules are founded.

1. *When Time is not taken into Account.*

**Rule.** — Divide the greater diameter, or number of teeth, by the lesser diameter or number of teeth; and the quotient is the number of revolutions the lesser will make, for one of the greater.

**Ex.** How many revolutions will a pinion of 20 teeth make, for 1 of a wheel with 125?

$$125 \div 20 = 6.25 \text{ or } 6\frac{1}{4} \text{ revolutions.}$$

*To find the number of revolutions of the last, to one 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.

$$\frac{10 \times 15 \times 18}{15 \times 25 \times 32} = 225 \text{ of a revolution the wheel will make to one of the pinion.}$$

**Ex. 2.** A wheel of 42 teeth giving motion to one of 12, on which shaft is a pulley of 21 inches diameter

driving one of 6; required the number of revolutions of the last pulley to one of the first wheel.

$$\frac{42 \times 21}{12 \times 6} = 12.25 \text{ or } 12\frac{1}{4} \text{ revolutions.}$$

## 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  $+ 1$ ; 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. 1.* 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.

$80 \div 25 = 3.2$ , ratio of velocity, and  $\frac{50}{3.2 + 1} = 11.9$ , the radius of the smaller wheel; then  $50 - 11.9 = 38.1$ , radius of larger; their diameters are  $11.9 \times 2 = 23.8$  and  $38.1 \times 2 = 76.2$  inches.

To obtain or diminish an accumulated velocity by means of wheels, pinions, or wheels, pinions, and pulleys, it is necessary that a proportional ratio of velocity should exist, and which is 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  $\frac{25 \times 36}{81} = 11.1$  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; coarse 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?

$5 \div 2 = 2.5$ , the ratio they must bear to each other.

Then suppose a pinion of 40 teeth be fixed upon for the spindle, —

$40 \times 2.5 = 100$  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 two 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.

$$25 \div 2 = 12.5, \text{ and } \frac{60 \times 12.5 \times 20}{100} = 150 \text{ teeth.}$$

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.

$$\frac{60 \times 12.5}{150 \times 100} = 20 \text{ teeth, or } \frac{60 \times 12.5 \times 20}{150} = 100 \text{ teeth.}$$

*Table of Change Wheels for Screw-cutting ; the leading Screw being of  $\frac{1}{2}$  inch pitch, or containing 2 threads in an inch.*

Number of threads in inch of screw.	Number 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	8 $\frac{1}{2}$	40	55	20	60	19	50	95	20	100
1 $\frac{1}{4}$	80	50	8 $\frac{3}{4}$	90	85	20	90	19 $\frac{1}{2}$	80	120	20	130
1 $\frac{1}{2}$	80	60	8 $\frac{1}{2}$	60	70	20	75	20	60	100	20	120
1 $\frac{3}{4}$	80	70	9 $\frac{1}{4}$	90	90	20	95	20 $\frac{1}{4}$	40	90	20	90
2	80	90	3 $\frac{1}{2}$	40	60	20	65	21	80	120	20	140
2 $\frac{1}{4}$	80	90	10	60	75	20	80	22	60	110	20	120
2 $\frac{1}{2}$	80	100	10 $\frac{1}{2}$	50	70	20	75	22 $\frac{1}{2}$	80	120	20	150
2 $\frac{3}{4}$	80	110	11	60	55	20	120	22 $\frac{3}{4}$	80	130	20	140
3	80	120	12	90	90	20	120	23 $\frac{1}{4}$	40	95	20	100
3 $\frac{1}{4}$	80	130	12 $\frac{1}{4}$	60	85	20	90	24	65	120	20	130
3 $\frac{1}{2}$	80	140	13	90	90	20	130	25	60	100	20	150
3 $\frac{3}{4}$	80	150	13 $\frac{1}{2}$	60	90	20	90	25 $\frac{1}{2}$	30	85	20	90
4	40	80	13 $\frac{3}{4}$	80	100	20	110	26	70	130	20	140
4 $\frac{1}{4}$	40	85	14	90	90	20	140	27	40	90	20	120
4 $\frac{1}{2}$	40	90	14 $\frac{1}{4}$	60	90	20	95	27 $\frac{1}{2}$	40	100	20	110
4 $\frac{3}{4}$	40	95	15	90	90	20	150	28	75	140	20	150
5	40	100	16	60	80	20	120	28 $\frac{1}{2}$	30	90	20	95
5 $\frac{1}{4}$	40	110	16 $\frac{1}{4}$	80	100	20	130	30	70	140	20	150
6	40	120	16 $\frac{1}{2}$	80	110	20	120	32	30	80	20	120
6 $\frac{1}{2}$	40	130	17	45	85	20	90	33	40	110	20	120
7	40	140	17 $\frac{1}{2}$	80	100	20	140	34	30	85	20	120
7 $\frac{1}{2}$	40	150	18	40	60	20	120	35	60	140	20	150
8	30	120	18 $\frac{1}{2}$	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 =  $\cdot 314$  inch.

*Ex. 2.* What must be the diameter of a wheel for a 9 pitch of 126 teeth?

$$\frac{126}{9} = 14 \text{ inches diameter, circular pitch } \cdot 349 \text{ inch.}$$

*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 feet per second.	4 feet per second.	6 feet per second.	8 feet 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	3·98
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

## PRACTICAL PROPERTIES OF WATER

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 nearly incompressible, 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.

*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 cistern 18 feet in length, 13 in width and  $9\frac{1}{2}$  in depth. *of water*

The terms of measurement or unity are in feet, 1 cubic foot of water = 62.5 lbs.; hence  $18 \times 9 \times 2 + 13 \times 9 \times 2 = 558 \times 4.5 \times 62.5 = 156937.5$  lbs. Weight of water on bottom =  $18 \times 13 \times 9 \times 62.5 = 131625$  lbs.

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

$$3 \times 3 \times 30 \times 62.5 = 16875 \text{ lbs. pressure.}$$

The weight of water or other fluid is as the quantity, but the pressure exerted is as the vertical height. Hence, as fluids press equally in every direction, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid, as the area of the vessel is to the sectional area of the column.

*Ex.* Let a cubical vessel, whose sides are each 4 square feet, have a tube inserted 1 inch in diameter, and 6 feet in height, and let both vessel and tube be filled with water; required the whole weight of the water therein contained, and also the whole pressure exerted intending to burst the vessel.

Cubic contents of the vessel = 8 feet, and each foot = 62.5 lbs.; then  $62.5 \times 8 = 500$  area of pipe's section = .7854 inches, and height 72 inches, also a cubic inch of water = .03617 lbs.; hence,  $.7854 \times 72 \times .03617 = 2$  lbs. + 500 = 502 lbs., total weight of the water.

Again; the whole height of the column = 96 inches; then  $.7854 \times 96 \times .03617 = 2.33$  lbs., pressure of column on an equal area.  $144$  square inches = 1 square foot, and  $\frac{144 \times 4 \times 6 \text{ sides}}{.7854}$   
 = 4400.4 times the area of the pipe's diameter in the whole surface; therefore,  $4400.4 \times 2.33 = 10253$  lbs., or total amount of pressure exerted.

*To find the velocity of water issuing from 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.

$$\sqrt{11} = 3.3166 \times 8.1 = 26.864 \text{ feet, velocity per second.}$$

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  $\frac{2}{3}$  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 coefficient 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  $\frac{2}{3}$ ds 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.

$$\begin{array}{l} \text{Square root of } .75 = .866. \\ \text{Then } \frac{6.5 \times .75 \times .866 \times 5.1 \times 2}{3} = 14.3839 \text{ cubic feet.} \end{array}$$

*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  $2 \times 5.1 = 10.2$  feet, velocity of the water per second. And  $6.5 \times .75 \times 2 \times 5.1 = 49.725$  cubic feet discharged in the same time.

The combined properties of gravity and fluidity which water possesses, renders 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 satis-

factorily decided, that, because of the non-elastic property of water, its greatest 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 this country, 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 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  $52\frac{1}{4}$  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 whe—

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;  $\frac{1}{9}$  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  $\cdot 001325$ .

*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.  $25 \times 1\cdot08 = 27$  feet, the wheel's diameter.

2d.  $\sqrt{25 \times 2} = 10$  feet, velocity of the wheel  
in feet per second.

Also:  $27 \times 2\cdot1 = 56\cdot7$ , say 57 buckets.

3d.  $27 \div 9 = 3$  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 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.

1. That turbines are equally adapted to great as to small waterfalls.

2. That they are capable of transmitting a useful effect to from 70 to 78 per cent. of the absolute power.

3. That their velocities may vary considerably from the maximum effect, without differing sensibly from it.

4. That they will work nearly as effectually when drowned to the depth of 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 receive variable quantities of water, without altering the ratio of the power to the effect.

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## STEAM POWER.

THERE is no application of science to the arts of more importance, and more extensive in its effects, than that of the employment of steam for driving all kinds of machinery. It is not my intention to enter into the details of the power of steam or the steam-engine, but to give some practical rules, the utility of which have been tested.

Steam is of great utility as a productive source of motive power; in this respect, its properties are, elastic force, expansive force, and reduction by condensation. *Elastic* 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°.

$$\frac{312 + 100}{177} = 2.32776 = 159 \text{ inches of mercury.}$$

*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  $\frac{1}{2}$ ; required the ratio of gain by uniform and expansive force.

$6 \div 2 = 3$ ; hyperbolic logarithm of 3 =  $1.0986 + 1 = 2.0986$ , ratio of effect; that is, supposing the whole effect of the steam to be 3, the effect by the steam being cut off at  $\frac{1}{2} = 2.0986$ .

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.

$$18 \div 4.5 = 4, \text{ and } 48 \div 4 = 12.$$

$$\text{Logarithm of } 4 + 1 = 2.38629.$$

$$\text{Then } 2.38629 \times 12 = 28.635 \text{ lbs. per square inch.}$$

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 lbs. 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 lbs.

$$\frac{15 + 30}{15} = 3 \text{ times its original bulk.}$$

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  $98^{\circ}$ ; and in sugar-refining, where such means are employed, the sirup is boiled at  $150^{\circ}$ .

*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  $212^{\circ}$  Fahrenheit. If, at this point of temperature, the water be not enclosed, but exposed to atmospheric pressure, ebullition will take place, and steam or vapor 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.	
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	9.93	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 vapor 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 boilers, 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.

Steam, independent of the heat indicated by an immersed thermometer, also contains heat that cannot be measured by any instrument at present known, and, in consequence of which, is termed latent or concealed heat; the only positive proof we have of its existence being that of incontestable results, or effects produced on various bodies. Thus, if one part, by weight of steam at  $212^{\circ}$ , be mixed with nine parts of water at  $62^{\circ}$ , the result is water at  $178.6^{\circ}$ ; therefore, each of the 9 parts of water has received from the steam  $116.6^{\circ}$  of heat, and consequently, the steam has diffused, or given out,  $116.6 \times 9 = 1049.4 - 33.4 = 1016^{\circ}$  of heat, which it must have contained.

Again; it is ascertained, by experiment, that if one gallon of water be transformed into steam at  $212^{\circ}$ , and that allowed to mix with water at  $52^{\circ}$ , the whole will be raised to the boiling point, or  $212^{\circ}$ . From these and other experiments, it is ascertained that the latent heat in steam varies from  $940^{\circ}$  to  $1044^{\circ}$ , the ratio of accumulation advancing from  $212^{\circ}$ , as the steam becomes more dense and of greater elastic force. Hence, the severity of a scald by steam to that of boiling water.

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.		213·2° F.
3·03.		
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 . . .		
Common water	} boiling point, 216° F.	} elastic force, 32·5 in.
Sea water . . .		
Common water	} boiling point, 220° F.	} elastic force, 35·1 in.
Sea water . . .		

Hence the propriety of procuring, for steam, water in its purest state.

*Effects produced by Air in its natural and also in a rarefied State.*

The weight or pressure of the atmosphere is equal to the weight of a column of water 34 feet in height, or to a column of mercury 30 inches in height, or to 14·7 lbs. average per square inch, at a mean temperature. But air, like all other gases, is rendered lighter by the application of heat; for then the particles of the mass are repelled from each other, or rarefied, and occupy a greater space. Rarefied air, being specifically lightest, mounts above that of common density; hence change of temperature, and the principal cause of winds.

*Table of the Expansion of Atmospheric Air by Heat.*

Degrees of Fahrenheit.	Bulk.	Degrees of Fahrenheit.	Bulk.	Degrees of Fahrenheit.	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 vapor arise through it, then, according to the vapor'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 lin. ft.	Diameter of pump in inches.	Number of gallons per lineal ft.	Number of cubic feet per lin. ft.
2	·136	·0218	8	2·176	·3490
2½	·172	·0276	8½	2·314	·3712
2¾	·212	·0340	8¾	2·456	·3840
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	12¼	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

See p. 151.

*Examples illustrative of the Utility of the Table.*

1. Required the quantity of water lifted by each stroke of the bucket of a 9½-inch pump, the length of the stroke being 2¼ feet.

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

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?

$$\frac{44}{1.224 \times 18} = 2 \text{ feet, the length of stroke.}$$

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?

$$\frac{25}{2.5 \times 16} = .625, \text{ or } 10\frac{1}{4} \text{ inches, nearly.}$$

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 vapor, 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  $36.67^2 \times .002288 \times 20 = 61.5 \text{ lbs.}$ , 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	
3	4.40	.044	Just perceptible.
4	5.87	.079	
5	7.33	.123	Gentle, pleasant wind.
10	14.67	.492	
15	22.00	1.107	Pleasant, brisk gale.
20	29.34	1.968	
25	36.67	3.075	Very brisk.
30	44.01	4.429	
35	51.34	6.027	High winds.
40	58.68	7.873	
45	66.01	9.963	Very high.
50	73.35	12.300	
60	88.02	17.715	A storm or tempest.
80	117.36	31.490	A great storm.
			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 seven-eighths 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	
<i>By G. Forrester, Liverpool,</i>	24°	21	18	14	9	3	

## FRICITION.

FRICITION 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 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. The friction accompanying the motion of two surfaces, between which no unguent is interposed, bears the same proportion to the force by which those surfaces are pressed together, whatever may be the amount of that force.

2. This friction is independent of the extent of the surfaces of contact.

3. Where unguents are interposed, a distinction is to be made between the case in which the surfaces are simply unctuous and in intimate contact with one another, and the case in which the surfaces are wholly separated from one another by an interposed stratum of the unguent. If the pressure upon a surface of contact of given dimensions be increased beyond a certain limit, the latter of these cases passes into the first; the stratum of unguent being pressed out, and the unctuous surfaces, which it separated from one

another, being brought into intimate contact. As long as either of these two states remain, the laws of its friction are not affected by the presence of the unguent; but, in the transition from the one state to the other, an exception is made to the independence of the friction upon the extent of the surface of contact; for, supposing the extent of two surfaces of contact, between which a stratum of unguent is interposed, and which sustain a given pressure, to be continually diminished, it is evident, that the portions of this pressure which take effect upon each element of the surfaces of contact will be continually increased, and that they may thus be so increased as to press out the interposed stratum of unguent, and cause the state of the surfaces to pass into that which is designated as unctuous, thereby changing the coefficient of friction. That law of friction, then, which is known as the law of :: the independence of the surface, is to be received, in the case where a stratum of unguents is interposed, only within certain limits.

It will be understood, from what has been said, that there are three states, in respect to friction, into which the surfaces of bodies in contact may be made successively to pass: one, a state in which no unguent is present; the second, a state in which the surfaces are unctuous, but intimately in contact; the third, a state in which the surfaces are separated by an entire stratum of the interposed unguent.

Throughout each of these states, the coefficient of friction is the same; but it is essentially different in the different states.

4. It is a law common to the friction of all the states of contact of two surfaces, that their friction, when in motion, is altogether independent of the velocity of the motion. M. Morin has verified this law, as well in various states of contact without interposed fluids, as in the cases where water, oils, grease, glutinous liquids, sirups, pitch, were interposed in a continuous stratum.

The variety of the circumstances under which these laws obtain in respect to the friction of motion, and the accuracy with which the phenomena of motion accord with them, may be judged of from one example, taken from the first set of experiments of M. Morin upon the friction of surfaces of oak, whose fibres were parallel to the direction of their motion upon one another. He caused the surfaces of contact to vary, their dimensions in the ratio of 1 to 84, — from less than 5 square inches to nearly 3 feet square; the forces which pressed them together he varied from 88 lbs. to 2205 lbs., and their velocities from the slowest possible to 9·8 feet per second, — causing them to be at one period accelerated motions, at another uniform, at a third retarded; yet, through all this wide range of variation, he in no instance found the coefficient of friction to deviate from the same fraction of 0·478 by more than  $\frac{1}{4}$  of the amount of the fraction.

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## RULES, TABLES, ETC., 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 wagon 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 91;) 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 4½ 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.

$$\frac{375 \times 4.5 \times 224}{1282} = 295 \text{ square feet, nearly; the fire-grate be-}$$

ing 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:—

$$295 \times .12 = 35.4 \text{ square feet of furnace bar.}$$

*Note.*—By *effective heating surface* is meant horizontal surfaces over fire, flame, or heated air; vertical or side surfaces requiring about 1½ feet to equal in effect 1 of horizontal sur-

**2.** To determine the proper dimensions for a wagon-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 wagon form, that may present an effective heating surface of 295 square feet.

$$\begin{aligned} \text{Bottom surface} &= 295 \div 2, \text{ or } 147.5 \text{ square feet.} \\ \text{Length} &. . . = \sqrt{147.5 \times 2}, \text{ or } 24.26 \text{ feet.} \\ \text{Width} &. . . = 24.26 \div 4, \text{ or } 6.06 \text{ feet.} \\ \text{Height} &. . . = 24.26 \div 3, \text{ or } 8.08 \text{ feet.} \end{aligned}$$

*Note.*—The amount of side or vertical surface equal twice the length of the boiler, added to the width, and multiplied by .75 to obtain that of effective surface; hence,

$$\frac{147.5 \times 1.75}{24.26 \times 2 + 6.06} = 4.7 \text{ feet, depth of side flue.}$$

**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?

$$\sqrt{86 \times 1.34} = 10.74 \times 2 = 21.48 \text{ feet circumference, or } \frac{21.48}{\pi} \text{ feet } 10 \text{ inches diameter, and } 21.48 \text{ feet in length.}$$

*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 two-thirds the whole height of the boiler

*Specified Particulars relative to the Boiler and Engine.*

Diameter of cylinders, . . . . .	14 inches.
Length of stroke, . . . . .	18 "
Lap of the valve, . . . . .	1 inch.
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., . . . . .	1½ 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

*Table of Dimensions for Steam-Engine Cylinders by celebrated Makers.*

Stationary Condensing Engines, by Boulton & Watt.			Marine Engines, by Maudslay, Napier, &c.			High-Pressure, or Non-Condensing Engines, by various makers.				
Nominal horse power.	Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horse power.	Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horse power.	Diameters of cylinders, the force of the steam being, per square inch,			
							25 lbs.	30 lbs.	40 lbs.	60 lbs.
6	14 $\frac{1}{2}$	3	10	20	2	1	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3	2 $\frac{1}{2}$
8	16 $\frac{1}{2}$	3	15	24	2 $\frac{1}{2}$	2	5 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	3 $\frac{1}{2}$
10	18	3 $\frac{1}{2}$	20	27	2 $\frac{3}{4}$	3	6 $\frac{1}{2}$	6	5	4 $\frac{1}{2}$
12	19 $\frac{1}{2}$	4	25	29 $\frac{1}{2}$	2 $\frac{3}{4}$	4	7 $\frac{1}{2}$	6 $\frac{1}{2}$	6	5
14	21	4 $\frac{1}{2}$	30	32	3	5	8 $\frac{1}{2}$	7 $\frac{1}{2}$	6 $\frac{1}{2}$	5 $\frac{1}{2}$
16	22 $\frac{1}{2}$	4 $\frac{1}{2}$	40	36	3 $\frac{1}{2}$	6	9	8 $\frac{1}{2}$	7 $\frac{1}{2}$	6 $\frac{1}{2}$
18	23 $\frac{1}{2}$	5	50	40	4	7	9 $\frac{1}{2}$	9	7 $\frac{1}{2}$	6 $\frac{1}{2}$
20	24 $\frac{1}{2}$	5	60	43	4	8	10 $\frac{1}{2}$	9 $\frac{1}{2}$	8 $\frac{1}{2}$	7 $\frac{1}{2}$
22	26	5	70	46 $\frac{1}{2}$	4 $\frac{1}{2}$	9	11	10 $\frac{1}{2}$	8 $\frac{1}{2}$	7 $\frac{1}{2}$
24	27	5 $\frac{1}{2}$	80	47 $\frac{1}{2}$	4 $\frac{1}{2}$	10	11 $\frac{1}{2}$	11	9 $\frac{1}{2}$	8 $\frac{1}{2}$
25	27 $\frac{1}{2}$	5 $\frac{1}{2}$	90	50	4 $\frac{1}{2}$	11	12 $\frac{1}{2}$	11 $\frac{1}{2}$	9 $\frac{1}{2}$	8 $\frac{1}{2}$
26	28	5 $\frac{1}{2}$	100	53	5	12	13	12	10 $\frac{1}{2}$	9 $\frac{1}{2}$
28	29	6	110	55 $\frac{1}{2}$	5 $\frac{1}{2}$	14	14	12 $\frac{1}{2}$	11 $\frac{1}{2}$	10
30	30	6	120	57	5 $\frac{1}{2}$	16	15	13 $\frac{1}{2}$	12	10 $\frac{1}{2}$
35	32 $\frac{1}{2}$	6 $\frac{1}{2}$	130	60 $\frac{1}{2}$	5 $\frac{1}{2}$	18	15 $\frac{1}{2}$	14	12 $\frac{1}{2}$	11 $\frac{1}{2}$
40	34 $\frac{1}{2}$	6 $\frac{1}{2}$	150	65	6	20	16 $\frac{1}{2}$	15 $\frac{1}{2}$	13 $\frac{1}{2}$	11 $\frac{1}{2}$
50	38 $\frac{1}{2}$	7	200	74 $\frac{1}{2}$	6	25	18 $\frac{1}{2}$	17 $\frac{1}{2}$	15 $\frac{1}{2}$	13 $\frac{1}{2}$
60	42 $\frac{1}{2}$	7	250	84	6	30	20 $\frac{1}{2}$	19 $\frac{1}{2}$	16 $\frac{1}{2}$	14 $\frac{1}{2}$

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 2 $\frac{1}{2}$  miles per hour, or 150 lbs. at the rate of 220 feet per minute.

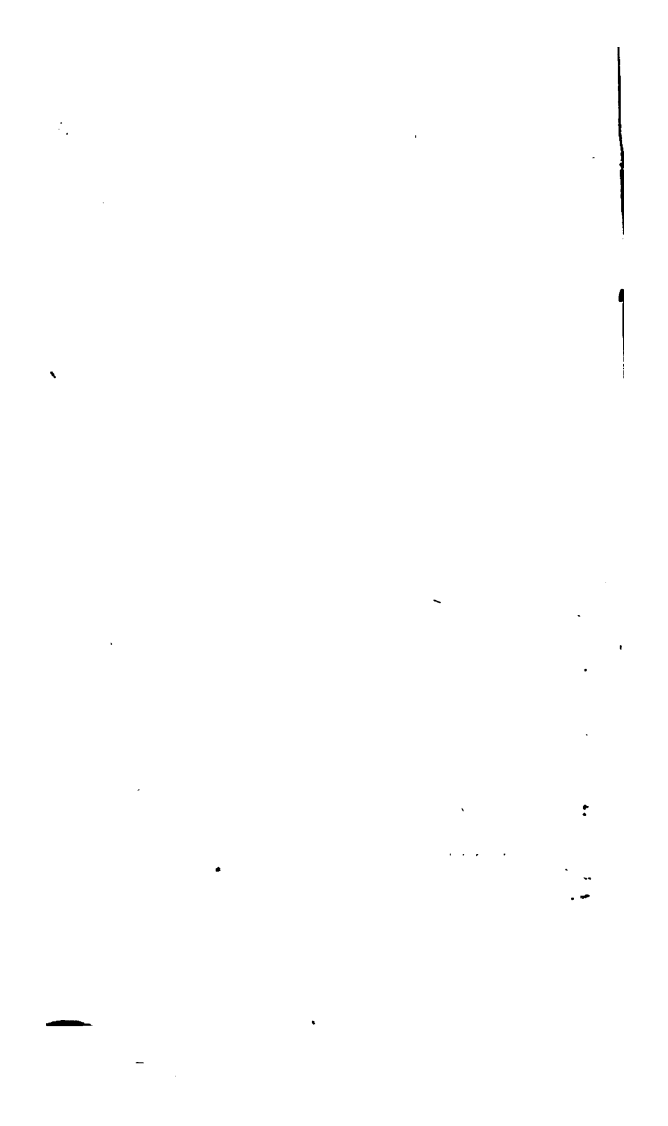
Table of Dimensions for Steam-Engine Cylinders by celebrated Makers.  
 THE UNIVERSITY OF TORONTO  
 TOPIC COMPANIES OF THE UNIVERSITY OF TORONTO  
 UNIVERSITY OF TORONTO

**PROPERTIES OF BODIES.**  
*Tables, combining the Specific Gravities and other Properties of Bodies. Water the Standard of Comparison, or 1000.*

Names.	METALS.										STONES, EARTHS, &c.				
	Specific Gravity.	Melting points in degrees of Fahrenheit.	Contraction in parts of an inch per lineal foot 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 laminae ductility.	Ratio of hardness.	Scale as conductors of electricity.	Ratio of power in the conduction of heat.	Names.	Specific Gravity.	Weight of a cubic foot in lbs.	Cubic feet in a ton.	Tons required to crush $\frac{1}{4}$ -inch cubes.	
Platinum . . . . .	19500	3280	—	—	3	5	—	—	3-8	Marble, average	2720	170-00	13	9-25	
Pure Gold . . . . .	19258	2016	—	—	1	1	1-8	3	10-0	Granite, do. . . . .	2651	165-68	13 $\frac{1}{2}$	6-2	
Mercury . . . . .	13500	—	—	—	—	—	—	6	—	Purbeck stone . . . . .	2601	162-56	13 $\frac{1}{2}$	9-0	
Lead . . . . .	11352	612	.319	.81	8	7	1-0	2	1-8	Portland do. . . . .	2570	160-62	14	4-5	
Pure Silver . . . . .	10474	1873	.156	1-45	2	2	2-4	2	9-7	Bristol do. . . . .	2554	159-62	14	—	
Bismuth . . . . .	9823	476	.193	8-51	—	—	2-0	—	—	Millstone . . . . .	2484	155-25	14 $\frac{1}{2}$	—	
Copper, cast . . . . .	8788	1996	—	15-08	5	3	—	1	8-9	Paving stone . . . . .	2415	150-93	14 $\frac{1}{2}$	5-7	
“ wrought . . . . .	8910	—	—	8-01	—	—	—	—	—	Craighith do. . . . .	2362	147-62	15	5-0	
Brass, cast . . . . .	7824	1900	.210	—	—	—	{ to any } degree	—	—	Grindstone . . . . .	2143	133-93	16 $\frac{1}{2}$	6-6	
“ sheet . . . . .	8396	—	—	12-23	6	6	—	—	8-6	Chalk, Brit. . . . .	2781	173-81	12 $\frac{1}{2}$	0-5	
Iron, cast . . . . .	7364	2786	.125	7-87	—	—	{ to any } degree	—	—	Brick . . . . .	2000	125-00	17	0-8	
“ bar . . . . .	7700	—	.137	25-00	4	8	4-7	4	3-7	Coal, Scotch . . . . .	1300	81-15	27 $\frac{1}{2}$	—	
Steel, soft . . . . .	7833	—	.133	58-91	—	—	—	—	—	“ Newcastle . . . . .	1270	79-37	27 $\frac{1}{2}$	—	
“ hard . . . . .	7816	—	—	—	—	—	{ to any } degree	—	—	“ Staffordsh. . . . .	1240	77-50	29	—	
Tin, cast . . . . .	7291	442	.278	2-11	8	4	1-2	5	3-0	“ Cannel . . . . .	1238	77-37	29	—	
Zinc, cast . . . . .	7190	773	.329	5-06	7	8	1-6	7	3-6						

WOODS							
Names.	Specific gravity, water, 1000.	Average wt. of a cubic ft. in lbs.	Cubic feet in a ton.	Ultimate cohe- sive strength of an inch square prism in lbs.	Comparative		
					Stiffness.	Strength.	Resilience.
English oak . . . . .	934	58	38½	11880	100	100	100
Riga do. . . . .	872	54	41½	12888	93	108	125
Dantzic do. . . . .	756	47	48	12780	117	107	99
American do. . . . .	672	42	53	10253	114	86	64
Beech . . . . .	852	48	45	12225	77	103	138
Alder . . . . .	800	46	48½	9540	63	80	101
Plane . . . . .	640	40	55	10935	78	92	108
Sycamore . . . . .	604	38	59	9630	59	81	111
Chestnut . . . . .	610	38	59	10656	67	89	118
Ash . . . . .	845	52	43	14130	89	119	160
Elm . . . . .	673	42	53	9720	78	82	86
Mahogany, 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. deal . . .	590	37	60	12346	104	104	104
Amer <sup>n</sup> . 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.			GASES.	
Names.	Specific gravity, water, 1000.	Weight of an imperial gallon in lbs.	Atmospheric air being the standard of comparison, or 1000.	
			Names.	Specific gravity.
Acid, sulphuric	1850	18.5	Hydriodic acid gas	4340
“ nitric . .	1271	12.7	Chlorine “ “	2500
“ muriatic .	1200	12.0	Carbonic “ “	1527
“ fluoric . .	1060	10.6	Nitrous oxide “	1527
“ citric . .	1034	10.3	Cyanogen “	1805
“ acetic . .	1062	10.6	Oxygen “	1111
Water from the Baltic . . . . .	1015	10.2	Carbonic oxide “	972
Water from the Dead Sea . . .	1240	12.4	Carbureted hydrogen “	972
Water from the Mediterranean	1029	10.3	Prussic acid “	937
Water, distilled	1000	10.0	Ammoniacal “	590
Oils, expressed :			Steam of water “	623
linseed . . . .	940	9.4	Hydrogen “	69
sweet almond	932	9.3	Weight of water at the common temperature :	
whale . . . . .	923	9.2	1 cubic in. =	.03617 lb.
hempseed . . .	926	9.3	1 “ ft. =	62.5 lbs.
olive . . . . .	915	9.2	1 “ “ =	6.25 imp. galls.
Oils, essential :			1.8 “ “ =	1 cwt.
cinnamon . . .	1043	10.4	1 cylin. in. =	.02842 lb.
lavender . . .	894	8.9	1 “ ft. =	49.1 lbs.
turpentine . . .	870	8.7	1 “ “ =	5 imp. galls.
amber . . . . .	868	8.7	2.262 feet =	1 cwt.
Alcohol . . . . .	825	8.2	11.2 imp. galls. =	1 cwt.
Ether, nitric . .	908	9.1	224 “ “ =	1 ton.
Proof spirit . . .	922	9.2		
Vinegar . . . . .	1009	10.1		



## PRACTICAL TABLES.

## WEIGHT OF METALS.

## WROUGHT IRON; SQUARE, ROUND, AND FLAT.

Table I. contains the weight of Square Iron in sizes, from  $\frac{1}{2}$  inch to six inches square, advancing by  $\frac{1}{2}$  inch; and from 6 to 12 inches square, advancing by  $\frac{1}{2}$  inch; and in lengths, from 1 foot to 18 feet. The sizes are arranged in the first column of each page, and the lengths along the top; the weight in lbs. immediately under the lengths, and in a line with the sizes.

Table II. contains the weight of Round Iron in sizes from  $\frac{1}{2}$  inch to 6 inches diameter, advancing by  $\frac{1}{2}$  inch; and from 6 to 12 inches diameter, advancing by  $\frac{1}{2}$  inch; and in lengths from 1 foot to 18 feet. The sizes, lengths, and weights are arranged as in Table I.

Table III. contains the weight of Flat Iron in widths, from  $\frac{1}{2}$  inch to 6 inches diameter, advancing by  $\frac{1}{2}$  inch; in thicknesses from  $\frac{1}{2}$  inch to 1 inch, advancing by  $\frac{1}{2}$  inch; and in lengths, from 1 to 18 feet. The widths, lengths, and weights, are arranged as in the preceding tables, and the thicknesses alongside of the widths.

TABLE I.—SQUARE IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{8}$	0.2	0.4	0.6	0.8	1.1	1.3	1.5	1.7	1.9
$\frac{1}{4}$	0.5	1.0	1.4	1.9	2.4	2.9	3.3	3.8	4.3
$\frac{3}{8}$	0.8	1.7	2.5	3.4	4.2	5.1	5.9	6.8	7.6
$\frac{1}{2}$	1.3	2.6	4.0	5.3	6.6	7.9	9.2	10.6	11.9
$\frac{5}{8}$	1.9	3.8	5.7	7.6	9.5	11.4	13.3	15.2	17.1
$\frac{3}{4}$	2.6	5.2	7.8	10.4	12.9	15.5	18.1	20.7	23.3
1	3.4	6.8	10.1	13.5	16.9	20.3	23.7	27.0	30.4
$1\frac{1}{8}$	4.3	8.6	12.8	17.1	21.4	25.7	29.9	34.2	38.5
$1\frac{1}{4}$	5.3	10.6	15.8	21.1	26.4	31.7	37.0	42.2	47.5
$1\frac{3}{8}$	6.4	12.8	19.2	25.6	32.0	38.3	44.7	51.1	57.5
$1\frac{1}{2}$	7.6	15.2	22.8	30.4	38.0	45.6	53.2	60.8	68.4
$1\frac{3}{4}$	8.9	17.9	26.8	35.7	44.6	53.6	62.5	71.4	80.3
$1\frac{7}{8}$	10.4	20.7	31.1	41.4	51.8	62.1	72.5	82.8	93.2
1 $\frac{7}{8}$	11.9	23.8	35.6	47.5	59.4	71.9	82.2	95.1	105.9
2	13.5	27.0	40.6	54.1	67.6	81.1	94.6	108.2	121.7
$2\frac{1}{8}$	15.3	30.5	45.8	61.1	76.3	91.6	106.8	122.1	137.4
$2\frac{1}{4}$	17.1	34.2	51.3	68.4	85.6	102.7	119.8	136.9	154.0
$2\frac{3}{8}$	19.1	38.1	57.2	76.3	95.3	114.4	133.5	152.5	171.6
$2\frac{1}{2}$	21.1	42.2	63.4	84.5	105.6	126.7	147.8	169.0	190.1
$2\frac{5}{8}$	23.3	46.6	69.9	93.2	116.5	139.8	163.0	186.3	209.6
$2\frac{3}{4}$	25.6	51.1	76.7	102.2	127.8	153.4	178.9	204.5	230.0
$2\frac{7}{8}$	27.9	55.9	83.8	111.8	139.7	167.6	195.7	223.5	251.5
3	30.4	60.8	91.2	121.7	152.1	182.5	212.9	243.3	273.7
$3\frac{1}{8}$	33.0	66.0	99.0	132.0	165.1	198.1	231.1	264.1	297.1
$3\frac{1}{4}$	35.7	71.4	107.1	142.8	178.5	214.2	249.9	285.6	321.3
$3\frac{3}{8}$	38.5	77.0	115.5	154.0	192.5	231.0	269.5	308.0	346.5
$3\frac{1}{2}$	41.4	82.8	124.2	165.6	207.0	248.4	289.8	331.3	372.7
$3\frac{5}{8}$	44.4	88.8	133.3	177.7	222.1	266.5	310.9	355.3	399.8
$3\frac{3}{4}$	47.5	95.1	142.6	190.1	237.7	285.2	332.7	380.3	427.8
$3\frac{7}{8}$	50.8	101.5	152.3	203.0	253.8	304.5	355.3	406.0	456.8

TABLE I.—SQUARE IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{4}$	2.1	2.3	2.5	2.7	3.0	3.2	3.4	3.6	3.8
$\frac{3}{8}$	4.8	5.2	5.7	6.2	6.7	7.1	7.6	8.1	8.6
$\frac{1}{2}$	8.5	9.3	10.1	11.0	11.8	12.0	13.5	14.4	15.2
$\frac{5}{8}$	13.2	14.5	15.8	17.2	18.5	19.8	21.1	22.4	23.8
$\frac{3}{4}$	19.0	20.9	22.8	24.7	26.6	28.5	30.4	32.3	34.2
$\frac{7}{8}$	25.9	28.5	31.1	33.6	36.2	38.8	41.4	44.0	46.6
1	33.8	37.2	40.6	43.9	47.3	50.7	54.1	57.5	60.8
$1\frac{1}{8}$	42.8	47.1	51.3	55.6	59.9	64.2	68.4	72.7	77.0
$1\frac{1}{4}$	52.8	58.1	63.4	68.6	73.9	79.2	84.5	89.8	95.0
$1\frac{3}{8}$	63.9	70.3	76.7	83.1	89.5	95.9	102.2	108.6	115.0
$1\frac{1}{2}$	76.0	83.6	91.2	98.9	106.5	114.1	121.7	129.3	136.9
$1\frac{3}{4}$	89.3	98.2	107.1	116.0	125.0	133.9	142.8	151.7	160.7
$1\frac{7}{8}$	103.5	133.9	124.2	134.6	144.9	155.3	165.6	176.0	186.3
$1\frac{1}{2}$	118.8	130.7	142.6	154.5	166.4	178.2	190.1	202.0	213.9
2	135.2	148.7	162.2	175.8	189.3	202.8	216.3	229.8	243.4
$2\frac{1}{8}$	152.6	167.9	183.2	198.4	213.7	228.9	244.2	259.5	274.7
$2\frac{1}{4}$	171.1	188.2	205.3	222.5	239.6	256.7	273.8	290.9	308.0
$2\frac{3}{8}$	190.7	209.7	228.8	247.9	266.9	286.0	305.1	324.1	343.2
$2\frac{1}{2}$	211.2	232.3	253.4	274.6	295.7	316.8	337.9	359.0	380.2
$2\frac{5}{8}$	232.9	256.2	279.5	302.8	326.1	349.4	372.7	396.0	419.3
$2\frac{3}{4}$	255.6	281.2	306.7	332.3	357.8	383.4	409.0	434.5	460.1
$2\frac{7}{8}$	279.4	307.3	335.3	363.2	391.1	419.1	447.0	475.0	502.9
3	304.2	334.6	365.0	395.4	425.8	456.2	486.7	517.1	547.5
$3\frac{1}{8}$	330.1	363.1	396.1	429.1	462.1	495.2	528.2	561.2	594.2
$3\frac{1}{4}$	357.0	392.7	428.4	464.2	499.9	535.6	571.3	607.0	642.7
$3\frac{3}{8}$	385.0	423.5	462.0	500.5	539.0	577.5	616.0	654.6	693.1
$3\frac{1}{2}$	414.1	455.5	496.9	538.3	579.7	621.1	662.5	703.9	745.3
$3\frac{5}{8}$	444.2	488.6	533.0	577.4	621.9	666.3	710.7	755.1	799.5
$3\frac{3}{4}$	475.3	522.9	570.4	617.9	665.5	713.0	760.5	808.1	855.6
$3\frac{7}{8}$	507.6	558.3	609.1	659.8	710.6	761.3	812.1	862.9	913.6

TABLE I.—SQUARE IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	54.1	108.2	162.3	216.3	270.4	324.5	378.6	432.7	486.8
4½	57.5	115.0	172.6	230.1	287.6	345.1	402.6	460.1	517.7
4¾	61.1	122.1	183.2	244.2	305.3	366.3	427.4	488.4	549.5
4⅝	64.7	129.4	194.1	258.8	323.5	388.2	452.9	517.6	582.3
4⅞	68.4	136.9	205.3	273.8	342.2	410.7	479.1	547.6	616.0
4⅘	72.3	144.6	216.9	289.2	361.5	433.8	506.1	578.4	650.7
4⅙	76.3	152.5	228.8	305.1	381.3	457.6	533.8	610.1	686.4
4⅚	80.3	160.7	241.0	321.3	401.7	482.0	562.3	642.7	723.0
5	84.5	169.0	253.4	337.9	422.4	506.9	591.4	675.8	760.3
5½	88.8	177.6	266.4	355.1	443.9	532.7	621.5	710.3	799.1
5¾	93.2	186.3	279.5	372.7	465.8	559.0	652.2	745.3	838.5
5⅝	97.7	195.3	293.0	390.6	488.3	585.9	683.6	781.3	878.9
5⅞	102.2	204.5	306.7	409.0	511.2	613.4	715.7	817.9	920.2
5⅘	107.0	213.5	320.9	427.8	534.8	641.7	748.7	855.6	962.6
5⅙	111.8	223.5	335.3	447.0	558.8	670.5	782.3	894.0	1005.8
5⅚	116.7	233.3	350.0	466.7	583.4	700.0	816.7	933.4	1050.0
6	121.7	243.3	365.0	486.7	608.3	730.0	841.6	973.3	1095.0
6½	132.0	264.1	396.1	528.2	660.2	792.2	924.3	1056.3	1188.4
6¾	142.8	285.6	428.4	571.3	714.1	856.9	999.7	1142.5	1285.3
6⅝	154.0	308.0	462.0	616.0	770.1	924.1	1078.1	1232.1	1386.1
7	165.6	331.2	496.9	662.5	828.2	993.8	1159.4	1325.1	1490.7
7½	177.7	355.3	533.0	710.7	888.4	1066.0	1243.7	1421.4	1599.0
7¾	190.1	380.3	570.4	760.5	950.7	1140.8	1331.0	1521.1	1711.2
7⅝	203.0	406.0	609.1	812.1	1015.1	1218.1	1421.2	1624.2	1827.2
8	216.3	432.7	649.0	865.3	1081.7	1298.0	1514.4	1730.7	1947.0
8½	230.1	460.1	690.2	920.3	1150.3	1380.4	1610.5	1840.5	2070.6
8¾	244.2	488.4	732.7	976.9	1221.1	1465.3	1709.5	1953.8	2198.0
8⅝	258.8	517.6	776.4	1035.2	1294.0	1552.8	1811.6	2070.4	2329.2
9	273.8	547.6	821.4	1095.2	1369.0	1642.8	1916.5	2190.3	2464.1

TABLE I.—SQUARE IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	540·8	594·9	649·0	703·1	757·2	811·3	865·3	919·4	973·5
4½	575·2	632·7	690·2	747·7	805·2	862·8	920·3	977·8	1035·3
4¾	610·6	671·6	732·7	793·7	854·6	915·8	976·9	1037·9	1099·0
4⅝	646·0	711·7	776·4	841·1	905·8	970·5	1035·2	1099·9	1164·6
4¾	684·5	752·9	821·4	889·8	958·3	1026·7	1095·2	1163·6	1232·1
4⅞	723·1	795·4	867·7	940·0	1012·3	1084·6	1156·9	1229·2	1301·5
4⅞	762·6	838·9	915·2	991·4	1067·7	1144·0	1220·2	1296·5	1372·8
4⅞	803·3	883·7	964·0	1044·3	1124·7	1205·0	1285·3	1365·7	1446·0
5	844·8	929·3	1013·8	1098·2	1182·7	1267·2	1351·7	1436·2	1520·6
5½	887·8	976·6	1065·4	1154·2	1243·0	1331·8	1420·5	1509·3	1598·1
5¾	931·7	1024·8	1118·0	1211·2	1304·4	1397·5	1490·7	1583·9	1677·0
5⅝	976·6	1074·2	1171·9	1269·5	1367·2	1464·9	1562·5	1660·2	1757·8
5¾	1022·4	1124·6	1226·9	1329·1	1431·4	1533·6	1635·8	1738·1	1840·3
5⅞	1069·5	1176·5	1283·4	1390·4	1497·3	1604·3	1711·2	1818·2	1925·2
5⅞	1117·6	1229·3	1341·1	1452·8	1564·6	1676·3	1788·1	1899·9	2011·6
5⅞	1160·0	1283·4	1400·1	1516·7	1633·4	1750·1	1866·7	1983·4	2100·1
6	1220·6	1338·3	1460·0	1581·6	1703·3	1825·0	1946·6	2068·3	2190·0
6¼	1320·4	1452·4	1584·4	1716·5	1848·6	1980·6	2112·6	2244·7	2376·7
6½	1428·2	1571·0	1713·8	1856·6	1999·4	2142·2	2285·1	2427·9	2570·7
6¾	1540·1	1694·1	1848·1	2002·2	2056·2	2310·2	2464·2	2618·2	2772·2
7	1656·3	1822·0	1987·6	2153·2	2318·8	2484·5	2650·1	2815·7	2981·4
7¼	1776·7	1954·4	2132·1	2309·7	2487·4	2665·1	2842·8	3020·4	3198·1
7½	1901·4	2091·5	2281·6	2471·8	2661·9	2852·0	3042·2	3232·3	3422·4
7¾	2030·2	2233·3	2436·3	2639·3	2842·3	3045·4	3248·4	3451·4	3654·4
8	2163·4	2379·7	2596·0	2812·4	3028·7	3245·0	3461·4	3677·7	3894·0
8¼	2300·7	2530·7	2760·8	2990·9	3220·9	3451·0	3681·1	3911·1	4141·2
8½	2442·2	2686·4	2930·6	3174·9	3419·1	3663·3	3907·5	4151·7	4396·0
8¾	2588·0	2846·8	3105·6	3364·4	3623·2	3882·0	4140·8	4399·6	4658·4
9	2737·9	3011·7	3285·5	3559·3	3833·1	4106·9	4380·7	4654·5	4928·

TABLE I.—SQUARE IRON

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9 $\frac{1}{4}$	289·2	578·4	867·7	1156·9	1446·1	1735·3	2024·5	2313·8	2603·0
9 $\frac{1}{2}$	305·1	610·1	915·2	1220·2	1525·3	1830·3	2135·4	2440·4	2745·5
9 $\frac{3}{4}$	321·3	642·7	964·0	1285·3	1606·7	1928·0	2249·3	2570·7	2892·3
10	337·9	675·8	1013·8	1351·7	1689·6	2027·5	2365·4	2703·4	3041·0
10 $\frac{1}{4}$	355·1	710·3	1065·4	1420·5	1775·7	2130·8	2486·0	2841·1	3196·2
10 $\frac{1}{2}$	372·7	745·3	1118·0	1490·7	1863·4	2236·0	2608·7	2981·4	3354·0
10 $\frac{3}{4}$	390·6	781·3	1171·9	1562·5	1953·1	2343·8	2734·4	3125·0	3515·7
11	409·0	817·9	1226·9	1635·8	2044·8	2453·8	2862·7	3271·7	3680·6
11 $\frac{1}{4}$	427·8	855·6	1283·4	1711·2	2139·1	2566·9	2994·7	3422·5	3857·3
11 $\frac{1}{2}$	447·0	894·0	1341·1	1788·1	2235·1	2682·1	3129·2	3576·2	4023·2
11 $\frac{3}{4}$	466·7	933·4	1400·1	1866·7	2333·4	2800·1	3266·8	3733·5	4200·2
12	486·7	973·3	1460·0	1946·6	2433·3	2919·9	3406·6	3883·2	4379·9

TABLE I.—SQUARE IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9 $\frac{1}{4}$	2892.2	3181.4	3470.6	3759.9	4049.1	4338.3	4627.5	4916.7	5206.0
9 $\frac{1}{2}$	3050.6	3355.6	3660.7	3965.7	4270.8	4575.8	4880.9	5186.0	5491.0
9 $\frac{3}{4}$	3213.3	3534.7	3856.4	4177.3	4498.6	4820.0	5141.3	5462.6	5784.0
10	3379.2	3717.1	4055.0	4393.0	4730.9	5068.8	5406.7	5744.6	6082.6
10 $\frac{1}{4}$	3551.4	3906.5	4261.6	4616.8	4971.9	5327.0	5682.2	6037.3	6392.4
10 $\frac{1}{2}$	3726.7	4099.4	4472.1	4844.7	5217.4	5590.1	5962.8	6335.4	6708.1
10 $\frac{3}{4}$	3906.3	4297.0	4687.5	5078.2	5468.8	5859.4	6250.0	6644.7	7031.3
11	4089.6	4498.6	4907.5	5316.5	5725.4	6134.4	6543.4	6952.3	7361.3
11 $\frac{1}{4}$	4278.1	47.5.9	5133.7	5561.6	5989.4	6417.2	6845.0	7272.8	7700.6
11 $\frac{1}{2}$	4470.2	4917.3	5364.3	5811.3	6258.3	6705.4	7152.4	7599.4	8046.4
11 $\frac{3}{4}$	4666.8	5133.5	5600.2	6066.9	6533.6	7000.3	7466.9	7933.6	8400.3
12	4866.6	5353.2	5839.9	6326.5	6813.2	7299.8	7786.5	8273.2	8759.8

TABLE II.—ROUND IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{8}$	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5
$\frac{3}{16}$	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.4
$\frac{1}{4}$	0.7	1.3	2.0	2.7	3.3	4.0	4.6	5.3	6.0
$\frac{5}{16}$	1.0	2.1	3.1	4.2	5.2	6.3	7.3	8.3	9.4
$\frac{3}{8}$	1.5	3.0	4.5	6.0	7.5	9.0	10.5	11.9	13.4
$\frac{7}{16}$	2.0	4.1	6.1	8.1	10.2	12.2	14.2	16.3	18.3
1	2.7	5.3	8.0	10.6	13.3	15.9	18.6	21.2	23.9
1 $\frac{1}{8}$	3.4	6.7	10.1	13.4	16.8	20.2	23.5	26.9	30.2
1 $\frac{1}{4}$	4.2	8.3	12.5	16.7	20.9	25.0	29.2	33.4	37.5
1 $\frac{3}{8}$	5.0	10.0	15.1	20.1	25.1	30.1	35.1	40.2	45.2
1 $\frac{1}{2}$	6.0	11.9	17.9	23.9	29.9	35.8	41.8	47.8	53.7
1 $\frac{5}{8}$	7.0	14.0	21.0	28.0	35.1	42.1	49.1	56.1	63.1
1 $\frac{3}{4}$	8.1	16.3	24.4	32.5	40.6	48.8	56.9	65.0	73.2
1 $\frac{7}{8}$	9.3	18.7	28.0	37.3	46.7	56.0	65.3	74.7	84.0
2	10.6	21.2	31.8	42.5	53.1	63.7	74.3	84.9	95.5
2 $\frac{1}{8}$	12.0	24.0	36.0	48.0	59.9	71.9	83.9	95.9	107.9
2 $\frac{1}{4}$	13.5	26.9	40.3	53.8	67.2	80.6	94.1	107.5	121.0
2 $\frac{3}{8}$	15.0	30.0	44.9	60.0	74.9	89.9	104.8	119.8	134.8
2 $\frac{1}{2}$	16.7	33.4	50.1	66.8	83.4	100.1	116.8	133.5	150.2
2 $\frac{5}{8}$	18.8	36.6	54.9	73.2	91.5	109.8	128.1	146.3	164.6
2 $\frac{3}{4}$	20.1	40.2	60.2	80.3	100.4	120.5	140.5	160.6	180.7
2 $\frac{7}{8}$	21.9	43.9	65.8	87.8	109.7	131.7	153.6	175.6	197.5
3	23.9	47.8	71.7	95.6	119.4	143.3	167.2	191.1	215.0
3 $\frac{1}{8}$	25.9	51.9	77.8	103.7	129.6	155.6	181.5	207.4	233.3
3 $\frac{1}{4}$	28.0	56.1	84.1	112.2	140.2	168.2	196.3	224.3	253.4
3 $\frac{3}{8}$	30.2	60.5	90.7	121.0	151.2	181.4	211.7	241.9	272.2
3 $\frac{1}{2}$	32.5	65.0	97.5	130.0	162.6	195.1	227.6	260.1	289.6
3 $\frac{5}{8}$	34.9	69.8	104.7	139.5	174.4	209.3	244.2	279.1	314.0
3 $\frac{3}{4}$	37.3	74.7	112.0	149.3	186.7	224.0	261.3	298.7	336.0
3 $\frac{7}{8}$	39.9	79.7	119.6	159.5	199.3	239.2	279.0	318.9	358.6

TABLE II.—ROUND IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{4}$	1.7	1.8	2.0	2.1	2.3	2.5	2.6	2.8	3.0
$\frac{3}{8}$	3.7	4.1	4.5	4.8	5.2	5.6	6.0	6.3	6.7
$\frac{1}{2}$	6.6	7.3	8.0	8.6	9.3	9.9	10.6	11.3	11.9
$\frac{5}{8}$	10.4	11.5	12.5	13.6	14.6	15.6	16.7	17.3	18.8
$\frac{3}{4}$	14.9	16.4	17.9	19.4	20.9	22.4	23.9	25.4	26.9
$\frac{7}{8}$	20.3	22.4	24.4	26.4	28.4	30.5	32.5	34.5	36.6
1	26.5	29.2	31.8	34.5	37.2	39.8	42.5	45.1	47.8
$1\frac{1}{8}$	33.6	37.0	40.3	43.7	47.0	50.4	53.8	57.1	60.5
$1\frac{1}{4}$	41.7	45.9	50.1	54.2	58.4	62.6	66.8	70.9	75.1
$1\frac{3}{8}$	50.2	55.2	60.2	65.2	70.3	75.3	80.3	85.3	90.3
$1\frac{1}{2}$	59.7	65.7	71.7	77.6	83.6	89.6	95.6	101.5	107.5
$1\frac{3}{4}$	70.1	77.1	84.1	91.1	98.1	105.2	112.2	119.2	126.2
$1\frac{7}{8}$	81.3	89.4	97.5	105.7	113.8	121.9	130.0	138.2	146.3
1 $\frac{7}{8}$	93.3	102.7	112.0	121.3	130.7	140.0	149.3	158.7	168.0
2	106.2	116.6	127.4	138.0	148.6	159.2	169.9	180.5	192.1
$2\frac{1}{8}$	119.9	131.9	143.9	155.8	167.8	179.8	181.8	193.8	205.8
$2\frac{1}{4}$	134.4	147.8	161.3	174.7	188.2	201.6	215.0	228.5	241.9
$2\frac{3}{8}$	149.8	164.7	179.7	194.7	209.7	224.6	239.6	254.6	269.6
$2\frac{1}{2}$	166.9	183.6	200.3	216.9	233.6	250.3	267.0	283.7	300.4
$2\frac{3}{4}$	182.9	201.2	219.5	237.8	256.1	274.4	292.7	311.0	329.3
$2\frac{7}{8}$	200.8	220.6	240.9	261.2	281.1	301.1	321.2	341.3	361.4
2 $\frac{7}{8}$	219.4	241.4	263.4	285.3	307.2	329.2	351.1	373.0	395.0
3	238.9	262.6	286.7	310.5	334.4	358.3	382.2	406.1	430.0
$3\frac{1}{8}$	259.3	285.2	311.1	337.0	363.0	388.9	414.8	440.7	466.7
$3\frac{1}{4}$	280.4	308.4	336.5	364.5	392.6	420.6	448.6	476.7	504.7
$3\frac{3}{8}$	302.4	332.6	362.9	393.1	423.4	453.6	483.8	514.1	544.3
$3\frac{1}{2}$	325.1	357.6	390.1	422.7	455.2	487.7	520.2	552.7	585.2
$3\frac{3}{4}$	348.9	383.7	418.6	453.5	488.4	523.3	558.2	593.1	627.9
$3\frac{7}{8}$	373.8	410.7	448.0	485.3	522.6	560.0	597.3	634.6	672.0
3 $\frac{7}{8}$	398.6	438.5	478.4	518.2	558.1	598.0	637.8	677.7	717.6

TABLE II.—ROUND IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	42.5	84.9	127.4	169.9	212.3	254.8	297.2	339.7	382.2
4½	45.2	90.3	135.5	180.7	225.9	271.0	316.2	361.4	406.6
4¾	48.0	95.9	143.9	191.8	239.8	287.7	335.7	383.6	431.6
4⅞	50.8	101.6	152.4	203.3	254.1	304.9	355.7	403.5	457.3
4⅝	53.6	107.5	161.3	215.0	268.8	322.6	376.3	430.1	483.8
4⅞	56.6	113.6	170.4	227.2	283.9	340.7	397.5	454.3	511.1
4¾	60.0	119.8	179.7	239.6	299.5	359.4	419.3	479.2	539.1
4⅞	63.1	126.2	189.3	252.4	315.5	378.6	441.7	504.8	567.8
5	66.8	133.5	200.3	267.0	333.8	400.5	467.3	534.0	600.8
5½	69.7	139.5	209.2	278.9	348.7	418.4	488.1	557.8	627.6
5¾	73.2	146.3	219.5	292.7	365.9	439.0	512.2	585.4	658.5
5⅞	76.7	153.4	230.1	306.8	383.5	460.2	536.9	613.6	690.8
5⅝	80.3	160.6	240.9	321.2	401.5	481.8	562.1	642.4	722.7
5⅞	84.0	168.0	252.0	336.0	420.0	504.0	588.0	672.0	756.0
5¾	87.8	175.6	263.3	351.1	438.9	526.7	614.4	702.2	790.0
5⅞	91.6	183.3	274.9	366.5	458.2	549.8	641.4	733.1	824.7
6	95.6	191.1	286.7	382.2	477.8	573.3	668.9	764.4	860.0
6½	103.7	207.4	311.1	414.8	518.5	622.2	725.9	829.6	933.3
6¾	112.2	224.3	336.5	448.6	560.8	673.0	785.1	897.3	1009.4
6⅞	121.0	241.9	362.9	483.8	604.8	725.8	846.7	967.6	1088.6
7	130.0	260.1	390.1	520.2	650.2	780.3	910.3	1040.4	1170.4
7½	139.5	279.1	418.6	558.2	697.7	837.3	976.8	1116.4	1255.9
7¾	149.3	298.7	448.0	597.3	741.6	896.0	1045.3	1194.6	1344.0
7⅞	159.5	318.9	478.4	637.8	797.3	956.7	1116.2	1275.6	1435.1
8	169.9	339.7	509.6	679.4	849.3	1019.1	1189.0	1356.8	1528.7
8½	180.7	361.4	542.1	722.6	903.5	1084.2	1264.9	1445.6	1624.8
8¾	191.8	383.6	585.4	767.2	959.0	1150.8	1342.6	1534.5	1723.3
8⅞	203.3	406.5	609.8	813.0	1016.8	1219.6	1422.8	1626.1	1822.3
9	215.0	430.1	645.1	860.2	1075.2	1290.2	1505.3	1720.8	1935.6

TABLE II.—ROUND IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	424.6	467.1	509.6	552.0	594.5	637.0	676.4	721.9	764.4
4½	451.7	496.9	542.1	587.3	632.4	677.6	722.8	761.0	813.1
4¾	479.5	527.5	575.4	623.4	671.3	719.3	767.2	815.2	863.1
4⅞	508.2	559.0	609.8	660.6	711.4	762.2	813.0	863.9	914.7
4⅝	537.6	591.4	645.1	698.9	752.6	806.4	860.2	913.9	967.7
4⅞	567.9	624.7	681.5	738.2	795.0	851.8	908.6	965.4	1022.2
4⅞	599.0	658.9	718.8	778.7	838.6	898.5	958.4	1018.3	1078.2
4⅞	630.9	694.0	757.1	820.2	883.3	946.4	1009.5	1072.6	1135.7
5	667.5	734.3	801.0	867.8	934.5	1001.3	1068.0	1134.8	1201.5
5½	697.3	767.0	836.8	906.5	976.2	1046.0	1115.7	1185.4	1255.2
5¾	731.7	804.9	878.1	951.2	1024.4	1097.6	1170.8	1243.9	1317.1
5⅞	767.0	813.7	920.4	997.1	1073.8	1150.5	1227.2	1303.9	1380.6
5⅝	803.0	883.3	963.6	1044.0	1124.3	1204.6	1284.9	1365.2	1445.5
5⅞	840.0	924.0	1008.0	1092.0	1176.0	1260.0	1344.0	1428.0	1512.0
5¾	877.8	965.5	1053.3	1141.1	1228.9	1316.6	1404.4	1492.2	1580.0
5⅞	916.3	1008.0	1099.6	1191.2	1282.9	1374.5	1466.1	1557.8	1649.4
6	955.5	1051.1	1146.6	1242.2	1337.7	1433.3	1528.8	1624.4	1719.9
6½	1037.0	1140.7	1244.4	1348.2	1451.9	1555.6	1659.3	1763.0	1866.7
6¾	1121.6	1233.8	1345.9	1458.1	1570.2	1682.4	1794.6	1906.7	2018.9
6⅞	1209.6	1330.6	1451.5	1572.5	1693.4	1814.4	1935.4	2056.3	2177.3
7	1300.5	1430.5	1560.6	1690.6	1820.7	1950.7	2088.8	2210.8	2340.9
7½	1395.4	1535.0	1674.5	1814.1	1953.6	2093.2	2232.7	2372.2	2511.8
7¾	1493.3	1643.6	1791.9	1941.3	2090.6	2239.9	2389.2	2538.6	2687.9
7⅞	1594.6	1754.0	1913.5	2072.9	2232.4	2391.8	2551.3	2710.8	2870.2
8	1698.6	1868.4	2038.3	2208.1	2378.0	2547.8	2717.7	2887.6	3057.4
8½	1809.0	1987.7	2168.4	2349.0	2529.7	2740.4	2891.1	3071.8	3252.5
8¾	1918.1	2109.9	2301.7	2493.5	2685.3	2879.1	3068.9	3260.7	3452.5
8⅞	2032.6	2235.9	2439.1	2642.4	2845.6	3048.9	3252.2	3455.4	3658.7
9	2150.4	2365.4	2580.5	2795.5	3010.6	3225.6	3440.6	3655.7	3870

TABLE II.—ROUND IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9 $\frac{1}{4}$	227.2	454.3	681.5	908.6	1135.8	1362.9	1590.1	1817.2	2044.4
9 $\frac{1}{2}$	239.6	479.2	718.8	958.4	1198.0	1437.6	1677.2	1916.8	2156.4
9 $\frac{3}{4}$	252.4	505.8	757.1	1009.5	1261.9	1514.3	1766.6	2019.0	2291.4
10	266.3	532.6	798.9	1065.2	1331.4	1597.7	1864.0	2130.3	2396.6
10 $\frac{1}{4}$	278.9	557.8	836.8	1115.7	1394.6	1673.5	1952.5	2231.4	2510.3
10 $\frac{1}{2}$	292.7	585.4	878.1	1170.8	1463.4	1756.1	2048.8	2341.5	2634.2
10 $\frac{3}{4}$	306.8	603.6	920.4	1227.2	1534.0	1840.8	2147.6	2454.4	2761.2
11	321.2	642.4	963.6	1284.9	1606.1	1927.3	2248.5	2569.7	2890.9
11 $\frac{1}{4}$	336.0	672.0	1008.0	1344.0	1680.0	2016.0	2352.0	2688.0	3024.0
11 $\frac{1}{2}$	351.1	702.2	1053.3	1404.4	1755.5	2106.6	2457.7	2808.8	3159.9
11 $\frac{3}{4}$	366.5	733.1	1099.6	1466.1	1832.7	2199.2	2565.8	2932.3	3298.8
12	382.2	764.4	1146.6	1528.8	1911.0	2293.2	2675.5	3057.7	3439.9

TABLE II.—ROUND IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9 $\frac{1}{4}$	2371-5	2498-7	2725-8	2953-0	3180-1	3407-3	3634-4	3861-6	4088-7
9 $\frac{1}{2}$	2396-0	2635-6	2875-2	3114-8	3354-4	3594-0	3833-6	4073-2	4312-8
9 $\frac{3}{4}$	2523-8	2776-1	3028-5	3280-9	3533-3	3785-6	4038-0	4290-4	4542-8
10	2668-9	2929-2	3195-5	3461-7	3728-0	3994-3	4260-6	4526-9	4793-2
10 $\frac{1}{4}$	2789-2	3068-2	3347-1	3626-0	3904-9	4183-9	4462-8	4741-7	5020-6
10 $\frac{1}{2}$	2926-9	3219-6	3512-3	3804-9	4097-6	4390-3	4683-0	4975-7	5268-4
10 $\frac{3}{4}$	3068-0	3374-8	3681-6	3988-4	4295-2	4602-0	4908-8	5215-6	5522-4
11	3212-2	3533-4	3854-6	4175-8	4497-0	4818-2	5139-5	5460-7	5781-9
11 $\frac{1}{4}$	3360-0	3696-0	4032-0	4368-1	4704-1	5040-1	5376-1	5712-1	6048-1
11 $\frac{1}{2}$	3511-0	3862-1	4213-2	4564-4	4915-5	5266-6	5619-7	5968-8	6319-9
11 $\frac{3}{4}$	3665-4	4031-9	4398-4	4765-0	5131-5	5498-0	5864-6	6231-1	6597-6
12	3822-1	4204-3	4586-5	4968-7	5350-9	5733-1	6115-3	6497-5	6879-7

TABLE III.—FLAT IRON.

Thk.	Wid.	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft	8 ft.	9 ft.
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{8}$	1	0.6	1.7	2.5	3.4	4.2	5.1	5.9	6.8	7.6
$\frac{1}{8}$	1 $\frac{1}{2}$	1.1	2.1	3.2	4.2	5.3	6.2	7.4	8.4	9.5
$\frac{1}{8}$	1 $\frac{1}{2}$	1.3	2.5	3.8	5.1	6.3	7.6	8.9	10.1	11.4
$\frac{1}{8}$	1 $\frac{3}{4}$	1.5	3.0	4.4	5.9	7.4	8.9	10.4	11.8	13.3
$\frac{1}{8}$	2	1.7	3.4	5.1	6.8	8.5	10.1	11.8	13.5	15.2
$\frac{1}{8}$	2 $\frac{1}{4}$	1.9	3.8	5.7	7.6	9.5	11.4	13.3	15.2	17.1
$\frac{1}{8}$	2 $\frac{1}{2}$	2.1	4.2	6.3	8.4	10.6	12.7	14.8	16.9	19.0
$\frac{1}{8}$	2 $\frac{3}{4}$	2.3	4.6	7.0	9.3	11.6	13.9	16.3	18.6	20.9
$\frac{1}{8}$	3	2.5	5.1	7.6	10.1	12.7	15.2	17.7	20.3	22.8
$\frac{1}{8}$	3 $\frac{1}{4}$	2.7	5.5	8.2	11.0	13.7	16.5	19.2	22.0	24.7
$\frac{1}{8}$	3 $\frac{1}{2}$	3.0	5.9	8.9	11.8	14.8	17.7	20.7	23.7	26.6
$\frac{1}{8}$	3 $\frac{3}{4}$	3.2	6.3	9.5	12.7	15.8	19.0	22.2	25.4	28.5
$\frac{1}{8}$	4	3.4	6.8	10.1	13.5	16.9	20.3	23.7	27.0	30.4
$\frac{1}{8}$	4 $\frac{1}{4}$	3.6	7.2	10.8	14.4	18.0	21.5	25.1	28.7	32.3
$\frac{1}{8}$	4 $\frac{1}{2}$	3.8	7.6	11.4	15.2	19.0	22.8	26.6	30.4	34.2
$\frac{1}{8}$	4 $\frac{3}{4}$	4.0	8.0	12.0	16.1	20.1	24.1	28.1	32.1	36.1
$\frac{1}{8}$	5	4.2	8.4	12.7	16.9	21.1	25.3	29.6	33.8	38.0
$\frac{1}{8}$	5 $\frac{1}{4}$	4.4	8.9	13.3	17.7	22.2	26.6	31.1	35.5	39.9
$\frac{1}{8}$	5 $\frac{1}{2}$	4.6	9.3	13.9	18.6	23.2	27.9	32.5	37.2	41.6
$\frac{1}{8}$	5 $\frac{3}{4}$	4.9	9.7	14.6	19.4	24.3	29.2	34.0	38.9	43.7
$\frac{1}{8}$	6	5.1	10.1	15.2	20.3	25.3	30.4	35.5	40.6	45.6
$\frac{1}{4}$	1	1.3	2.5	3.8	5.1	6.3	7.6	8.9	10.1	11.4
$\frac{1}{4}$	1 $\frac{1}{2}$	1.6	3.2	4.8	6.3	7.9	9.5	11.1	12.7	14.3
$\frac{1}{4}$	1 $\frac{1}{2}$	1.9	3.8	5.7	7.6	9.5	11.4	13.3	15.2	17.1
$\frac{1}{4}$	1 $\frac{3}{4}$	2.2	4.4	6.7	8.9	11.1	13.3	15.5	17.7	20.0
$\frac{1}{4}$	2	2.5	5.1	7.6	10.1	12.7	15.2	17.7	20.3	22.8
$\frac{1}{4}$	2 $\frac{1}{4}$	2.9	5.7	8.3	11.4	14.3	17.1	20.0	22.8	25.7
$\frac{1}{4}$	2 $\frac{1}{2}$	3.2	6.3	9.5	12.7	15.8	19.0	22.2	25.4	28.5

TABLE III.—FLAT IRON.

Th'k.	Wid.	10ft	11ft	12ft	13ft	14ft	15ft	16ft	17ft	18ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1/4	1	8.5	9.3	10.1	11.0	11.8	12.7	13.5	14.4	15.2
	1 1/4	10.6	11.6	12.7	13.7	14.8	15.8	16.9	17.9	19.0
	1 1/2	12.7	13.9	15.2	16.5	17.7	19.0	20.3	21.5	22.8
	1 3/4	14.8	16.3	17.7	19.2	20.7	22.2	23.7	25.1	26.6
1/2	2	16.9	18.6	20.3	22.0	23.7	25.4	27.0	28.7	30.4
	2 1/4	19.0	20.9	22.8	24.7	26.6	28.5	30.4	32.3	34.2
	2 1/2	21.1	23.2	25.3	27.5	29.6	31.7	33.8	35.9	38.0
	2 3/4	23.2	25.6	27.9	30.2	32.5	34.9	37.2	39.5	41.8
3/4	3	25.3	27.9	30.4	33.0	35.5	38.0	40.6	43.1	45.6
	3 1/4	27.5	30.2	33.0	35.7	38.5	41.3	43.9	46.7	49.4
	3 1/2	29.6	32.5	35.5	38.5	41.4	44.4	47.3	50.3	53.2
	3 3/4	31.7	34.9	38.0	41.2	44.4	47.5	50.7	53.9	57.0
1	4	33.8	37.2	40.6	43.9	47.3	50.7	54.1	57.6	60.8
	4 1/4	35.9	39.5	43.1	46.7	50.3	53.9	57.5	61.0	64.6
	4 1/2	38.0	41.8	45.6	49.4	53.2	57.0	60.8	64.6	68.4
	4 3/4	40.1	44.1	48.2	52.2	56.2	60.2	64.2	68.2	72.2
1 1/4	5	42.2	46.5	50.7	54.9	59.1	63.4	67.6	71.8	76.0
	5 1/4	44.4	48.8	53.2	57.7	62.1	66.5	71.0	75.4	79.9
	5 1/2	46.5	51.1	55.6	60.4	65.1	69.7	74.4	79.0	83.6
	5 3/4	48.6	53.4	58.3	63.2	68.0	72.9	77.7	82.6	87.5
1 1/2	6	50.7	55.6	60.6	65.6	70.9	76.0	81.1	86.2	91.2
	1	12.7	13.9	15.2	16.5	17.7	19.0	20.3	21.5	22.8
	1 1/4	15.8	17.4	19.0	20.6	22.2	23.8	25.3	26.9	28.5
	1 1/2	19.0	20.9	22.8	24.7	26.6	28.5	30.4	32.3	34.2
1 3/4	1 3/4	22.2	24.4	26.6	28.8	31.1	33.3	35.5	37.7	39.9
	2	25.3	27.9	30.4	33.0	35.5	38.0	40.6	43.1	45.6
	2 1/4	28.5	31.4	34.2	37.1	39.9	42.8	45.6	48.5	51.3
	2 1/2	31.7	34.9	38.0	41.2	44.4	47.5	50.7	53.9	57.0

TABLE III.—FLAT IRON.

Thk.	Wid.	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft	8 ft	9 ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{8}$	2 $\frac{1}{2}$	3.5	7.0	10.5	13.9	17.4	20.9	24.4	27.9	31.4
$\frac{1}{4}$	3	3.8	7.6	11.4	15.2	19.0	22.8	26.6	30.4	34.2
	3 $\frac{1}{2}$	4.1	8.2	12.4	16.5	20.6	24.7	28.8	33.0	37.1
	3 $\frac{3}{4}$	4.4	8.9	13.3	17.7	22.2	26.6	31.1	35.5	39.9
$\frac{3}{8}$	3 $\frac{1}{2}$	4.6	9.5	14.3	19.0	23.6	28.5	33.3	38.0	42.8
	4	5.1	10.1	15.2	20.3	25.3	30.4	35.5	40.6	45.6
	4 $\frac{1}{2}$	5.4	10.8	16.1	21.5	26.9	32.3	37.7	43.1	48.5
$\frac{1}{2}$	4 $\frac{1}{2}$	5.7	11.4	17.1	22.8	28.5	34.2	39.9	45.6	51.3
	4 $\frac{3}{4}$	6.0	12.0	18.1	24.1	30.1	36.1	42.1	48.2	54.2
	5	6.3	12.7	19.0	25.3	31.7	38.0	44.4	50.7	57.0
$\frac{5}{8}$	5 $\frac{1}{2}$	6.7	13.3	20.0	26.6	33.3	39.9	46.6	53.2	59.9
	5 $\frac{3}{4}$	7.0	13.9	20.9	27.9	34.9	41.8	48.8	55.8	62.7
	5 $\frac{1}{2}$	7.3	14.6	21.9	29.2	36.4	43.7	51.0	58.3	65.6
$\frac{3}{4}$	6	7.6	15.2	22.8	30.4	38.0	45.6	53.2	60.8	68.4
	1	17	3.4	5.1	6.8	8.5	10.1	11.8	13.5	15.2
	1 $\frac{1}{4}$	2.1	4.2	6.3	8.4	10.6	12.7	14.8	16.9	19.0
$\frac{7}{8}$	1 $\frac{1}{2}$	2.5	5.1	7.6	10.1	12.7	15.2	17.7	20.3	22.8
	1 $\frac{3}{4}$	3.0	5.9	8.9	11.8	14.8	17.7	20.7	23.7	26.6
	2	3.4	6.8	10.1	13.5	16.9	20.3	23.7	27.0	30.4
$\frac{1}{2}$	2 $\frac{1}{2}$	3.8	7.6	11.4	15.2	19.0	22.8	26.6	30.4	34.2
	2 $\frac{3}{4}$	4.2	8.4	12.7	16.9	21.1	25.3	29.6	33.6	38.0
	2 $\frac{1}{2}$	4.6	9.3	13.9	18.6	23.2	27.9	32.5	37.2	41.8
$\frac{1}{2}$	3	5.1	10.1	15.2	20.3	25.3	30.4	35.5	40.6	45.6
	3 $\frac{1}{4}$	5.5	11.0	16.5	22.0	27.5	32.9	38.4	43.9	49.4
	3 $\frac{1}{2}$	5.9	11.8	17.7	23.7	29.6	35.5	41.4	47.3	53.2
	3 $\frac{3}{4}$	6.3	12.7	19.0	25.3	31.7	38.0	44.4	50.7	57.0
$\frac{1}{2}$	4	6.8	13.5	20.3	27.0	33.6	40.6	47.3	54.1	60.8

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TABLE III.—FLAT IRON.

Thk.	Wid.	10ft	11ft	12ft	13ft	14ft	15ft	16ft	17ft	18ft
Inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{8}$	$2\frac{1}{2}$	34.9	36.3	41.8	45.3	48.8	52.3	55.8	59.3	62.7
$\frac{1}{4}$	3	38.0	41.8	45.6	49.4	53.2	57.0	60.8	64.6	68.4
	$3\frac{1}{2}$	41.2	45.3	49.4	53.6	57.7	61.8	65.9	70.0	74.2
	$3\frac{3}{4}$	44.4	48.8	53.2	57.7	62.1	66.5	71.0	75.4	79.9
	$3\frac{7}{8}$	47.5	52.3	57.0	61.8	66.5	71.3	76.0	80.8	85.5
$\frac{1}{2}$	4	50.7	55.8	60.8	65.9	70.9	76.0	81.1	86.2	91.2
	$4\frac{1}{4}$	53.9	59.3	64.7	70.0	75.4	80.8	86.2	91.6	97.0
	$4\frac{1}{2}$	57.0	62.7	68.4	74.2	79.9	85.6	91.3	97.0	102.7
	$4\frac{3}{4}$	60.2	66.2	72.2	78.3	84.3	90.3	96.3	102.3	108.4
$\frac{3}{4}$	5	63.3	69.7	76.0	82.4	88.7	95.0	101.4	107.7	114.0
	$5\frac{1}{4}$	66.5	73.2	79.8	86.5	93.1	99.8	106.5	113.1	119.8
	$5\frac{1}{2}$	69.7	76.7	83.7	90.6	97.6	104.5	111.5	118.5	125.5
	$5\frac{3}{4}$	72.9	80.2	87.5	94.7	102.0	109.3	116.6	123.9	131.2
$1$	6	76.0	83.6	91.2	98.9	106.5	114.1	121.7	129.3	136.9
	1	16.9	18.6	20.3	22.0	23.7	25.4	27.0	28.7	30.4
	$1\frac{1}{4}$	21.1	23.2	25.3	27.5	29.6	31.7	33.8	35.9	38.0
	$1\frac{1}{2}$	25.3	27.9	30.4	33.0	35.5	38.0	40.6	43.1	45.6
$1\frac{3}{4}$	$1\frac{3}{4}$	29.6	32.5	35.5	38.5	41.4	44.4	47.3	50.3	53.2
	2	33.8	37.2	40.6	43.9	47.3	50.7	54.1	57.5	60.8
	$2\frac{1}{4}$	38.0	41.8	45.6	49.4	53.2	57.0	60.8	64.6	68.4
	$2\frac{1}{2}$	42.2	46.5	50.7	54.9	59.1	63.4	67.6	71.8	76.0
$2\frac{3}{4}$	$2\frac{3}{4}$	46.5	51.1	55.8	60.4	65.1	69.7	74.4	79.0	83.6
	3	50.7	55.8	60.8	65.9	70.9	76.0	81.1	86.2	91.2
	$3\frac{1}{4}$	54.9	60.4	65.9	71.4	76.9	82.4	87.9	93.3	98.8
	$3\frac{1}{2}$	59.2	65.1	71.0	76.9	82.8	88.7	94.6	100.6	106.5
$3\frac{3}{4}$	$3\frac{3}{4}$	63.3	69.7	76.0	82.4	88.7	95.0	101.4	107.7	114.0

TABLE III.—FLAT IRON

Thk.	Wid.	1 ft	2 ft	3 ft	ft 5	5 ft	6 ft	7 ft	8 ft	9 ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{8}$	4 $\frac{1}{4}$	7.2	14.4	21.5	28.7	35.9	43.1	50.3	57.4	64.5
$\frac{1}{8}$	4 $\frac{1}{2}$	7.6	15.2	22.8	30.4	38.0	45.6	53.2	60.8	68.4
$\frac{1}{8}$	4 $\frac{3}{4}$	8.0	16.1	24.1	32.1	40.1	48.2	56.2	64.2	72.2
$\frac{1}{4}$	5	8.4	16.9	25.3	33.8	42.2	50.7	59.1	67.6	76.0
$\frac{1}{4}$	5 $\frac{1}{4}$	8.9	17.7	26.6	35.3	44.4	53.2	62.1	71.0	79.9
$\frac{1}{4}$	5 $\frac{1}{2}$	9.3	18.6	27.9	37.2	46.5	55.8	65.1	74.4	83.7
$\frac{1}{4}$	5 $\frac{3}{4}$	9.7	19.4	29.2	38.9	48.6	58.3	68.0	77.7	87.5
$\frac{3}{8}$	6	10.1	20.3	30.4	40.6	50.7	60.8	70.9	81.1	91.2
$\frac{1}{2}$	1	2.1	4.2	6.3	8.4	10.6	12.7	14.8	16.9	19.0
$\frac{1}{2}$	1 $\frac{1}{4}$	2.6	5.3	7.9	10.6	13.2	15.8	18.5	21.1	23.6
$\frac{1}{2}$	1 $\frac{1}{2}$	3.2	6.3	9.5	12.7	15.8	19.0	22.2	25.4	28.5
$\frac{1}{2}$	1 $\frac{3}{4}$	3.7	7.4	11.1	14.8	18.5	22.2	25.9	29.6	33.3
$\frac{3}{4}$	2	4.2	8.4	12.7	16.9	21.1	25.3	29.9	33.8	38.0
$\frac{3}{4}$	2 $\frac{1}{4}$	4.8	9.5	14.3	19.0	23.8	28.5	33.3	38.0	42.8
$\frac{3}{4}$	2 $\frac{1}{2}$	5.3	10.6	15.8	21.1	26.4	31.7	37.0	42.2	47.5
$\frac{3}{4}$	2 $\frac{3}{4}$	5.8	11.6	17.4	23.2	29.0	34.8	40.7	46.5	52.3
$\frac{1}{2}$	3	6.3	12.7	19.0	25.3	31.7	38.0	44.4	50.7	57.0
$\frac{1}{2}$	3 $\frac{1}{4}$	6.9	13.7	20.6	27.5	34.3	41.2	48.1	54.9	61.8
$\frac{1}{2}$	3 $\frac{1}{2}$	7.4	14.8	22.2	29.6	37.0	44.4	51.8	59.2	66.5
$\frac{1}{2}$	3 $\frac{3}{4}$	7.9	15.8	23.6	31.7	39.6	47.5	55.5	63.4	71.3
$\frac{3}{4}$	4	8.4	16.9	25.3	33.8	42.2	50.7	59.1	67.6	76.0
$\frac{3}{4}$	4 $\frac{1}{4}$	9.0	18.0	26.9	35.9	44.9	53.9	62.9	71.8	80.8
$\frac{3}{4}$	4 $\frac{1}{2}$	9.5	19.0	28.5	38.0	47.5	57.0	66.5	76.1	85.6
$\frac{3}{4}$	4 $\frac{3}{4}$	10.0	20.1	30.1	40.1	50.2	60.2	70.2	80.3	90.3
$\frac{1}{2}$	5	10.6	21.1	31.7	42.3	52.8	63.4	73.9	84.5	95.1
$\frac{1}{2}$	5 $\frac{1}{4}$	11.1	22.2	33.3	44.4	55.5	66.5	77.6	88.7	99.8
$\frac{1}{2}$	5 $\frac{1}{2}$	11.6	23.2	34.9	46.5	58.1	69.7	81.3	92.9	104.6
$\frac{1}{2}$	5 $\frac{3}{4}$	12.1	24.3	36.4	48.6	60.7	72.9	85.0	97.2	109.3

TABLE III.—FLAT IRON.

Th'k.	Wid.	10ft	11ft	12ft	13ft	14ft	15ft	16ft	17ft	18ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{8}$	4 $\frac{1}{2}$	71.6	79.0	86.2	93.4	100.5	107.7	114.9	122.1	129.3
$\frac{1}{8}$	4 $\frac{1}{2}$	76.0	83.6	91.2	98.9	106.5	114.1	121.7	129.3	136.9
$\frac{1}{8}$	4 $\frac{1}{2}$	80.3	88.3	96.3	104.3	112.4	120.4	128.4	136.4	144.5
$\frac{1}{8}$	5	84.5	92.9	101.4	109.8	118.3	126.7	135.2	143.6	152.1
$\frac{1}{8}$	5 $\frac{1}{2}$	88.7	97.6	106.5	115.4	124.2	133.1	142.0	150.8	159.7
$\frac{1}{8}$	5 $\frac{1}{2}$	93.0	102.2	111.5	120.8	130.1	139.4	148.7	158.0	167.3
$\frac{1}{8}$	5 $\frac{1}{2}$	97.2	106.9	116.6	126.3	136.0	145.8	155.5	165.2	174.9
$\frac{1}{8}$	6	101.4	111.5	121.7	131.9	141.9	152.1	162.2	172.4	182.5
$\frac{1}{4}$	1	21.1	23.2	25.3	27.5	29.6	31.7	33.8	35.9	38.0
$\frac{1}{4}$	1 $\frac{1}{2}$	26.4	29.0	31.7	34.3	37.0	39.6	42.2	44.9	47.5
$\frac{1}{4}$	1 $\frac{1}{2}$	31.7	34.8	38.0	41.2	44.4	47.5	50.7	53.9	57.0
$\frac{1}{4}$	1 $\frac{1}{2}$	37.0	40.7	44.4	48.1	51.8	55.5	59.2	62.8	66.5
$\frac{1}{4}$	2	42.2	46.5	50.7	54.9	59.1	63.4	67.6	71.8	76.0
$\frac{1}{4}$	2 $\frac{1}{2}$	47.5	52.3	57.0	61.8	66.5	71.3	76.0	80.8	85.5
$\frac{1}{4}$	2 $\frac{1}{2}$	52.8	58.1	63.4	68.6	73.9	79.2	84.5	89.8	95.0
$\frac{1}{4}$	2 $\frac{1}{2}$	58.1	63.9	69.7	75.5	81.3	87.1	92.9	98.7	104.5
$\frac{1}{4}$	3	63.3	69.7	76.0	82.4	88.7	95.0	101.4	107.7	114.0
$\frac{1}{4}$	3 $\frac{1}{2}$	68.7	75.5	82.4	89.3	96.1	103.0	109.9	116.7	123.6
$\frac{1}{4}$	3 $\frac{1}{2}$	73.9	81.3	88.7	96.1	103.5	110.9	118.2	125.7	133.1
$\frac{1}{4}$	3 $\frac{1}{2}$	79.2	87.1	95.1	103.0	110.9	118.8	126.8	134.7	142.6
$\frac{1}{4}$	4	84.5	92.9	101.4	109.8	118.3	126.7	135.2	143.6	152.1
$\frac{1}{4}$	4 $\frac{1}{2}$	89.8	98.8	107.8	116.7	125.7	134.7	143.7	152.6	161.6
$\frac{1}{4}$	4 $\frac{1}{2}$	95.1	104.6	114.1	123.6	133.1	142.6	152.1	161.6	171.1
$\frac{1}{4}$	4 $\frac{1}{2}$	100.3	110.4	120.4	130.4	140.5	150.5	160.5	170.6	180.6
$\frac{1}{2}$	5	105.6	116.2	126.8	137.3	147.9	158.4	169.0	179.6	190.1
$\frac{1}{2}$	5 $\frac{1}{2}$	110.9	122.0	133.1	144.2	155.3	166.4	177.5	188.5	199.6
$\frac{1}{2}$	5 $\frac{1}{2}$	116.2	127.8	139.4	151.0	162.6	174.3	185.9	197.5	209.1

TABLE III.—FLAT IRON

Th'k.	Wid.	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft	8 ft	9 ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
6	6	12·7	25·3	38·0	50·7	63·4	76·0	88·7	101·4	114·1
1	1	2·5	5·1	7·6	10·1	12·7	15·2	17·7	20·3	22·8
1½	1½	3·2	6·3	9·5	12·7	15·6	19·0	22·2	25·4	28·5
1½	1½	3·6	7·6	11·4	15·2	19·0	22·8	26·6	30·4	34·2
1½	1½	4·4	8·9	13·3	17·7	22·2	26·6	31·1	35·5	39·9
2	2	5·1	10·1	15·2	20·3	25·3	30·4	35·5	40·6	45·6
2½	2½	5·7	11·4	17·1	22·8	28·5	34·2	39·9	45·6	51·3
2½	2½	6·3	12·7	19·0	25·3	31·7	38·0	44·4	50·7	57·0
2½	2½	7·0	13·9	20·9	27·9	34·9	41·8	48·8	55·8	62·7
3	3	7·6	15·2	22·8	30·4	38·0	45·6	53·2	60·9	68·4
3½	3½	8·2	16·5	24·7	33·0	41·2	49·4	57·7	65·9	74·2
3½	3½	8·9	17·7	26·6	35·5	44·4	53·2	62·1	71·0	79·9
3½	3½	9·5	19·0	28·5	38·0	47·5	57·0	66·5	76·1	85·6
4	4	10·1	20·3	30·4	40·6	50·7	60·8	70·9	81·1	91·2
4½	4½	10·8	21·5	32·3	43·1	53·9	64·6	75·4	86·2	97·0
4½	4½	11·4	22·8	34·2	45·6	57·0	68·4	79·9	91·3	102·7
4½	4½	12·0	24·1	36·1	48·2	60·2	72·2	84·3	96·3	108·4
5	5	12·7	25·3	38·0	50·7	63·4	76·0	88·7	101·4	114·0
5½	5½	13·3	26·6	39·9	53·2	66·5	79·8	93·1	106·5	119·8
5½	5½	13·9	27·9	41·8	55·8	69·7	83·7	97·6	111·5	125·5
5½	5½	14·6	29·1	43·7	58·3	72·9	87·4	102·0	116·6	131·2
6	6	15·2	30·4	45·6	60·8	76·0	91·2	106·5	121·7	136·9
1	1½	5·1	10·1	15·2	20·3	25·3	30·4	35·5	40·6	45·6
1	2	6·8	13·5	20·3	27·0	33·8	40·6	47·8	54·1	60·8
1	3	10·1	20·3	30·4	40·6	50·7	60·8	70·9	81·1	91·2
1	4	13·5	27·0	40·6	54·1	67·6	81·1	94·6	108·1	121·7
1	5	16·9	33·8	50·7	67·6	84·5	101·4	118·3	135·2	152·1
1	6	20·3	40·6	60·8	81·1	101·4	121·7	141·9	162·2	182·5

TABLE III.—FLAT IRON.

Th'k.	Wid.	10ft	11ft	12ft	13ft	14ft	15ft	16ft	17ft	18ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
6	6	126·7	139·4	152·1	164·8	177·4	190·1	202·8	215·4	228·1
1	1	25·3	27·9	30·4	33·0	35·5	38·0	40·6	43·1	45·6
1½	1½	31·7	34·9	38·0	41·2	44·4	47·5	50·7	53·9	57·0
1½	1½	38·0	41·8	45·6	59·4	53·2	57·0	60·8	64·6	68·4
1½	1½	44·4	48·8	53·2	57·7	62·1	66·5	71·0	75·4	79·9
2	2	50·7	55·8	60·8	65·9	70·9	76·0	81·1	86·2	91·2
2½	2½	57·0	62·7	68·4	74·2	79·9	85·5	91·3	97·0	102·7
2½	2½	63·3	69·7	76·0	82·4	88·7	95·0	101·4	107·7	114·0
2½	2½	69·7	76·7	83·7	90·6	97·6	104·5	111·5	118·5	125·5
3	3	76·0	83·6	91·2	98·9	106·5	114·1	121·7	129·3	136·9
3½	3½	82·4	90·6	98·9	107·1	115·3	123·6	131·8	140·0	148·3
3½	3½	88·7	97·6	106·5	115·4	124·2	133·1	142·0	150·8	159·7
3½	3½	95·1	104·6	114·1	123·6	133·1	142·6	152·1	161·6	171·1
4	4	101·4	111·5	121·7	131·8	141·9	152·1	162·2	172·4	182·5
4½	4½	107·7	118·5	129·3	140·1	150·8	161·6	172·4	183·2	193·9
4½	4½	114·1	125·5	136·9	148·3	159·7	171·1	182·5	193·9	205·3
4½	4½	120·4	132·4	144·5	156·5	168·6	180·6	192·6	204·7	216·7
5	5	126·7	139·4	152·1	164·8	177·4	190·1	202·8	215·4	228·1
5½	5½	133·1	146·4	159·7	173·0	186·3	199·6	212·9	226·2	239·5
5½	5½	139·4	153·3	167·3	181·2	195·2	209·2	223·1	237·0	250·9
5½	5½	145·7	160·3	174·9	189·5	204·0	218·6	233·2	247·8	262·3
6	6	152·1	167·3	182·5	197·7	212·9	228·1	243·3	258·5	273·7
1½	1½	50·7	55·8	60·8	65·9	70·9	76·0	81·1	86·2	91·2
1	2	67·6	74·4	81·1	87·9	94·6	101·4	108·1	114·9	121·7
1	3	101·4	111·5	121·7	131·7	141·9	152·1	162·2	172·4	182·5
1	4	135·2	149·7	162·2	175·7	189·3	202·8	216·7	229·8	243·3
1	5	169·0	185·9	202·8	219·7	236·6	253·5	270·4	287·3	304·2
1	6	202·8	223·1	243·3	263·6	283·9	304·2	324·4	344·7	365·0

The tables are all calculated to the nearest tenth of a pound. To the weights of bars of Wrought Iron, add  $\frac{1}{80}$ th part for bars of Soft Steel; and from the same weights subtract  $\frac{1}{14}$ th part for bars of Cast Iron.

*Proportional Breadths for hexagonal or six-sided Nuts for Wrought-Iron Bolts.*

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

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

WEIGHTS OF IRON, COPPER, ETC.

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

Thickness in parts of an inch.		Thickness by the wire gauge.			
1	40	No.	Iron.	Copper.	Brass.
$\frac{1}{2}$	125	1	19.5	14.5	13.75
$\frac{3}{8}$	9.5	2	19	13.9	13.2
$\frac{1}{4}$	5	3	11	19.75	19.1
$\frac{5}{16}$	7.5	4	10	11.6	11
$\frac{3}{16}$	13	5	8.74	10.1	9.61
$\frac{1}{8}$	19.5	6	8.19	9.4	8.83
$\frac{7}{16}$	15	7	7.5	8.7	8.25
$\frac{1}{2}$	17.5	8	6.86	7.9	7.54
$\frac{5}{8}$	20	9	6.24	7.2	6.86
$\frac{3}{4}$	22.5	10	5.62	6.5	6.18
$\frac{7}{8}$	25	11	5	5.8	5.5
$\frac{15}{16}$	27.5	12	4.38	5.08	4.81
$\frac{1}{16}$	30	13	3.75	4.34	4.19
$\frac{1}{8}$	35	14	3.12	3.6	3.43
$\frac{1}{4}$	40	15	2.48	2.97	2.9
Thickness in parts of an inch.		Thickness by the wire gauge.			
1	40	No.	Iron.	Copper.	Brass.
$\frac{1}{2}$	125	16	2.5	2.9	2.75
$\frac{3}{8}$	9.5	17	2.18	2.62	2.4
$\frac{1}{4}$	5	18	1.86	2.15	2.04
$\frac{5}{16}$	7.5	19	1.7	1.97	1.87
$\frac{3}{16}$	13	20	1.54	1.78	1.69
$\frac{1}{8}$	19.5	21	1.4	1.62	1.54
$\frac{7}{16}$	15	22	1.25	1.45	1.37
$\frac{1}{2}$	17.5	23	1.12	1.3	1.23
$\frac{5}{8}$	20	24	1	1.16	1.1
$\frac{3}{4}$	22.5	25	.9	1.04	.99
$\frac{7}{8}$	25	26	.8	.92	.88
$\frac{15}{16}$	27.5	27	.72	.83	.79
$\frac{1}{16}$	30	28	.64	.74	.7
$\frac{1}{8}$	35	29	.56	.64	.61
$\frac{1}{4}$	40	30	.5	.58	.55

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

"	4	"	$\frac{1}{16}$	"
"	7	"	$\frac{1}{8}$	"
"	11	"	$\frac{3}{16}$	"
"	16	"	$\frac{1}{4}$	"
"	22	"	$\frac{5}{16}$	"

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

## 192 COMPARATIVE WEIGHTS OF BODIES.

being that of a common sheet, so designated, viz., 4 feet by 2 feet, in lbs., thus:—

A 70 lb. plate is	$\frac{3}{16}$ ths	of an inch in thickness.	307
" 46½ "	" "	" "	" "
" 23 "	" "	" "	" "
" 11½ "	" "	" "	" "
" 6 "	" "	" "	" "

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 lbs. lead is	$\frac{1}{16}$ th	of an inch in thickness.
6 " " "	" "	" " " " "
7½ " " "	" "	" " " " "
11 " " "	" "	" " " " "
15 " " "	" "	" " " " "

## COMPARATIVE WEIGHTS OF DIFFERENT BODIES.

Bar iron being 1,	Cast iron being 1,
Cast iron = .95	Bar iron = 1.07
Steel = 1.02	Steel = 1.08
Copper = 1.16	Brass = 1.16
Brass = 1.09	Copper = 1.21
Lead = 1.48	Lead = 1.56

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

$$728 \times 1.16 = 844.48 \text{ lbs.}$$

2. A model of dry pine, weighing 32½ lbs., and in which the iron for its construction forms no material portion of the weight, what may I anticipate its weight to be in cast iron?

$$32.5 \times 16 = 520 \text{ lbs.}$$

*Note.*—It frequently occurs, in the formation or construction of models, that neither the quality nor condition of the timber can be properly estimated; and, in such cases, it may be a near enough approximation to reckon 15 lbs. of cast iron to each lb. of model.

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

Thickness in parts of an inch.	Wrought iron.	Copper.		Lead.	
		lbs.	lbs.	lbs.	lbs.
$\frac{1}{32}$	.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	9½ " "	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  $7\frac{1}{4}$  inches, its length  $6\frac{1}{2}$  feet, and the metal  $\frac{1}{8}$  of an inch in thickness.

$$7.5 + .125 = 7.625 \times 1.52 \times 6.25 = 72.4 \text{ lbs.}$$

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

$$3 + .25 = 3.25 \times 3.867 \times 18.5 = 232.5 \text{ lbs.}$$

*Note.*—Weight of a cubic inch of

Lead	equal	.4103	lb.
Copper, sheet	"	.3225	"
Brass, do.	"	.3057	"
Iron, do.	"	.279	"
Iron, cast	"	.263	"
Tin, do.	"	.2636	"
Zinc, do.	"	.26	"
Water	"	.03617	"

WEIGHT OF CAST IRON BALLS. AT

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
2½	1-57	6½	33-62	10½	148-28
2¾	2-15	6¾	37-80	10¾	159-40
3	2-86	7	42-35	11	171-06
3¼	3-72	7¼	47-21	11¼	183-29
3½	4-71	7½	52-47	11½	196-10
3¾	5-80	7¾	58-06	11¾	209-43
4	7-26	8	64-09	12	223-40
4¼	8-81	8¼	70-49	12¼	237-94
4½	10-57	8½	77-32	12½	253-13
4¾	12-55	8¾	84-56	12¾	268-97
5	14-76	9	92-24	13	285-37
5¼	17-12	9¼	100-39	13¼	302-41
5½	19-93	9½	108-98	13½	320-80
5¾	22-91	9¾	118-06	13¾	338-81
6	26-18	10	127-63	14	357-93

1. What will be the weight of a hollow ball or shell of cast iron, the external diameter being 9½, and internal diameter 8¾ inches?

Opposite 9½ are 118-06, and  
Opposite 8¾ 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 6½ 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 132.)

Then  $\frac{6.5^3}{1.56} = \sqrt[3]{176} = 5.6$  inches, the diameter.

The weights of Balls are as the cubes of their diameters:

$$D^3 \times 1.1 \div 8 = \text{Weight in lbs. Cast Iron}$$

$$2^3 = 8 \quad 110 \text{ lbs.} \div 8 = 216$$

$$216 \times 1.1 = 237.6 \div 8 = 29.7 \text{ lbs.}$$

$$29.7 \div 1.1 = 27 \text{ lbs.}$$

## TIMBER MEASURE.

**TABLES BY WHICH TO FACILITATE THE MEASUREMENT OF TIMBER.**

### 1. Flat or Board Measure.

*+ ... each foot ...*

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

" 12 = 1.0000

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

1. Required the number of square feet in a board or plank 16 1/2 feet in length, and 9 1/4 inches in breadth.

Opposite 9 1/4 is .8125  $\times$  16.5 = 13.4 square feet.

2. A board 1 foot 2 1/4 inches in breadth, and 21 feet in length; what is its superficial content in square feet?

Opposite 2 1/4 is .2292, to which add the 1 foot.

Then 1.2292  $\times$  21 = 25.8 square feet.

3. In a board 15 1/2 inches at one end, 9 inches at the other, and 14 1/2 feet in length, how many square feet?

$$\frac{15.5 + 9}{2} = 12 \frac{1}{2}, \text{ or } 1.0208; \text{ and } 1.0208 \times 14.5 = 14.8 \text{ sq. ft.}$$

*+ These Areas are the Decimals of a foot ...*

## 2. Cubic or Solid Measure.

Mean ½ girth in inches.	Cubic ft. in each lineal ft.	Mean ½ girth in inches.	Cubic ft. in each lineal ft.	Mean ½ girth in inches.	Cubic ft. in each lineal ft.
6	·25	14	1·361	22	3·362
6½	·272	14½	1·41	22½	3·438
6¾	·294	14¾	1·46	22¾	3·516
6¾	·317	14¾	1·511	22¾	3·598
7	·340	15	1·562	23	3·673
7½	·364	15½	1·615	23½	3·754
7¾	·39	15¾	1·668	23¾	3·835
7¾	·417	15¾	1·722	23¾	3·917
8	·444	16	1·777	24	4
8½	·472	16½	1·833	24½	4·084
8¾	·501	16¾	1·89	24¾	4·168
8¾	·531	16¾	1·948	24¾	4·254
9	·562	17	2·006	25	4·34
9½	·594	17½	2·066	25½	4·428
9¾	·626	17¾	2·126	25¾	4·516
9¾	·659	17¾	2·187	25¾	4·605
10	·694	18	2·25	26	4·694
10½	·73	18½	2·313	26½	4·785
10¾	·766	18¾	2·376	26¾	4·876
10¾	·803	18¾	2·442	26¾	4·969
11	·84	19	2·506	27	5·062
11½	·878	19½	2·574	27½	5·158
11¾	·918	19¾	2·64	27¾	5·252
11¾	·959	19¾	2·709	27¾	5·348
12	1	20	2·777	28	5·444
12½	1·042	20½	2·898	28½	5·542
12¾	1·085	20¾	2·917	28¾	5·64
12¾	1·129	20¾	2·99	28¾	5·74
13	1·174	21	3·062	29	5·84
13½	1·219	21½	3·136	29½	5·941
13¾	1·265	21¾	3·209	29¾	6·044
13¾	1·313	21¾	3·285	29¾	6·146

30

6·250

also in addition in the beginning  
of the

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  $21\frac{1}{2}$  inches, and its length 16 feet, what are its contents in cubic feet?

$$3.136 \times 16 = 50.176 \text{ cubic feet.}$$

$$\pi r^2 h = 0.785 d^2 h$$

$$\frac{h^2 h}{11 \times 8} = 0.785 h^2 h$$

## CAST METAL CYLINDERS.

The cylinders are solid, each 1 foot in length.

Diam.	Iron.	Copper.	Brass.	Lead.
inches.	lbs.	lbs.	lbs.	lbs.
1	2.5	3.0	2.9	3.9
2	9.8	12.0	11.4	15.5
3	22.1	27.0	25.8	34.8
4	39.3	47.9	45.8	61.9
5	61.4	74.9	71.6	96.7
6	88.4	107.8	103.0	139.3
7	120.3	146.8	140.2	189.6
8	157.1	191.7	183.2	247.7
9	198.8	242.7	231.8	313.4
10	245.4	299.5	286.2	387.0

## CAST IRON PIPES.

This table shows the weight of pipes 1 foot long, of bores from 1 inch to 12 inches in diameter, advancing by  $\frac{1}{2}$  of an inch; and of thicknesses from  $\frac{1}{4}$  of an inch to  $1\frac{1}{2}$  inches, advancing by  $\frac{1}{4}$  of an inch.

*Formulae:*  
 $D = \text{diameter in inches}$   
 $D^2 \times 0.00000785 \times L = \text{cubic contents}$   
 $Circumference \times 0.00000785 \times L = \text{...}$

## CAST IRON PIPES.

*Weight of*  
*Diam. thickness of the metal of pipes*

bore.	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$
in.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	3.1	5.1	7.4	10.0	12.9	16.1	19.6	23.5	27.6
1 $\frac{1}{4}$	3.7	6.0	8.6	11.5	14.7	18.3	22.1	26.2	30.7
1 $\frac{1}{2}$	4.3	6.9	9.8	13.0	16.6	20.4	24.5	29.0	33.7
1 $\frac{3}{4}$	4.9	7.8	11.1	14.6	18.4	22.6	27.0	31.8	36.8
2	5.5	8.8	12.3	16.1	20.3	24.7	29.5	34.5	39.9
2 $\frac{1}{4}$	6.1	9.7	13.5	17.6	22.1	26.8	31.9	37.3	43.0
2 $\frac{1}{2}$	6.7	10.6	14.7	19.2	23.9	28.9	34.4	40.0	46.0
2 $\frac{3}{4}$	7.4	11.5	16.0	20.7	25.7	31.1	36.8	42.8	49.1
3	8.0	12.4	17.2	22.2	27.6	33.3	39.3	45.6	52.2
3 $\frac{1}{4}$	8.6	12.3	18.4	23.8	29.5	35.4	41.7	48.3	55.2
3 $\frac{1}{2}$	9.2	14.2	19.6	25.3	31.3	37.6	44.2	51.1	58.3
3 $\frac{3}{4}$	9.8	15.2	20.9	26.9	33.1	39.7	46.6	53.8	61.4
4	10.4	16.1	22.1	28.4	35.0	41.9	49.1	56.6	64.4
4 $\frac{1}{4}$	11.1	17.1	23.4	30.0	36.9	44.1	51.6	59.4	67.6
4 $\frac{1}{2}$	11.7	18.0	24.5	31.4	38.7	46.2	54.0	62.1	70.6
4 $\frac{3}{4}$	12.3	18.9	25.8	33.0	40.5	48.3	56.5	64.9	73.6
5	12.9	19.8	27.0	34.5	42.3	50.5	58.9	67.6	76.7
5 $\frac{1}{4}$	13.5	20.7	28.2	36.1	44.2	52.6	61.4	70.4	79.8
5 $\frac{1}{2}$	14.1	21.6	29.5	37.6	46.0	54.8	63.8	73.2	82.8
5 $\frac{3}{4}$	14.7	22.6	30.7	39.1	47.9	56.9	66.3	76.0	85.9
6	15.3	23.5	31.9	40.7	49.7	59.1	68.7	78.7	88.8
6 $\frac{1}{4}$	16.0	24.4	33.1	42.2	51.5	61.2	71.2	81.2	92.0
6 $\frac{1}{2}$	16.6	25.3	34.4	43.7	53.4	63.4	73.4	84.2	95.1
6 $\frac{3}{4}$	17.2	26.2	35.6	45.3	55.2	65.3	76.1	87.0	98.2
7	17.8	27.2	36.8	46.8	56.8	67.7	78.5	89.7	101.2
7 $\frac{1}{4}$	18.4	28.1	38.1	48.1	58.9	69.8	81.0	92.5	104.2
7 $\frac{1}{2}$	19.0	29.0	39.1	49.9	60.7	72.0	83.5	95.3	107.4
7 $\frac{3}{4}$	19.6	29.7	40.5	51.4	62.6	74.1	85.9	98.0	110.5
8	20.0	30.8	41.7	52.9	64.4	76.2	88.4	100.8	113.5
8 $\frac{1}{4}$	20.9	31.7	43.0	54.5	66.3	78.4	90.8	103.5	116.6
8 $\frac{1}{2}$	21.7	32.9	44.4	56.2	68.3	80.8	93.5	106.5	119.9
8 $\frac{3}{4}$	22.1	33.6	45.4	57.5	70.0	82.7	95.7	109.1	123.7
9	22.7	34.5	46.6	59.1	71.8	84.8	98.2	111.8	125.6
9 $\frac{1}{4}$	23.3	35.4	47.9	60.6	73.6	87.0	100.6	114.6	128.9
9 $\frac{1}{2}$	23.9	36.4	49.1	62.1	75.5	89.1	103.1	117.4	131.9
9 $\frac{3}{4}$	24.6	37.3	50.3	63.7	77.3	91.3	105.5	120.1	135.0
10	25.2	38.2	51.5	65.2	79.2	93.4	108.0	122.8	138.1
10 $\frac{1}{4}$	25.8	39.1	52.8	66.7	81.0	95.6	110.4	125.6	141.1
10 $\frac{1}{2}$	26.4	40.0	54.0	68.3	82.8	97.7	112.9	128.4	144.2
10 $\frac{3}{4}$	27.0	41.0	55.2	69.8	84.7	99.9	115.4	131.2	147.3
11	27.6	41.9	56.5	71.3	86.5	102.0	117.8	133.9	150.3
11 $\frac{1}{4}$	28.2	42.8	57.7	72.9	88.4	104.2	120.3	136.7	153.4
11 $\frac{1}{2}$	28.8	43.7	58.9	74.4	90.2	106.3	122.7	139.4	156.4
11 $\frac{3}{4}$	29.5	44.6	60.1	75.9	92.0	108.5	125.2	142.2	159.6
12	30.1	45.6	61.4	77.5	93.6	110.6	127.6	145.0	162.6

TABLE FOR COMPOSITIONS OF BRASS, &amp;c.

3	parts	copper,	0	tin,	1	zinc,	for	yellow	brass.	
2	"	"	0	"	1	"	for	Spelter.		
4	"	"	1	"	$\frac{1}{2}$	"	for	lathe	bushes.	
4	"	"	1	"	$\frac{1}{3}$	"	still	harder.		
6	"	"	1	"	0	"	for	bearings	of	shafts.
5	"	"	1	"	$\frac{1}{2}$	"	for	harder	bearings.	
7	"	"	1	"	0	"	fit	for	pulley	blocks.
8	"	"	1	"	0	"	fit	for	wheels.	
9	"	"	1	"	0	"	gun	metal.		

The effect of different degrees of heat on different bodies, according to Fahrenheit's scale, are shown below:—

	Degrees.
Cast iron thoroughly melted, . . . . .	20577
Cast iron begins to melt, . . . . .	17977
Greatest heat of a common smith's forge, . . . . .	17327
Flint glass furnace, strongest heat, . . . . .	15897
Welding heat of iron, greatest, . . . . .	13427
Swedish copper melts, . . . . .	4587
Brass melts, . . . . .	3807
Iron red-hot in the twilight, . . . . .	884
Heat of a common fire, . . . . .	790
Iron bright red in the dark, . . . . .	752
Zinc melts, . . . . .	700
Mercury boils, . . . . .	672
Lead melts, . . . . .	594
The surface of polished steel becomes uniformly a deep blue, . . . . .	580
The surface of polished steel becomes a pale straw color, . . . . .	460
A mixture of 3 tin and 2 lead melts, . . . . .	332

## CENTRE,

In a general sense, denotes a point equally remote from the extremes of a line, surface, or solid.

## CENTRE OF ATTRACTION

Of a body, is that point into which, if all its matter is collected, its action upon any remote particle would still be the same.

## CENTRE OF EQUILIBRIUM

Is the same, in respect to bodies immersed in a fluid, as the centre of gravity is to bodies in free space.

## CENTRE OF FRICTION

Is that point in the base of a body on which it revolves, into which, if the whole surface of the base and the mass of the body were collected, and made to revolve about the centre of the base of the given body, the angular velocity destroyed by its friction would be equal to the angular velocity destroyed in the given body by its friction in the same time.

## CENTRE OF GRAVITY

Of any body, or system of bodies, is that point upon which the body, or system of bodies, acted upon only by the force of gravity, will balance itself in all positions; hence it follows, that, if a line or plane, passing through the centre of gravity, be supported, the body or system will be also supported.

## CENTRE OF GYRATION

Is that point into which, if the whole mass were collected, a given force, applied at a given distance, would produce the same angular velocity in the same time as if the bodies were disposed at their respective distances.

This point differs from the *Centre of Oscillation* only in this, that, in the latter case, the motion is produced

by the gravity of the body ; but, in the former, the body is put in motion by some other force, acting at one place only.

## COHESION

Is that species of attraction which, uniting particle to particle, retains together the component parts of the same mass ; being thus distinguished from *adhesion*, or that species of attraction which takes place between the surfaces of similar or dissimilar bodies. The absolute cohesion of solids is measured by the force necessary to pull them asunder. Thus, if a rod of iron be suspended in a vertical position, having weight attached to its lower extremity till the rod breaks, the whole weight attached to the rod, at the time of fracture, will be the measure of its cohesive force, or absolute cohesion.

The particles of solid bodies, in their natural state, are arranged in such a manner, that they are in equilibrium in respect to the forces which operate on them ; therefore, when any new force is applied, it is evident that the equilibrium will be destroyed, and that the particles will move among themselves till it be restored. When the new force is applied to pull the body asunder, the body becomes longer in the direction of the force, which is called the *extension* ; and its area, at right angles to the direction of the force, contracts. When the force is applied to compress the body, it becomes shorter in the direction of the force, which is called the *compression* ; and the area of its section, at right angles to the force, expands. In either case, a part of the heat, or any fluid that occupies the pores or interstices of the body, before the new force was made to act upon it, will be expelled.

## CASE-HARDENING.

The hardness and polish of steel may be united, in a certain degree, with the firmness and cheapness of

malleable iron, by what is called *case-hardening*; an operation much practised, and of considerable use.

It is a superficial conversion of iron into steel, and only differs from *cementation* in being carried on for a shorter time. Some artists pretend to great secrets in the practice of this art, using saltpetre, sal-ammoniac, and other fanciful ingredients, to which they attribute their success. But it is now an established fact, that the greatest effect may be produced by a perfectly tight box, and animal carbon alone.

The goods intended to be case-hardened, being previously finished, with the exception of polishing, are stratified with animal carbon, and the box containing them luted with equal parts of sand and clay. They are then placed in the fire, and kept at a light red heat for half an hour, when the contents of the box are emptied into water. Delicate articles, like files, may be preserved by a saturated solution of common salt, with any vegetable mucilage, to give it a pulpy consistence. The carbon here spoken of is nothing more than any animal matter, such as horns, hoofs, skins, or leather, just sufficiently burned to admit of being reduced to powder. The box is commonly made of iron, but the use of it, for occasional case-hardening upon a small scale, may easily be dispensed with, as it will answer the same end to envelop the articles with the composition above directed to be used as a lute, drying it gradually before it is exposed to a red heat, otherwise it will probably crack. It is easy to infer, that the depth of the steel, induced by case-hardening, will vary with the time the operation is continued. It may be varied from one hour to four, according to the depth of steel required. In one hour, it will scarcely be the thickness of a fourpence, and therefore may be removed by violent abrasion, though sufficient to answer well for fire-irons, and a multitude of other utensils, in the common usage of which its hardness prevents its being easily scratched, and its polish preserved by friction with so soft a material as leather.



*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 min.	Length of stroke in feet.	Velocity in feet per minute.	Number of revolutions per min.
2	160	40	1½	186	62
2½	177½	35½	2	200	50
3	192	32	2½	212½	42½
3½	208	29	2¾	217½	39½
4	214	26½	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	24½
7	245	17½	5½	253	23
8	256	16	6	264	22

*Of the Parallel Motion in a Steam-Engine.*

When the power from the piston is communicated by means of a beam or lever moving upon an axis, the parallel motion becomes a very important portion of the machine; for then it forms the link of connection, and by its properties renders the action of alternate circular motion, and reciprocating vertical motion, mutually agreeable, thereby properly insuring to the piston rod a truly direct line to that of the cylinder; but to effect this, the greatest degree of exactitude of the various parts is required, otherwise extra friction is created, and the effective power of the engine proportionately diminished.



## 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 re-

quired. Thus, the log. of 450 is 2.653213, and the log. of 7464 is 3.872972. Or, the log. of 378.5 is 2.576066, 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.

$$\begin{array}{r} \text{Given logarithm} \quad . . . = 3.233568 \\ \text{Next less is the log. of } 1712 = 3.233504 \end{array}$$

$$\text{Remainder} \quad \quad \quad 64$$

$$\text{Tab. Diff.} = 253, \text{ and } \frac{64}{253} = .25$$

$$\text{Hence the number required} = 1712.25.$$

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 25791.

$$\text{Log. of } 25791 = 1.411468$$

Multiplied by  $\frac{\quad}{2}$  the power required.

Logarithm  $\frac{2.822936}{\quad}$  indicated number or square required = 665175.

**Ex. 2.** What is the cube of 307146?

$$\text{Logarithm} = 1.487345$$

Multiplied by  $\frac{\quad}{3}$  the power required.

Logarithm  $\frac{4.462035}{\quad}$  indicated number or cube required = 289757.

**Ex. 3.** Required the square root of 365.

$$\text{Log.} = \frac{2.562293}{2} = 1.281146 \text{ indicated number or root} = 19.105.$$

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

$$\text{Log.} = \frac{4.091491}{3} = 1.363830 \text{ indicated number or root} = 23.1116.$$

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."

TABLE — WATER IN PIPES.

This table shows the quantity and weight of water contained in one fathom of length of pipes of different bores from 1 inch to 12 inches in diameter, advancing by half inch. The weight of a cubic foot of water is taken at 1000 ounces avoirdupois, and the imperial gallon at 10 lbs.

*In a length of Six feet*

Diameter in inches.	Quantity in cubic inches.	Quantity in imperial gallons.	Weight in lbs. avoirdupois.
$\frac{1}{2}$	14.14	0.051	0.51
1	56.55	0.205	2.05
$1\frac{1}{2}$	127.23	0.460	4.60
2	226.19	0.818	8.18
$2\frac{1}{2}$	353.43	1.278	12.78
3	508.94	1.841	18.41
$3\frac{1}{2}$	692.72	2.506	25.06
4	904.78	3.272	32.72
$4\frac{1}{2}$	1145.11	4.142	41.42
5	1413.72	5.113	51.13
$5\frac{1}{2}$	1710.60	6.187	61.87
6	2035.75	7.363	73.63
$6\frac{1}{2}$	2389.18	8.641	86.41
7	2770.88	10.022	100.22
$7\frac{1}{2}$	3180.86	11.505	115.05
8	3619.11	13.090	130.90
$8\frac{1}{2}$	4085.64	14.777	147.77
9	4580.44	16.567	165.67
$9\frac{1}{2}$	5103.52	18.459	184.59
10	5654.87	20.453	204.53
$10\frac{1}{2}$	6234.49	22.550	225.50
11	6842.39	24.748	247.48
$11\frac{1}{2}$	7478.56	27.049	270.49
12	8143.01	29.452	294.52

*See p. 95.*

6' 11" 142  
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### CHANGES INDUCED IN THE STRUCTURE OF IRON SUBSEQUENT TO MANUFACTURE.

The important purposes to which iron is applied have always rendered it a subject of peculiar interest; and at no period has its importance been so general and extensive as at the present time, when its application is almost daily extending, and there is scarcely any thing connected with the arts to which, either directly or indirectly, it does not in some degree contribute. My object is to point out some peculiarities in the habitudes of iron, which appear to have almost wholly escaped the attention of scientific men, and which, although in some degree known to practical mechanics, have been generally considered by them as isolated facts, and not regarded as the results of a general law. The circumstances, however, well deserve the attention of scientific men, on account of the very important consequences to which they lead.

The two great distinctions, which exist in malleable wrought iron, are known by the names of *red-short* and *cold-short* qualities. The former of these comprises the tough, fibrous iron, which generally possesses considerable strength when cold; the latter shows a bright, crystallized fracture, and is very brittle when cold, but works ductile while hot. These distinctions are perfectly well known to all those who are conversant with the qualities of iron; but it is not generally known that there are several ways by which the tough, red-short iron becomes rapidly converted into the crystallized; and that, by this change, its strength is diminished to a very great extent. The importance which attaches to this subject will not be denied. The principal causes which produce this change are percussion, heat, and magnetism; and it is doubtful whether either of these means will produce this effect; and there appear strong reasons for supposing that, generally, they are all in

some degree concerned in the production of the observed results. The most common exemplification of the effect of heat, in crystallizing fibrous iron, is by breaking a wrought-iron furnace-bar; which, whatever quality it was of in the first instance, will, in a short time, invariably be converted into crystallized iron; and, by heating, and rapidly cooling by quenching with water a few times, any piece of wrought iron, the same effect may be far more speedily produced. In these cases, we have at least two of the above causes in operation—heat and magnetism. In every instance of heating iron to a very high temperature, it undergoes a change in its electric or magnetic condition; for, at very high temperatures, iron entirely loses its magnetic powers, which return, as it gradually cools to a lower temperature. In the case of quenching the heated iron with water, we have a still more decisive assistance from the electric and magnetic forces; for Sir Humphrey Davy long since pointed out, that all cases of vaporization produced negative electricity in the bodies in contact with the vapor;—a fact which has lately excited a good deal of attention, in consequence of the discovery of large quantities of negative electricity in effluent steam. These results, however, are practically of but little consequence; but the effects of percussion are at once various, extensive, and of high importance. We shall trace these effects under several different circumstances.

In the manufacture of some descriptions of hammered iron, the bar is first rolled into shape, and then one-half the length of the bar is heated in a furnace, and immediately taken to the tilt-hammer and hammered; and the other end of the bar is then heated and hammered in the same manner. In order to avoid any unevenness in the bar, or any difference in its color where the two distinct operations have terminated, the workman frequently gives the bar a few blows with the hammer on that part which he first operated upon. That part of the bar has, however, by this time,

## 154 CHANGES IN THE STRUCTURE OF IRON.

become comparatively cold; and, if this cooling process has proceeded too far when it receives this additional hammering, that part of the bar immediately becomes crystallized, and so extremely brittle that it will break to pieces by merely throwing it on the ground, though all the rest of the bar will exhibit the best and toughest quality imaginable. This change, therefore, has been produced by percussion as the primary agent. We here see the effects of percussion in a very instructive form. And it must be observed, that it is not the excess of hammering which produces the effect, but the absence of a sufficient degree of heat at the time the hammering takes place; and the evil may probably be all produced by five or six blows of the hammer, if the bar happens to be of a small size. In this case, we witness the combined effects of percussion, heat, and magnetism. When the bar is hammered at the proper temperature, no such crystallization takes place, because the bar is insensible to magnetism; but, as soon as the bar becomes of that lower degree of temperature at which it can be affected by magnetism, the effect of the blows it receives is to produce magnetic induction; and that magnetic induction, and consequent polarity of its particles, when assisted by further vibrations from additional percussion, produces a crystallized texture. For it is perfectly well known that, in soft iron, magnetism can be almost instantaneously produced by percussion; and it is probable that, the higher the temperature of the bar at the time it receives the magnetism, the more likely will it be to allow of that rearrangement of its molecules which would constitute the crystallization of the iron. It is not difficult to produce the same effects by repeated blows from a hand-hammer on small bars of iron; but it appears to depend upon something peculiar in the blow, which, to produce the effect, must occasion a complete vibration among the particles in the neighborhood of the part which is struck. And it is remarkable that the effects of the blows, in all cases,

seem to be confined within certain limited distances of the spot which receives the strokes.

Dr. Wollaston first pointed out that the forms in which native iron is disposed to break, are those of the regular octahedron and tetrahedron, or rhomboid, consisting of these forms combined. The tough and fibrous character of wrought iron is entirely produced by art; and we see, in these changes that have been described, an effort at returning to the natural and primal form;—the crystalline structure, in fact, being the natural state of a large number of metals;—and Sir Humphrey Davy has shown, that all those which are fusible by ordinary means assume the form of regular crystals by slow cooling. The general conclusion, to which these remarks lead us, appears to leave no doubt that there is a constant tendency in wrought iron, under certain circumstances, to return to the crystallized state; but that this crystallization is not necessarily dependent upon time for its development, but is determined solely by other circumstances, of which the principal is, undoubtedly, vibration. Heat, within certain limits, though greatly assisting the rapidity of the change, is certainly not essential to it; but magnetism, induced either by percussion or otherwise, is an essential accompaniment of the phenomena attending the change.

## STRENGTH OF JOURNALS OF SHAFTS.

Mr. Buchanan's rule is—The cube root of the weight in cwts. is nearly equal to the diameter of the journal;—it being prudent to make the journal a little more than less, and to make a due allowance for wearing.

*Ex.* What is the diameter of a journal of a water-wheel shaft, 13 feet long, the weight of the wheel being 15 tons?

By Mr. B.'s rule,

$$\sqrt[3]{15 \times 20} = 6.7, \text{ or } 7 \text{ inches diameter.}$$

By Mr. Tredgold's rule,

$$\text{Weight in the middle, } \frac{3360}{500} \times 13 = 873 \sqrt[3]{873} = 9\frac{1}{2} \text{ inches diameter.}$$

$$\text{Weight equally distributed, } 33600 \times 13 = 436800 \sqrt[3]{\frac{436800}{10}} = 7.65 \text{ inches.}$$

*To resist Torsion or Twisting.*

It is obvious that the strength of revolving shafts\* are directly as the cubes of their diameters and revolutions; and inversely, as the resistance they have to overcome.

Mr. Robertson Buchanan, in his essay on the Strength of Shafts, gives the following data, deduced from several experiments, viz.: That the fly-wheel shaft of a 50-horse-power engine, at 50 revolutions per minute, requires to be  $7\frac{1}{2}$  inches diameter; and therefore, the cube of this diameter, which is = 421.875, serves as a multi-

\* Shafts, here, are understood as the journals of shafts, the bodies of shafts being generally made square.

plier to all other shafts in the same proportion; and, taking this as a standard, he gives the following multipliers, viz. : —

For the shaft of a steam-engine, water-wheel, or any shaft connected with a first power, . . . . .	400
For shafts in inside of mills, to drive smaller machinery, or connected with the shafts above, . . . . .	200
For the small shafts of a mill or machinery, . . . . .	100

From the foregoing, the following rule is derived, viz. : The number of horses' power a shaft is equal to, is directly as the cube of the diameter and number of revolutions; and inversely, as the above multipliers.

*Ex. 1.* When the fly-wheel shaft of a 45-horse-power steam-engine makes 90 revolutions per minute, what is the diameter of the journal ?

$$\frac{45 \times 400}{90} = 200 \quad \sqrt[3]{200} = 5\frac{8}{10} \text{ inches diameter.}$$

*Ex. 2.* The velocity of a shaft is 80 revolutions per minute, and its diameter is 3 inches; what is its power ?

$$\frac{3^3 \times 80}{400} = 5.4 \text{ horses' power.}$$

*Ex. 3.* What will be the diameter of the shaft in the first example, when used as a shaft of the second multiplier ? \*

$$\frac{5.8}{1.25} = 4.64, \text{ or } \frac{\sqrt[3]{45 \times 200}}{90} = 4\frac{6}{10} \text{ inches diameter.}$$

The following is a table of the diameters of shafts, being the first movers, or having 400 for their multipliers.

\* The diameters of the second movers will be found by dividing the numbers in the Table by 1.25, and the diameters of the third movers, by dividing the numbers by 1.56.

## DIAMETERS OF THE

Horse Power.	Revolutions.									
	10	15	20	25	30	35	40	45	50	55
	Inches Diameter.									
4	5.5	4.8	4.5	4.	3.7	3.8	3.5	3.3	3.2	3.1
5	5.9	5.1	4.7	4.4	4.1	3.9	3.7	3.6	3.5	3.3
6	6.3	5.5	5.	4.6	4.4	4.1	4.	3.8	3.7	3.6
7	6.6	5.8	5.2	4.9	4.6	4.4	4.2	4.	3.9	3.7
8	6.9	6.	5.5	5.1	4.8	4.6	4.4	4.2	4.1	4.
9	7.2	6.3	5.7	5.5	5.	4.8	4.5	4.4	4.2	4.1
10	7.4	6.6	5.9	5.6	5.2	4.9	4.7	4.6	4.4	4.2
12	7.9	6.9	6.3	5.8	5.6	5.4	5.2	5.	4.8	4.6
14	8.3	7.2	6.7	6.2	5.9	5.6	5.4	5.2	5.	4.7
16	8.7	7.6	7.1	6.6	6.1	5.8	5.6	5.4	5.2	5.
18	9.	7.9	7.5	7.	6.6	6.2	5.8	5.6	5.4	5.2
20	9.3	8.1	7.7	7.2	6.8	6.4	5.9	5.7	5.6	5.4
25	10.	8.5	8.	7.4	7.1	6.8	6.3	6.	5.9	5.6
30	10.7	9.3	8.4	7.9	7.4	7.1	6.9	6.7	6.5	6.3
35	11.4	9.8	8.9	8.4	7.9	7.4	7.1	6.9	6.6	6.5
40	11.7	10.5	9.3	8.8	8.3	7.8	7.4	7.2	6.9	6.7
45	12.	10.6	9.7	9.2	8.7	8.1	7.6	7.4	7.	6.8
50	12.6	11.	10.	9.3	9.	8.5	8.	7.8	7.4	7.3
55	13.4	11.4	10.4	9.8	9.1	8.8	8.4	8.	7.5	7.4
60	13.6	12.	10.8	10.	9.3	9.	8.6	8.2	7.7	7.6

Stones Per Hr.	Revolutions.									
	60	65	70	75	80	85	90	95	100	105
	Inches Diameter.									
4	3.	2.9	2.9	2.8	2.7	2.7	2.6	2.6	2.6	2.5
5	3.3	3.2	3.1	3.	3.	2.9	2.9	2.8	2.8	2.7
6	3.5	3.5	3.4	3.3	3.2	3.2	3.	3.	2.9	2.9
7	3.6	3.6	3.5	3.4	3.4	3.3	3.3	3.2	3.1	3.1
8	3.9	3.8	3.7	3.6	3.5	3.5	3.4	3.4	3.3	3.2
9	4.	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.4	3.3
10	4.1	4.	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.4
12	4.4	4.3	4.2	4.1	4.	3.9	3.8	3.8	3.7	3.6
14	4.5	4.4	4.4	4.3	4.2	4.1	4.	4.	3.9	3.8
16	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.2	4.1	4.
18	5.	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.2
20	5.2	5.1	5.	4.8	4.6	4.6	4.5	4.5	4.4	4.4
25	5.5	5.4	5.3	5.2	5.1	4.9	4.8	4.7	4.6	4.6
30	5.9	5.8	5.7	5.6	5.5	5.3	5.2	5.1	5.	4.9
35	6.3	6.1	5.9	5.7	5.6	5.5	5.4	5.3	5.2	5.2
40	6.6	6.4	6.2	6.	5.9	5.8	5.7	5.6	5.6	5.5
45	6.7	6.5	6.4	6.2	6.1	6.	5.9	5.8	5.7	5.6
50	7.2	6.9	6.8	6.6	6.5	6.4	6.2	6.	5.9	5.8
55	7.3	7.2	7.	6.7	6.6	6.5	6.3	6.2	6.1	6.
60	7.4	7.3	7.2	6.9	6.8	6.8	6.7	6.6	6.4	6.2

It is a well known fact, that a cast iron rod will sustain more torsional pressure than a malleable iron rod of the same dimensions; that is, a malleable iron rod will be twisted by a less weight than what is required to wrench a cast iron rod of the same dimensions.

When the strength of malleable is less than that of cast iron to resist torsion, it is stronger than cast iron to resist lateral pressure, and that is in proportion as 9 is to 14.

From the foregoing, it is easy for the millwright to make his shafts of the iron best suited to overcome the resistance to which they will be subject, and the proportion of the diameters of their journals, according to the iron of which they are made.

*Ex.* What will be the diameter of a malleable iron journal to sustain an equal weight with a cast iron journal of 7 inches diameter.

$$7^3 = 343.$$

$$\Delta 14 : 343 :: 9 : 220\frac{1}{2}; \text{ now } \sqrt[3]{220.5} = 6.04 \text{ inches diameter.}$$

### STRENGTH OF WHEELS.

The arms of wheels are as levers fixed at one end, and loaded at the other; and, consequently, the greatest strain is upon the end of the arm next the axle. For that reason, all arms of wheels should be strongest at that part, and tapering toward the rim.

The rule for the breadth and thickness of arms, according to their length and number in the wheel, is as follows: Multiply the power or weight acting at the end of the arm by the cube of its length; the product of which, divided by 2656 times the number of arms multiplied by the deflection, will give the breadth, and cube of the depth.

*Ex.* Suppose the force acting at the circumference of a spur-wheel to be 1600 lbs., the radius of wheel 6

feet, and number of arms 8, and let the deflection not exceed  $\frac{1}{10}$ th of an inch.

$$\frac{1600 \times 6^3}{2656 \times 8 \times 1} = 163 = \text{breadth and cube of the depth}$$

Let the breadth be 2.5 inches; therefore,  $\frac{163}{2.5} = 65.2$ ;

which is equal to the cube of the depth. Now the cube root of 65.2 is nearly 4.03 inches: this, consequently, is the depth or dimension of each arm in the direction of the force.

*Note.* — When the depth at the rim is intended to be half that of the axes, use 1640 as a divisor instead of 2656.

The teeth are as beams, or cantilevers, fixed at one end and loaded at the other. The rule applying directly to them where the length of the beam is the length of the teeth, and the depth the thickness of the teeth. For the better explanation of the rule, the following example is given.

*Ex.* The greatest power acting at the pitch line of the wheel is 6000 lbs., and the thickness of the teeth  $1\frac{1}{2}$  inch, the length of the teeth being 0.25 feet; it is required to determine the breadth of the teeth.

$$\frac{6000 \times 0.25}{212 \times 1.5^3} = \frac{1500}{477} = 3.2 \text{ inches, the breadth required.}$$

In order that the teeth may be capable of offering a sufficient resistance after being worn by friction, the breadth thus found should be doubled; therefore, in the above example, the breadth should be 6.4, or say  $6\frac{1}{2}$  inches.

The following data are gleaned from experiments, which are, therefore, valuable, and of much use to the practical mechanic.

*Rule.* — Multiply the breadth of the teeth by the square of the thickness, and divide the product by the length; the quotient will be the proportional strength in horses' power, with a velocity of 2.27 feet per second.

*Ex.* What is the power of a wheel; the teeth of which are 6 inches broad, 1.5 inch thick, and 1.8 inch long, and revolving at the velocity of 3 feet per second?

$$\frac{.5^3 \times 6}{1.8} = \frac{13.5}{1.8} = 7.5, \text{ strength at 2.27 feet per second; then}$$

$$2.27 : 7.5 :: 3 = \frac{7.5 \times 3}{2.27} = 9.91 \text{ horses' power.}$$

*Rule.* — The pitch is found by multiplying the thickness by 2.1, and the length is found by multiplying the thickness by 1.2.

*Ex.* The thickness being 2 inches, what is the pitch and length?

$$2 \times 2.1 = 4.2, \text{ pitch.}$$

$$2 \times 1.2 = 2.4, \text{ length.}$$

*Note.* — The breadth of the teeth, as commonly executed by the best mechanics, seems to be from about twice to thrice the pitch.

Pitch in in.	Thickness in inches.	Breadth in inches.	Length in inches.	Horses' power, at 2.27 feet per second.	Horses' power, at 3 feet per second.	Horses' power, at 6 feet per second.
4.2	2.	8.	2.40	13.33	17.61	35.23
3.99	1.9	7.6	2.28	13.03	15.90	31.80
3.78	1.8	7.2	2.16	10.80	14.27	28.54
3.57	1.7	6.8	2.04	9.63	12.72	25.54
3.36	1.6	6.4	1.92	8.53	11.27	22.54
3.15	1.5	6.	1.80	7.50	9.91	19.82
2.94	1.4	5.6	1.68	6.53	8.63	17.26
2.73	1.3	5.2	1.56	5.63	7.44	14.88
2.52	1.2	4.8	1.44	4.80	6.34	12.68
2.31	1.1	4.4	1.32	4.03	5.32	10.64
2.10	1.	4.	1.20	3.33	4.40	8.81
1.89	.9	3.6	1.08	2.70	3.67	7.14
1.68	.8	3.2	.96	2.13	2.81	5.62
1.47	.7	2.8	.84	1.63	2.15	4.30
1.26	.6	2.4	.72	1.20	1.63	3.18
1.05	.5	2.	.60	.83	1.10	2.20

## TABLES

OF THE

## CIRCUMFERENCES OF CIRCLES,

TO THE

NEAREST FRACTION OF PRACTICAL MEASUREMENT;

ALSO THE

## AREAS OF CIRCLES

IN INCHES AND DECIMAL PARTS, LIKEWISE IN  
FEET AND DECIMAL PARTS, AS MAY BE  
REQUIRED.

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*Rules that may render the following Tables more generally useful.*

1. Any of the areas in inches multiplied by  $\cdot 04328$ , or the areas in feet multiplied by  $6\cdot 232$ , the product is the number of imperial gallons at 1 foot in depth.

2. Any of the areas in feet multiplied by  $\cdot 03704$ , 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  $\cdot 263$ , the product equal the weight in lbs. of cast iron.

*Note.*—The French cubic metre, or unit of solid measure, equal  $35\cdot 31716$  English cubic feet. Also the litre, or unit for measures of capacity, equal  $61\cdot 028$  English cubic inches, or about  $\cdot 463$  of an imperial gallon.

Dia. in inch.	Circum. in inch.	Area in sq. inch.	Side of = squ.	Dia. in inch.	Cir. in ft. - in.	Area in sq. inch.	Ar. in sq. ft.
$\frac{1}{8}$	.196	.0030	.554	3 in.	9 $\frac{3}{8}$	7.068	2 $\frac{1}{8}$
$\frac{1}{4}$	.392	.0122	.1107	3 $\frac{1}{8}$	9 $\frac{1}{4}$	7.669	2 $\frac{3}{8}$
$\frac{3}{8}$	.589	.0276	.1661	3 $\frac{1}{4}$	10 $\frac{1}{4}$	8.295	2 $\frac{7}{8}$
$\frac{1}{2}$	.785	.0490	.2115	3 $\frac{1}{2}$	10 $\frac{3}{8}$	8.946	3 in.
$\frac{5}{8}$	.981	.0767	.2669	3 $\frac{3}{8}$	11	9.621	3 $\frac{1}{8}$
$\frac{3}{4}$	1.178	.1104	.3223	3 $\frac{1}{2}$	11 $\frac{1}{8}$	10.320	3 $\frac{1}{4}$
$\frac{7}{8}$	1.374	.1503	.3771	3 $\frac{3}{4}$	11 $\frac{3}{8}$	11.044	3 $\frac{3}{8}$
$\frac{1}{2}$	1.570	.1963	.4331	3 $\frac{7}{8}$	12 $\frac{1}{8}$	11.793	3 $\frac{7}{8}$
$\frac{9}{8}$	1.767	.2485	.4995	4 in.	1 0 $\frac{1}{8}$	12.566	.0879
$\frac{5}{4}$	1.963	.3068	.5438	4 $\frac{1}{8}$	1 0 $\frac{1}{4}$	13.364	.0935
$1\frac{1}{8}$	2.159	.3712	.6093	4 $\frac{1}{4}$	1 1 $\frac{1}{8}$	14.186	.0993
$1\frac{1}{4}$	2.356	.4417	.6646	4 $\frac{1}{2}$	1 1 $\frac{1}{4}$	15.033	.1052
$1\frac{3}{8}$	2.552	.5185	.7200	4 $\frac{3}{8}$	1 2 $\frac{1}{8}$	15.904	.1113
$1\frac{1}{2}$	2.748	.6013	.7754	4 $\frac{1}{2}$	1 2 $\frac{1}{2}$	16.800	.1176
$1\frac{5}{8}$	2.945	.6903	.8308	4 $\frac{3}{4}$	1 3 $\frac{1}{8}$	17.720	.1240
						18.665	.1306
				5 in.	1 3 $\frac{3}{8}$	19.635	.1374
				5 $\frac{1}{8}$	1 4 $\frac{1}{8}$	20.629	.1444
1 in.	3 $\frac{1}{8}$	.7854	$\frac{7}{8}$	5 $\frac{1}{4}$	1 4 $\frac{1}{4}$	21.647	.1515
1 $\frac{1}{8}$	3 $\frac{1}{4}$	.9940	$7\frac{1}{8}$ & $\frac{3}{32}$	5 $\frac{1}{2}$	1 4 $\frac{3}{8}$	22.690	.1588
1 $\frac{1}{4}$	3 $\frac{3}{8}$	1.227	1 in.	5 $\frac{3}{8}$	1 5 $\frac{1}{8}$	23.758	.1663
1 $\frac{3}{8}$	4 $\frac{1}{8}$	1.484	$1\frac{1}{8}$	5 $\frac{1}{2}$	1 5 $\frac{3}{8}$	24.850	.1739
1 $\frac{1}{2}$	4 $\frac{1}{4}$	1.767	$1\frac{1}{4}$	5 $\frac{3}{4}$	1 6	25.967	.1817
1 $\frac{3}{4}$	4 $\frac{3}{8}$	2.074	$1\frac{3}{8}$	5 $\frac{7}{8}$	1 6 $\frac{1}{8}$	27.108	.1897
1 $\frac{5}{8}$	5 $\frac{1}{8}$	2.405	$1\frac{5}{8}$	6 in.	1 6 $\frac{3}{8}$	28.274	.1979
1 $\frac{3}{4}$	5 $\frac{1}{4}$	2.761	$1\frac{3}{4}$	6 $\frac{1}{8}$	1 7 $\frac{1}{8}$	29.464	.2062
				6 $\frac{1}{4}$	1 7 $\frac{3}{8}$	30.679	.2147
				6 $\frac{1}{2}$	1 8	31.919	.2234
				6 $\frac{3}{8}$	1 8 $\frac{1}{8}$	33.183	.2322
				6 $\frac{1}{2}$	1 8 $\frac{3}{8}$	34.471	.2412
				6 $\frac{5}{8}$	1 9 $\frac{1}{8}$	35.784	.2504
				6 $\frac{3}{4}$	1 9 $\frac{3}{8}$	37.122	.2598
2 in.	6 $\frac{1}{4}$	3.141	1 $\frac{1}{2}$	7 in.	1 10	38.484	.2693
2 $\frac{1}{8}$	6 $\frac{3}{8}$	3.546	1 $\frac{3}{8}$	7 $\frac{1}{8}$	1 10 $\frac{1}{8}$	39.871	.2791
2 $\frac{1}{4}$	7	3.976	2 in.	7 $\frac{1}{4}$	1 10 $\frac{1}{4}$	41.282	.2889
2 $\frac{3}{8}$	7 $\frac{1}{8}$	4.430	2 $\frac{1}{8}$	7 $\frac{3}{8}$	1 11 $\frac{1}{8}$	42.718	.2990
2 $\frac{1}{2}$	7 $\frac{3}{4}$	4.908	2 $\frac{3}{8}$	7 $\frac{1}{2}$	1 11 $\frac{1}{4}$	44.178	.3092
2 $\frac{3}{4}$	8 $\frac{1}{4}$	5.412	2 $\frac{5}{8}$	7 $\frac{3}{4}$	1 11 $\frac{3}{8}$	45.663	.3195
2 $\frac{5}{8}$	8 $\frac{3}{8}$	5.939	2 $\frac{7}{8}$	7 $\frac{5}{8}$	2 0	47.173	.3299
2 $\frac{3}{4}$	9	6.491	2 $\frac{7}{8}$	7 $\frac{7}{8}$	2 0 $\frac{1}{8}$	48.707	.3403

AREAS OF CIRCLES.

Dia. in inch.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.	Dia. in inch.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.
8 in.	2 11/16	50.265	.3518	13 in.	3 4 1/2	132.732	.9291
8 1/8	2 1 1/2	51.848	.3629	13 1/8	3 5 1/8	135.297	.9470
8 1/4	2 1 5/8	53.456	.3741	13 1/4	3 5 5/8	137.886	.9642
8 3/8	2 2 1/8	55.088	.3856	13 3/8	3 6	140.500	.9835
8 1/2	2 2 1/2	56.745	.3972	13 1/2	3 6 1/2	143.139	1.0019
8 5/8	2 3	58.426	.4089	13 5/8	3 6 5/8	145.802	1.0206
8 3/4	2 3 1/4	60.132	.4209	13 3/4	3 7	148.489	1.0294
8 7/8	2 3 3/8	61.862	.4330	13 7/8	3 7 1/2	151.201	1.0584
9 in.	2 4 1/4	63.617	.4453	14 in.	3 7 1/2	153.938	1.0775
9 1/8	2 4 1/2	65.396	.4577	14 1/8	3 8 1/8	156.699	1.0968
9 1/4	2 5	67.200	.4704	14 1/4	3 8 1/4	159.485	1.1193
9 3/8	2 5 1/8	69.029	.4832	14 3/8	3 9	162.295	1.1360
9 1/2	2 5 1/2	70.882	.4961	14 1/2	3 9 1/2	165.130	1.1569
9 5/8	2 6	72.759	.5093	14 5/8	3 9 5/8	167.989	1.1749
9 3/4	2 6 1/4	74.662	.5226	14 3/4	3 10 1/4	170.873	1.1961
9 7/8	2 7	76.588	.5361	14 7/8	3 10 3/4	173.782	1.2164
10 in.	2 7 1/2	78.540	.5497	15 in.	3 11 1/4	176.715	1.2370
10 1/8	2 7 3/4	80.515	.5636	15 1/8	3 11 1/2	179.672	1.2577
10 1/4	2 8	82.516	.5776	15 1/4	3 11 3/4	182.654	1.2785
10 3/8	2 8 1/8	84.540	.5917	15 3/8	4 0	185.661	1.2996
10 1/2	2 8 1/2	86.590	.6061	15 1/2	4 0 1/2	188.692	1.3208
10 5/8	2 9	88.664	.6206	15 5/8	4 1	191.748	1.3422
10 3/4	2 9 1/4	90.762	.6353	15 3/4	4 1 1/4	194.828	1.3637
10 7/8	2 10 1/8	92.885	.6499	15 7/8	4 1 3/4	197.933	1.3855
11 in.	2 10 1/2	95.033	.6652	16 in.	4 2 1/4	201.062	1.4074
11 1/8	2 10 3/4	97.205	.6804	16 1/8	4 2 5/8	204.216	1.4295
11 1/4	2 11	99.402	.6958	16 1/4	4 3	207.394	1.4517
11 3/8	2 11 1/8	101.623	.7113	16 3/8	4 3 1/8	210.597	1.4741
11 1/2	3 0	103.869	.7270	16 1/2	4 3 1/2	213.825	1.4967
11 5/8	3 0 1/8	106.139	.7429	16 5/8	4 4	217.077	1.5195
11 3/4	3 0 1/4	108.434	.7590	16 3/4	4 4 1/4	220.353	1.5424
11 7/8	3 1 1/8	110.753	.7752	16 7/8	4 5	223.654	1.5655
12 in.	3 1 1/2	113.097	.7916	17 in.	4 5 1/2	226.980	1.5888
12 1/8	3 2	115.466	.8082	17 1/8	4 5 5/8	230.330	1.6123
12 1/4	3 2 1/4	117.859	.8250	17 1/4	4 6	233.705	1.6359
12 3/8	3 2 3/8	120.276	.8419	17 3/8	4 6 1/8	237.104	1.6597
12 1/2	3 3	122.718	.8590	17 1/2	4 6 1/2	240.528	1.6836
12 5/8	3 3 1/8	125.185	.8762	17 5/8	4 7	243.977	1.7078
12 3/4	3 3 1/4	127.676	.8937	17 3/4	4 7 1/4	247.450	1.7321
12 7/8	3 4 1/8	130.192	.9113	17 7/8	4 8	250.947	1.7567

Dia. in inch.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.	Dia. in inch.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.
18	4 8 $\frac{1}{2}$	254-469	1-7812	23	6 0 $\frac{1}{2}$	415-476	2-8903
18 $\frac{1}{2}$	4 8 $\frac{3}{4}$	258-016	1-8061	23 $\frac{1}{2}$	6 0 $\frac{3}{4}$	420-004	2-9100
18 $\frac{1}{4}$	4 9	261-587	1-8311	23 $\frac{1}{4}$	6 1	424-557	2-9518
18 $\frac{3}{4}$	4 9 $\frac{3}{4}$	265-182	1-8562	23 $\frac{3}{4}$	6 1 $\frac{3}{4}$	429-135	2-9937
18 $\frac{1}{2}$	4 10	268-803	1-8816	23 $\frac{1}{2}$	6 1 $\frac{1}{2}$	433-737	3-0129
18 $\frac{3}{4}$	4 10 $\frac{3}{4}$	272-447	1-9071	23 $\frac{3}{4}$	6 2 $\frac{1}{4}$	438-363	3-0261
18 $\frac{1}{4}$	4 10 $\frac{1}{4}$	276-117	1-9328	23 $\frac{1}{4}$	6 2 $\frac{1}{4}$	443-014	3-0722
18 $\frac{3}{4}$	4 11 $\frac{1}{4}$	279-811	1-9586	23 $\frac{3}{4}$	6 3	447-690	3-1081
19	4 11 $\frac{1}{2}$	283-529	1-9847	2 0	6 3 $\frac{1}{2}$	452-390	3-1418
19 $\frac{1}{2}$	5 0	287-272	1-9941	2 0 $\frac{1}{2}$	6 4	461-864	3-2075
19 $\frac{1}{4}$	5 0 $\frac{1}{4}$	291-039	2-0371	2 0 $\frac{1}{4}$	6 4 $\frac{1}{4}$	471-436	3-2731
19 $\frac{3}{4}$	5 0 $\frac{3}{4}$	294-831	2-0637	2 0 $\frac{3}{4}$	6 5	481-106	3-3110
19 $\frac{1}{2}$	5 1	298-648	2-0904	2 1	6 6	490-875	3-4081
19 $\frac{3}{4}$	5 1 $\frac{1}{4}$	302-489	2-1172	2 1 $\frac{1}{4}$	6 7	500-741	3-4775
19 $\frac{1}{4}$	5 2	306-355	2-1443	2 1 $\frac{1}{4}$	6 8	510-706	3-5468
19 $\frac{3}{4}$	5 2 $\frac{1}{4}$	310-245	2-1716	2 1 $\frac{3}{4}$	6 8 $\frac{1}{2}$	520-769	3-6101
20	5 2 $\frac{1}{2}$	314-160	2-1990	2 2	6 9	530-930	3-6870
20 $\frac{1}{2}$	5 3	318-099	2-2265	2 2 $\frac{1}{2}$	6 10	541-189	3-7583
20 $\frac{1}{4}$	5 3 $\frac{1}{4}$	322-063	2-2543	2 2 $\frac{1}{4}$	6 11 $\frac{1}{4}$	551-547	3-8302
20 $\frac{3}{4}$	5 4	326-051	2-2822	2 2 $\frac{3}{4}$	7 0	562-002	3-9042
20 $\frac{1}{2}$	5 4 $\frac{1}{4}$	330-064	2-3103	2 3	7 0 $\frac{1}{2}$	572-556	3-9761
20 $\frac{3}{4}$	5 4 $\frac{3}{4}$	334-101	2-3386	2 3 $\frac{1}{4}$	7 1	583-208	4-0500
20 $\frac{1}{4}$	5 5	338-163	2-3670	2 3 $\frac{1}{4}$	7 2	593-958	4-1241
20 $\frac{3}{4}$	5 5 $\frac{1}{4}$	342-250	2-3956	2 3 $\frac{3}{4}$	7 3	604-807	4-2000
21	5 5 $\frac{1}{2}$	346-361	2-4244	2 4	7 3 $\frac{1}{2}$	615-753	4-2760
21 $\frac{1}{2}$	5 6	350-497	2-4533	2 4 $\frac{1}{2}$	7 4	626-798	4-3521
21 $\frac{1}{4}$	5 6 $\frac{1}{4}$	354-657	2-4824	2 4 $\frac{1}{4}$	7 5	637-941	4-4302
21 $\frac{3}{4}$	5 7	358-841	2-5117	2 4 $\frac{3}{4}$	7 6	649-182	4-5083
21 $\frac{1}{2}$	5 7 $\frac{1}{4}$	363-051	2-5412	2 5	7 7	660-521	4-5861
21 $\frac{3}{4}$	5 7 $\frac{3}{4}$	367-284	2-5708	2 5 $\frac{1}{4}$	7 7 $\frac{1}{2}$	671-958	4-6655
21 $\frac{1}{4}$	5 8	371-543	2-6007	2 5 $\frac{1}{4}$	7 8	683-494	4-7467
21 $\frac{3}{4}$	5 8 $\frac{1}{4}$	375-826	2-6306	2 5 $\frac{3}{4}$	7 9	695-128	4-8274
22	5 9	380-133	2-6608	2 6	7 10 $\frac{1}{2}$	706-860	4-9081
22 $\frac{1}{2}$	5 9 $\frac{1}{2}$	384-465	2-6691	2 6 $\frac{1}{2}$	7 11	718-690	4-9961
22 $\frac{1}{4}$	5 9 $\frac{1}{4}$	388-822	2-7016	2 6 $\frac{1}{4}$	7 11 $\frac{1}{4}$	730-618	5-0731
22 $\frac{3}{4}$	5 10	393-203	2-7224	2 6 $\frac{3}{4}$	8 0	742-644	5-1573
22 $\frac{1}{2}$	5 10 $\frac{1}{2}$	397-608	2-7632	2 7	8 1	754-769	5-2278
22 $\frac{1}{4}$	5 11	402-038	2-7980	2 7 $\frac{1}{4}$	8 2	766-992	5-3264
22 $\frac{3}{4}$	5 11 $\frac{1}{4}$	406-493	2-8054	2 7 $\frac{3}{4}$	8 2 $\frac{1}{2}$	779-313	5-4112

AREAS OF CIRCLES.

Dia. in ft. in.		Cir. in ft. in.		Area in sq. inch.		Area in sq. ft.		Dia. in ft. in.		Cir. in ft. in.		Area in sq. in.		Area in sq. ft.	
2	8	8	4 $\frac{1}{2}$	804-249	5-5850	3	6	10	11 $\frac{1}{2}$	1385-44	9-6212				
2	8 $\frac{1}{2}$	8	5 $\frac{1}{2}$	816-865	5-6729	3	6 $\frac{1}{2}$	11	0 $\frac{1}{2}$	1401-98	9-7364				
2	8 $\frac{1}{2}$	8	6 $\frac{1}{2}$	829-578	5-7601	3	6 $\frac{1}{2}$	11	1 $\frac{1}{2}$	1418-62	9-8518				
2	8 $\frac{1}{2}$	8	6 $\frac{1}{2}$	842-390	5-8491	3	6 $\frac{1}{2}$	11	2 $\frac{1}{2}$	1435-36	9-9671				
2	9	8	7 $\frac{1}{2}$	855-300	5-9398	3	7	11	3	1452-20	10-084				
2	9 $\frac{1}{2}$	8	8 $\frac{1}{2}$	868-308	6-0291	3	7 $\frac{1}{2}$	11	3 $\frac{1}{2}$	1469-14	10-202				
2	9 $\frac{1}{2}$	8	9 $\frac{1}{2}$	881-415	6-1201	3	7 $\frac{1}{2}$	11	4 $\frac{1}{2}$	1486-17	10-320				
2	9 $\frac{1}{2}$	8	10	894-619	6-2129	3	7 $\frac{1}{2}$	11	5 $\frac{1}{2}$	1503-30	10-439				
2	10	8	11 $\frac{1}{2}$	907-922	6-3051	3	8	11	6 $\frac{1}{2}$	1520-53	10-559				
2	10 $\frac{1}{2}$	8	11 $\frac{1}{2}$	921-323	6-3981	3	8 $\frac{1}{2}$	11	7	1537-86	10-679				
2	10 $\frac{1}{2}$	9	0	934-822	6-4911	3	8 $\frac{1}{2}$	11	7 $\frac{1}{2}$	1555-28	10-800				
2	10 $\frac{1}{2}$	9	1	948-419	6-5863	3	8 $\frac{1}{2}$	11	8 $\frac{1}{2}$	1572-81	10-922				
2	11	9	1 $\frac{1}{2}$	962-115	6-6815	3	9	11	9	1590-43	11-044				
2	11 $\frac{1}{2}$	9	2 $\frac{1}{2}$	975-908	6-7772	3	9 $\frac{1}{2}$	11	10	1608-15	11-167				
2	11 $\frac{1}{2}$	9	3 $\frac{1}{2}$	989-800	6-8738	3	9 $\frac{1}{2}$	11	10 $\frac{1}{2}$	1625-97	11-291				
2	11 $\frac{1}{2}$	9	4 $\frac{1}{2}$	1003-79	6-9701	3	9 $\frac{1}{2}$	11	11 $\frac{1}{2}$	1643-89	11-415				
3	0	9	5	1017-87	7-0688	3	10	12	0 $\frac{1}{2}$	1661-90	11-534				
3	0 $\frac{1}{2}$	9	5 $\frac{1}{2}$	1032-06	7-1671	3	10 $\frac{1}{2}$	12	1 $\frac{1}{2}$	1680-02	11-666				
3	0 $\frac{1}{2}$	9	6 $\frac{1}{2}$	1046-35	7-2664	3	10 $\frac{1}{2}$	12	2	1698-23	11-793				
3	0 $\frac{1}{2}$	9	7 $\frac{1}{2}$	1060-73	7-3662	3	10 $\frac{1}{2}$	12	2 $\frac{1}{2}$	1716-54	11-920				
3	1	9	8 $\frac{1}{2}$	1075-21	7-4661	3	11	12	3 $\frac{1}{2}$	1734-94	12-048				
3	1 $\frac{1}{2}$	9	9	1089-79	7-5671	3	11 $\frac{1}{2}$	12	4 $\frac{1}{2}$	1753-45	12-176				
3	1 $\frac{1}{2}$	9	9 $\frac{1}{2}$	1104-46	7-6691	3	11 $\frac{1}{2}$	12	5 $\frac{1}{2}$	1772-05	12-305				
3	1 $\frac{1}{2}$	9	10 $\frac{1}{2}$	1119-24	7-7791	3	11 $\frac{1}{2}$	12	6	1790-76	12-435				
3	2	9	11 $\frac{1}{2}$	1134-12	7-8681	4	0	12	6 $\frac{1}{2}$	1809-56	12-566				
3	2 $\frac{1}{2}$	10	0 $\frac{1}{2}$	1149-09	7-9791	4	0 $\frac{1}{2}$	12	7 $\frac{1}{2}$	1828-46	12-697				
3	2 $\frac{1}{2}$	10	0 $\frac{1}{2}$	1164-16	8-0846	4	0	12	8 $\frac{1}{2}$	1847-45	12-829				
3	2 $\frac{1}{2}$	10	1 $\frac{1}{2}$	1179-32	8-1891	4	0 $\frac{1}{2}$	12	9 $\frac{1}{2}$	1866-55	12-962				
3	3	10	2 $\frac{1}{2}$	1194-59	8-2951	4	1	12	9 $\frac{1}{2}$	1885-74	13-095				
3	3 $\frac{1}{2}$	10	3 $\frac{1}{2}$	1209-95	8-4026	4	1 $\frac{1}{2}$	12	10 $\frac{1}{2}$	1905-03	13-229				
3	3 $\frac{1}{2}$	10	4	1225-42	8-5091	4	1 $\frac{1}{2}$	12	11 $\frac{1}{2}$	1924-42	13-364				
3	3 $\frac{1}{2}$	10	4 $\frac{1}{2}$	1240-98	8-6171	4	1 $\frac{1}{2}$	13	0 $\frac{1}{2}$	1943-91	13-499				
3	4	10	5 $\frac{1}{2}$	1256-64	8-7269	4	2	13	1	1963-50	13-635				
3	4 $\frac{1}{2}$	10	6 $\frac{1}{2}$	1272-39	8-8361	4	2 $\frac{1}{2}$	13	1 $\frac{1}{2}$	1983-18	13-772				
3	4 $\frac{1}{2}$	10	7 $\frac{1}{2}$	1288-25	8-9462	4	2 $\frac{1}{2}$	13	2 $\frac{1}{2}$	2002-96	13-909				
3	4 $\frac{1}{2}$	10	8	1304-20	9-0561	4	2 $\frac{1}{2}$	13	3 $\frac{1}{2}$	2022-84	14-047				
3	5	10	8 $\frac{1}{2}$	1320-25	9-1686	4	3	13	4 $\frac{1}{2}$	2042-82	14-186				
3	5 $\frac{1}{2}$	10	9 $\frac{1}{2}$	1336-40	9-2112	4	3 $\frac{1}{2}$	13	5	2062-90	14-325				
3	5 $\frac{1}{2}$	10	10 $\frac{1}{2}$	1352-65	9-3936	4	3 $\frac{1}{2}$	13	5 $\frac{1}{2}$	2083-07	14-464				
3	5 $\frac{1}{2}$	10	11 $\frac{1}{2}$	1369-00	9-5061	4	3 $\frac{1}{2}$	13	6 $\frac{1}{2}$	2103-85	14-603				

Dia. in ft. in.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.	Dia. in ft. in.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.
4 4	13 7 $\frac{1}{2}$	2123-72	14-748	5 2	16 2 $\frac{1}{2}$	3019-07	20-965
4 4 $\frac{1}{2}$	13 8 $\frac{1}{2}$	2144-19	14-890	5 2 $\frac{1}{2}$	16 3 $\frac{1}{2}$	3043-47	21-135
4 4 $\frac{1}{2}$	13 8 $\frac{1}{2}$	2164-75	15-033	5 2 $\frac{1}{2}$	16 4 $\frac{1}{2}$	3067-96	21-305
4 4 $\frac{1}{2}$	13 9 $\frac{1}{2}$	2185-42	15-176	5 2 $\frac{1}{2}$	16 5 $\frac{1}{2}$	3092-56	21-476
4 4 5	13 10 $\frac{1}{2}$	2206-18	15-320	5 3	16 5 $\frac{1}{2}$	3117-25	21-647
4 4 5 $\frac{1}{2}$	13 11 $\frac{1}{2}$	2227-05	15-465	5 3 $\frac{1}{2}$	16 6 $\frac{1}{2}$	3142-04	21-819
4 4 5 $\frac{1}{2}$	14 0	2248-01	15-611	5 3 $\frac{1}{2}$	16 7 $\frac{1}{2}$	3166-92	21-992
4 4 5 $\frac{1}{2}$	14 0 $\frac{1}{2}$	2269-06	15-757	5 3 $\frac{1}{2}$	16 8 $\frac{1}{2}$	3191-91	22-166
4 6	14 1 $\frac{1}{2}$	2290-22	15-904	5 4	16 9	3216-99	22-333
4 6 $\frac{1}{2}$	14 2 $\frac{1}{2}$	2311-48	16-051	5 4 $\frac{1}{2}$	16 9 $\frac{1}{2}$	3242-17	22-515
4 6 $\frac{1}{2}$	14 3	2332-83	16-200	5 4 $\frac{1}{2}$	16 10 $\frac{1}{2}$	3267-46	22-621
4 6 $\frac{1}{2}$	14 4	2354-28	16-349	5 4 $\frac{1}{2}$	16 11 $\frac{1}{2}$	3292-83	22-866
4 7	14 4 $\frac{1}{2}$	2375-83	16-498	5 5	17 0	3318-31	23-043
4 7 $\frac{1}{2}$	14 5 $\frac{1}{2}$	2397-48	16-649	5 5 $\frac{1}{2}$	17 0 $\frac{1}{2}$	3343-88	23-221
4 7 $\frac{1}{2}$	14 6 $\frac{1}{2}$	2419-22	16-800	5 5 $\frac{1}{2}$	17 1 $\frac{1}{2}$	3369-56	23-330
4 7 $\frac{1}{2}$	14 7 $\frac{1}{2}$	2441-07	16-951	5 5 $\frac{1}{2}$	17 2 $\frac{1}{2}$	3395-33	23-578
4 8	14 7 $\frac{1}{2}$	2463-01	17-104	5 6	17 3 $\frac{1}{2}$	3421-20	23-768
4 8 $\frac{1}{2}$	14 8 $\frac{1}{2}$	2485-05	17-257	5 6 $\frac{1}{2}$	17 4 $\frac{1}{2}$	3447-16	23-938
4 8 $\frac{1}{2}$	14 9 $\frac{1}{2}$	2507-19	17-411	5 6 $\frac{1}{2}$	17 4 $\frac{1}{2}$	3473-23	24-119
4 8 $\frac{1}{2}$	14 10 $\frac{1}{2}$	2529-42	17-565	5 6 $\frac{1}{2}$	17 5 $\frac{1}{2}$	3499-39	24-401
4 9	14 11	2551-76	17-720	5 7	17 6 $\frac{1}{2}$	3525-66	24-483
4 9 $\frac{1}{2}$	14 11 $\frac{1}{2}$	2574-19	17-876	5 7 $\frac{1}{2}$	17 7 $\frac{1}{2}$	3552-01	24-666
4 9 $\frac{1}{2}$	15 0	2596-72	18-033	5 7 $\frac{1}{2}$	17 8	3578-47	24-850
4 9 $\frac{1}{2}$	15 1	2619-35	18-189	5 7 $\frac{1}{2}$	17 8 $\frac{1}{2}$	3605-03	25-034
4 10	15 2 $\frac{1}{2}$	2642-08	18-347	5 8	17 9 $\frac{1}{2}$	3631-68	25-220
4 10 $\frac{1}{2}$	15 3 $\frac{1}{2}$	2664-91	18-506	5 8 $\frac{1}{2}$	17 10 $\frac{1}{2}$	3658-44	25-405
4 10 $\frac{1}{2}$	15 3 $\frac{1}{2}$	2687-83	18-665	5 8 $\frac{1}{2}$	17 11 $\frac{1}{2}$	3685-29	25-592
4 10 $\frac{1}{2}$	15 4 $\frac{1}{2}$	2710-85	18-825	5 8 $\frac{1}{2}$	17 11 $\frac{1}{2}$	3712-24	25-779
4 11	15 5 $\frac{1}{2}$	2733-97	18-985	5 9	18 0	3739-28	25-964
4 11 $\frac{1}{2}$	15 6 $\frac{1}{2}$	2757-19	19-147	5 9 $\frac{1}{2}$	18 1 $\frac{1}{2}$	3766-43	26-155
4 11 $\frac{1}{2}$	15 6 $\frac{1}{2}$	2780-51	19-309	5 9 $\frac{1}{2}$	18 2 $\frac{1}{2}$	3793-67	26-344
4 11 $\frac{1}{2}$	15 7 $\frac{1}{2}$	2803-92	19-471	5 9 $\frac{1}{2}$	18 3 $\frac{1}{2}$	3821-02	26-534
5 0	15 8 $\frac{1}{2}$	2827-44	19-635	5 10	18 3 $\frac{1}{2}$	3848-46	26-725
5 0 $\frac{1}{2}$	15 9 $\frac{1}{2}$	2851-05	19-798	5 10 $\frac{1}{2}$	18 4 $\frac{1}{2}$	3875-99	26-916
5 0 $\frac{1}{2}$	15 10	2874-76	19-963	5 10 $\frac{1}{2}$	18 5 $\frac{1}{2}$	3903-63	27-108
5 0 $\frac{1}{2}$	15 10 $\frac{1}{2}$	2898-56	20-128	5 10 $\frac{1}{2}$	18 6 $\frac{1}{2}$	3931-36	27-301
5 1	15 11 $\frac{1}{2}$	2922-47	20-294	5 11	18 7	3959-20	27-494
5 1 $\frac{1}{2}$	16 0	2946-47	20-461	5 11 $\frac{1}{2}$	18 7 $\frac{1}{2}$	3987-13	27-688
5 1 $\frac{1}{2}$	16 1	2970-57	20-629	5 11 $\frac{1}{2}$	18 8 $\frac{1}{2}$	4015-16	27-883
5 1 $\frac{1}{2}$	16 1 $\frac{1}{2}$	2994-77	20-797	5 11 $\frac{1}{2}$	18 9 $\frac{1}{2}$	4043-28	28-078

AREAS OF CIRCLES.

Dia. in ft. in.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.	Dia. in ft. in.	Cir. in ft. in.	Area in sq. in.	Area in sq. ft.
6 0	18 10 $\frac{1}{2}$	4071-51	28-274	6 6	20 5	4778-37	33-183
6 0 $\frac{1}{2}$	18 10 $\frac{1}{2}$	4099-83	28-471	6 6 $\frac{1}{2}$	20 5 $\frac{1}{2}$	4809-05	33-396
6 0 $\frac{1}{4}$	18 11	4128-25	28-668	6 6 $\frac{1}{4}$	20 6 $\frac{1}{4}$	4839-83	33-619
6 0 $\frac{1}{2}$	19 0	4156-77	28-866	6 6 $\frac{1}{2}$	20 7	4870-70	33-824
6 1	19 1 $\frac{1}{2}$	4185-39	29-065	6 7	20 8 $\frac{1}{2}$	4901-68	34-039
6 1 $\frac{1}{4}$	19 2 $\frac{1}{4}$	4214-11	29-264	6 7 $\frac{1}{4}$	20 8 $\frac{3}{4}$	4932-75	34-255
6 1 $\frac{1}{2}$	19 2 $\frac{1}{2}$	4242-92	29-466	6 7 $\frac{1}{2}$	20 9 $\frac{1}{2}$	4963-92	34-471
6 1 $\frac{3}{4}$	19 3 $\frac{1}{4}$	4271-83	29-665	6 7 $\frac{3}{4}$	20 10 $\frac{1}{4}$	4995-19	34-688
6 2	19 4 $\frac{1}{2}$	4300-85	29-867	6 8	20 11 $\frac{1}{4}$	5026-26	34-906
6 2 $\frac{1}{4}$	19 5 $\frac{1}{4}$	4329-95	30-069	6 8 $\frac{1}{4}$	21 0 $\frac{1}{4}$	5058-02	35-125
6 2 $\frac{1}{2}$	19 6	4359-16	30-271	6 8 $\frac{1}{2}$	21 0 $\frac{1}{2}$	5089-58	35-344
6 2 $\frac{3}{4}$	19 6 $\frac{3}{4}$	4388-47	30-475	6 8 $\frac{3}{4}$	21 1 $\frac{1}{4}$	5121-24	35-564
6 3	19 7 $\frac{1}{2}$	4417-87	30-679	6 9	21 2 $\frac{1}{4}$	5153-00	35-784
6 3 $\frac{1}{4}$	19 8 $\frac{1}{4}$	4447-37	30-884	6 9 $\frac{1}{4}$	21 3 $\frac{1}{4}$	5184-86	36-006
6 3 $\frac{1}{2}$	19 9 $\frac{1}{2}$	4476-97	31-090	6 9 $\frac{1}{2}$	21 4	5216-82	36-227
6 3 $\frac{3}{4}$	19 9 $\frac{3}{4}$	4506-67	31-296	6 9 $\frac{3}{4}$	21 4 $\frac{1}{4}$	5248-87	36-450
6 4	19 10 $\frac{1}{2}$	4536-47	31-503	6 10	21 5 $\frac{1}{4}$	5281-02	36-674
6 4 $\frac{1}{4}$	19 11 $\frac{1}{4}$	4566-36	31-710	6 10 $\frac{1}{4}$	21 6 $\frac{1}{4}$	5313-27	36-897
6 4 $\frac{1}{2}$	20 0 $\frac{1}{2}$	4596-35	31-919	6 10 $\frac{1}{2}$	21 7 $\frac{1}{2}$	5345-62	37-122
6 4 $\frac{3}{4}$	20 1 $\frac{1}{4}$	4626-44	32-114	6 10 $\frac{3}{4}$	21 7 $\frac{3}{4}$	5378-07	37-347
6 5	20 1 $\frac{1}{2}$	4656-63	32-337	6 11	21 8 $\frac{1}{4}$	5410-62	37-573
6 5 $\frac{1}{4}$	20 2 $\frac{1}{4}$	4686-92	32-548	6 11 $\frac{1}{4}$	21 9 $\frac{1}{4}$	5443-26	37-700
6 5 $\frac{1}{2}$	20 3 $\frac{1}{2}$	4717-30	32-759	6 11 $\frac{1}{2}$	21 10 $\frac{1}{4}$	5476-00	38-027
6 5 $\frac{3}{4}$	20 4 $\frac{1}{4}$	4747-79	32-970	6 11 $\frac{3}{4}$	21 11	5508-84	38-256

Diam. in ft. and in.	Circum. in ft. and in.	Area in feet.	Diam. in ft. and in.	Circum. in ft. and in.	Area in feet.
7 0	21 11 $\frac{1}{8}$	38-4846	10 0	31 5	78-5400
1	22 3	39-4060	1	31 8 $\frac{1}{8}$	79-8540
2	22 6 $\frac{1}{8}$	40-3388	2	31 11 $\frac{1}{4}$	81-1795
3	22 9 $\frac{1}{4}$	41-2825	3	32 2 $\frac{1}{8}$	82-5160
4	23 0 $\frac{3}{8}$	42-2367	4	32 5 $\frac{1}{4}$	83-8627
5	23 2 $\frac{1}{8}$	43-2022	5	32 8 $\frac{1}{8}$	85-2211
6	23 6 $\frac{1}{4}$	44-1787	6	32 11 $\frac{1}{4}$	86-5903
7	23 11	45-1656	7	33 2 $\frac{1}{8}$	87-9697
8	24 1 $\frac{1}{8}$	46-1638	8	33 6 $\frac{1}{8}$	89-3608
9	24 4 $\frac{1}{8}$	47-1730	9	33 9 $\frac{1}{4}$	90-7627
10	24 7 $\frac{1}{4}$	48-1926	10	34 0 $\frac{3}{8}$	92-1749
11	24 10 $\frac{3}{8}$	49-2236	11	34 3 $\frac{1}{2}$	93-5986
8 0	25 1 $\frac{1}{2}$	50-2656	11 0	34 6 $\frac{1}{8}$	95-0334
1	25 4 $\frac{3}{8}$	51-3178	1	34 9 $\frac{1}{4}$	96-4783
2	25 7 $\frac{1}{8}$	52-3816	2	35 0 $\frac{3}{8}$	97-9347
3	25 11	53-4562	3	35 4 $\frac{1}{4}$	99-4021
4	26 2 $\frac{1}{8}$	54-5412	4	35 7 $\frac{1}{4}$	100-8797
5	26 5 $\frac{1}{4}$	55-6377	5	35 10 $\frac{3}{8}$	102-3689
6	26 8 $\frac{1}{8}$	56-7451	6	36 1 $\frac{1}{8}$	103-8691
7	26 11 $\frac{1}{4}$	57-8628	7	36 4 $\frac{1}{4}$	105-3794
8	27 2 $\frac{1}{4}$	58-9920	8	36 7 $\frac{1}{2}$	106-9013
9	27 5 $\frac{1}{4}$	60-1321	9	36 10 $\frac{1}{8}$	108-4342
10	27 9	61-2826	10	37 2 $\frac{1}{4}$	109-9772
11	28 0 $\frac{1}{8}$	62-4445	11	37 5 $\frac{1}{4}$	111-5319
9 0	28 3 $\frac{1}{4}$	63-6174	12 0	37 8 $\frac{1}{8}$	113-0976
1	28 6 $\frac{3}{8}$	64-8006	1	37 11 $\frac{1}{4}$	114-6732
2	28 9 $\frac{1}{2}$	65-9951	2	38 2 $\frac{1}{8}$	116-2607
3	29 0 $\frac{3}{8}$	67-2007	3	38 5 $\frac{1}{4}$	117-8590
4	29 3 $\frac{1}{4}$	68-4166	4	38 8 $\frac{1}{8}$	119-4674
5	29 7	69-6440	5	39 0	121-0876
6	29 10 $\frac{1}{4}$	70-8823	6	39 3 $\frac{1}{4}$	122-7187
7	30 1 $\frac{1}{4}$	72-1309	7	39 6 $\frac{1}{8}$	124-3598
8	30 4 $\frac{3}{8}$	73-3910	8	39 9 $\frac{1}{4}$	126-0127
9	30 7 $\frac{1}{2}$	74-6620	9	40 0 $\frac{3}{8}$	127-6765
10	30 11 $\frac{1}{8}$	75-9433	10	40 3 $\frac{1}{4}$	129-3504
11	31 1 $\frac{3}{4}$	77-2362	11	40 6 $\frac{1}{8}$	131-0360

AREAS OF CIRCLES.

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Diam. in ft. and in.			Circum. in ft. and in.			Area in feet.		
13	0	40 10	132.7326	16	0	50 3 $\frac{1}{2}$	201.0624	
	1	41 1 $\frac{1}{2}$	134.4391		1	50 6 $\frac{1}{2}$	203.1615	
	2	41 4 $\frac{1}{2}$	136.1574		2	50 9 $\frac{1}{2}$	205.2726	
	3	41 7 $\frac{1}{2}$	137.8867		3	51 0 $\frac{1}{2}$	207.3946	
	4	41 10 $\frac{1}{2}$	139.6260		4	51 3 $\frac{1}{2}$	209.5264	
	5	42 1 $\frac{1}{2}$	141.3771		5	51 6 $\frac{1}{2}$	211.6703	
	6	42 4 $\frac{1}{2}$	143.1391		6	51 10	213.8251	
	7	42 8	144.9111		7	52 1 $\frac{1}{2}$	215.9896	
	8	42 11 $\frac{1}{2}$	146.6949		8	52 4 $\frac{1}{2}$	218.1662	
	9	43 2 $\frac{1}{2}$	148.4896		9	52 7 $\frac{1}{2}$	220.3537	
	10	43 5 $\frac{1}{2}$	150.2943		10	52 10 $\frac{1}{2}$	222.5510	
11	43 8 $\frac{1}{2}$	152.1109	11	53 1 $\frac{1}{2}$	224.7603			
14	0	43 11 $\frac{1}{2}$	153.9384	17	0	53 4 $\frac{1}{2}$	226.9806	
	1	44 2 $\frac{1}{2}$	155.7758		1	53 8	229.2105	
	2	44 6	157.6250		2	53 11 $\frac{1}{2}$	231.4625	
	3	44 9 $\frac{1}{2}$	159.4852		3	54 2 $\frac{1}{2}$	233.7055	
	4	45 0 $\frac{1}{2}$	161.3553		4	54 5 $\frac{1}{2}$	235.9682	
	5	45 3 $\frac{1}{2}$	163.2373		5	54 8 $\frac{1}{2}$	238.2430	
	6	45 6 $\frac{1}{2}$	165.1303		6	54 11 $\frac{1}{2}$	240.5287	
	7	45 9 $\frac{1}{2}$	167.0331		7	55 2 $\frac{1}{2}$	242.8241	
	8	46 0 $\frac{1}{2}$	168.9479		8	55 6	245.1316	
	9	46 4	170.8735		9	55 9 $\frac{1}{2}$	247.4500	
	10	46 7 $\frac{1}{2}$	172.8091		10	56 0 $\frac{1}{2}$	249.7781	
11	46 11 $\frac{1}{2}$	174.7565	11	56 3 $\frac{1}{2}$	252.1184			
15	0	47 1 $\frac{1}{2}$	176.7150	18	0	56 6 $\frac{1}{2}$	254.4696	
	1	47 4 $\frac{1}{2}$	178.6832		1	56 9 $\frac{1}{2}$	256.8303	
	2	47 7 $\frac{1}{2}$	180.6634		2	57 0 $\frac{1}{2}$	259.2033	
	3	47 10 $\frac{1}{2}$	182.6545		3	57 4	261.5872	
	4	48 2 $\frac{1}{2}$	184.6555		4	57 7 $\frac{1}{2}$	263.9807	
	5	48 5 $\frac{1}{2}$	186.6684		5	57 10 $\frac{1}{2}$	266.3864	
	6	48 8 $\frac{1}{2}$	188.6923		6	58 1 $\frac{1}{2}$	268.8031	
	7	48 11 $\frac{1}{2}$	190.7260		7	58 4 $\frac{1}{2}$	271.2293	
	8	49 2 $\frac{1}{2}$	192.7716		8	58 7 $\frac{1}{2}$	273.6678	
	9	49 5 $\frac{1}{2}$	194.8282		9	58 10 $\frac{1}{2}$	276.1171	
	10	49 8 $\frac{1}{2}$	196.8946		10	59 2	278.5761	
11	50 0	198.9730	11	59 5 $\frac{1}{2}$	281.0472			

# 172 SQUARE AND CUBE ROOTS OF NUMBERS.

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	4-8059	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	8-0522	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	5-6146
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	5-0784	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	14-2829	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	5-3719	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	5-4289	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 = 4-5355

“ “ “ 20 = 4-4721

**Ans.** = 4-4721 × .321 + 4-4721 = 4-507, &c., the root required.

## MISCELLANEOUS NOTES.

## VARNISHES.

[From Dr. Ure's Dictionary of Arts and Manufactures.]

*White Spirit Varnish.*—Sandarach, 250 parts; mastic in tears, 64; elemi resin, 32; Venice turpentine, 64; alcohol of 85 per cent., 1000 parts by measure. The turpentine is to be added after the resins are dissolved. This is a brilliant varnish, but not so hard as to bear polishing.

*Varnish for the Wood Toys of Spa.*—Tender copal, 75 parts; mastic, 12·5; Venice turpentine, 6·5; alcohol of 95 per cent., 100 parts by measure; water, ounces—for example, if the other be taken in ounces. The alcohol must be first made to act upon the copal, with the aid of a little oil of lavender or camphor, if thought fit; and, the solution being passed through a linen cloth, the mastic must be introduced. After it is dissolved, the Venice turpentine, previously melted in a water bath, should be added. The lower the temperature at which these operations are carried on, the more beautiful will the varnish be. This varnish ought to be very white, very drying, and capable of being smoothed with pumice-stone and polished.

*Varnish for Cabinet-Makers.*—Pale shellac, 750 parts; mastic, 64; alcohol of 90 per cent., 1000 parts by measure. The solution is made in the cold, with the aid of frequent stirring. It is always muddy, and is employed without being filtered. With the same resins and proof spirit, a varnish is made for the book-binders, to do over their morocco leather.

*Crystal Varnish.*—Procure a bottle of Canada balsam, which can be had at any druggist's; draw out the cork, and set the bottle of balsam at a little distance

from the fire, turning it round several times, until the heat has thinned it; then have something that will hold as much as double the quantity of balsam; carry the balsam from the fire, and, while fluid, mix it with the same quantity of good turpentine, and shake them together until they are well incorporated. In a few days, the varnish is fit for use; particularly if it is poured into a half-gallon glass or stone bottle, and kept in a gentle warmth. This varnish is used for maps, prints, charts, drawings, paper ornaments, &c.

*The Chinese Varnish* is obtained from a tree which grows in Cochin-China, China, and Siam. It forms the best of all varnishes.

*Gold Lacker.*— Put into a clean four-gallon tin 1 lb. ground turmeric, 1½ oz. powdered gamboge, 3¼ lbs. powdered gum sandarach, ¼ lb. shellac, and 2 galls. spirits of wine. After being dissolved and strained, add 1 pint of turpentine varnish, well mixed.

*Red Spirit Lacker.*— 2 galls. spirits of wine; 1 lb. dragon's-blood; 3 lbs. Spanish annotto; 3¼ lbs. gum sandarach; 2 pints turpentine; — made exactly as the gold lacker.

*The Varnish of Watin, for Gilded Articles.*— Gum lac in grain, 125 parts; gamboge, 125; dragon's-blood, 125; annotto, 125; saffron, 32. Each resin must be dissolved in 1000 parts by measure of alcohol of 90 per cent. Two separate tinctures must be made with the dragon's-blood and annotto, in 1000 parts of such alcohol; and a proper proportion of each should be added to the varnish, according to the shade of golden color wanted.

*Transfer Varnish.*— For fixing engravings or lithographs upon wood, a varnish called *mordant* is used in France, which differs from others chiefly in containing more Venice turpentine, to make it sticky. It consists of sandarach, 250 parts; mastic in tears, 64; rosin, 125; Venice turpentine, 250; alcohol, 1000 parts by measure.

*Common Mastic Varnish.*— Put as much gum mastic,

unpicked, into the gum-pot, as may be required; and to every 2½ lbs. of gum, pour in 1 gall. of cold turpentine; set the pot over a very moderate fire, and stir it. Be careful, when the steam of the turpentine rises near the mouth of the pot, to cover with a piece of woollen cloth, and carry it out of doors, as the vapor is very apt to catch fire. A few minutes' low heat will perfectly dissolve 8 lbs. of gum, which will, with 4 galls. of turpentine, produce, when strained, 4½ galls. of varnish; to which add, while yet hot, 5 pints of pale turpentine varnish, which improves the body and hardness of the mastic varnish.

*Pale Brass Lacker.*—2 galls. spirits of wine; 3 oz. Cape aloes; cut small 1 lb. fine pale shellac; 1 oz. gamboge, cut small; no turpentine;—varnish made exactly as before. But observe, that those who make lackers frequently want some paler and some darker; and sometimes inclining more to the particular tint of certain of the component ingredients. Therefore, if a 4 oz. phial of a strong solution of each ingredient be prepared, a lacker of any tint can be produced at any time.

*Iron-Work Black.*—Put 48 lbs. asphaltum into an iron pot, and boil for 4 hours; during the first 2 hours, introduce 7 lbs. litharge, 3 lbs. dried copperas, and 10 galls. boiled; add 1-eighth lb. run of dark gum, with 2 galls. hot oil. After pouring the oil and gum, continue the boiling 2 hours, or until it will roll into hard pills, like Japan. When cool, thin it off with 30 galls. turpentine, or until it is of proper consistence. This varnish is intended for the iron-work of coaches and other carriages, &c.

*To make Cloth, Silk, &c. water-proof.*—Mix equal quantities of alum and acetate of lead, and dissolve the mixture in a gallon and a half of boiling water. When the solution has cooled, remove the supernatant liquid from the sediment, which consists of sulphate of lead, and it is ready for use. Any article of dress, when well saturated in this liquid, and allowed to dry

slowly, bears the action of boiling water, and does not permit it to pass through, although steam and air penetrate it freely.

*Cement for China, Glass, &c.* — To 1 oz. gum mastic add as much spirits of wine as will dissolve it; soak 1 oz. isinglass in water till it is quite soft, then dissolve it in pure brandy till of the consistence of glue; to this add  $\frac{1}{4}$  oz. gum ammoniac, well rubbed and mixed. Put now the two mixtures together in a vessel over a gentle heat, till properly united, and the cement is ready for use. It must be kept in a phial well stopped; and, when about to be used, it ought to be set in boiling water to soften.

*Preparation for Silver Solution.* — Take 1 pint of pure rain or distilled water; add to it 2 oz. cyanide of potassium; shake them together occasionally, until the latter is entirely dissolved, and allow the liquid to become clear; then add  $\frac{1}{4}$  oz. oxide of silver, which will very speedily dissolve; and, after a short time, a clear, transparent solution will be obtained.

*Preparation of Gold Solution.* — Warm a pint of pure rain water, and dissolve in it 2 oz. cyanide of potassium; then add  $\frac{1}{4}$  oz. oxide of gold; the solution will at first be yellowish, but will soon subside to white.

#### SOLDERS.

*For Lead.* — Melt 1 part of block tin, and, when in a state of fusion, add 2 parts of lead. Resin should be used with this solder.

*For Tin.* — Pewter, 4 parts; tin, 1; bismuth, 1; melt them together. Resin is also used with this solder.

*For Iron.* — Tough brass, with a small quantity of borax.

*Circular or Cylindrical*  
CAPACITY OF CISTERNS IN GALLONS.

*For each 10 Inches in Depth.*

		<i>gallons</i>			<i>gallons</i>
2	feet diameter, . . .	19.5	8	feet diameter, . . .	313.33
2½	" " . . .	30.6	8½	" " . . .	353.72
3	" " . . .	44.06	9	" " . . .	396.56
3½	" " . . .	59.97	9½	" " . . .	461.40
4	" " . . .	78.33	10	" " . . .	489.20
4½	" " . . .	99.14	11	" " . . .	592.40
5	" " . . .	122.40	12	" " . . .	705.
5½	" " . . .	148.10	13	" " . . .	827.4
6	" " . . .	176.25	14	" " . . .	959.6
6½	" " . . .	206.85	15	" " . . .	1101.6
7	" " . . .	239.88	20	" " . . .	1958.4
7½	" " . . .	275.40	25	" " . . .	3059.9

## SCREWS.

*Table showing the Number of Threads to an Inch in  
V-thread Screws.*

Diam. in inches, . . .	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
No. of threads, . . .	20	18	16	14	12	11	10	9	8	7	7	6
Diam. in inches, . . .	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{5}{8}$
No. of threads, . . .	6	5	5	$4\frac{1}{2}$	$4\frac{1}{2}$	4	4	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$
Diam. in inches, . . .	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	$5\frac{3}{4}$	6	6
No. of threads, . . .	3	3	$2\frac{7}{8}$	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{1}{2}$

The depth of the threads should be half their pitch. The diameter of a screw, to work in the teeth of a wheel, should be such, that the angle of the threads does not exceed  $10^{\circ}$ .

178      WEIGHTS OF VARIOUS SUBSTANCES.

RECAPITULATION OF WEIGHTS OF VARIOUS  
SUBSTANCES.

Names.	Cubic foot in lbs.	Cubic inch in lbs.
Cast iron . . . .	450.55	.2607
Wrought iron . .	486.65	.2816
Steel . . . . .	489.8	.2834
Copper . . . . .	555.	.32118
Lead . . . . .	708.75	.41015
Brass . . . . .	537.75	.3112
Tin . . . . .	456.	.263
White pine . . .	29.56	.0171
Salt water (sea) .	64.3	.03721
Fresh water . . .	62.5	.03616
Air . . . . .	.07529	—
Steam . . . . .	.03689	—

CAST IRON expands  $\frac{1}{182000}$  of its length for one degree of heat; greatest change in the shade, in this climate,  $\frac{1}{1170}$  of its length; exposed to the sun's rays,  $\frac{1}{1000}$ ; shrinks in cooling from  $\frac{1}{8}$  to  $\frac{1}{8}$  of its length; is crushed by a force of 93,000 lbs. upon a square inch; will bear, without permanent alteration, 15,300 lbs. upon a square inch, and an extension of  $\frac{1}{1200}$  of its length. Weight of modulus of elasticity for a base of an inch square, 18,400,000 lbs.; height of modulus of elasticity, 5,750,000 feet.

WROUGHT IRON expands  $\frac{1}{143000}$  of its length for one degree of heat; will bear, on a square inch, without permanent alteration, 17,800 lbs., and an extension in length of  $\frac{1}{1400}$ ; cohesive force is diminished  $\frac{1}{3000}$  by an increase of one degree of heat. Weight of modulus of elasticity for a base of an inch square, 24,920,000 lbs.; height of modulus of elasticity, 7,550,000 feet.

Let  $S$  = the Specific Gravity of a body  
 $I$  = cubic inches Content. do  
 $F$  = cubic Feet do do

then;  $\frac{S}{1728} = I \dots \frac{IS}{1728} = \text{ounces}$

$\frac{IS}{27.648} = \text{lbs} \dots \frac{FS}{0.16} = \text{lbs}$

$\frac{FS}{1.79} = \text{cwt} + \frac{FS}{35.8} = \text{Tons}$

B. Beran

Force required to punch a hole  
 $\frac{1}{2}$  inch diameter in Iron & Copper

Thickness of Plate inches	Iron lbs pressure	Copper lbs pressure
0.08	6025	3983 -
0.17	11,950	7.883
0.24	17 100	11.520

Taking 1 inch diameter of hole & 1 inch thickness of plate as units, then 150,000 is the constant for wrought iron & 96,000 for Copper plate.

Let  $C$  be the constant,  $D =$  the diameter of the punch in inches, &  $T =$  the thickness of the plate. then  $C \times D \times T =$  the required pressure in lbs. or.

$$150,000 \times D \times T = \text{force for wrought iron}$$

$$96,000 \times D \times T = \text{do Copper plate}$$

Oil used on the punch reduces the requisite pressure about 8 per cent.

W. J. ...  
...