DESCRIPTION
OF AN
ENGINE
FOR
DIVIDING MATHEMATICAL INSTRUMENTS.

BY MR. J. RAMSDEN,
MATHEMATICAL INSTRUMENT-MAKER.

Publiſhed by ORDER of the
COMMISSIONERS OF LONGITUDE. a

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PREFACE.

MR. *Ramſden*, Mathematical Inſtrument-maker, in *Piccadilly*, was paid the Sum of 615 *l.* by certificate from the Commiſſioners of Longitude, upon delivering to them, upon oath, a full and complete written Explanation and Deſcription of his Engine for Dividing Mathematical Inſtruments (accompanied with proper Drawings) and of the Manner of Uſing the ſame, and alſo of the Engine by which a
b the Endleſs Screw, being a principal Part of the ſaid Dividing Engine, was made; and upon agreeing and entering into articles with them for aſſigning over the Right and Property of the ſaid Engine to them, for the Uſe of the Public; and engaging himſelf to give to the ſaid Commiſſioners, and ſuch other Perſons, being Mathematical Inſtrument-makers, not exceeding Ten, as ſhall be appointed by them, during the ſpace of Two years, from the 28th of *October* 1775 to the 28th of *October* 1777, ſuch Inſtruction and Information with regard to the making and uſing of the ſaid Engine, as may be fully ſufficient to enable
c any intelligent workman to conſtruct and uſe other Engines of the ſame kind; and alſo binding himſelf
d to divide all Octants and Sextants, by the ſaid Engine,

which

which ſhall be brought to him by any Mathematical Inſtrument-makers for that purpoſe, at the rate of Three Shillings for each Octant, and at the rate of Six Shillings for each braſs Sextant, with Nonius Diviſions to Half Minutes, for ſo long a time as the ſaid Commiſſioners ſhall think proper to permit the ſaid Engine to remain in his poſſeſſion: of which Sum of 615 *l.* paid to the ſaid Mr. *Ramſden*, 300 *l.* was given him as a Reward for the Improvement made by him in the Art of Dividing Inſtruments by means of the ſaid Dividing Engine, and for Diſcovering the ſame; and the remaining 315 *l.* in conſideration of his making over the Property in the ſaid Engine to the Commiſſioners of Longitude, for the Uſe of the Public, and for the other Conſiderations before-mentioned.

In order to render this Inſtrument more extenſively uſeful, the Commiſſioners of Longitude ordered the written Explanation, with Drawings, of the Dividing Engine, to be prepared for Publication: and it is now publiſhed accordingly.

GREENWICH,
Nov. 28, 1776.

NEVIL MASKELYNE,
ASTRONOMER-ROYAL.

PLATE I

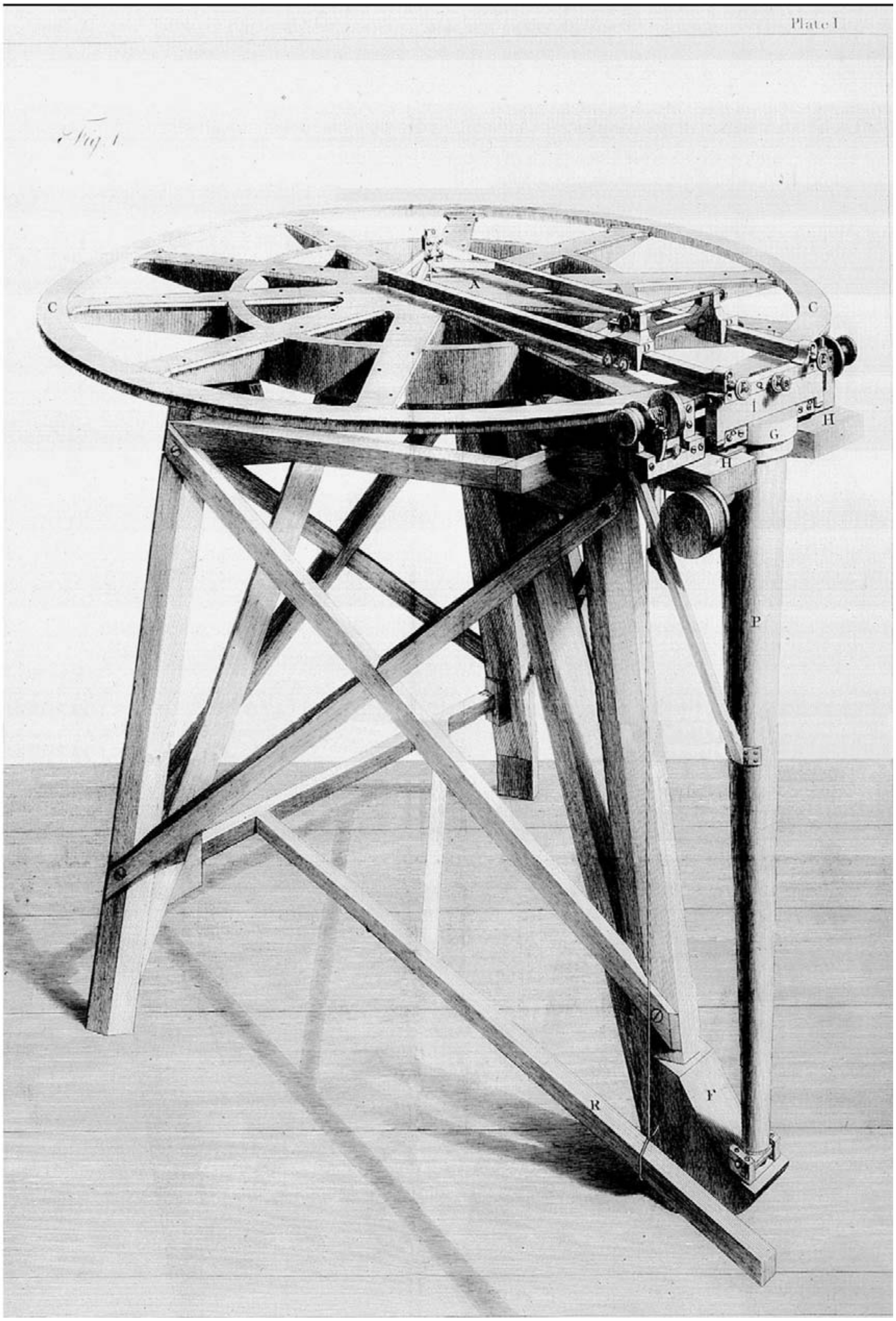

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PLATE II

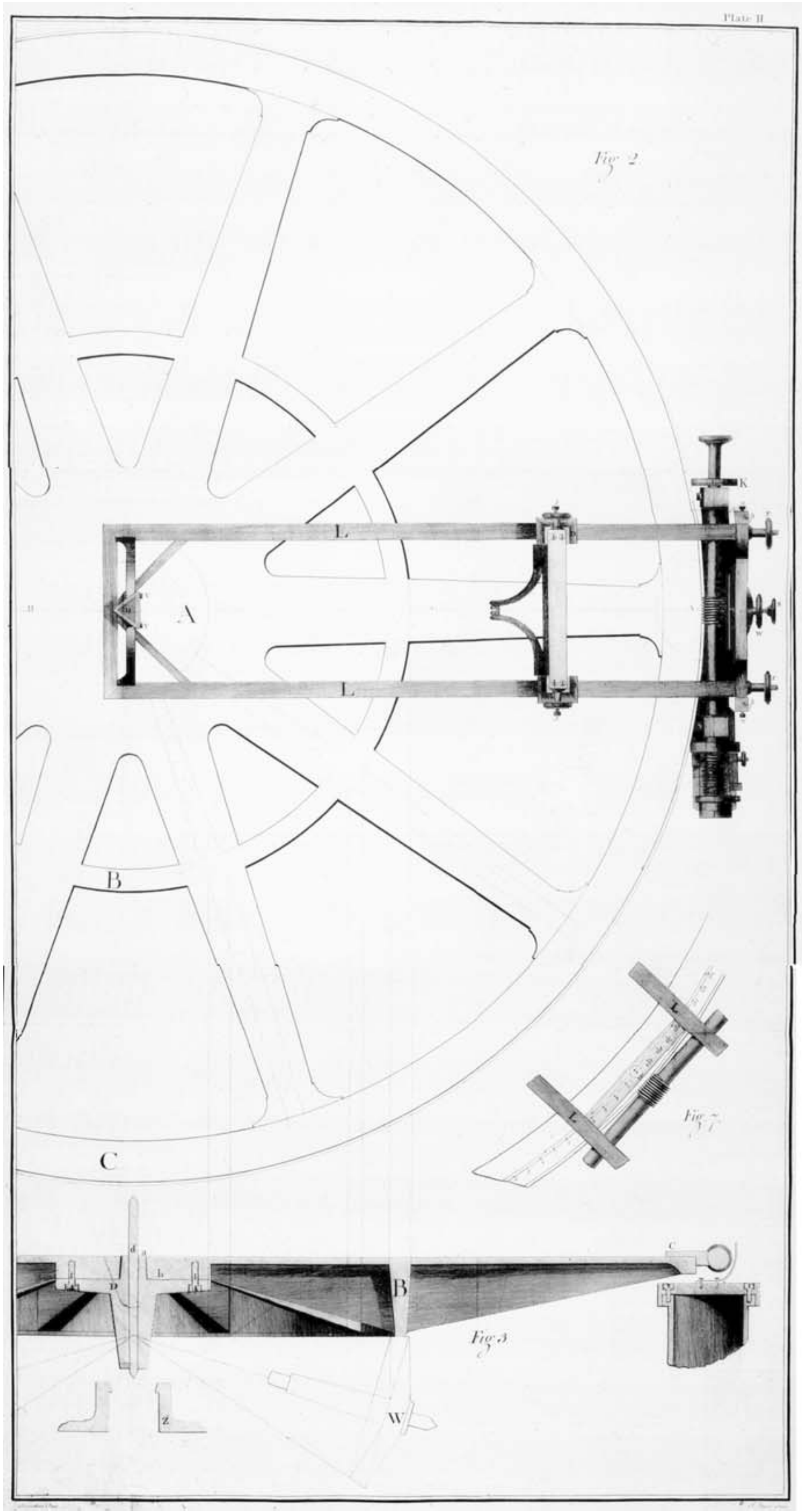
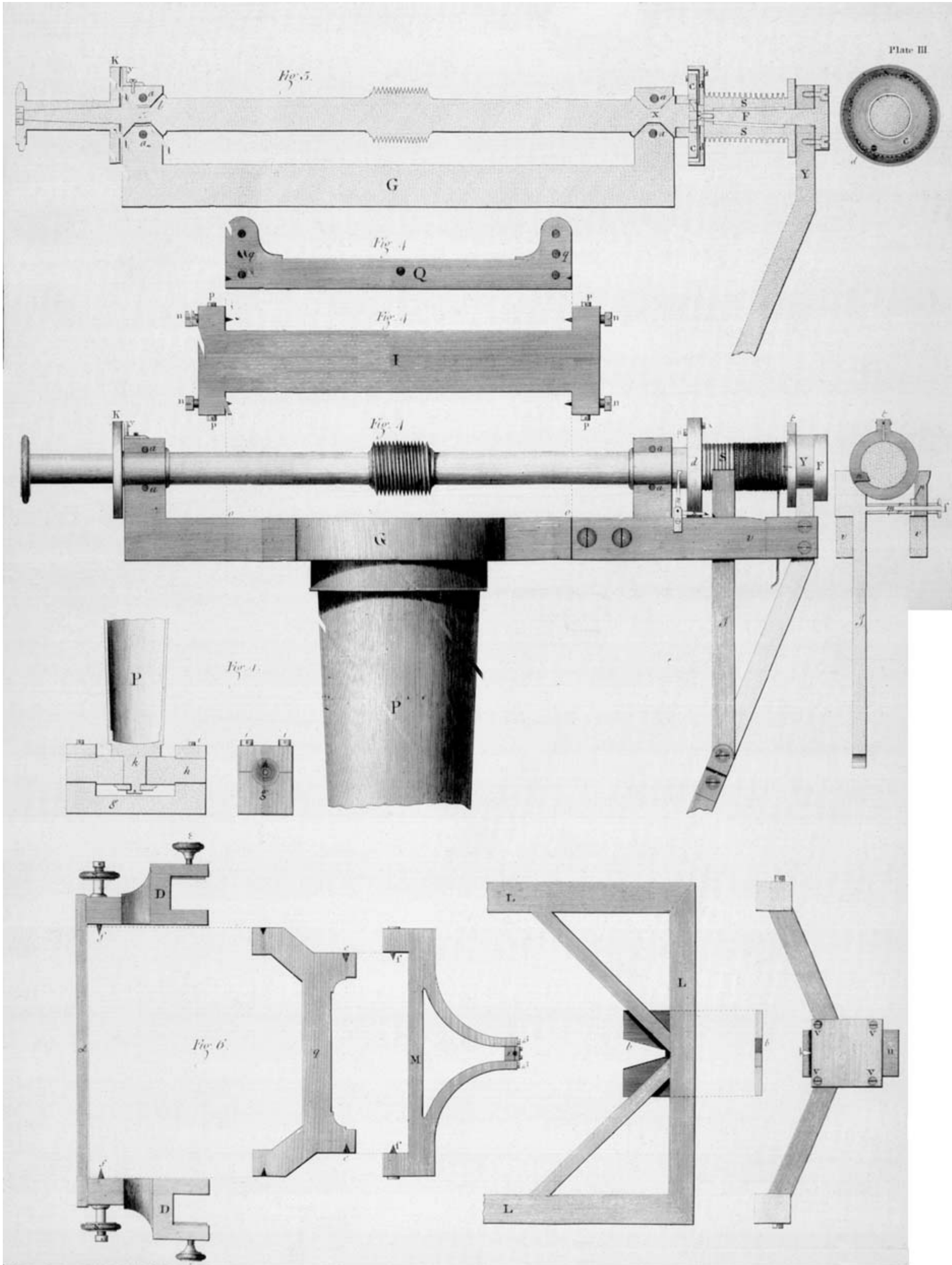


PLATE III



DESCRIPTION OF THE ENGINE

FOR DIVIDING

MATHEMATICAL INSTRUMENTS.

THIS Engine conſiſts of a large Wheel of Bell-metal, a
b ſupported on a mahogany ſtand, having three legs, c
which are ſtrongly connected together by braces, ſo as to make it perfectly ſteady. On each leg of the ſtand is placed
d a conical friction-pully, whereon the Dividing-wheel reſts: to prevent the Wheel from ſliding off the friction-pullies, the
e bell-metal center under it turns in a ſocket on the top of the ſtand.

The Circumference of the Wheel is ratched or cut (by a method which will be deſcribed hereafter) into 2160 Teeth, f
g in which an endleſs Screw acts. Six revolutions of the Screw will move the Wheel a ſpace equal to one degree.

Now a Circle of Braſs being fixed on the Screw Arbor, having its Circumference divided into Sixty Parts, each Diviſion will conſequently anſwer to a Motion of the Wheel of
h Ten Seconds, Six of them will be equal to a Minute, &c.

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Several different Arbors of tempered ſteel are truly ground a
b into the Socket in the center of the Wheel. The upper parts of the arbors that ſtand above the plane are turned of various ſizes, to ſuit the centers of different pieces of work to be divided.

When any Inſtrument is to be divided, the Center of it is very exactly fitted on one of theſe Arbors, and the Inſtrument is fixed down to the plane of the Dividing-wheel by means of ſcrews, which fit into holes made in the Radii of the Wheel for that purpoſe.

The Inſtrument being thus fitted on the plane of the Wheel, the Frame which carries the Dividing-point is connected at one end by finger ſcrews with the frame which carries the endleſs ſcrew; while the other end embraces that part of the ſteel arbor, which ſtands above the Inſtrument to be divided,
c by an angular notch in a piece of hardened ſteel: by this means both ends of the frame are kept perfectly ſteady and free from
d any ſhake.

The frame carrying the Dividing-point or Tracer is made to ſlide on the frame which carries the endleſs Screw to any diſtance from the center of the Wheel, as the Radius of the Inſtrument to be divided may require, and may be there faſtened by tightening two clamps; and the Dividing-point or Tracer being connected with the clamps by the double-jointed frame admits a free and eaſy motion towards or from the center for cutting the diviſions, without any lateral ſhake. e

From

From what has been ſaid it appears, that an Inſtrument thus fitted on the Dividing-wheel may be moved to any angle by the ſcrew and divided circle on its arbor, and that this angle may be marked on the Limb of the Inſtrument with the greateſt exactneſs by the Dividing-point or Tracer, which can only move in a direct line tending to the center, and is altogether freed from thoſe inconveniences that attend cutting by means of a ſtraight edge. This method of drawing lines will alſo prevent any error that might ariſe from an expanſion or contraction of the metal during the time of dividing. a

The Screw-frame is fixed on the top of a conical Pillar, which turns freely round its axis, and alſo moves freely towards or from the center of the Wheel, ſo that the Screw-frame may be intirely guided by the frame which connects it with the center: by this means any excentricity of the Wheel and the Arbor would not produce any error in the dividing; and, by a particular contrivance, which will be deſcribed hereafter, the ſcrew when preſſed againſt the Teeth of the Wheel always moves parallel to itſelf; ſo that a Line joining the center of the Arbor and the Tracer continued, will always make equal angles with the ſcrew. b c

Figure 1. repreſents a perſpective view of the Engine.

Fig. 2. is a plan of half dimenſions; of which Fig. 3. repreſents a ſection on the line ΠΛ. d

The large wheel A is 45 inches in diameter, and has ten radii, each being ſupported by edge-bars, as repreſented in Fig. 3. Theſe bars and radii are connected by the circular ring B. 24 inches in diameter, and 3 deep: and, for greater ſtrength, the whole is caſt in one piece in bell-metal. e f

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As the whole weight of the wheel A reſts on its ring B, the edge-bars are deepeſt where they join it; and from thence their depth diminiſhes, both towards the center and the circumference, as repreſented in Fig. 3.

The ſurface of the wheel A was worked very even and flat, and its circumference turned true. The ring C *, of fine braſs, a
was fitted very exactly on the circumference of the wheel, and was faſtened thereon with ſcrews, which, after being ſcrewed
b as tight as poſſible, were well riveted. The face of a large chuck being turned very true and flat in the lath, the flat- c
Fig. 3. tened ſurface A of the wheel was faſtened againſt it with holdfaſts: and the two ſurfaces and circumference of the ring C; d
a hole through the center and the plane part (b) round it, and the lower edge of the ring B were turned at the ſame time.

D is a piece of hard bell-metal, having the hole, which receives the ſteel arbor (d), made very ſtraight and true. This bell-metal was turned very true on an arbor, and the face, e
which reſts againſt the wheel at (b), was turned very flat, ſo that the ſteel arbor (d) might ſtand perpendicular to the plane f
of the wheel: this bell-metal was faſtened to the wheel by ſix ſteel ſcrews (l).

A braſs ſocket Z is faſtened on the center of the mahogany g
ſtand, and receives the lower part of the bell-metal piece D, being made to touch the bell-metal in a narrow part near the mouth, to prevent any obliquity of the wheel from bending the arbor: good fitting is by no means neceſſary here; ſince any ſhake in this ſocket will produce no bad effect, as will appear hereafter when I deſcribe the cutting frame.

The

* See a ſection of the ring at C, Fig. 3.

The wheel was then put on its ſtand, the lower edge of the ring B, reſting on the circumference of three conical friction-pullies W, to facilitate its motion round its center. The axis of one of theſe pullies is in a line joining the center of the wheel and the middle of the endleſs ſcrew, and the other two placed ſo as to be at equal diſtances from each other. Fig. 1, 2, & 3. a

b F is a block of wood ſtrongly faſtened to one of the legs of the ſtand; the piece (g) is ſcrewed to the upper ſide of the block, and has half holes, in which the tranſverſe axis (h) turns: the half holes are kept together by the ſcrews (i). Fig. 1. Fig. 4. c

The lower extremity of the conical pillar P terminates in a cylindric ſteel pin (k), which paſſes through and turns in the tranſverſe axis (h), and is confined by a cheek and ſcrew. Fig. 1 & 4. Fig. 4.

To the upper end of the conical pillar is faſtened the frame G, in which the endleſs ſcrew turns: the pivots of the ſcrew are formed in the manner of two fruſtrums of cones joined by a cylinder, as repreſented at X. Theſe pivots are confined between half holes, which preſs only on the conical parts, and do not touch the cylindric parts: the half holes are kept together by ſcrews (a), which may be tightened at any time, to prevent the ſcrew from ſhaking in the frame. Fig. 4. d e Fig. 5. f

On the ſcrew arbor is a ſmall wheel of braſs K, having its outſide edge divided into 60 parts, and numbered at every 6th diviſion with 1, 2, &c. to 10. The motion of this wheel is ſhewn by the index (y) on the ſcrew frame G. Fig. 1, 2, 4, 5. g Fig. 4 & 5.

H repreſents part of the ſtand, having a parallel ſlit in the direction towards the center of the wheel, large enough to re- Fig. 1. h

ceive

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ceive the upper part of the conical braſs pillar P, which carries the ſcrew and its frame: and as the reſiſtance, when the wheel is moved by the endleſs ſcrew, is againſt that ſide of the ſlit H which is towards the left hand, that ſide of the ſlit is faced with braſs, and the pillar is preſſed againſt it by a ſteel ſpring on the oppoſite ſide: by this means the pillar is ſtrongly ſupported laterally, and yet the ſcrew may be eaſily preſſed from or againſt the circumference of the wheel, and the pillar will turn freely on its axis to take any direction given it by the frame L. a b c

Fig. 4. At each corner of the piece I are ſcrews (n) of tempered ſteel, having poliſhed conical points: two of them turn in conical holes in the ſcrew-frame near (o), and the points of the other two ſcrews turn in holes in the piece Q; the ſcrews (p) are of ſteel, which being tightened prevent the conical pointed ſcrews from unturning when the frame is moved. d e

Fig. 1. 2. 6. L is a braſs frame which ſerves to connect the endleſs ſcrew, its frame, &c. with the center of the wheel: each arm of this frame is terminated by a ſteel ſcrew, that may be paſſed through Fig. 4. any of the holes (q) in the piece Q, as the thickneſs of work to be divided on the wheel may require, and are faſtened by Fig. 1 & 2. the finger-nuts (r). f

At the other end of this frame is a flat piece of tempered Fig. 6. ſteel (b), wherein is an angular notch: when the endleſs ſcrew is preſſed againſt the teeth on the circumference of the wheel, Fig. 1 & 2. which may be done by turning the finger-ſcrew S, to preſs againſt the ſpring (t), this notch embraces and preſſes againſt Fig. 2. the ſteel arbor (d). This end of the frame may be raiſed or g h

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preſſed by moving the priſmatic ſlide (u), which may be fixed at any height by the four ſteel ſcrews (v). Fig. 1. 2. 6. a

The bottom of this ſlide has a notch (k), whoſe plane is parallel to the endleſs-ſcrew, and by the point of the arbor (d) reſting in this notch, this end of the frame is prevented from tilting: the ſcrew S is prevented from unturning by tightening the finger-nut (w). Fig. 1 & 6. Fig. 3. b Fig. 1. 2.

The teeth on the circumference of the wheel were cut by the following method.

Having conſidered what number of teeth on the circumference would be moſt convenient, which in this Engine is 2160, or 360 multiplied by 6, I made two ſcrews of the ſame dimenſions, of tempered ſteel, in the manner hereafter deſcribed, the interval between the threads being ſuch as I knew by calculation would come within the limits of what might be turned off the circumference of the wheel: one of theſe ſcrews, which was intended for ratching or cutting the teeth, was notched acroſs the threads, ſo that the ſcrew, when preſſed againſt the edge of the wheel and turned round, cut in the manner of a ſaw. Then having a ſegment of a circle a little greater than 60 degrees, of about the ſame radius with the wheel, and the circumference made true, from a very fine center, I deſcribed an arch near the edge, and ſet off the chord of 60 degrees on this arch. This ſegment was put in the place of the wheel, the edge of it was ratched, and the number of revolutions and parts of the ſcrew contained between the interval of the 60 degrees were counted. The radius was corrected in the proportion of 360 revolutions, which ought c d

to

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to have been in 60 degrees, to the number actually found: and the radius, ſo corrected, was taken in a pair of beam-compaſſes: while the wheel was on the lath, one foot of the compaſſes was put in the center, and with the other a circle was deſcribed on the ring; then half the depth of the threads of the ſcrew being taken in dividers was ſet from this circle outtwards, and another circle was deſcribed cutting this point; a hollow was then turned on the edge of the wheel of the ſame curvature as that of the ſcrew at the bottom of the threads: the bottom of this hollow was turned to the ſame radius or diſtance from the center of the wheel as the outward of the two circles before-mentioned.

a b c

Fig. 3. The wheel was now taken off the lath, the bell-metal piece D was ſcrewed on as before directed, which after this ought not to be removed. d

Fig. 1, 2, 3. From a very exact center, a circle was deſcribed on the ring C, about $\frac{4}{10}$ of an inch within where the bottom of the teeth would come; this circle was divided with the greateſt exactneſs I was capable of, firſt into 5 parts, and each of theſe into 3; theſe parts were then biſected 4 times (that is to ſay) ſuppoſing the whole circumference of the wheel to contain 2160 teeth, this being divided into 5 parts, each would contain 432 teeth, which being divided into 3 parts, each of them would contain 144, and this ſpace biſected 4 times would give 72, 36, 18, and 9; therefore each of the laſt diviſions would contain 9 teeth: but, as I was apprehenſive ſome error might ariſe from quinqueſection and triſection, in order to examine the accuracy of the diviſions,
Fig. 7. I deſcribed another circle on the ring C, $\frac{1}{10}$ inch within the former, and divided it by continual biſections, as 2160, 1080, 540,

e f

540, 270, 135, 67½, and 33¾; and, as the fixed wire (to be defcribed prefently) croffed both the circles, I could examine their agreement at every 135 revolutions (after ratching could examine it at every 33¾); but, not finding any fenfible difference between the two fetts of divifions, I, for ratching, made choice of the former; and, as the coincidence of the fixed wire with an interfection could be more exactly determined than with a dot or divifion, I therefore made ufe of interfections in both circles before defcribed. a b

The arms of the frame L were connected by a thin piece of brafs of ¾ of an inch broad, having a hole in the middle of $\frac{4}{10}$ of an inch in diameter; acrofs this hole a filver wire was fixed exactly in a line to the center of the wheel; the coincidence of this wire with the interfections was examined by a lens $\frac{7}{10}$ inch focus, fixed in a tube which was attached to one of the arms L*. Now, a handle or winch being fixed on the end of the fcrew, the divifion marked 10 on the circle K was fet to its index, and, by means of a clamp and adjufting fcrew for that purpofe, the interfection marked 1 on the circle C was fet exactly to coincide with the fixed wire; the fcrew was then carefully preffed againft the circumference of the wheel, by turning the finger-fcrew S; then, removing the clamp, I turned the fcrew by its handle 9 revolutions, till the interfection marked 240 came nearly to the wire; then, unturning the finger-fcrew S, I releafed the fcrew from the wheel, and turned the wheel back till the interfection marked 2 exactly coincided with the wire, and, by means of the clamp before-mentioned, the divifion 10 on the circle being fet to its index, the fcrew was preffed againft the edge of Fig 7. c d e, f

* The Interfections are marked for the fake of illuftration, though properly invifible, they lying under the brafs plate.

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the wheel by the finger-ſcrew S; the clamps were removed, and the ſcrew turned 9 revolutions till theinter ſection marked 1 nearly coincided with the fixed wire; the ſcrew was releaſed from the wheel by unturning the finger-ſcrew S, as before, the wheel was turned back till the interſection 3 coincided with the fixed wire; the diviſion 10 on the circle being ſet to its index, the ſcrew was preſſed againſt the wheel as before, and the ſcrew was turned 9 revolutions, till the interſection 2 nearly coincided with the fixed wire, and the ſcrew was releaſed; and I proceeded in this manner till the teeth were marked a round the whole circumference of the wheel. This was repeated three times round, to make the impreſſion of the ſcrew deeper. I then ratched the wheel round continually in the ſame direction without ever diſengaging the ſcrew, and in ratching b the wheel about 300 times round the teeth were finiſhed.

Now it is evident, if the circumference of the wheel was even one tooth or ten minutes greater than the ſcrew would require, this error would in the firſt inſtance be reduced to $\frac{1}{240}$ part of a revolution or two ſeconds and a half; and theſe errors or inequalities of the teeth were equally diſtributed round the wheel at the diſtance of 9 teeth from each other. Now, as the ſcrew in ratching had continually hold of ſeveral teeth at the ſame time, and theſe conſtantly changing, the above-mentioned inequalities ſoon corrected themſelves, and the teeth c were reduced to a perfect equality. The piece of braſs which carries the wire was now taken away, and the cutting ſcrew was alſo removed, and a plain one (hereafter deſcribed) put in its place: on one end of the ſcrew is a ſmall braſs circle, having its edge divided into 60 equal parts, and numbered at every

ſixth

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ſixth diviſion, as before-mentioned. On the other end of the ſcrew is a ratchet-wheel C, having 60 teeth, covered by the hollowed circle (d), which carries two clicks that catch upon the oppoſite ſides of the ratchet, when the ſcrew is to be moved forwards. The cylinder S turns on a ſtrong ſteel arbor F, which paſſes through and is firmly ſcrewed to the piece Y: this piece, for greater firmneſs, is attached to the ſcrew-frame G by the braces (v): a ſpiral groove or thread is cut on the outſide of the cylinder S, which ſerves both for holding the ſtring and alſo giving motion to the lever J on its center by means of a ſteel tooth (n), that works between the threads of the ſpiral. To the lever is attached a ſtrong ſteel pin (m), on which a braſs ſocket (r) turns: this ſocket paſſes through a ſlit in the piece (p), and may be tightened in any part of the ſlit by the finger-nut (f): this piece ſerves to regulate the number of revolutions of the ſcrew for each tread of the treadle R. Fig. 5. Fig. 4. Fig. 1.

a b c d e f g

T is a braſs box containing a ſpiral ſpring; a ſtrong gut is faſtened and turned 3 or 4 times round the circumference of this box; the gut then paſſes ſeveral times round the cylinder S, and from thence down to the treadle R. Now, when the treadle is preſſed down, the ſtring pulls the cylinder S round its axis, and the clicks catching hold of the teeth on the ratchet carry the ſcrew round with it, till, by the tooth (n) working in the ſpiral groove, the lever J is brought near the wheel (d), and the cylinder ſtopped by the ſcrew head (x) ſtriking on the top of the lever J; at the ſame time the ſpring is wound up by the other end of the gut paſſing round the box T. Now, when the foot is taken off the treadle, the ſpring unbending itſelf pulls back the cylinder, the clicks leaving the ratchet and Fig. 1. Fig. 4. Fig. 1.

h

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Fig. 4. ſcrew at reſt till the piece (t) ſtrikes on the end of the piece (p): the number of revolutions of the ſcrew at each tread is limited by the number of revolutions the cylinder is allowed to turn back before the ſtop ſtrikes on the piece (p).

When the endleſs ſcrew was moved round its axis with a conſiderable velocity, it would continue that motion a little Fig. 1 & 4. after the cylinder S was ſtopped: to prevent this the angular lever η was made; that when the lever J comes near to ſtop the ſcrew (x), it, by a ſmall chamfor, preſſes down the piece $\varkappa$ of the angular lever; this brings the other end η of the ſame lever forwards, and ſtops the endleſs ſcrew, by the ſteel pin μ ſtriking upon the top of it: the foot of the lever is raiſed again by a ſmall ſpring preſſing on the brace (v). a b c

Fig. 1.2.6. D, two clamps, connected by the piece α, ſlide one on each arm of the frame L, and may be fixed at pleaſure by the four finger-ſcrews ε, which preſs againſt ſteel ſprings to avoid ſpoiling the arms: the piece (q) is made to turn without ſhake between the two conical pointed ſcrews (f), which are prevented from unturning by tightening the finger-nuts N.

Fig. 6. The piece M is made to turn on the piece (q), by the conical pointed ſcrews (f) reſting in the hollow centers (e). d

As there is frequent occaſion to cut diviſions on inclined planes, for that purpoſe the piece γ, in which the tracer is fixed, has a conical axis at each end, which turn in half holes: when the tracer is ſet to any inclination, it may be fixed there by tightening the ſteel ſcrews β. e f

Deſcription of the Engine by which the endleſs Screw of the Dividing-engine was cut.

FIG. 9. repreſents this Engine of its full dimenſions ſeen a
from one ſide.

Fig. 8. the upper ſide of the ſame as ſeen from above.

A repreſents a triangular bar of ſteel, to which the trian- b
gular holes in the pieces B and C are accurately fitted, and may be fixed on any part of the bar by the ſcrews D.

E is a piece of ſteel whereon the ſcrew is intended to be cut; which, after being hardened and tempered, has its pivots c
turned in the form of two fruſtums of cones, as repreſented in the drawings of the Dividing-engine *. Theſe pivots were very exactly fitted to the half holes F and T, which were kept together by the ſcrews Z.

H repreſents a ſcrew of untempered ſteel, having a pivot I, which turns in the hole K. At the other end of the ſcrew is a hollow center, which receives the hardened conical point of the ſteel pin M. When this point is ſufficiently preſſed againſt the ſcrew, to prevent its ſhaking, the ſteel pin may be fixed by d e
tightening the ſcrews Y.

N is a cylindric nut, moveable on the ſcrew H; which, to f
prevent any ſhake, may be tightened by the ſcrews O. This nut g
is connected with the ſaddle-piece P by means of the interme- h
diate univerſal joint W, through which the arbor of the ſcrew H paſſes. A front view of this piece, with a ſection acroſs the ſcrew-

* Fig. 5.

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ſcrew-arbor is repreſented at X. This joint is connected with the nut by means of two ſteel ſlips S, which turn on pins between the cheeks T on the nut N. The other ends of theſe ſlips S turn in like manner on pins (a). One axis of this joint turns in a hole in the cock (b), which is fixed to the ſaddle-piece, and the other turns in a hole (d), made for that purpoſe in the ſame piece on which the cock (b) is fixed. By this means, when the ſcrew is turned round, the ſaddle-piece will ſlide uniformly along the triangular bar A. a

K is a ſmall triangular bar of well-tempered ſteel, which ſlides in a groove of the ſame form on the ſaddle-piece P. The point of this bar or cutter is formed to the ſhape of the thread intended to be cut on the endleſs ſcrew. When the cutter is ſet to take proper hold of the intended ſcrew, it may be fixed by tightening the ſcrews (e), which preſs the two pieces of braſs G upon it. b c

Having meaſured the circumference of the Dividing-wheel, I found it would require a ſcrew about one thread in a hundred coarſer than the guide-ſcrew H. The wheels on the guide-ſcrew arbor H, and that on the ſteel E, on which the ſcrew was to be cut, were proportioned to each other to produce that effect, by giving the wheel L 198 teeth and the wheel Q 200. Theſe wheels communicated with each other by means of the intermediate wheel R, which alſo ſerved to give the threads on the two ſcrews the ſame direction. d

The ſaddle-piece P is confined on the bar A by means of the pieces (g), and may be made to ſlide with a proper degree of tightneſs by the ſcrews (n)

T H E   E N D.