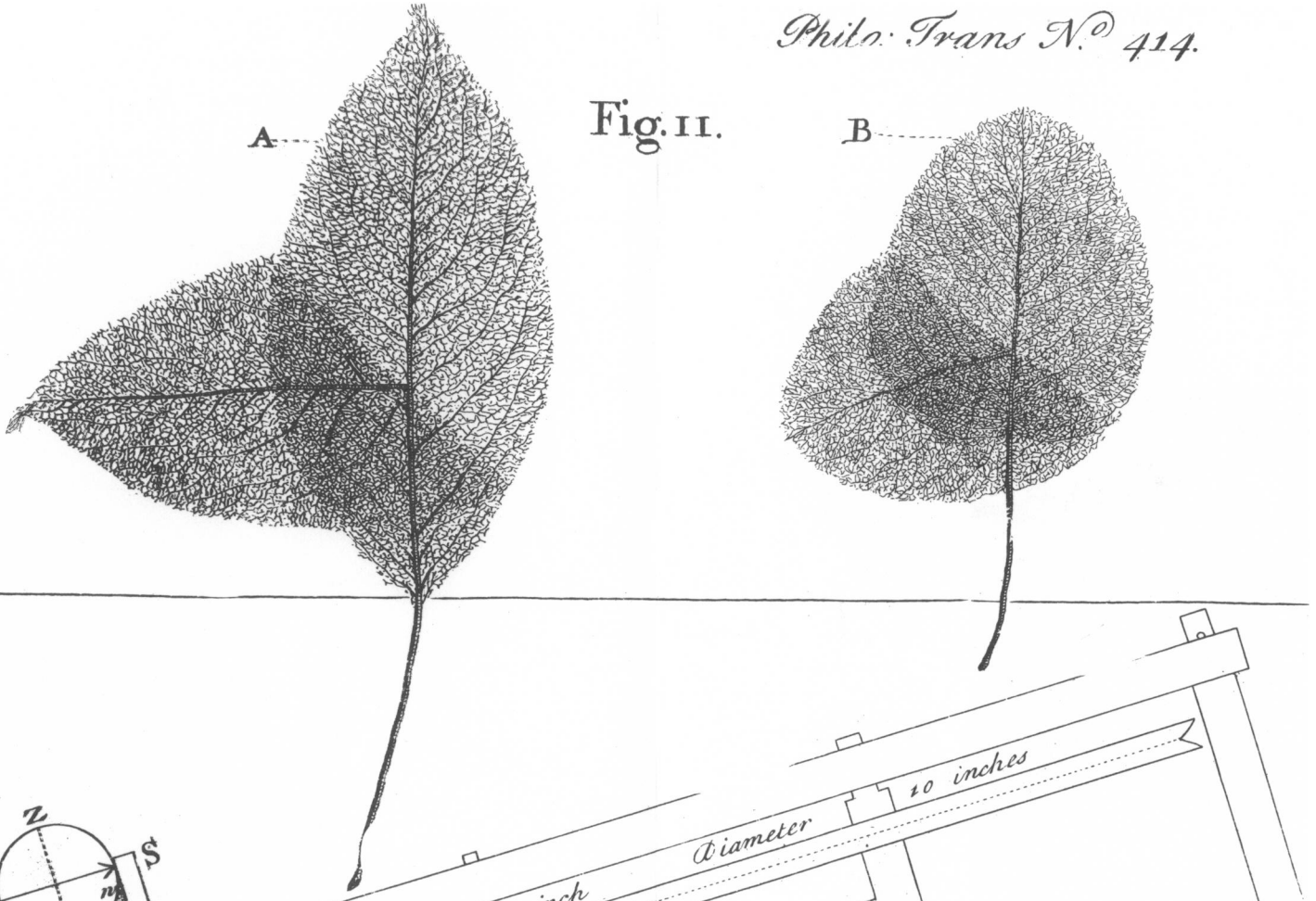
Fig. 11.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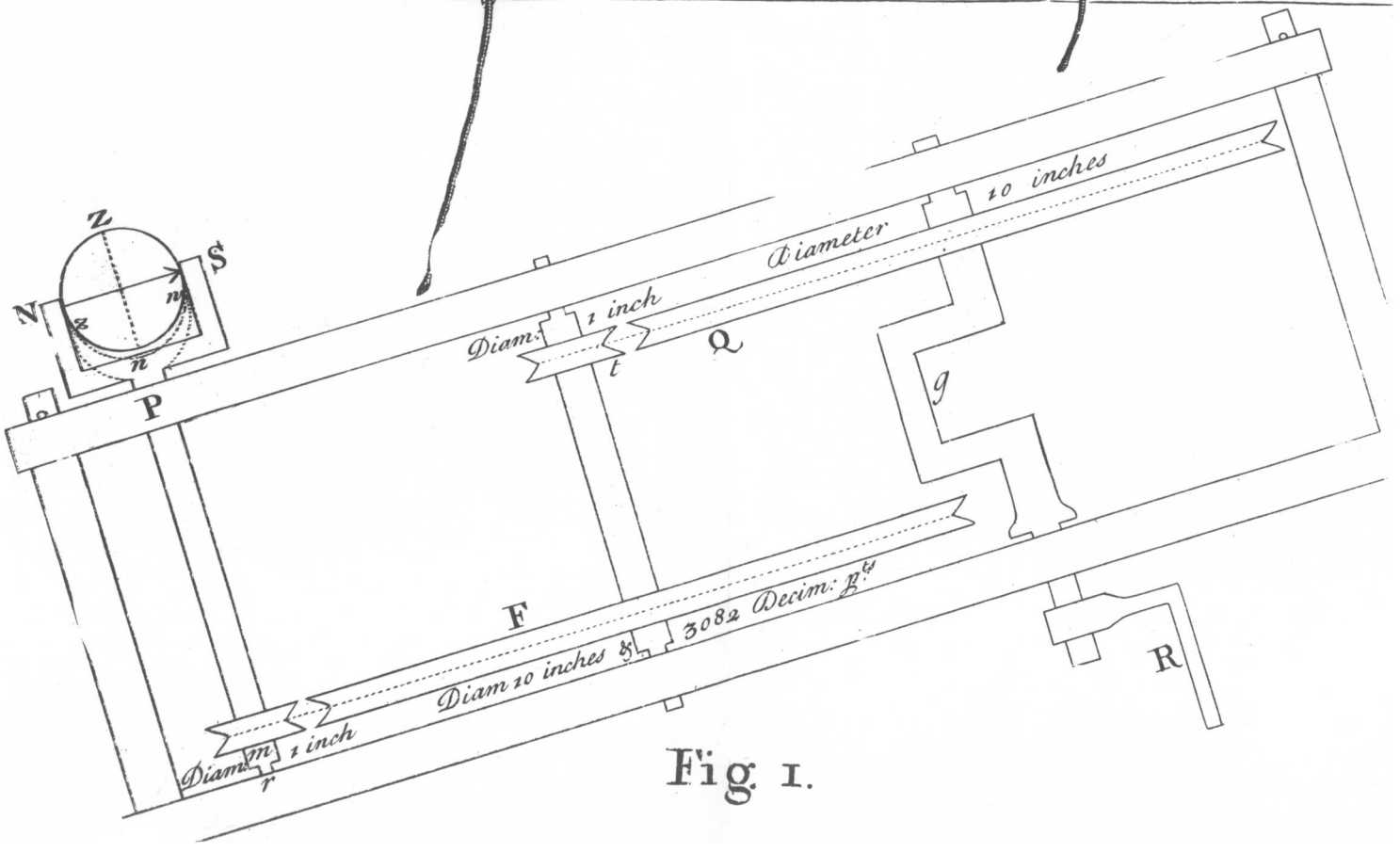
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Fig. 1.

I. *Magnetical Obſervations and Experiments*; *by* Servington Savery, *Eſq*; *of* Shilſton.

PRECOGNITA.

I. THAT which I call the Magnetical Line, is the Poſition of a Dipping-Needle when it ceaſeth from oſcillating, and is at Reſt in the magnetical Meridian of the Place.

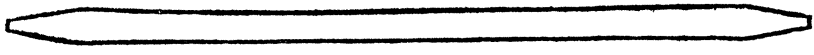
II. By the Word Magnet (unleſs diſtinguiſhed) I would be underſtood to mean not a Loadſtone only, but either that, or Iron or Steel, when they have permanent Polarity, or any thing elſe (if to be found) which has a ſenſible magnetical or polar Attraction.

III. Of the magnetical Needle, I always call that the North End which (if hung horizontally) naturally turns to the North, and that the South End which turns to the South: But when I uſe the Words Pole of a Needle, I call that the North Pole thereof which turns to the South, and that the South Pole of it which turns to the North.

IV. Of Touched Iron or Steel (or of Untouched, ſo long as it remains in a Poſture which gives it Polarity) as well as of the Loadſtone itſelf, I call that the North Pole which attracts the North End (*i. e.*) the South Pole of the Needle, and that the South Pole which attracts the South End, or North Pole of the Needle: Or in other Words, I call that the North Pole, in all Sorts of Magnets, which is endued with the ſame kind of Vertue which the North Pole of the Earth hath, and conſequently is repelled thereby: *E contra*, &c.

V. I prepared Nails of ſeveral Sizes, from the ſmalleſt Sort of Bellows-Nails to the largeſt Sort of Rafter-Nails, one or two of each Sort, or more of the ſmaller: I held each of them perpendicularly with its Point upwards, and placing thereon the plain Side of a File horizontally, I filed off a little from the Point thereof (more or leſs according to the Size of the Nail, perhaps about the Thickneſs of a Six-pence from a Six-penny one). Then on a plain Hone, held horizontally, I placed the Nail upright, with its Point downward, and ſo rubbed off the Strokes of the File. Then I rubbed it a little on a Piece of Leather. *Note*, The truer this little narrow Plain is, and more exactly perpendicular to the Nail's Axle, the better.

VI. I prepared Iron Bars of different Lengths after the following Manner: I made each End in the Shape of the lower Fruſtum of a Pyramid, cut tranſverſe to its Axis about the Middle, or a little higher up. Then I filed the Ends of the Bar as plain and perpendicular to its Axis as I could, and poliſhed them with a Hone, *&c.* as I did the Nails. *See the Figure.*



VII. One of the Needles I uſed untouched, for trying Experiments, was made thus: I took ſome Iron Wire, about the Size of a ſmall Knitting-Needle, and in Length about two Inches and a half. With a Hammer I made it juſt flat enough in the Middle, to be able to fix the Point of a Punch pointed, to as true a Cone as I could; its Sides (as I gueſs) made an Angle with each other at the Vertex of about 45 Gr. or more; in the Middle of the Wire I punched a Hole at leaſt half

half Way through the Thickneſs thereof, and wrought the Hole with a Drill (pointed like the Punch) that it might be truly round, and cleanſed off the Aſperity which the Punch and Drill had raiſed round the Hole, leſt it ſhould injure the Top of the Pin when it was placing thereon. Then I bended it in this Form,

taking Care to bend it the right Way, that the Hole might be on the under Side. Then I marked one End, by flatting it a little with a Hammer, that it might be known from the other. Then placing it on a ſharp Pin, to find which End was heavieſt, I made both alike in Weight, and deprived it of all fixed Magnetiſm. Then I brought it again to as true a Poiſe as I could, by rubbing the heavieſt End on a Whetſtone, and not a File, which might give it Magnetiſm again. I fitted a Pin for it of braſs Wire, full ſo ſmall as the middle Strings of a Spinnet, making the Point very meagre and round as well as ſharp, and obſerved it frequently with a Lens of two Inches Focus; and if it appeared flat, I mended it on a Hone, and took great Care in putting on the Needle, not to hurt the tender Point of the Pin. I put a Glaſs over it, to keep off all manner of fanning by the Air, the leaſt Degree whereof did ſpoil the Experiments.

VIII. A ſecond Needle, which I thought better than the former, I made thus: In the middle of ſuch a Piece of Wire as the former was made of, I wrought a Hole through it as perpendicular as I could to its Axis, or Length, and ſo ſmall as any of thoſe which are drilled through the Pillars of a Watch, if not ſmaller.

ler. And having bended the Wire in this Form,

I marked one End thereof, and drove into the Hole a ſmall braſs Pin fitted to it, which was very round and ſharp at the Point, which reſted on a deep Plano-Concave Lens of Glaſs well poliſhed. (*See the Figure.*) I fitted a Box for it with a Glaſs over it; which Glaſs was faſtened with a Ring of braſs Wire, as the Glaſſes of Teleſcopes are; which Ring kept out Air, otherwiſe had been needleſs. The Glaſs Concave was fixed in the great End of a thin Braſs Ferule (like that off a Staff) juſt fit for it, and the ſmall End of the Ferule was fixed in a Hole made for it in the Middle of the Bottom of the Box: I alſo put a Ring of thin Braſs on the Top of the Lens, not only to keep it in ſteady, but to prevent the Pin from going in betwixt the Lens and the Ferule, which ſpoils its Point. Doubtleſs a Concave of Diamond is much better.

Whenſoever I uſed one of either Sort of theſe Needles (eſpecially for ſuch Experiments as required it to be perfectly void of fixed Polarity) I was obliged to keep it in a Motion either librating up and down like the Beam of a Pair of Scales, or trembling (which is a ſhort pendulous Oſcillation from Side to Side) or elſe both librating and trembling at the ſame Time; which ſaid two Motions being at right Angles with each other, are not inconſiſtent: And if the Needle is truly poiſed, the horizontal Verticity is neither obſtructed nor accelerated by the Librations, becauſe they are at right Angles therewith, nor by the Tremblings, becauſe the two Ends perfectly balance one another in contrary Motion.

tion. The Service they do, is to abate that Friction on the Pin's Point, which retards the horizontal Verticity; for when the Friction is divided between the horizontal Verticity, and the Librations or Tremblings (either of the two latter rolling on the Pin more ſpeedily) the far greater Part of the Friction is ſpent on the Librations, or Tremblings, and conſequently there is but little left to retard the horizontal Verticity. I take ſuch a Needle to be far better for my Purpoſe than the common ones, which have a heavy Socket of Braſs, or Steel, in the Middle, uſeful only to render them portable, but very detrimental in nice Experiments; becauſe the Weight of the Socket not only blunts the Pin ſooner, but alſo encreaſeth the Friction, though the ſame Acuteneſs of the Pin ſhould be ſuppoſed to continue. To renew the Tremblings when they began to abate, I rarely jogged the Box on the Table, for fear of giving it (and the Needle within it) a circular Motion, which obſtructs the Deſign: But I found it beſt to do it, by jogging the Table gently. When I had Occaſion to turn the Needle to any other Point of the Compaſs, I elevated that Part of the Box which was under one End, until it reſted on the Bottom, and in that Poſture could turn it as I would; but before I could let down the Box again to an horizontal Poſition, was forced to wait till the Needle was very ſtill, and to let down the elevated Side eaſily, and with a direct Motion; otherwiſe the Needle, as ſoon as both its Ends were free, would have more or leſs of an horizontal Motion.

Moſt

Moſt of the known Properties of all Sorts of Magnets which have been diſcovered by the Obſervations and Experiments of ſeveral Perſons, including one or two of my own, are the following.

I. THAT the Loadſtone, by an inviſible Force which differs from that of Gravitation, and alſo of Electricity, draws unto itſelf Loadſtone, Iron, and Steel; and with the ſame Kind of Force, or Power, does not (at leaſt very ſenſibly) attract any other Body whatſoever.

II. That the Loadſtone attracts Loadſtone, Iron and Steel with a polar Attraction; and that whatſoever Attraction is not polar, is not magnetical.

III. That the two oppoſite Parts of a Loadſtone attract moſt vigorouſly, and are called the Poles thereof. The Middle between its two Poles doth not attract at all, and may be called its Æquinoctial; and from either Pole to the Middle, the attracting Force does gradually abate.

IV. That in the ſame, and every Loadſtone, the one of its Poles is in Vertue (or rather in Direction) contrary to the other, and therefore they need to be diſtinguiſhed from each other; which is done by adding North or South. The North-Pole of one Loadſtone will not attract, but repel the North Pole of another, though they are poſſeſſed of ſimilar directive Vertue; neither will the South Poles of any two Loadſtones attract, but mutually repel one another: But the North Pole of one Loadſtone, and the South Pole of any other, do mutually attract each other; and though their directive Vertue is contrary, yet the unknown Cauſe of their Attraction and Repulſion ſeems to be the ſame.

V. That

V. That there is no Difference (at leaſt I could never find it) between the Force or Strength of Attraction and that of Repulſion in the ſame Pole of any Loadſtone or Magnet, unleſs when a ſmall one approaches ſo near to a large one, as to have its Polarity more or leſs diminiſhed thereby.

The preceding Properties convince me, that there is no ſuch thing in Nature as magnetical Attraction without Polarity, which is conſtituted of Attraction and Repulſion; and theſe two Powers being always equally ſtrong in the ſame Pole of every Magnet, I take it to be a plain Contradiction, to ſay this or that Loadſtone has a ſtrong Attraction, but a weak Polarity or Direction.

VI. That no interpoſed Body whatſoever (unleſs it is magnetical) though the moſt ſolid in Nature, was ever known in the leaſt to impede or divert any of the Effects of a Magnet; but it is always found to attract magnetical Bodies full ſo powerfully at the ſame Diſtance, as if nothing at all was between.

VII. That every Fruſtum of a Loadſtone is an entire or perfect Loadſtone, having in itſelf both Poles as the whole Stone had; and that the Poles in each Fruſtum have their Direction (as near as the Figure of it will admit) in the ſame parallel Line wherein they were directed both in it and the whole Stone, before it was ſeparated therefrom: For the Polarity of every Fragment is uſually, if not always (before they are ſeparated) parallel to that of the whole Stone, and conſequently to that of each other: And if ever it is found otherwiſe, I cannot but think that Loadſtone wants of Perfection.

Fig. 1.

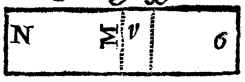
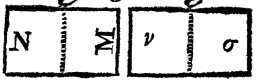
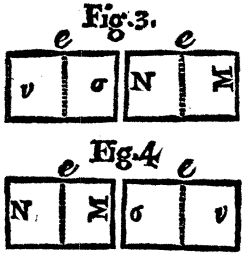


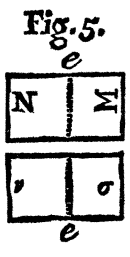
Fig. 2.

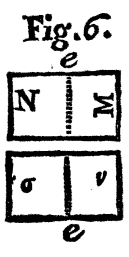


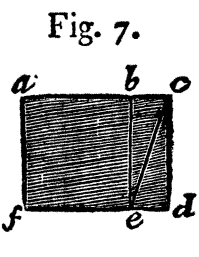
Let N Σ ν σ, *Fig.* 1*ſt*, be a Loadſtone in the Form of an oblong right-angled Parallelopipedon, whoſe Polarity is Length-ways, N being its North Pole, *e*, the pricked Line, its Equinoctial (or Middle betwixt its Poles) where it has no Attraction, and σ its South Pole. Let it be biſſected at *e*, tranſverſe to its Polarity, or Length. Each of its Fruſta (repreſented *Fig.* 2.) when they are placed too remote to act on each other) will infallibly be poſſeſſed of both Poles (with its Equinoctial in its Middle) as the whole Stone was before its Biſſection: And though originally the one Fruſtum N Σ was all over a North Pole, and the other ν σ all over a South Pole, while they adhered to one another, yet now they are divided, and placed beyond the Reach of each other's Vertue, one half of the Fruſtum N Σ from the Place of its *quondam* Contact Σ, to its Middle *e*, does inſtantly become a South Pole, and attract ſtrongly at the Place of Contact aforeſaid, which Attraction is gradually leſs and leſs until it is abated to nothing at *e*. So alſo one half of the Fruſtum ν σ, from the Place of its former Contact ν to its Middle or Equinoctial *e*, inſtantly becomes a North Pole (gradually abating in Strength from ν to *e*) though the whole Fruſtum, before its Separation from the other, was a South Pole: The Polarity being alſo directed the ſame Way in each Fruſtum that it was in it (and the whole Stone) be-

fore the Biſſection. The Caſe alſo would have been the ſame, if the Stone had been divided unequally at *x*, or elſewhere tranſverſe to its Polarity, *Fig.* 1*ſt*, and of each Fruſtum, one half would have been a North Pole, and the other half a South one, with its Equinoctial in the Middle as before. The whole Stone will lift a larger Iron than either Fruſtum; but both Fruſta, while out of the Reach of one another's Vertue, will each of them lift his Iron, both of which Irons will be heavier than what the whole Stone could lift before it was divided. If the ſaid Fruſta are again joined cloſe together at the ſame Ends which originally adhered, *Fig.* 1*ſt*, being as they ſtand directed towards each other *Fig.* 2*d*; or if the oppoſite Ends of both are joined together, as they ſtand directed towards each other, *Fig.* 3*d*, I do not ſee (provided the









Joint is very good, that there may be a Contact all over it ſo good as a Workman can make) why they ſhould not compoſe again one entire Loadſtone, ſo good as it was before it was divided, in all Reſpects (Allowance being firſt given for the Waſte in ſawing it aſunder, and mending the Joint) and their joined Poles mutually attracting one another, attract nothing elſe at the Joint (which being in the Middle, would become

its Equinoctial) but tranſmitting their Vertue through one another, the Pole Σ of the one Fruſtum, *Fig.* 2*d*, wholly ſpends itſelf in ſtrengthening the ſimilar Pole σ of the other Fruſtum, by weakning the Pole ν thereof, *& vice verſâ.* And if their Lengths ſhould be unequal, like the Fruſta of *Fig.* 1*ſt*, divided at *x*, the Equinoctial would not be at *x*, where they were joined together again, but always at *e* the Middle of their whole conjunct Length, as it uſeth to be in one entire Loadſtone of the ſame Bigneſs from Pole to Pole: For I apprehend if any Loadſtone ſhould be wrought very Tapering from one Pole to the other, that the Equinoctial could not be preciſely in the Middle thereof, but according to what Degree of Taperneſs it is wrought to, be removed nearer to the great End: But theſe Things, for want of proper Loadſtones, I cannot try, nor yet the following on *Fig.* 7*th*, which repreſents a Loadſtone in the Form of a Parallelopipedon right angled, in Thickneſs one Inch, its Breadth *a f* 6 Inches; its Length *a c* 7 Inches or more, having its Polarity not perfectly length-ways in it, but a little oblique, as the Shade-Lines repreſent it. If there is cut off from one of it's Ends *c d*, the Parallelopipedon *b c d e* one Inch from the ſaid End, it will be one Inch ſquare, and ſix Inches long: I ſuppoſe this leſſer Fruſtum would have its Polarity changed, and the Direction thereof, inſtead of running from *e* ſomewhat towards *d*, would run from *e* towards *c* in the Diagonal Line *e c*, or in ſome Line or other between the Lines *e b* and *e c*. I alſo imagine, that if a Cube was cut off, within a little Time after, from one End, the Polarity therein would be directed as it was therein, while all the ſaid Fruſta adhered

toge-

together; but if the leſſer Fruſtum *b c d e* ſhould long remain ſeparated from the whole Stone, before the ſaid Cube was cut off, that the Polarity of the Cube would be more or leſs fixed, and conform itſelf more or leſs to the Direction of the Line *e c*. However, this is certain, that if the two Fruſta are joined together, as they ſtand directed *Fig.* 2, or *Fig.* 3, with the North Pole of one to the South Pole of the other, they aſſiſt one another in lifting Iron. If joined *Fig.* 4*th* with the South Pole of one againſt the South Pole of the other, by repelling they reciprocally deſtroy each other's Vertue, and alſo hinder one another's Attraction at the North Poles, which are not joined. If they are placed together, as in *Fig.* 5*th*, though they endeavour to avoid one another, yet they do not deſtroy each other's Vertue ſo much as in the preceding Caſe, nor yet at all if there is a perfect Contact: For if this Poſture of two Magnets actually adhering would diminiſh their Vertue, one Part of the ſame Loadſtone would deſtroy another Part of itſelf, and in a very ſhort Time there would be no ſuch Thing as Magnetiſm. In this Poſture they mutually help one another's Attraction, becauſe their Polarities are directed the ſame Way. If they are applied, as in *Fig.* 6*th*, with their Sides together, and their Polarities contrarily directed, the North Pole of the one (at either End) attracting the South Pole of the other, and the South Pole the North, they ſcarcely injure one another's Vertue by ſo lying together, but hinder each other from attracting other Things, by ſpending their Vertue on each other.

VIII. That all magnetical Attraction (as alſo Repulſion) is mutual; for Iron or Steel attract the Load-

ſtone, as that does Iron or Steel, and they alſo one another.

IX. That every Loadſtone communicates Vertue to Iron or Steel, not only by Contact, but even by an Approach of them within its attractive Sphere, more or leſs as nearer to, or farther from its Body; and likewiſe its Poles, alſo according to the Shape, Bulk and ſpecifick Vertue thereof, and Figure of the Iron or Steel, and their Proportion of Magnitude to one another. I apprehend, that though a great Magnet (I mean of ſuch as are ſimilar in Figure and ſpecifick Vertue) will lift conſiderably larger Irons than a ſmall one, yet the ſmall one ſhall give to the ſame Piece of Steel (provided it is not too large for it to conquer) well nigh (if not altogether, as to Senſe) ſo ſtrong a Touch as the great one. And I have experienced, that if the ſmall one is ſpecifically pretty much better, it will give the ſame ſmall Piece of Steel a conſiderably ſtronger Touch than the great one can, though the great one is capable of lifting perhaps three or four Times ſo much as the ſmall one. *Note*, That if the great one is ſo ſtrong as to give the ſmall Piece of Steel ſo much Vertue as it is capable of receiving (for there is, I ſuppoſe, a *ne plus ultra*) that then ſhould the ſmall Stone be ever ſo much better, it cannot mend the Touch given by the great one. Some write, that the Loadſtone loſes none of its Vertue by communicating of it to Iron or Steel, which I ſomewhat doubt the Truth of, eſpecially if the Stone is ſmall in Proportion to the Steel, in which Caſe I have known touched Steel loſe conſiderable Vertue.

X. That Steel is not only more receptive, but more retentive of Magnetiſm than common Iron; Iron or Steel

Steel hammered hard, than the ſame while ſoft; but Steel hardened by quenching, than either of them. My Obſervation has been, that Steel cannot be ſeaſoned too hard for Retenſion (nor, as I think, for Reception) of Magnetiſm; but may ſometimes warp too crooked for its intended Uſe, and muſt be made right again ſome Way or other, either with a Grinding-Stone, or (if that will not do) by heating it to a blue Colour, and gently hammering it while hot; but if it can be helped, the Temper for the blue Colour is too ſoft.

XI. It has been obſerved, that oblong Pieces of Iron or Steel applied any how to the Loadſtone, receive Vertue chiefly (ſome ſay only) as to their Lengths. This was what induced me to explain *Fig. 7th*, in the Middle of *Pag.* 304. For I think it a parallel Caſe with this here, and ſuppoſe that the Vertue may incline to run length-ways even in the Loadſtone itſelf. However, I think if it muſt be allowed to be length-ways, it is ſometimes found to be very irregular in pretty long Pieces, as North Pole againſt North Pole, South Pole againſt South Pole ſeveral Times in the ſame Piece, which ſeveral contrary Polarities have been obſerved by ſeveral in Wires, and I have ſeen in a round Bar (of which Irregularity, and the Method of curing it, more hereafter) But ſuch contrary Polarities ſeem unaccountable.

XII. That ſuch Iron and Steel as has magnetick Vertue communicated to it, does alſo communicate thereof to other Iron or Steel after the ſame Manner a Loadſtone does. Which Vertue, after never ſo many Communications, is, as to its Nature, perfectly the ſame with that of the Stone itſelf, having both Poles,

and will touch other Steel, and that a Compaſs, ſo well as the Loadſtone itſelf, and ſo vigorous, if uſed as hereafter is directed.

XIII. That the Earth contains within it, at or near its Center, a Loadſtone or Magnet (probably ſpherical) large enough very ſenſibly to affect magnetical Bodies all over the Surface of the Earth. The Poles of its Attraction are conſiderably diſtant from thoſe of its own, which are the ſame with thoſe of the Earth's Diurnal Rotation. This internal Magnet muſt either be looſe from the Body of the Earth, and revolve within it very little ſlower, or elſe, if it is fixed to the Earth, the very Polarity itſelf muſt have changed its Situation in reſpect of the ſaid Magnet, One, of which, ſeveral recorded Obſervations in diſtant Years ſufficiently prove. The former ſeems moſt probable: However, I imagine (was it not for the Charge and Trouble) an Experiment might be made which would ſhew whether or no it is poſſible in Nature for the Poles of the ſaid Central Magnet to change their Situation in reſpect of itſelf, as well as of the Earth, as will appear when I give the Deſcription of it.

XIV. That every Loadſtone within its attractive Sphere has a Power (the nearer either of its Poles the greater) to keep one Piece of Iron ſuſpended to another, eſpecially if that to which it is ſuſpended is the largeſt, and their Ends be bright and clean, where they touch one another; and if the ſuſpended Iron is not too heavy, the other will draw it up from either Pole of the naked Loadſtone actually touching it, and will alſo keep it ſuſpended, till at a conſiderable Diſtance therefrom; but will not draw it off in

ſuch

ſuch manner from the Armour of unarmed Stone, if the Armour and Iron are both of them bright and clean at their Contact. Hence it muſt follow,

XV. That an armed Loadſtone can lift more with either of its Poles, uſed ſingly, than the ſame can lift naked; and this it will do, though the Armour ſhould be narrow, and touch very little of the Stone; how much more then will it lift, when the plated Part thereof covers all the End of the Stone, and ſecures all the Vertue of that Pole to which it is applied, leading it to the other End which attracts? I take ſoft Iron to be ſo good for Armour as the choiceſt Steel, if not better.

XVI. That not only Steel or Iron regularly touched, but alſo oblong Iron void of permanent Vertue (ſo long as it has a tranſient Vertue by Poſition of either of its Ends towards the Pole of a Loadſtone large enough to affect it at a conſiderable Diſtance) will perform all that any Loadſtone can, though not with the ſame Degree of Power: For either of them will attract, keep one Piece of Iron ſuſpended to another, and communicate ſome Degree of permanent Polarity to Steel well hardened, as I have experienced, and alſo to an Iron Wire.

XVII. That the Earth's central Loadſtone, or Magnet, has all the ſame Vertues which others have, and no diſcovered ones beſides; and though we cannot approach it, yet it acts as others do at a proportionable Diſtance. I have experienced, that it will keep a prepared Six-penny (or with more Difficulty a Ten-penny) Nail ſuſpended to a prepared Iron Bar about $\frac{7}{8}$ of an Inch ſquare, and 5 or 6 Feet long, in an erect Poſture with either of its Ends downwards. I hung up the Bar in a Room

by

by a Loop of ſmall Cord faſtened at the End which was upwards; I then carefully wiped the lower End of the Bar, and the Point of the Nail, that there might be no Duſt, or Moiſture, to prevent a good Contact, taking Care not to touch either of them with my Finger, leſt Perſpiration ſhould ſully them. Then holding the Nail under the Bar very erect, with its Point upwards, I kept it cloſe to the Bar, by only one Finger held under the Head of it, for the Space of 30 or 40 Seconds or more. Then I withdrew my Finger very gently, and directly downwards, that the Nail might not oſcillate; and if it fell off, I wiped its Point as before, and tried it again at ſome other Part of the Plain at the Bottom of the Bar; for I always found it would more readily hang at one Place than another, and uſually the Middle was not ſo well as towards one of the Edges or Corners, and the Succeſs better nigh one Edge or Corner than another. If both Ends of the Bar are equal in Bigneſs, and the Preparation of their Ends ſimilar, it is indifferent which End is downward, if it has no permanent Vertue: But if it has no more than an inchoate or imperfect Degree of fixed Polarity, one End will anſwer better, and the other worſe, in Proportion to the Degree of imperfect Polarity which it has.

XVIII. That of a ſoft Iron Bar void of fixed Polarity, ſo ſoon as it is in an erect Poſition, the higher Part from the Middle upward becomes a North Pole in North, or a South Pole in South magnetick Latitude. And, *e contra*, the lower Part from the Middle downward becomes a South Pole in North, and a North Pole in South Latitude: But ſo ſoon as ever the Bar is inverted, the Polarity will be ſhifted in it,

and

and in North Latitude the End newly placed upward becomes the North Pole, though it was a South one immediately before, and the other End the South Pole, though it was its North one juſt before. The Caſe is the ſame, if ſuch a Bar is placed horizontally in or near the magnetical Meridian; for the End directed toward the North will conſtantly be a South Pole, and that which is directed toward the South, a North one; and ſo ſoon as ever the Ends of the Bar are ſhifted, the Polarity, in reſpect of the Bar, is ſhifted alſo (but not in reſpect of the Earth) for which Reaſon this Vertue is called Tranſient, and is communicated by the Earth's central Magnet in ſuch Manner as other Loadſtones are ſaid to do, *Page* 309*th*, *Prop.* 16*th*.

XIX. Since in North Latitude the North Pole of the Earth's central Magnet not only gives the Vertue of a South Pole to that End of a Bar which is neareſt to it, but alſo helps it to lift Iron when neither the Bar nor Iron lifted has any permanent Vertue; the ſaid Magnet muſt therefore neceſſarily help the South Pole of any Loadſtone or Touched Steel in lifting Iron, but hinder its North Pole. This agrees with common Experience, the North Pole of a Magnet being unable to lift ſo much as its South one in North Latitude, but more in South Latitude.

XX. The preceding plainly ſhews the Reaſon why an armed Magnet, when both of its Poles are applied to a Piece of Iron, will lift ſeveral times ſo much as with either Pole ſingle. For the North Pole of the Magnet, by ſending its Vertue through the attracted Iron, powerfully helps the South Pole of the ſaid Magnet in attracting. Again, the ſtrengthened South Pole

muſt more powerfully increaſe the Attraction of the North Pole: And ſince the Poles mutually aſſiſt one another's Attraction, with a Power much greater than if they themſelves are not aſſiſted, the conjunct Poles muſt neceſſarily lift at leaſt twice ſo much as both of them can lift ſeparately. I once tried, and found the South Pole armed to lift 1125 Grains, and both Poles united 5760 with a little more Difficulty. The Ratio is about 1 to a little more than 5.

XXI. That if a Bar of Iron or Steel (not having the leaſt Degree of fixed Vertue) is placed in any Poſture (except at, or near to a right Angle with the magnetical Line) it will not only for the preſent receive a tranſient Polarity thereby, but if it ſo remains long enough, the ſaid Polarity will gradually become fixed or permanent, more or leſs, according to the Hardneſs or Softneſs of the Bar, Time it has remained in that Poſition, Angle its Length makes with the magnetical Line, and Proportion of the Length thereof to its Bigneſs, the longeſt (*cæteris partibus*) uſually receiving moſt Vertue: And ſometimes when all theſe Advantages concur, the Polarity will be ſenſibly permanent in a little Time, and not require a very long Time to be rendered pretty ſtrong.

XXII. That by placing the ſaid Bar afterwards in the ſame Poſition, only with its Ends ſhifted, it will gradually loſe its gained Magnetiſm, and at length have its Polarity changed.

XXIII. Mr. *Boyle* found one of his Loadſtones much impaired by lying long in a wrong Poſture; I ſuppoſe he meant a repelling one, with its North Pole towards the North Pole of the Earth. Alſo by applying one Pole of a very ſmall Piece of Loadſtone to the

ſame

ſame Pole of a large one, he ſoon changed the Polarity of the former, but could not effect it on a Piece of any conſiderable Bigneſs, though he tried ſome Hours. I have changed the Polarity of a ſmall Fruſtum of Loadſtone ſuddenly, and without a Contact, by holding one of its Poles nigh the ſame Pole of a Piece of Touched Steel much leſs than a common Caſe-Knife, at above $\frac{1}{8}$ of an Inch diſtant, which would make the Fruſtum leap to it. I repeated theſe Changes frequently with the ſame Fruſtum.

From this, and ſome of the preceding Experiments, I conclude, that if two parallelopiped Loadſtones equal in Magnitude and ſimilar in Subſtance, Figure and Vertue, are placed cloſe together as in *Fig. the 4th*, with the North Pole of the one directed againſt the ſame Pole of the other, or with the South Pole of the one againſt the South Pole of the other, and the Direction of their Polarities magnetically Eaſt and Weſt, they will by Repulſion (as it were in a Duel) reciprocally deſtroy one another in an equal, though long Time: But if they are placed (in the ſame Situation in reſpect of one another, *viz.* North Pole againſt North Pole, or South Pole againſt South Pole) with the Direction of their Polarities in or near to the magnetical Line, that Stone (in North Latitude) whoſe South Pole ſtands directed to, or pretty much towards the attractive Point of the Earth's central Magnet receiving Aſſiſtance therefrom, will not loſe Vertue ſo faſt as the other, and conſequently never loſe all its Vertue till it has perfectly deſtroyed the Polarity of its Antagoniſt, which it will do in leſs Time, and afterward give it ſome Polarity again contrary to what it had at firſt.

XXIV. That Magnetiſm not only in touched Iron and Steel, but alſo in the Loadſtone itſelf, is ſoon deſtroyed by Fire.

XXV. That though Fire deſtroys fixed Magnetiſm in Steel or Iron, yet if they are ſet to cool in an erect Poſture, or rather in the Direction of the magnetical Line, they will gain more or leſs fixed Vertue by the Time they are cold; but eſpecially Steel heated to a ſeaſoning Height, and in that Poſition cooled ſuddenly under Water, which I have found to fix its Polarity ſo throughly, as that with its North Pole held downward, it would attract the North End of a Dial Needle.

XXVI. That while a Piece of Iron of ſome Magnitude is held at one Pole of a Loadſtone, it will increaſe the Attraction of the other Pole thereof, and enable it to lift ſomewhat more.

XXVII. That if either Pole of a Magnet large enough, toucheth one End of an oblong Piece of Steel (not too big and long for the Magnet eaſily to act on) it will tranſmit its own Vertue to the other End of the Steel which is fartheſt off, and make it a Pole of its own Kind, whilſt the End which touches the Stone has Vertue of the contrary Pole: But the Vertue uſually is not ſo ſtrong in the End which is untouched, as in that which is; though I do not know but in ſome Time it may gain more, and the other loſe ſome, until the Vertue in each End is nearly equal.

XXVIII. That any Loadſtone put into a Diſh with its Polarity in an horizontal Situation, and the ſaid Diſh, with the Stone in it, put to ſwim in the Middle of a large Veſſel of Water, will turn itſelf, with the Diſh wherein it is, until its South Pole is directed in the Horizon towards the magnetical North Pole of the central

central Magnet (by the Force of its Attraction thereof, and Repulſion of the oppoſite Pole) and there reſt after a ſmall Vibration or two.

XXIX. That the Fly of a Compaſs (becauſe it is a perfect Magnet, *Prop.* 12) if it turns eaſy on its Pin, muſt neceſſarily conform its Poles to the magnetical Meridian as the Loadſtone does, and for the ſame Reaſon.

XXX. Alſo becauſe Steel regularly touched is a perfect Magnet, the North Ends of the Flies of ſeveral Compaſſes muſt all of them repel one another, and ſo muſt their South Ends: But the North End of one and the South End of any other, do mutually attract each other, as is ſaid of Loadſtones, *Prop. 4th.* And in North Latitude the North End of a Needle will conſequently vibrate towards the Top of a tranſient Bar erected, and the South End towards the Bottom.

XXXI. That a Needle firſt equally poiſed, then touched and put to oſcillate on its Pivots in the magnetical Meridian, will in North Latitude have its North End (*i. e.* its South Pole) depreſſed until it directs to the North-attracting Point of the central Magnet; where, after ſeveral Oſcillations, it will at laſt reſt: And in South Latitude the South End will be depreſſed after the ſame Manner.

XXXII. That not only a touched horizontal Needle, which has permanent Polarity, will endeavour to conform itſelf to the magnetical Meridian, but alſo one that has no other than tranſient Vertue, and is with the greateſt Care freed from fixed Magnetiſm (if made and uſed as in the *Præcogn.*) will do ſo too, though with this Difference, that which End ſoever happens to be placed neareſt towards the magnetical North will faintly

faintly turn thither; and if that End is not ſuffered to remain ſo too long, then the other End, placed neareſt to the North, will turn thither as the firſt did. In trying this Experiment, I ſometimes found, that when the Needle had reſted in the Meridian only a few Minutes, it gained a perceptible permanent Vertue, ſo that its other End would not be attracted to the magnetical North, unleſs it was placed conſiderably nearer thereto than I had placed the firſt End; and having ſo ſtood ſome Time, loſt again the ſaid inchoate Permanency, and received Polarity, the contrary Way. Once, while I dined, and ſat but a little Time after, I could not make the End which I left towards the South, to ſtand towards the North, unleſs I placed it very true in the Meridian; ſo that I was forced to free it again from Magnetiſm before I could uſe it to repeat the ſame, or try the following Experiment; for the leaſt Fixedneſs of Polarity in the Needle would more or leſs obſtruct both.

At the magnetical Eaſt or Weſt of the Needle's Pin, ſo nice as I could gueſs it, I held at a great Diſtance, either the South Pole of a Loadſtone, or lower End (which is the South Pole) of an erected Bar (both of them anſwered alike) and gradually approached it nearer, in a direct Line, toward the Pin, until it began to attract the Needle, which I obſerved was as I expected at the South End: I then changed the Ends of the Needle, and gradually approached the South Pole of a Magnet as before, and conſtantly found it to attract that End which was toward the South; and the North Pole of the Magnet, after the ſame manner, would attract the North End of the Needle when it had only tranſient Vertue.

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I remember, that in my younger Days I once diverted myſelf with making an horizontal Needle, and a Dial-Box for it, one of my School-fellows having a Load-ſtone. Before I could have the Uſe of the Stone, I often held my Needle within its Box, ſometimes with its intended South End towards the Bottom of a Window Bar (having lately ſeen one of my Companions try it with his Pocket Needle, which was touched) and at other Times I would hold the Needle's North End at the Top of the Bar. I obſerved the Needle, which was hung very tender, to make Vibrations at either End of the Bar. I happened to ſet it down in the Window at a good Diſtance therefrom, and found the South End more inclined to vibrate to the Bar's Bottom than the North End, and ſeeing it to have ſome Vertue, I thought of encreaſing it by taking the Needle out of the Box, and applying it to touch the Bar with its proper Ends. By this Method alone it gained ſuch a Degree of Polarity as would conſtantly turn its proper End to the North, if it was kept trembling; but if I placed its contrary End to the Bar, the Polarity would be changed preſently. By this Way of Management I could give it but a faint Verticity, which was ſoon more vigorous when I got the Uſe of the Stone, though it was ſmall, and not of the beſt, and the Needle ſoft Iron. And this was all, at that Time, I knew of Magnetiſm, having never read the particular Properties of the Stone, nor ſeen one before, nor heard of the untouched Needle's Verticity, or its vibrating to a Bar.

Having within the Space of a few Years paſt had a freſh Inclination to make ſome magnetical Experiments,

riments, amongſt other Thoughts the above-mentioned came into my Mind, That Iron, not having any fixed Polarity at all, might (if it moved tenderly enough) conform its Ends to the magnetical Meridian; which at length put me on making ſuch Needles as are deſcribed in the Beginning, of which either Sort anſwered my Expectations abovementioned. Afterwards I touched one of the firſt Sort of Needles (deſcribed *Præcogn. 7th*, whoſe Length was 2 $\frac{1}{2}$ Inches, and Weight ℈ and *Gr.* ij) on a Piece of tranſient Iron (made for Armour of a Magnet) which meaſured in Inches each Side of the broad plated Part about 1 $\frac{1}{2}$, the parallelopiped Part in Length 2, and in Breadth (equal to its Thickneſs) $\frac{1}{8}$. So its whole Length was full 3 Inches and $\frac{1}{8}$. Its Weight *Troy* was ℥iij ℈ij. This held with its Length directed in the magnetical Line, gave the ſaid Needle Vertue enough to vibrate about four times in one Minute. I held the Needle, while touching, in an horizontal Situation, with its North End directed towards the North, and placing its Middle about the Top of the Iron, drew it along Southward: Likewiſe placing its Middle about the Bottom of the ſaid Iron, I drew it Northward, that the South End might be touched as well as the North. I afterwards touched it my new Way (hereafter mentioned) with the ſaid Piece of Armour, and a ſmall Piece of tranſient Iron, which made it vibrate about ſix times, and I believe it would have made more Vibrations, had the Needle been hardened Steel.

Having no other than a ſmall Loadſtone of a very irregular Shape, I was loath to diminiſh it enough to bring it into a tolerable Figure to receive Armour, but did only grind a little Place plain at each Pole, where

where I bound it on with Thread when I had ground it. The Weight thereof naked was but 3vij ℈ij *Gr.* vj; its armed South Pole would only lift 3vij ℈ß *Gr.* iij, which was a Key. The not knowing where to get a better, made me think of improving what I had. I conſidered, that ſince a larger Stone of the ſame ſpecifick Vertue would lift more, it might poſſibly communicate more Vertue than mine could to the ſame Piece of Steel, but could not fail of ſo doing to a much greater Piece; and having obſerved that touched Steel would communicate ſome Vertue as well as attract, I got ſome Steel Wire (the largeſt in the Shop where I could meet with any) which having cut into equal Pieces, and filed their Ends ſo tranſverſly as I could, and very plain, I made a Standard with a Plate of Iron, into which I could but juſt thruſt the ſhorteſt; and filing all the reſt till they would but juſt enter the ſaid Standard, I reduced them nicely to the ſame Length. Then having marked one End of each of them with the Edge of a File, I ſeaſoned them very hard, and made them, Ends and all, very bright. Each of them meaſured in Length about 2.74 Inches, and weighed 36 Grains or more. I weighed one of them, and they were all of the ſame Piece of Wire, therefore could not differ much in Weight. With my Loadſtone I touched 37 of them, one by one, making their marked Ends their South Poles. I laid them Side by Side at about half an Inch Diſtance from one another on a Board, with their marked Ends toward the ſame Edge thereof, and took Care that they ſhould not touch one another after they came from the Stone, before they were all of them touched thereon. Then having Thread and Armour made like this (one Piece marked, which

I applied to the marked Ends of the Wires) in a readineſs, I ſpeedily did thruſt them together into a Bundle, and caſting the Thread 2 or 3 times round them, with my Fingers I formed the Bundle into a regular Hexagon as ſoon as I could, and then bound them faſt from End to End, and bound faſt the Armour. I took the Number 37, becauſe that would form a regular Hexagon at each End, and ſo will alſo 19 or 7. Finding this artificial Magnet exceed my natural one, I held the Artificial in one Hand, and the Natural in the other, the North Pole of the one againſt the South Pole of the other, and placing their Armour on the Middle of one of my Wires, drew the Magnets aſunder, and ſo touched both Ends of the Wire at the ſame Inſtant. In that manner I touched one by one a ſecond Set of Wires, which I managed like the firſt, and bound on the Armour of the firſt Set to the ſecond. The South Pole lifted a Key, Weight *Troy* ℥ij ʒij ℈ij *Gr.* v. Both Poles united would, with Difficulty, lift the ſaid Key with Weights faſtened to it, the whole ℔j *Troy*. I next tried with 19 Wires, for which I made Armour of a proportionable Size; but that did not anſwer ſo well, I thought, as 37, though I repeated the Touch. Afterward I took 7, which I thought performed according to its Quantity as well as the 37. Therefore I ever after uſed the Number 7.

In the next Place I thought of mending this Way of Touching, by placing all the 7, or more of them, with their marked Ends toward the North in a long ſmall Trench, whoſe Depth was juſt fit for one of them, to keep it from rolling away while I was touching it and its Fellows. The North End of one touching

ing the South End of the other, and adhering by their magnetick Vertue, I placed the two Magnets, as before, at their conjunct Middle (not letting them remain there a Moment) and then inſtantly and ſpeedily drew one Magnet to one End of the Wires, and the other Magnet to the other End of them; by which Method I touched them, as it were, all at once, and as if they had been but one entire long Wire. I found this Way not only more expeditious, but more advantageous, giving all of them a ſtronger Touch: But the Wire at each End was not ſo ſtrongly touched as the reſt; therefore I placed more Wires in the Trench than I had Occaſion for, and laid aſide thoſe at each End, whoſe Vertue was weaker. One of theſe Wires, when it was thus newly touched, would lift a prepared Nail 4.75 Inches long, in Weight *Troy* 3vij *Gr.* vj or vij (*i. e.*) more than 426 Grains. The Weight of the Wire can be had in that of the Nail 11.8$\frac{1}{3}$ times. I placed all the 7 ſeparately in the magnetical Line for about two Days; in which Time all of them had loſt ſome Vertue, yet one of them would with Difficulty lift the Nail aforeſaid, which it lifted ſomewhat eaſier juſt after the Touch; and that which had loſt moſt Vertue, would eaſily lift a Nail of 4$\frac{1}{2}$ Inches long, in Weight 306 Grains.

Having ſuch Succeſs, I got ſeven round Bars of Steel to be made, from End to End of one Size, ſo that they would but juſt go through a Hole made on Purpoſe in a Plate of Iron, and tried their Lengths in a Standard as I did the others, and marked one End of each of them with the Corner of a File in this Manner, that I might be able to ſee the Mark when they were bound together, leſt either of them ſhould be placed

with its End the wrong Way. Their Diameters were about $\frac{1}{8}$ of an Inch, and their Lengths about 12 $\frac{1}{4}$ Inches good Meaſure. I hardned and cleanſed them as I did the Wires, but one of them happening to break by a Fall in touching, I got it ſupplied, and, for Fear of ſuch another Accident, reduced them to almoſt a blue Colour. I laid them one after another in a Trench planed for them, in a long Piece of Wood about the Depth of half their Diameter, putting their marked Ends all one Way: I made a Hole in the Trench a few Inches from one End of the Piece of Wood, and put a Pin in it to keep the Bars from ſliding to the Ground, and elevated the other End till it was, as I gueſſed, in the magnetical Line. I then touched them with two of my Magnets as before, and this I found the beſt Way of all. When they were finiſhed, and armed with proper Armour, the North Pole lifted above half a Year after ℔j *Troy*, and the South Pole conſiderably more. In making one of theſe, I met with an odd Accident; for after I had begun to touch it, apprehending it was a ſmall Matter bigger than the reſt, I attempted to mend it on a Grinding-ſtone, whoſe Axes were directed about 14 or 15 Degrees from Eaſt towards North, and from Weſt towards South. I was not careful to keep its Poles the proper Way in grinding, but held the Bar ſometimes a-croſs to the Stone, which would make it jar, at other times, with the North Pole toward the North. Afterward I touched it again with the reſt, but could not give it an Attraction equal to that of the others. I happened to try with my Dial-Needle whether the Change of Polarity was in the very Middle of the Bars, or nearer to one End than the other, and in this Bar found ſeveral Polarities contrary to my

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Expectation, but how many I am not certain, being ſeveral Years ſince, and I not heeding it nicely. As I held it erect, the Bottom was a South Pole, further up no Attraction, the Pole changing a little higher (I think one third Part of the Bar's Length) a ſtrong North Pole, and about ⅔ up a ſtrong South Pole, and at the Top a ſtrong North Pole, the Middle between each Pole not attracting. Whether the jarring on the Grinding-ſtone while held in a wrong Poſture was, as I ſuppoſe, the Cauſe of this irregular Vertue, or whether I might at firſt, by Miſtake, touch it the contrary Way, I durſt not poſitively aſſert; but all my Care and Labour would not help it by touching: For, as the Vertue became ſtronger in the Ends, ſo did alſo the Polarities in the other Parts of the Bar. I was ſomewhat concerned at this Diſappointment, doubting it muſt have been new ſeaſoned, which would have created the Trouble of cleanſing and poliſhing it the ſecond Time. I thought firſt that I would try to cure it by putting it over freſh Wood-Coals in an horizontal Poſture, with its intended South Pole directed towards the magnetical North, which I did, and ſo kept it until it was blue. Then I took it out of the Fire, and cooled it in almoſt the ſame Poſture, for I think the North Pole thereof was elevated. I tried it without retouching, and found it perfectly cured, the Polarity regular throughout, and (which I was ſurprized at) attracted full ſo ſtrongly as either of the reſt.

I next endeavoured to procure Magnetiſm in Steel, without the Aſſiſtance of any Magnet (except the Earth's central one.)

Finding

Finding my artificial Magnets, rightly uſed, would communicate more Vertue to other Steel than they themſelves had, and obſerving that erect Bars had ſome Vertue from the Earth's Magnet, and having alſo experienced that Iron, which had only tranſient Vertue, would, when in an erect Poſture, or in the magnetical Line, give a ſmall Degree of fixed Polarity. (*Vide ſupra, Pag.* 317.)

I ordered nine Steel Bars 0.75 of an Inch ſquare, and 16 Inches long, to be made. Some of them, through the Smith's Fault, were a little leſs; the Weight of the heavieſt was, after it was finiſhed, 3 ℔ *Avoirdupois*. I made them moderately bright by grinding, and filed their Ends ſo plain as I could, and tranſverſe to their Lengths, by help of a Carpenter's Square; then marked one End of them, and, when hardened, I ſcowred them bright, and poliſhed their Ends very well. I fitted a Piece of Armour for each End of one Bar, and marked the Piece which was for the marked End of the Bar, and bound faſt both Pieces of Armour to the ſame Bar, one at each End: Then ſtanding with my Face toward the Weſt, and holding the Palm of my Left Hand upward, I placed therein one of the Bars without Armour with its marked End Northward, and graſped it faſt at its Middle, with my Fingers on the Weſt Side, and the Ball of my Thumb on the Eaſt Side, where I alſo laid along my whole Thumb to keep it ſteady: So the upper Part of the Bar was open from End to End. Thus holding it, I elevated the South End thereof until I gueſſed it was in the magnetical Line; and holding with my Right Hand the armed Bar, with the Poles of the Armour downward, and the marked End toward the North depreſſed to the magnetical

magnetical Line, I placed the Pole of the upper Armour about 4 or 5 Inches from the Top of the unarmed Bar, and ſo ſoon as ever it touched the Bar, I began, with the greateſt Speed I could make, to draw it downward until I was paſt the Middle, and from thence to the Bottom gradually ſlower. When it was at the Bottom I permitted it to reſt there about 1 or 2 Seconds. After the ſame Manner applying the Pole of the lower Armour to the unarmed Bar about 4 or 5 Inches from its Bottom, I drew it upward, ſpeedily at firſt, ſlower when above the Middle, letting it reſt a little at the Top. Having upwards and downwards alternately repeated the Touch on the ſame Side of the Bar, I touched the oppoſite Side thereof, which was next my Hand, in the ſame Manner, and afterwards the two other Sides. Then holding the unarmed Bar erect, I uſed to ſee if it had gained any fixed Polarity by holding my ſmall Needle at the Top and at the Bottom of the Bar; for if it had gained any Vertue by the Touch, it would attract the Needle ſtronger, at the ſame Diſtance, when the marked End of the Bar was held downward, than when it was held upward. If I found it had gained any ſenſible Vertue, I took off the Armour from the firſt Bar, and bound it to the ſecond which I had touched, and after the ſame Manner touched the firſt Bar with the ſecond, as I had touched the ſecond with the firſt. And when by Trial with the Compaſs Needle I found the armed Bar had communicated to the other more Vertue than was in itſelf, I took off the Armour and bound it to that which was newly touched, and therewith retouched that which I had diſarmed. In a few Repetitions of changing the Armour from Bar

to

to Bar, and touching the weakeſt, I procured in both of them (without the Aſſiſtance of either of the other ſeven) a fixed Polarity to ſuch a Degree as that the North Pole, or unmarked End of either of them held downward, would attract the North End of the Needle, though much fainter than if the North Pole of the Bar had been upward, and Poſition did not now change their Polarities, but only weaken them: Therefore I now call their Vertue perfectly permanent. Four or five Repetitions more encreaſed their Vertue to ſuch a Degree as that the South Pole of one of them would lift a Ten-penny Nail prepared, and after 2 or 3 Repetitions more a common Door Key of an Iron Box-Lock, Weight *Troy* ℥j and above ℈ij, not by the Bow, but by its lower End, which was wrought ſomewhat globular and poliſhed. In the laſt Place I got a Piece of Inch Deal above three Inches broad and 7 or 8 Feet long, in the Middle whereof, at about 5 or 6 Inches from one End, I made a Hole through with a large Gimlet, into which I drove an Iron or Steel Pin, whoſe Length (beſides what went into the Wood) was a little leſs than the Thickneſs of one of the Bars. Then I placed the biggeſt Bar on the ſaid Board with its marked End cloſe to the Pin, and its Length parallel to that of the Board, and with an Awl made four ſmall Holes in the Board, one of them on each Side of the Bar about an Inch from the Bottom, and about the Thickneſs of a Sixpence, from its Sides, and the other two after the ſame Manner, about an Inch from the Top. I drove into them Pins of large Wire half an Inch long, beſides what was in the Board. The Pins were to keep the Bars from ſliding out of their Places in touching. Then removing that, and placing

any other Bar between the ſaid Pins, with its marked End cloſe againſt the great Pin, I placed the marked End of the ſaid biggeſt Bar cloſe againſt the unmarked End of the other, and made four Holes on its Sides, and drove Pins in them as before, and ſo continued to do, until the Board was full: It held half a Dozen Bars. I took Care to place the marked End of every Bar directed towards the great Iron Pin which was to keep them from ſliding down to the Ground, when the other End of the Board was elevated, to ſtand in the magnetical Line. The Board ſtanding with one End on the Ground, and the other leaning againſt the Wall, at the South End of the Room, I took the armed Bar, which had Vertue, and placed its North Pole's Armour about the Middle of the higheſt Bar, whoſe Middle I could reach to (keeping the Armour of the South Pole a little upon one Side of the Bars, juſt ſo far as I might be ſure not to touch them with that End) and then immediately drew it from thence downward to the Bottom of the loweſt Bar: After the ſame Manner placing the Armour of the South Pole on the Middle of the loweſt Bar (and holding the armed North Pole on one Side, that it might not touch) I drew it upward to the Top of the higheſt Bar, whoſe Top I could reach. And if the End of any Bar was a little under that which it reſted againſt, I uſed to put a ſizeable Chip under it, that the Armour might not hitch in drawing it over the Places of their Contacts. I uſually touched the Bars on all four of their Sides, then took out the loweſt, and (letting the reſt gently ſlide down to the Iron Pin) placed it at the Top, that thoſe which were firſt at the Top might in their Turns take their Places in the Middle, and be well touched.

I commonly reſted at the End of each Bar in drawing (as in the ſingle Bar before mentioned, *Pag.* 325.) When I found thoſe on the Board conſiderably ſtronger than my armed one, I took out that which I thought attracted beſt, and bound the Armour to it, putting the other in its Room. After ſeveral repeated Touchings, the biggeſt of them being ℔iij *Avoirdupois*, would be ſuſpended by its North Pole to the South Pole of one of the beſt of the others. They did not lift one another, or attract ſo well when their Ends were applied centrally, as when applied to one another (as is expreſſed in the Figure) near to their oppoſite Corners. The Line *m* in the End of each Bar repreſents the Manner I uſed to mark their intended South Poles. With one of theſe armed, I touched a ſmall ſquare Bar of Steel (placed betwixt two of the great ones) the Length whereof was 2.156 Inches, the Breadth of each Side 0.27 (or ſomewhat more than $\frac{1}{4}$ of an Inch) the Weight 3 v *Gr.* iv (*i. e.* 304 Grains) it would lift afterwards an Iron $5\frac{1}{4}$ Inches long, weighing ʒiv ʒj ʒj or, 2000 *Gr.* 304 can be had 6.578 times in 2000. So it lifted above $6\frac{1}{2}$ times its own Weight. With this little Bar naked I touched a ſmall Dial-Needle made of Steel (the Socket in the Middle was alſo Steel, and not Braſs, as uſual) I ſeaſoned it very hard, and cleanſed it well, and with much Care, not to break it, becauſe ſo hard. It weighs not full 4 Grains, has lifted two prepared Six-penny Nails, one at each End, while it was held in an horizontal Poſture with its South Pole towards the North. It alſo lifted a Key by the Bow, as it was held perpendicularly

dicularly with its South Pole downward, the Weight whereof was 3j 3ij *Gr.* xv good Weight (*i. e.* 115 Grains or better) Wherefore ſince the Needle weighed leſs than 4 Gr. which is the 29th Part of 116, we may reckon it lifted full 29 times its own Weight by the Force of one Pole, the Key having no permanent Vertue before.

I never ſaw this Communication of Magnetiſm outdone by the Loadſtone itſelf, as it is commonly uſed; but what a good one would do, uſed as I did the Steel, I know not for want thereof, but doubt, unleſs Steel could be made better than it uſually is, a ſtronger Degree of Attraction therein is ſcarce to be hoped for from the Uſe of the beſt of Loadſtones.

I uſually find the attractive Power in ſquare Bars cut plain over tranſverſe to their Lengths, to be ſtrongeſt, not in the Middle of their Ends, but much nearer to their Corners or Sides, and to be greater at one Corner or Side than another; and this not only in ſuch as are of touched Steel, but in Iron ones having no Polarity, but from their Poſition. The ſame I obſerved in round Bars, if their Ends are not convex.

In ſome of my large Steel Bars (as alſo in ſome of the round Bars) I found the North Pole ſtrongeſt, in others the South. I know not the Cauſe thereof; for though I touched the weaker End twice ſo often as the ſtronger, it would ſtill continue to be ſo, when the ſtrongeſt had been well touched before. I imagine it muſt be owing to ſome Inequality of the Steel occaſioned by the different Degree of Heat taken at the Forging; different Degree of Heat when the Smith deſiſted hammering; different Degree of Heat in making the Iron into Steel, or Quantity of what is uſed in doing it; Fineneſs of

the Iron whereof the Steel was made, ſome ſmall Difference in Magnitude, or Difference in ſeaſoning, it being almoſt impoſſible to make both Ends equally hard; but that both Ends of mine might be ſo, I had a Fire made long enough to heat their whole Length at one and the ſame Time.

I left ſeveral of the Bars on the Board whereon they were touched, and in the ſame Poſition to one another, as well as to the Earth, for ſome Months, to ſee whether they would loſe any of their Vertue; but if they did, it was ſo little as I could not be ſure thereof.

I alſo tried whether what I mentioned concerning Loadſtones (*beginning at Page* 303) would hold in 5 or 6 Bars regularly touched and placed to one another in the ſame Manner; and found that at ſome of the Joinings it anſwered pretty well, but not ſo well at others, uſually beſt at the two extream Joints, and worſe at the middle ones. When I held the Dial-Needle at a good Diſtance from the Bars (perhaps 6 or 8 Inches) the Attraction was more regular, and the different Poles of the two Bars at their Contact was not ſo eaſily diſcernable; but when I held it within 2 or 3 Inches Diſtance, both of the Poles diſcovered themſelves more or leſs at every Joint. Perhaps the Cauſe may be the Want of a better Contact, the Ends of the Bars not being true Plains; or it may be partly owing to their conjunct Length (though I cannot ſee how that ſhould cauſe it) or ſome Irregularity in the Vertue of each particular Bar. For it has been obſerved, that very oblong Iron, as Wire, is capable of having a North Pole in both Ends, and a South one in its Middle; or, as my round Bar beforementi-

mentioned, ſeveral Polarities in no greater Length than about one Foot. My Bars were not made of *German*, but more ordinary Steel, of about 4 *d. per* lb.

I never yet tried the Experiment of weighing Pieces of oblong Steel juſt before, and preſently after the Touch, but ſuppoſe (from Mr. *Norman*'s Experiment, *New Attractive*, *Chap.* vi.) that my own Conjectures are right, *viz.* That oblong Steel of a convenient Length and Weight, perhaps 3 or 4 Feet, and 10 or 11 Ounces, may, if weighed with a very nice Beam, made of Iron or Steel, the Cords of the Scales being of a common Length, ſeem to loſe a Grain or two of its Weight (more or leſs according to the Subſtance of the Beam, Shortneſs of the Cords, and Degree of Magnetiſm in the touched Steel). I ſay, ſeem to loſe, becauſe the touched Steel with one of its Poles attracts the Beam not juſt at the End thereof to which it is ſuſpended, but there, and, more or leſs, all the Way between the ſaid Point of Suſpenſion and the Middle of the Beam. This muſt make it apparently (not really) to ponderate leſs, as is the Caſe of Stilliards, demonſtrated by the Doctrine of the Leaver: Alſo the other half of the Beam being ſomewhat attracted by the other Pole of the Steel, aſſiſts the Weights which are laid againſt the Steel, and encreaſeth the Miſtake, which is greater or leſs, according to the Poſture of the Steel, whether (if horizontal) it is parallel or perpendicular to the Beam, or (if in an erect Poſture) according to which Pole is upward. My Thoughts are, that Steel after the Touch (Allowance being made for what is rubbed off by touching, which I take to be inſenſible, if done on ſoft Armour) muſt, if in an horizontal Poſture, neceſſarily draw

draw ſomewhat more Weight than before; or if in an erect Poſture in North Latitude with the South Pole downward more, and upwards leſs than in an horizontal Poſture: But theſe Differences are ſo ſmall as no Experiment I can think on will render ſenſible in the leaſt Degree, becauſe of the vaſt Diſtance between the Surface of the Earth and the attractive Point of the internal Magnet: For ſince Attraction and Repulſion are at the ſame Diſtance equal, I ſay the one Pole of a Bar of Steel 10 or 20 Feet long, directed toward the attractive Point of the Magnet, ſuppoſed at the Diſtance of but one or two Miles, is not ſenſibly nearer to it than the other (I mean in reſpect to Attraction) how much more inſenſible then muſt the far greater Diſtance of 2000 Miles render it, which is not ſo remote as Mr. *Whiſton* (Longitude and Latitude found by the Dipping-Needle, *Pag.* 48. *Line* 12) ſuppoſes it to be. I cannot think fit to call the Point to which the Needle tends a reſpective Point, as Mr. *Norman* does, ſince his Experiments, *Chap.* VI. do not convince me (by reaſon of the Diſtance thereof from the Surface of the Earth) that it is not an attractive one. If therefore Steel after the Touch is ever found to weigh (with a Beam of Matter not magnetical, and in a Place at too great Diſtance from any Iron or Magnet to be ſenſibly affected thereby) either more or leſs than before, it muſt be occaſioned by the Augmentation or Diminution of its Quantity of Matter by the Touch. The former ſeems impoſſible, becauſe a Magnet loſes no ſenſible Weight by having 10000 Pieces of Steel ſucceſſively touched on its Armour; nor is the latter probable, unleſs the Weight of the Magnet is encreaſed, or Part of the Subſtance

of

of the Steel ground off by touching: And if the Quantity of Steel is, by rubbing, diminiſhed, the Lightneſs is not owing to its having Magnetiſm, but to its Defect of Matter. Before an Experiment of this Nature is made, the Piece of Steel ſhould be well hardned, poliſhed, and wiped very clean, and if warm by rubbing or handling, ſhould be permitted to cool before it is weighed. Then being weighed with a Braſs Beam, let it afterward be well touched on the ſoft Armour of a Magnet, then wiped clean, and permitted to cool, before it is weighed after the Touch. Care muſt alſo be taken that no Iron Bar, or other Magnet, be in the Window, or any other Part of the Room above, or that underneath, large enough to affect it, which a Magnet, the Brads of the Floor, or other Iron in the ſame Room, or about the Operator, ſuch as a Key, Knife, Buckles, or the like, may more or leſs do, according to their Diſtance and Situation: And I have ſeen a Brad in the Floor make the End of a large horizontal Needle dip to it at the Diſtance of above an Inch.

Mr. *Whiſton* in his ſaid Book, *Pag.* 47, ſuppoſes the Surface of the Earth's central Magnet to be diſtant in Miles from the Surface of the Earth 3400, and accordingly, *Pag.* 48, computes the Semidiameter of the ſaid Magnet to be about 575; both which Sums added, make the Semidiameter of the Earth to be about 3975 Miles; which is about 7 Miles leſs than Mr *Norwood* makes it by reckoning 69½ Miles to a Degree, which multiplied by 360, makes 25020 in the whole Circumference, and the Radius (by *Van Ceulen*'s Proportion of the Circumference to the Diameter) I find to be 3982.0566, *&c.* which 7 Miles is but a Trifle in 3975, or 3982.

I ſhall

I ſhall then ſuppoſe the Earth's Radius (in Miles) 3975, from whence I compute the Circumference 24975.6615,9603,8855, &c. And one Degree 69.3768.3776,6774.5988,3, &c.

Mr. *Whiſton*, *Pag.* 53, ſays that the Northern magnetick Pole was then about 13½ Degrees from the North Pole of the Earth: The Sine of which in natural Numbers is 233,4454 to the Radius 1000,0000.

1. As the Earth's Radius (in Miles) 3975, to the above-mentioned Sine of 13 Deg. 30 Min. 233,4454. So the ſaid Magnet's Radius 575 Miles to the Tabular Number 33.7688,3144,6540.8805,0311, &c.

2. As the Tabular Radius 1000,0000, to the ſaid Tabular Number, ſo (in Miles) is the Earth's Radius to the Radius of the Parallel of 13½ *Gr.* on the ſaid Magnet's Surface: Or, ſo is the Earth's whole Circumference to the Circumference of the Central Magnet's ſaid Parallel: Or, ſo is one Degree of the Earth's great Circle in Miles to one Degree of the ſaid Parallel of 13½ *Gr.* on the ſaid Magnet's Surface 2.3427,7474,0840,2028,43, &c.

The ſaid Degree reduced into Feet, and into Inches, is,

In Feet and Parts 12369,8506,3163,6271,0156,59, &c.

In Inches and Parts 148438.2075,7963,5252,1879,14, &c. Which 2.3427, &c. Miles the North magnetick Pole of the central Loadſtone moves in ſomewhat leſs Time than 4 ſolar Minutes, *viz.* in about 4 Minutes by the diurnal apparent Motion of the fixed Stars) But for as much as the *Ratio* of the internal Magnet's Diameter to that of the Earth, is not probably calculated to Perfection, I ſhall proceed as if the ſaid Pole of the Magnet moved the ſaid Space perfectly in the Time of four Stellar Minutes.

For

For want of a more convenient Inſtrument, I took a Whirligig of Wood, ſomewhat more than $\frac{1}{4}$ of an Inch thick, and in Diameter at leaſt 1.8 Inch. It was turned truly round, and had in its Diameter nigh to, and equidiſtant from the Centre two Holes made, into which, as uſual, was a Thread put, of about 40 Inches long, and about 20 when it was put in, and the two Ends tied together. I went with it to a Clock, whoſe Pendulum oſcillated Seconds, and working the Whirligig ſtrong enough to make its Returns, or Vibrations, keep equal Times with the Pendulum's Oſcillations, I ſuddenly caught the Whirligig at the End of one Vibration before it began another, and then (untwiſting the double Thread gradually with my Fingers) I told how many Turns or Revolves it had made in that one Vibration, and found the Thread untwiſted with 58 Turns (which is but half the Number in one Vibration, becauſe in the whole Vibration it was twiſted the like Number of Turns the other Way) which doubled makes 116 Turns in each Vibration, and in one Second of Time. I computed the mean Velocity of the Circumference thereof in each Second of Time to be about 54 Feet 7 Inches 9645,4606, *&c.* Parts. By this it is plain, that a Globe (as well as a Wheel) of 6 Inches in Circumference, if truly centered, is eaſily capable of being kept in Motion on its Poles, ſo ſwift that its Æquator ſhall have the Velocity of 51 Feet 5410,4429,8, *&c.* Parts, by making 103.0820.8859, *&c.* Turns in one Second. This is the proper Velocity for ſuch an Experiment, becauſe it is nearly equal to that of the North magnetick Pole of the internal Loadſtone along the Parallel of 13½ Degrees from the Poles of its Rotation.

The Velocity of the ſaid magnetical Pole of the internal Loadſtone is, as above, in the Time of 4 Minutes, in Inches and Decimal Parts 148438.2075,7963, 5252,1879,14.

And therefore in the Time of one Minute 37109. 5518,9490,8813,0469,786, and in one Second 618.4925,3158,1813, 5507,8297, which 618.4925, *&c.* Inches reduced to Feet and Decimal Parts, is 51.5410,4429,8, *&c.*

Suppoſe then a Terrella was made of juſt 6 Inches in Circumference N ≈ S *n* (*Vid. Fig.* 1. *Pl.*) contrived to gyrate on Poles ≈ *n* choſen in any two oppoſite Points of its magnetical Æquator, and the Axis of its Rotation ≈ *n* ſituated (as near as Art can do it) in the magnetical Line; for in this Poſture of the Axis the magnetical Poles of the Terrella will be equally wrought on by the Earth's attractive Point all the Way as it is turned round, which can be in no other Poſture whatſoever: For if the Axis of its Rotation makes the leaſt Angle with the magnetical Line; as the Terrella is turned round, the magnetick Poles of it will be attracted and repelled more when on one Side than when on the other, which ought not to be, becauſe it is probable it may have the ſame Effect which a large Magnet would have, if held within the Attraction, and conſequently change the Polarity, as by a Touch, and not purely by the Gyration thereof.

The Circle N ≈ S *n* repreſents the Terrella in Circumference juſt 6 Inches (having both, or at leaſt one, of its attractive Poles nicely marked) cemented, or bound with Thread faſt to a cylindrical Veſſel of Wood, or Braſs pretty thin, that it may not be too heavy, with its Polarity N S tranſverſe to the Axis of the

ſaid

ſaid cylindrical Veſſel, whoſe Diameter on the Inſide ought to be equal to that of the Terrella, and its Depth not leſs than the Radius. Or, if the Terrella is truly globular, inſtead of the cylindrical there may be a concave Veſſel (repreſented by the pricked Line *x n w*) leſs than a Hemiſphere, and its Diameter of Concavity ſomewhat leſs than that of the Terrella; ſo ſhall their Contact be wholly at the Brim of the Veſſel, which will keep the Terrella central. And this may be better than a Cylinder, becauſe lighter, and the moſt of its Parts nearer to the Axis of its Verticity. Either of theſe is to be centrally fixed to the Arbor *n m*, which, together with its Pivot *r*, ſhould be made of Braſs, and the Pivot Work in a Hole made fit for it in a Horſe's Tooth, or ſome ſuch Thing: The End of the Pivot ſhould reſt on the Bottom of the Hole, that it may move the eaſier. The Collar at P, in which the Arbor turns round, may be made of Tooth alſo, and both that and the Pivot aforeſaid ſhould be kept well oiled, or greaſed, to prevent their being heated by ſo rapid a Motion as is neceſſary, and ſo ſhould alſo the other Axles. This is to be kept in Motion by a Gut-ſtring (as the Spill of a Spinning-Turn is moved) tied pretty ſtrait round the little Wheel at *m*, and the greater one at F, which String is repreſented by the pricked Line. And the Wheel F is turned after the ſame Manner, by a larger Gut-ſtring round the Wheels *t* and Q, which muſt be ſtrained very ſtraight, that it may not ſlide on the Wheels. To prevent which Inconvenience, this String (and the other, if need be) may be rubbed well with powdered Roſin. I think a Gut-ſtring round a great Wheel and leſſer one, will work eaſier than the beſt of Clock-work, and without rattling

or jarring, which the latter, when in a rapid Motion, is ſubject to, and therefore I cannot approve of it, nor is the multiplying Power of the Wheels *m* F, being 10.3082, *&c.* ſo nearly to be calculated for a Wheel and Pinion; but, if good Work, it may be allowed in the Wheels *t* Q, which move ſlower: But that I apprehend will needleſly encreaſe the Charge. The Diameter of each Wheel at the Bottom of the Trench, where the String touches it, is mentioned in the Draught. The whole may be made to turn with one's Hand, either with a Crank Q *g* in the Arbour of the Wheel Q, or with a Turner like that of a Grinding-ſtone R.

Mr. *W*———*n*, *Page* 78, makes one Revolution of the central Magnet, in reſpect of the Earth, to be not leſs than 1920 Years, which I have reduced to 701280 Days, to which I add 1920 Days, which makes the Sum 703200, being the Number of Revolutions, nearly, which the Earth and the ſaid Magnet with it, makes in 1920 Years in reſpect of the fixed Stars. Now ſince the magnetick Pole of a Terrella 6 Inches in Circumference, centered as above is directed, and moving with the Velocity of 51 Feet 5410,4429, *&c.* Parts in the Time of one Second, by making 103.9820,8859, *&c.* Turns, moves equally rapid with that of the central Magnet, it may be expected that 703200 of its Revolutions ſhould gradually tranſlate each of its Poles one entire Circle, which 703200 Revolutions (at 103.0820, *&c. per* Second) will be finiſhed in the Time of 6821 Seconds 7476,9272,396 Parts, or $1^{h}\ 53'\ 41''\ 44'''\ 51''''\ 41'''''$. Or,

351600 Revolut. tranſlate it ½ a Circle in 3410.8738, 4636,198″, or $0.\ 56'\ 50''\ 52'''\ 25''''\ 50'''''$.

175800

175800 Revolut. tranſlate it $\frac{1}{4}$ of a Circle in 1705.4319, 2318,099″, or 0.28′ 25″ 26‴ 12⁗ 55⁗′.

117200 Revolut. tranſlate it $\frac{1}{6}$ of a Circle in 1136.9579, 4878,732″, or 0.18′ 56″ 57‴ 28⁗ 36⁗′.

If the Terrella's Circumference is more than 6 Inches, the magnetical Poles thereof may be placed ſo oblique to the Axis of the Cylinder, as that in turning round they may each of them deſcribe a leſſer Circle (or as it may be called a Parallel of Latitude) juſt 6 Inches in Circumference, and that will cauſe no Alteration in the Swiftneſs of the Motion of the Machine, which is to be moved as follows, *viz.* The Perſon that works it muſt keep his Eye on a Pendulum oſcillating Seconds, and turn the Crank (or Turner) once round at each Oſcillation, ſo ſhall the Number of the Terrella's Revolutions, and Celerity of the Motion of its Poles be as is above-mentioned.

But if the Terrella is larger than 6 Inches in Circumference, and its Polarity tranſverſe to the Axis of its Rotation, the Pendulum may be lengthened in Proportion of the Squares of their Circumferences, and the Crank muſt then make one Turn at each Oſcillation of the Pendulum ſo lengthened; and by that Means it will move with the ſame Celerity which was above propoſed; but then the 703200 Revolutions will not be finiſhed in leſs Time than 6821 Seconds (or rather Oſcillations) made by the lengthened Pendulum.

If by the keeping a Terrella in Motion in ſuch a Poſture, and with ſuch Celerity as is aforeſaid, the magnetical Poles thereof, in reſpect of the Terrella, remain immoveable, I think this is a plain Demonſtration that the central Magnet is looſe from the Earth,

Earth, and revolves within it a little ſlower, as is conjectured by ſeveral, and to me ſeems moſt probable.

But if the magnetical Poles, by ſuch a Motion as is deſcribed, ſhould in reſpect of the Terrella be tranſlated with a Motion retrograde to that wherein it was kept by the Machine, I ſhould think it poſſible for the diurnal Motion of the central Magnet to tranſlate the Polarity thereof farther Weſtward by the Vertue of its own Effluvia, which are continually left a little behind, as it revolves on its Axle Eaſtward, and that the ſaid Magnet is fixed to the Earth. But theſe Things ſeem uncertain.

However, I think it not impoſſible to reduce the Period of the Motion of the magnetical Pole, in reſpect of the Earth, to a tolerable Calculation in much leſs Time than an entire Revolution thereof, by meaſuring daily the Quantity thereof: For effecting which, I have thought on a new Way of making a Needle not above 6 Feet long, with ſome Engine-work to its Box, which, I believe, I can demonſtrate will render it viſible daily to a naked Eye, that the Variation is changed: But I have no Time at preſent to deſcribe it, being but juſt able to finiſh this; but if it may be acceptable, ſhall readily communicate it on Notice.