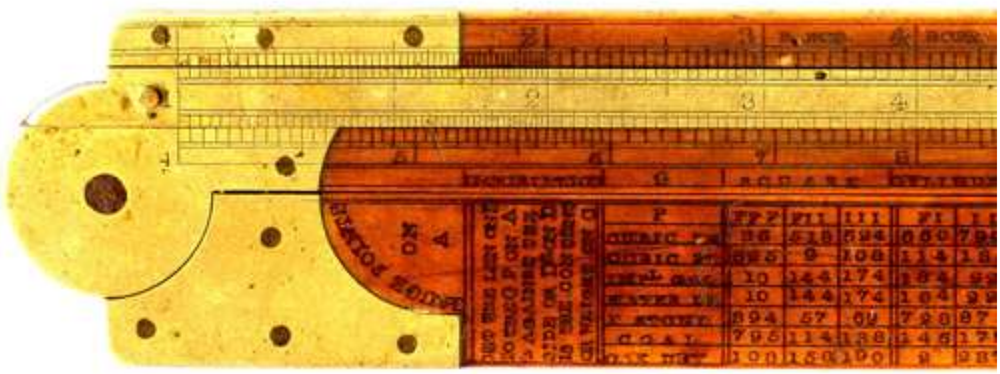
Robert Hawthorn Sliding Rule manual

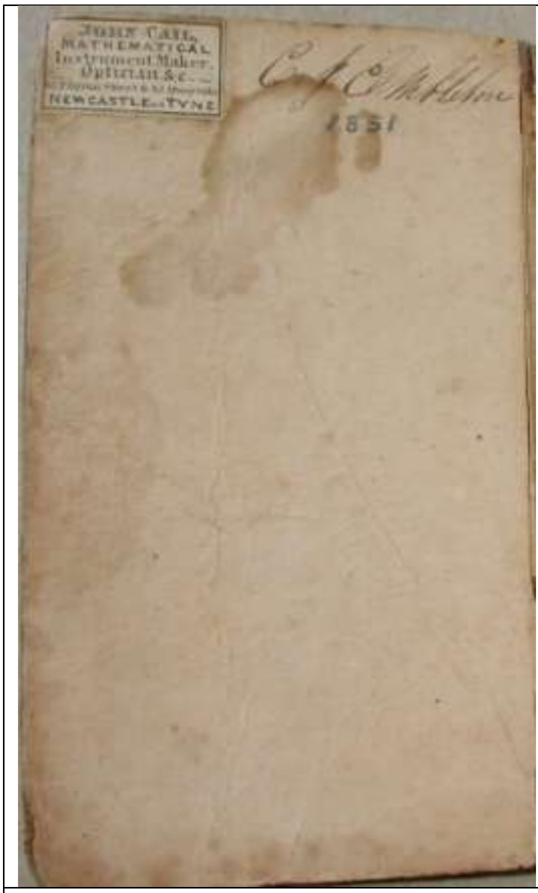
The mechanic's improved sliding rule as improved and arranged by Robert Hawthorn, Civil Engineer, Newcastle-upon-Tyne, 1841



This slide rule has been in the present owner's family since it was brought to Australia in 1851. It comprises a two foot folding boxwood rule with a brass hinge, marked in inches and provided with tables of useful constants. There is as well a brass slide let into one side that can be used for a variety of calculations. On its back it is marked in inches, so can be used as a depth gauge or to extend the range of the rule to three feet. Its front has logarithmic scales which can be used for calculations involving multiplication, division, squares, square roots etc for the determination of areas, volumes and more complex quantities.

The accompanying instruction manual, dated 1841, explains how to make a wide range of calculations, many using constants called 'gauge (or guage) points' listed on the rule. An interesting feature is that some of the calculations involve reversing the slide end-over-end. The booklet has a sticker marked 'John Cail, Mathematical Instrument Maker, Optician Etc, 61 Pilgrim Street and 45 Quayside, Newcastle on Tyne'. The manual is 80 by 134 mm with cardboard covers.

The images were made with a digital camera as the binding was too delicate for scanning.



INSTRUCTIONS

FOR THE USE OF

THE MECHANICS'

IMPROVED SLIDING RULE,

AS IMPROVED AND ARRANGED

BY ROBERT HAWTHORN,

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1841.

[ENTERED AT STATIONERS' HALL.]

THE Slide Rule is so extensive in its use, and so important in its application, that any improvement in rendering it more simple and making it better understood, or more general in operation, needs no apology.

In the alterations and additions which will be found attached to this rule, I trust that simplicity and readiness of, and considerably extended application, will be sufficiently apparent; especially the various Gauge Points, and Tables for the Strength of Materials, such as Ropes, Chains, Cast and Malleable Iron, Woods, Stone, &c.; also the Temperature of Steam, Power of Engines, Governors, Specific Gravity, and several other tables, all of which will be found highly useful, and readily applicable to almost every purpose connected with the measurement, strength, and weight of materials.

INSTRUCTIONS,

FOR THE USE OF

THE MECHANICS' SLIDING RULE.

DESCRIPTION OF THE RULE.

One face of the Rule is marked with inches, divided into eighths, and contains several tables; the first, next the joint, is the Direct Cohesion of Bars, one inch square; the second is the Transverse Strength of Beams, 1 inch square and 12 inches long; these two tables express the extreme weight or load the bars and beams will bear before breaking. In the second table it will be found that an inch square beam of cast iron, 12 inches long, also loaded on the centre, will bear with safety 860lb. with a deflection of [illegible] part of an inch (this data will do for common joists in buildings, &c.) The third is a table of Specific Gravities, the fourth is Lineal Measure, the fifth Square, and the sixth Cubic Measure, with the weight and measure of Coals at London and Newcastle. Both edges have scales, one divided into twelfths and the other into tenths.

On the other face of the Rule is the slide and lines of numbers, with a table of Guage Points for square, cylinder, and globe; for weight and strength of ropes, chains, and iron; regular polygons; governors, the properties of the circle, and the power of high pressure engines, with the temperature of steam at different pressures, &c. &c.

LINES OF NUMBERS.

There are four lines marked A, B, C, D; the first three lines A, B, C, are exactly alike, consisting of two radii, numbered from the left to the right with figures 1, 2, 3, 4, 5, 6, 7, 8, 9; 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. The line D is a single line of numbers, commonly called the girt line, and also figured from right to left with 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 1, 2, 3, 4, 5, 6, 7, 8, 9, 30, 1, 2, 3, 4, 5, 6, 7, 8, 9, 40; the lines B and C slide between A and D.

NUMERATION.

Upon a perfect knowledge of Numeration depends the facility of using the Slide Rule, and with which the learner ought to make himself thoroughly acquainted. The value set upon the numbers and divisions must in all cases be such as the nature of the question requires.

If the 1 on the left upon A, B, C, be called one tenth, the middle 1 will be one unit, and the remaining figures towards the right will also be whole numbers; should the first 1 represent one unit, the middle 1 will be 10, and the 10 at the far end 100; but if the first 1 be called 10, the next will be 100, and the end 1000, always increasing in a ten-fold proportion, according to the value set upon the first 1. The line A, B, C, from 1 to 2, is divided into ten parts, and each part subdivided into five; from 2 to 3 and from 3 to 4 is also divided into ten parts, each sub-divided into two, and from 4 to 5 and so on to 10, is divided into ten parts only. The figures and divisions on the line D are valued in the same manner as above in a ten-fold proportion; when the 4 on the left represents four-tenths the 10 will be 1, the 20 will be 2, the 30 will be 3, and the 40 on the right will be 4, all the intermediate divisions being valued accordingly.

MULTIPLICATION.

In Multiplication three numbers are given to find a fourth, unity constantly being one of the three. If the numbers be whole, mixed, or decimal fractions, the proportion will be, as the multiplier on B is to unity on A, so is the multiplicand on A to the product on B; or as the multiplier on A is to unity on B, so is the multiplicand on B to the product on A.

I.

Required the product of 13 by 9?

Set 9 on B to 1 on A, and against 13 upon A is 117, the answer on B. Again, set 9 on A to 1 on B, and against 13 on B is 117 on A, the answer as before.

II.

Required the product of 8 by 14?

Set 14 on B to 1 on A, and against 8 upon A is 112, the answer on B. The answer may also be found on A, as in the first example.

III.

Required the product of 82 by 12·5?

Set 12·5 on A to 1 on B, and against 82 on B is 1025 on A.

DIVISION.

This rule is performed in the same manner as Multiplication; only in Multiplication the answer is found on the line opposite the unit, whilst in Division the answer is on the same line with the unit that you are using; that is, as unity on A is to the divisor on B, so is the dividend upon B to the quotient on A; or this operation may also be performed by placing the divisor on A to unity on B, and against the dividend upon A is the quotient on B.

I.

Required the quotient of 117 by 9?

Set 9 on B to 1 on A, and against 117 on B is 13 on A; or set 9 on A to 1 on B, and against 117 on A is 13 on B.

II.

Required the quotient of 300 by 12·5?

Set 12·5 on B to 1 on A, and against 300 on B is 24 on A, the answer; or the operation may be reversed, as in the last example.

RULE OF THREE DIRECT.

Three numbers are given to find a fourth that shall have the same proportion to the third as the second has to the first.

The rule is, as the first term on A is to the second on B, so is the third term on A to the fourth on B, carefully observing that the first and third terms be found on the same line, and the second and fourth upon the other; or the operation may be performed by finding the first and third terms on B, and the second and fourth on A.

I.

If 13 yards cost £16, how much will 39 yards cost?

Set 13 on A to 16 on B, and against 39 on A is £48, the answer, on B; or set 13 on B to 16 on A, and against 39 on B is £48 on A.

II.

If 3 cwt. of iron cost 31s. 6d. how much will 10 tons cost at the same rate?

Set 3 on A to 31½ on B, and against 10 tons on A is £105 on B, the answer. The slide placed thus, A is a line of tons, and B of the corresponding value in pounds, against any number at the same price;

or A a line of cwts., and B of the corresponding value in shillings.

RULE OF THREE INVERSE.

In using this rule the slide is to be inverted, then the operations will be performed the same way as in the Rule of Three Direct.

I.

If 8 horses can perform a piece of work in 12 hours, how many horses will perform the same in 4 hours?

First invert your slide, then set 12 hours on C to 8 on A, and against 4 upon C stands 24 on A, the answer.

II.

A safety valve lever 30 inches long, 6 inches between the fixed end and centre of the valve, what pressure on the under side of the valve will raise a weight of 20lb. placed at the end of the lever?

Set 30 on C to 20 on A, and against 6 on C is 100lb., the force required, on A.

III.

A common steelyard, whose lever is 43·5 inches long, the fulcrum 1·5 inches from one end, and a

weight of 112lb. attached to the short end, required the weight at the opposite end of the lever to equipoise the steelyard?

Set 1·5 on C to 112 on A, and against 42 on C (the long end of the lever) is 4lb., the weight on A.

SQUARE AND CUBE ROOT.

When 16 on the line C is opposite to 4 on the line D, then C is a table of squares and D a table of roots; so that opposite to any number on C is its square root on D; thus,

16, 25, 36, 49, 64, 81, 100, &c. the squares on C;
4, 5, 6, 7, 8, 9, 10, &c. the roots on D;
and in the same way all the squares and roots of the intermediate numbers may be found.

The cube of any number may be found by placing the number on C to 10 on D, and against the same number on D is the cube on C.

To find the mean proportion between two numbers, or the mean square of unequal sided timber.

As one number or one side on C, is to the same number or side on D, so is the other number or side upon C, to the number or mean square sought for on D.

I.

Required the mean proportion between 9 and 16?

Set 9 on C to 9 on D, and against 16 upon C is 12 on D.

II.

Required the mean square of a piece of timber 40 inches broad and 10 inches thick?

Set 10 on C to 10 on D, and against 40 upon C is 20 on D.

MEASURE OF SUPERFICIES

Is performed on the lines A and B; if the length be given in feet and the width in inches, the divisor or guage point is 12 on A, to which the width on B must be set, and against the length on A will be found the number of square feet on B.

When the length and breadth are taken in inches, the guage point is 144 on A; but if all in feet, then multiply the length by the breadth, which will give the number in square feet.

I.

Required the number of square feet in a board 16 inches broad and 18 feet long?

Set 16 on B to 12 (the guage point) on A, and against 18 on A is 24 upon B, the answer.

II.

Required the contents of 12 boards of the same dimensions as above?

Set 24 feet (the number contained in one board) on A to 1 on B, and against 12 on B is 288 feet on A. In like manner the contents of any number of boards may be found.

Land Surveying.

The guage points are the square chains, perches, and yards, contained in an acre. When the dimensions are in chains, the guage point is unit, or 10; if perches, 160; but if in yards, 4840 on the line A, to which the length on B must be set; and against the breadth on A will be the acres on B.

I.

How many acres are contained in a piece of land 10 chains 25 links in length, and 8 chains 80 links in breadth?

Set 10·25 on B to 1 on A, and against 8·8 on A is 9 acres on B, the answer.

II.

Required the contents of a field 71 perches long and 22·5 perches broad?

Set 71 on B to 160 on A (the guage point), and against 22·5 upon A is 10·01 acres on B.

III.

A piece of ground 880 yards in length and 44 yards in breadth, how many acres does it contain?

Set 880 on B to 4840 (the guage point) on A, and against 44 on A is 8 acres on B.

Circle.

The diameter being given, to find the area, or the area being given, to find the Diameter.

I.

The guage point 794 will be found under areas in the division with diameter.

Set 1 on B to 794 on A, then the line D is diameters, and the line C areas in square inches or feet.

II.

Having the area given, to find the circumference, or the circumference given, to find the area.

The guage point will be found also under areas, and adjoining circumference.

Set 1 on B to 786 (the guage point) on A; then the line D is circumferences, and C areas; or against any circumference on D is the area on C.

III.

Having the diameter given to find the circumference, or the circumference given to find the diameter.

The guage point is on the right of the last one on the rule.

Set 1 on B to 3·14 (the guage point) on A; then the line B is diameters, and A circumferences; or against any diameter on B is the circumference on A.

Polygons.

Rule.—As the guage point on A is to 1 on B, so is the length of one side of the polygon on D to the area on C.

I.

What is the area of a polygon with five sides, each side 5 inches long?

Set 1 on B to 364 (the guage point) on A, and against 5 on D is 43 square inches on C, the area.

II.

Required the area of a figure with twelve sides, each side being 4½ inches long?

Set 1 on B to 559 (the guage point) on A, and against 4½ on D is 226·7, the area, on C.

In like manner may the area of all the intermediate polygons be found by using the respective guage points which are given on the rule.

As octagon axles are frequently used, a ready method for finding their area is by taking the diameter between the opposite sides; the guage point in which case is 755.

I.

Required the area of an octagon axle 20 inches between opposite sides?

Set 1 on B to 775 on A, and against 20 on D is 331·3, the area, on C.

MENSURATION OF SOLIDS.

In the first place it is necessary to explain the guage points on the rule, which are now to be made use of for the purpose of measuring and finding the weight of solid bodies, all of which will be found on the line A.

1. The length of all bodies, round or square, must be found on the line B, and set to the guage point on A.

2. The squares and diameters must be had on the line D, opposite which will be found the contents, weight, or answer, on the line C; or as the length on B is to the guage point on A, so is the square or diameter on D to the answer on C.

In the table for squares, under F, F, F, are the guage points for dimensions that are taken feet long, feet wide, and feet thick, in a line with what is requisite to be measured or weighed.

Dimensions that are taken feet long and inches square, the guage points are under F, I, I; and when the dimensions are taken all in inches, the guage points will be found under I, I, I.

For cylinders, feet long and inches diameter, the guage points are under F, I; and for dimensions taken inches long and inches diameter, the guage points are under I, I.

A globe, having only one dimension, must be either feet or inches diameter; if feet, the gauge points are under F; if inches, under I.

The rule for a globe is, as the diameter on B is to the gauge point on A, so is the diameter again on D to the content weight, or answer, on C.

In finding the weight or measure of unequal sided bodies, the mean square must first be found as already explained in the use of the square root.

I.

Required the cubic feet contained in a cistern whose length is 28 feet, breadth 7 feet, and depth 6 feet?

First find the mean between the length and breadth by setting 28 on C to 28 on D, and against 7 on C you have 14 feet, the mean square on D; the gauge point is in a line with cubic feet, and under F, F, F.

Set 6, the depth, on B, to 625 (the gauge point) on A, and against 14 on D is 1176 cubic feet on C, the answer.

II.

How many cubic feet are contained in a piece of timber, 20 inches square and 10 feet long?

The gauge point in this case will be found in a line with cubic feet, and under F, I, I.

Set 10, the length, on B, to 9 (the gauge point) on A, and against 20, the square, on D, is 27¾ feet, the contents, on C.

III.

If the dimensions of the same piece of timber are taken in inches, the gauge point will be found under I, I, I.

Set 120, the length in inches on B, to 108 (the gauge point) on A, and against 20 on D is 27¾ feet on C, as before. If the cubic inches are required, make use of the gauge point in a line with cubic inches, and proceed as above.

Round timber is generally measured by taking the girt or circumference, one-fourth of which is considered the square; the operation is then precisely as the two last examples; this method is not correct, but is the one almost invariably used in practice. Where accuracy is wanted, the best way is to find the diameter as explained under circle, and proceed as in the following example.

CYLINDER.

I.

Required the cubic inches in a cylinder, 40 inches long and 20 inches diameter.

The gauge point 799 is in a line with cubic inches, and under I, I

Set 40 on B to 799 on A, and against 20 on D is 12566·4, the cubic inches, on C.

II.

Required the number of cubic feet in the same cylinder, the length taken in feet?

In the same line with cubic feet, and under F, I, is 114, the guage point.

Set 3·33, the length in feet, on B, to 114 on A, and against 20 on D is 7·27 cubic feet on C, the answer.

GLOBE.

I.

In a globe 5 feet diameter, how many cubic feet?

Set 5 on B to 119 (the guage point) on A, and against 5 on D is 65·45 cubic feet on C.

II.

Required the cubic inches in a globe 12 inches diameter?

Set 12 on B to 119 (the guage point) on A, and against 12 on D is 904·78, the contents on C.

A globe is two-thirds the cubic contents of a cylinder, whose height and diameter are the same as the diameter of the globe.

FLUID MEASURE.

I.

How many imperial gallons does a column of water contain, whose height is 24 feet, and diameter 12 inches?

Set 24 on B to 184 (the guage point) on A, (which point is in the same line with imperial gallons and under F, I,) and against 12 on D is 117·4 gallons, the answer on C.

N.B. The guage point for old wine gallon is 153, and ale gallon 188, which are not put on the rule in consequence of the late Act of Parliament rendering them of little use.

II.

Required the number of imperial gallons contained in a vessel 36 inches square?

The guage point 174 is under $\frac{\text{square}}{1,\ 1,\ 1,}$ and in a line with imperial gallons;

Set 36 on B to 174 on A, and against 36 on D is 168 gallons on C.

N.B. The gauge point for old wine gallon is 145, and old ale gallon 176.

III.

What number of imperial gallons are contained in a vessel 36 inches deep and 15 inches diameter?

Set 36 on B to 22 (the guage point) on A, and against 15 on D is 22·94 gallons, the answer, on C.

N.B. The guage point for old wine gallon is 183, and ale gallon 224.

CASK GUAGING.

Casks are generally calculated of four forms or varieties, viz.:—

1. The middle frustum of a spheroid.
2. The middle frustum of a parabolic spindle.
3. The lower frustums of two equal paraboloids.
4. The lower frustums of two equal cones.

When the difference between the end and bung diameters does not exceed 6 inches, then the mean diameter of the cask will be found by multiplying the difference between bung and head diameters for a cask of the

1st form by ·68.
2nd.......... ·62.
3rd.......... ·55.
4th.......... ·5.

The respective products in each case must be added to the head diameters for the mean diameter of the cask, with which and the length proceed exactly as in the last examples.

I.

Required the number of imperial gallons in a cask in all the four varieties, whose length is 30 inches, bung diameter 24, and head diameter 18 inches?

1st Variety.—Set 30 on B to 22 (the guage point) on A, and against 22·08 (the mean diameter) on D is 41.4 gallons on C.

2nd Variety.—Set 30 on B to 22 (the guage point) on A, and against 21·72 (the mean diameter) on D is 40 gallons on C.

3rd Variety.—Set 30 on B to 22 (the guage point) on A, and against 21·3 (the mean diameter) on D is 38·5 gallons on C.

4th Variety.—Set 30 on B to 22 on A, and against 21 on D is 37·7 gallons on C.

The contents in old ale or wine gallons may be found in the same way as above by taking the respective guage points as given in fluid measure.

MALT GUAGING.

Take the mean length, breadth, and depth of the floor or cistern, then find the mean square as directed in the square root.

I.

How many malt bushels are in a cistern whose length is 96 inches, breadth 64, and depth 32 inches?

Set 32 on B (the depth) to 138 (the gauge point) on A, and against 78·3 (the mean square) on D is 88·6 bushels on C.

II.

Required the number of bushels in a floor 20 feet long, 11½ broad, and 10 inches deep?

Find the mean square as directed above, which is 15.

Set 10 on B to 960 (the gauge point) on A, and against 15 on D is 146 bushels on C.

WEIGHT OF FLUID AND SOLID BODIES.

These operations are performed exactly in the same way as the measuring of all solid bodies, only the result will be in pounds weight, instead of cubic inches, cubic feet, gallons, &c.

WATER.

I.

Required the weight in lbs. of a column of water 6 feet long and 12 inches diameter?

Set 6 on B to 134 (the gauge point) on A (which is under $\frac{\text{cylinder}}{\text{F. L.}}$ and in a line with water lb.), and against 12 on D is 293lbs., the answer, on C.

II.

What weight of water will be contained in a cistern 3 feet deep and 30 inches square?

Set 3 on B to 144 (the guage point) on A, and against 30 on D is 1168lbs., the answer, on C.

Freestone and Coal.

I.

A column 12 feet high and 13·54 inches diameter, what will be its weight in lbs. in freestone and coal?

1st. Freestone.—Set 12 on B to 723 (the guage point) on A, and against 13·54 on D is 1682lb. on C.

2nd. Coal.—Set 12 on B to 146 (the guage point) on A, and against 13·54 on D is 940lb. the answer, on C.

II.

Required the weight in lbs. of a cubic yard of freestone and coal, dimensions in inches?

Freestone.—The gauge point is in a line with freestone, and under $\frac{\text{square}}{\text{I. I. I.}}$

Set 36 on B to 69 (the gauge point) on A, and against 36 on D is 4234·5lb. the weight on C.

Coal.—You will find the gauge point 138. Answer 2115lb.

Oak and Fir Timber.

I.

A log of timber 20 feet long and 12 inches square, required its weight in oak and fir, both being dry?

Oak.—Set 20 on B to 158 (the gauge point) on A, which is in a line with dry oak, and under $\frac{\text{square}}{\text{F. I. I.}}$, and against 12 on D is 1138lb. on C.

Fir.—The gauge point is 22.

Set 20 on B to 22 on A, and against 12 on D is 817lb. the answer, on C.

Brass, Copper, and Lead.

I.

Required the weight of a bar of each metal 6 feet long and $4\frac{1}{2}$ inches square?

Brass.—The guage point 174, is in a line with brass, and $\frac{\text{square}}{\text{F. I. I.}}$

Set 6 on B to 174 on A, and against $4\frac{1}{2}$ on D is 437lb., the weight on C.

Copper.—You have 163, the gauge point.

Set 6 on B to 163 on A, and against $4\frac{1}{2}$ on D is 466lb. on C.

Lead. Gauge point 126. Answer 601lb.

II.

Required the weight in lbs. of a globe 6 inches diameter, of brass, copper, and lead?

Set 6 on B to 397 (the gauge point) on A, and against 6 on D is 34lb. the weight in brass, on C.

Copper.—The gauge point 371 is under $\frac{\text{globe}}{\text{I.}}$ weight 36·3lb., the answer.

Lead.—The gauge point 229 is under $\frac{\text{globe}}{\text{I.}}$ weight 47lb., the answer.

Steel, Cast and Malleable Iron.

I.

What is the weight of a shaft or bar 9 feet long and 4 inches square in each of these metals?

Observe the gauge points are in a line with the name of the metal sought, and under $\frac{\text{square}}{\text{F. I. I.}}$, the dimensions being feet long and inches square.

Steel.—Set 9 on B to 163 (the gauge point) on A, and against 4 on D is 492lb. on C.

Cast-Iron.—Set 9 on B to 2 (the gauge point) on A, and against 4 on D is 450lb. on C.

Wrought-Iron.—You have 186 the gauge point, and 485lb. the weight.

II.

Required the weight of a cylinder 9 inches long and 6 inches diameter of each metal.

The gauge points will be found under $\frac{\text{cylinder}}{\text{I. I.}}$ the dimensions being all in inches.

Steel.—Set 9 on B to 278 (the gauge point) on A, and against 6 on D is 72·9lb. the weight, on C.

Cast-Iron.—Set 9 on B to 304 (the gauge point) on A, and against 6 on D is $66\frac{3}{4}$lb. on C.

Wrought-Iron.—The gauge point is 283, and the weight 71·85lb.

Octagon Axles.

I.

What is the weight of an octagon shaft in cast and wrought-iron, 9 feet long, measuring 4 inches across between opposite sides on its end?

The gauge points in this case are, for cast-iron 242, and for wrought-iron 225.

Cast-Iron.—Set 9 on B to 242 on A, and against 4 upon D is 372·3lb. on C.

Wrought-Iron.—Set 9 on B to 225 on A, and against 4 on D is 401·6lb. on C.

Ropes, Chains, and small Bar Iron.

I.

Rope.—What is the weight of a rope 20 yards long and 4½ inches circumference?

In the third table of gauge points, in a line with ropes, and under $\frac{\text{weight}}{\text{yards}}$ is 47; the gauge point is also marked rope, on the line A.

Set 20 on B to 47 on A, and against 4½ on D is 54lb. on C.

II.

Chain.—Required the weight of a short link chain 25 yards long and eight-sixteenths of an inch diameter?

The gauge point 52 is in a line with chains, and under $\frac{\text{weight}}{\text{yards}}$.

Set 25 on B to 52 on A, and against 8 on D is 192lb. on C.

III.

Iron, square.—Required the weight of a bar of iron 10 feet long and four-eighths of an inch square?

The gauge point is in a line with square iron and under feet.

Set 10 on B to 12 (the gauge point) on A, and against 4 on D is 8·34lb. on C.

IV.

Iron, round.—What is the weight of a bolt 20 feet long and four-eighths of an inch diameter?

Set 20 on B to 152 (the gauge point) on A, and against 4 on D is 13lb. on C.

The respective gauge points for chains, square and round iron, are also noted on the line A.

STRENGTH OF MATERIALS.

Ropes.

I.

What is the extreme strain or weight a 5-inch rope will bear before breaking? What weight will it safely work with in ordinary cases? And what weight in practice is usually assigned to it as applied to inclined planes?

In a line with ropes, the respective gauge points will be found; under $\frac{\text{strain}}{\text{extreme}}$ is 140, under $\frac{\text{work}}{\text{with}}$ 320, and under $\frac{\text{incline}}{\text{planes}}$ is 50, the three points required.

Extreme Strain.—Set 1 on B to 140 (the gauge point) on A, and against 5 on D is 11,200lb. on C, the weight the rope will bear before breaking.

Work with.—Set 1 on B to the gauge point 320 on A, and against 5 on D is 4890lb. on C, the weight it will safely work with.

Inclined Planes.—Set 1 on B to 50 on A, and against 5 on D is 3125lb. on C, the load usually assigned.

N.B. In calculating the load upon the rope of an inclined plane. If the load is to ascend, *add* the friction and weight of rope and carriages to the load for the real weight upon the rope; but if the load is to descend, then *deduct* the friction of carriages and rope from the load for the real weight upon the rope.

II.

Required the circumference of a rope that will bear or carry before breaking 11,200lb.? That will safely work with 4890lb.? And to work an inclined plane agreeable to the data usually allowed in practice when the load is 3125lb.?

First extreme Strain.—Set 1 on B to 140 (the gauge point) on A, and against 11,200 on C is 5, the circumference of the rope in inches on D.

The other two answers are found exactly after the same manner, by referring to the respective gauge points.

Observe, the weight or load is always found on C, and the size or circumference of the rope on D.

Chains.

1st.—What is the extreme weight or strain a chain seven-sixteenths of an inch diameter will bear before breaking?

2nd.—What weight will the same safely work with?

3rd.—What weight or load usually assigned on inclined planes?

Look for the respective gauge points in the same line with chains, and under $\frac{\text{strain}}{\text{extreme}}$ is 30, under $\frac{\text{work}}{\text{with}}$ is 78, and under $\frac{\text{incline}}{\text{planes}}$ is 13.

1st.—Set 1 on B to 30 on A, and against 7 (the diameter in sixteenths) on D is 10,200lb., the extreme strain on C.

2nd.—Set 1 on B to 78 (the gauge point) on A, and against 7 on D is 3925lb. on C, the load the chain will safely work with.

3rd.—Set 1 on B to 13 on A, and against 7 on D is 2350lb. on C, the load usually assigned when applied to inclined planes.

If the load or weight be given, to find the diameter of the chain; proceed exactly in the same manner as in the last cases, only observe to find the weight or strain in pounds on C, against which will be found the diameter of the chain in sixteenth parts of an inch on D.

N.B. The friction and weight of carriages must be added or deducted in calculating the real load in the same way as done with ropes as applied to inclined planes.

IRON.

I.

Required the extreme strain that a bar of ordinary iron 8-eighths of an inch square will bear before breaking? The load or weight it will safely carry when applied as a suspension bar, screw, bolt, &c.?

1st.—Set 1 on B to 642 on A (the gauge point, which will be found in a line with square iron, and under $\frac{\text{strain}}{\text{extreme}}$), and against 8 (the number of eighths square), on D is 62,200lb. on C, the extreme strain; this will also be found in the Table of direct Cohesion of Bars.

2nd.—Set 1 on B to 265 on A (the gauge point under $\frac{\text{work}}{\text{with}}$), and against 8 on D is 15,100lb., which the bar ought safely to carry, when applied as described above.

II.

How many pounds weight will a round bar or bolt of ordinary iron, six-eighths of an inch diameter, carry before breaking? And what weight will it safely suspend or work with?

In a line with round iron, and under the respective heads, will be found the two gauge points.

1st. EXTREME STRAIN.—Set 1 on B to 816 (the gauge point) on A, and against 6 on D is 2760lb. on C.

2nd. SUSPEND OR WORK WITH.—Set 1 on B to 338 (the gauge point) on A, and against 6 (the diameter in eighths) on D is 665lb., the answer on C.

Piston rods are found after the same manner, only observe the gauge point is 32, to which unit or 10 upon B must be set, and against the weight or extreme load on the piston on C, is the diameter of the rod in eighths of an inch on D.

CAST-IRON BEAMS.

In finding the strength of beams, supported at each end and loaded on the centre, the gauge point must be found on the line B; for beams 1 inch thick the point is 36.

I.

Required the weight in lbs. a beam will bear on its centre before breaking, 3 feet long, 2 inches deep, and 1 inch thick?

Set 3 on A to 36 (the gauge point) on B, and against 2 on D is 3000lb. on C.

II.

What load will a beam carry on its centre, before breaking, 6 feet long, 4 inches deep, and 1 inch thick?

Set 6 on A to 36 on B, and against 4 on D is 6000lb. on C.

III.

Required the extreme weight a beam will bear, loaded as above, 8 feet long, 4 inches deep, and 1 inch thick?

Set 8 on A to 36 on B, and against 4 on D is 4500lb. on C.

The preceding examples on the strength of beams is the extreme weight they will bear before breaking, but when practically applied, the strength ought to be from 3 to 10 times this data, depending upon the nature and purpose for which the beam is required; for joisting, three times will be found generally sufficient, but for machinery, such as engine beams, &c. ten times the data will not be more, in many cases, than can be safely relied upon. These remarks apply

to cast-iron only; wrought-iron beams will bear about one-ninth more, but the allowance for practical purposes need not exceed one-half that of cast-iron.

WROUGHT-IRON BEAMS,

Supported in the centre, and the weight applied at each end.

The gauge points in this case will also be found on B; for beams 1 inch thick the point is 204.

I.

What is the extreme weight a scale beam will carry at each end, 5 feet long, 5 inches deep, and 1 inch thick?

Set 5 feet on A to (the gauge point) 204 on B, and against 5 (the depth) on D is 6375lb.

II.

Required the extreme weight an engine beam will carry at each end, 15 feet long, 10 inches deep, and 1 inch thick?

Set 15 upon A to 204 on B, and against 10 on D is 8500lb. on C.

For practical purposes the allowance on wrought-iron beams is about one-half that of cast-iron. It is necessary to remark that in both cases the examples and gauge points are given for beams 1 inch thick, the strength being always in direct proportion to the thickness; that is, twice the thickness will carry twice the weight, or one-half the thickness only half the weight.

GOVERNORS.

RULE.—Invert your slide; then as unity or 1 on C is to 187 (the gauge point) on A, so is the square root of the pendulum or arms to which the balls are attached in inches on C to the number of revolutions per minute on A.

I.

Required the number of revolutions per minute of a steam engine governor, whose pendulums or arms are 36 inches long?

With the slide inverted; set 1 on C to 187 on A, and against 6 (the square root of the pendulum or arm) on C is 31·25 on A, the number of revolutions.

POWER OF STEAM ENGINES.

HIGH PRESSURE ENGINES.

RULE.—As the pressure of the steam per square inch on the safety valve on B, is to the gauge point

250 on A, so is the diameter of the cylinder on D, to the horses' power on C.

I.

A cylinder, 30 inches diameter, steam 25lb. per square inch on the safety valve, required the number of horses' power?

Set 25, the pressure of steam, on B, to 250 on A, and against 30, the diameter of the cylinder, on D, is 56 horses' power, on C.

II.

A cylinder, 20 inches diameter, steam 35lb. on the safety valve, the number of horses' power are required? Ans. 35 horses' power.

BOULTON AND WATT'S DOUBLE POWERED ENGINES.

I.

Required the number of horses' power of a cylinder 24 inches diameter?

The gauge point is 18 on A, to which 1 on B must be set.

Place 1 on B to 18 on A, and against 24 on D is 20 on C, the number of horses' power.

When the slide is thus set, the line D is diameters and C horses' power.

FALLING BODIES.

The velocity acquired by heavy bodies falling near the surface of the earth, is 16$\frac{1}{12}$ feet the first second, 64·3 feet in two seconds, and 257 in four seconds; therefore, if you set 257 on C to 4 on D, the line D is the number of seconds, and the line C is the number of feet fallen.

I.

Suppose a stone dropped from Mr. Green's balloon reached the earth at the end of 12 seconds, required the height of the balloon from the earth?

Set 257 on C to 4 on D, and against 12 on D is 2315 feet, the answer, on C.

WEIGHT OF CAST-IRON PIPES.

RULE.—As the thickness of the pipe on B, is to 102 on A (the gauge point for pipes 12 inches long), so is the mean diameter on A, to the weight in pounds, on B.

I.

Required the weight of a cast-iron pipe 12 inches long, the bore 10 inches, and thickness ½ an inch.

Set ·5 on B to 102 (the gauge point) on A, and against 10½ (the mean diameter) on A, is 51·3lb. on B.

II.

What is the weight of a pipe 12 inches long, 13 inches diameter in the bore, and 1 inch thick?

Set 1 on B to 102 on A, and against 14 (the mean diameter) on A, is 137lb. on B.

III.

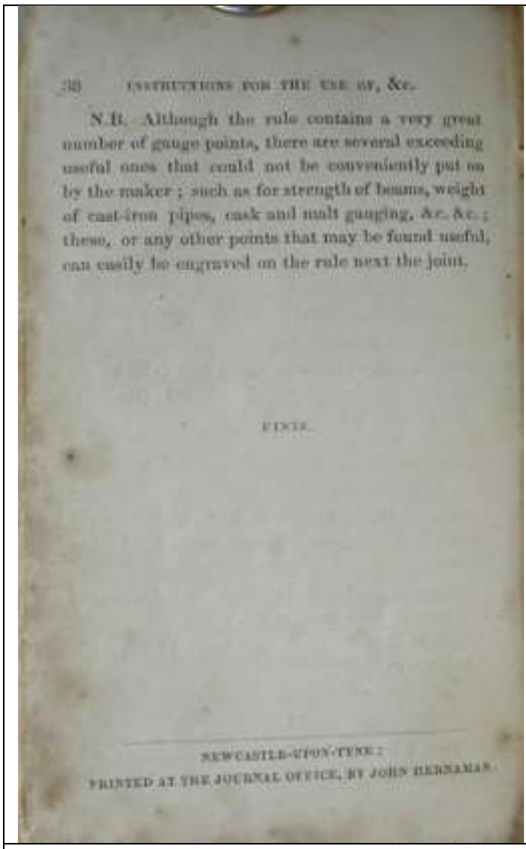
Required the weight in cwts. of a pipe one fathom or 6 feet long, 10 inches diameter inside, and half an inch thick?

The gauge point, in this case, is 191 on A, to which the thickness must be set.

Set ·5 on B to 191 on A, and again at 10½ on A is 2·74 cwts. on B.

IV.

A pipe, 1 fathom long, 13 inches bore, and 1 inch thick, required its weight? Ans. 7·34 cwts.



[illegible] INSTRUCTIONS FOR THE USE OF, &c.

N.B. Although the rule contains a very great number of gauge points, there are several exceeding useful ones that could not be conveniently put on by the maker; such as for strength of beams, weight of cast-iron pipes, cask and malt gauging, &c. &c.; these, or any other points that may be found useful, can easily be engraved on the rule next the joint.

FINIS.

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