~~Mr Edward Dunn~~

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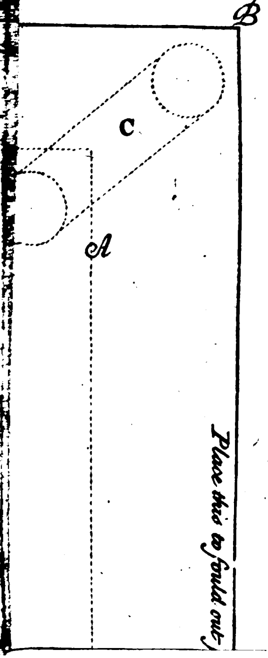

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THE

Artificial Clock-maker:

A

TREATISE

OF

Watch and Clock-work,

Shewing to the meaneſt Capacities,

The ART of *Calculating Numbers* to all Sorts of MOVEMENTS; the Way to *Alter Clock-work*; to Make CHIMES, and Set them to Muſical Notes; and to Calculate and Correct the Motion of PENDULUMS.

ALSO

Numbers for divers MOVEMENTS:

With the Antient and Modern

Hiſtory of Clock-work;

And many *Inſtruments*, *Tables*, and other Matters, never before publiſhed in any other Book.

The FOURTH EDITION, with large EMENDATIONS.

By *W. D.* F. R. S.

LONDON,

Printed for JAMES, JOHN and PAUL KNAPTON, at the Crown, in Ludgate Street. MDCCXXXIV.

TO THE

READER,

Concerning the Third Edition.

Altho' this little Book was a Part of the Diversion of my Juvenile Years, and drawn up when I was Young, and afterwards twice Published, yet having been for some time scarce, and much called for, I have reviewed it for a 3d Impression. Neither do I think it unbecoming my Riper Years, or my Profession to do so, by Reason it hath done some, not inconsiderable, Good in the World, not only among the Clock-Makers, *and their poor Apprentices, but also among many Gentlemen and others, that delight in Mechanical Studies and Exercises: To whom it hath been an Innocent and vertuous Diversion.*

Upon this Review (the last I shall ever make) I have thought it necessary to make many, and considerable Alterations: Of which I would have given a List, in Justice to the Purchasers of the former Editions (as I did in the second Impression) but that it is almost impossible. For all the

Supplement to the Second Edition, so far as I thought it might be of Use, is thrown into proper Places of the Book it self, and so many things are expunged; so many added, and so many amended, that the Book is in a manner New. So that could I have given the particulars of the Alterations, yet no Purchaser of the former Editions would think it worth his while to transcribe them, but rather buy the Book a new, since it is rendered, I hope, more compleat, and the Purchase is but small.

THE

THE PREFACE.

THE following Book was at first drawn up in a rude Manner, only to please my Self, and divert the vacant Hours of a Solitary Country Life. But it is now published, purely in hopes of its doing some good in the World among such, whose Genius and Leisure lead them to Mechanical Studies, or those whose Business and Livelihood it is.

Many there are, whose Fault or Calamity it is, to have Time lying upon their Hands; and for want of innocent, do betake themselves to hurtful Pleasures. This is the too common Misfortune of some Gentlemen. Among some of the looser Sort of which, if this Book shall find Acceptance, it may be a Means to compose their rambling Spirits; and by an innocent Guile, initiate them in other Studies, of greater Use to themselves, their Family, and Country. However, it may hinder their Commission of many Sins, which are the Effects of Idleness.

If there be any one Person, in whom these good Effects are produced, I shall think my idle Hours well bestowed, and bless God for it. However, upon the Account of the Innocence of my End in publishing this Book, and that it was written only as the harmless (I may add also the vertuous) Sport of leisure Hours; I think my Self excusable to God and the World, for the Expence of so much Time, on a Subject different from my Profession.

But besides, I think there are some little Obligations of Justice and Charity lying upon me to publish the ensuing Papers for the Sake of those, whose Business the Mechanical Part is. I take it to be a Charity to the Trade; because there are many (altho' Excellent in the Working-part) who are utterly unskilled in the Artificial-part of it. And then it is a Debt I pay: because I owe somewhat of Health, as well as Diversion to the Study, and Practice of this sort of Mechanicks. And the best Requital I can make for my Trespass, is to publish what I have had better Opportunities perhaps of Learning than many Workmen have.

And further yet; there is another Reason, which much prevailed with me to publish this Book, *viz.* Because no Body, that I know of, hath prevented

vented me, by treating ſo plainly and intelligibly of this Subject, as to be underſtood by a Vulgar Workman. I have often wondered at it, that ſo uſeful and delightful a Part of Mechanical Mathematicks ſhould lie in any obſcurity, in an Age wherein ſuch noble Improvements have been made therein, and when many Books are daily publiſhed upon every Subject. I ſpeak here of this Art remaining in Obſcurity; not as if nothing was ever written of it, and I the Inventer of Automatical Computation.

But although I cannot aſſume the Glory of being the firſt Writer upon this Subject, yet very few have as yet done it; of which I ſhall next give ſome Account.

Cardan, *Kircher*, and *Scottus* promiſed it; but I do not find they ever publiſhed any thing to the Purpoſe of it. Our great Mr. *Oughtred* I take to be the firſt that ever wrote to any Purpoſe about the Calculation of *Automata*: And I believe he was the Firſt that brought that Art under Rules, in his little Treatiſe called *Automata*. Which was firſt ſurreptitiouſly publiſhed in *Engliſh* in a little Book called *Horolog. Dialogues*, in the Year 1675; and afterwards far more compleatly in *Latin*, at the Theatre in *Oxon*, among

Mr. *Oughtred's Opusc. Mathem.* in the Year 1677.

What Mr. *Oughtred* had wrapt up in his Algebraick obscure Characters, was afterwards put into plainer Language by that excellent Mathematician Sir *Jon. Moor*, with some Additions of his own; which you have in his *Math. Compend.* and since him, by Mr. *Leyborn*, in his *Pleasure with Profit.*

I hope I shall not be judged to have transgressed the Rules of Modesty, in coming after these Men; neither should I venture that Censure, but for two Reasons. One is, I find by Experience, that what they have written, is understood by very few Workmen, and therefore I have endeavoured, with all industry, to make the Matter as plain as I could for such. For which Reason, I hope the more learned Reader will excuse my using many Words, when fewer would have served his Turn; and that I have condescended to low Things, (and to him needless) as teaching the Golden-rule, *&c.* The other Reason is, That what those three have Written, relates only, or chiefly to the Watch-part. To which I have added several other Things of my own: particularly the Calculation of the Clock-part, *&c.* which I my Self have reduced to Rules. And to Name no

more,

more, the Hiſtorical-part hath not been ſo much as attempted before, that I know of.

These Reaſons will, I hope, excuſe me with the moſt cenſorious Reader, not only for preſuming to write after ſo accurate a Piece, as Mr. *Oughtred's* is; but alſo the Novelty of the Subject, will I hope procure for me a candid Interpretation of the Faults that I may have unwittingly committed.

To the preceeding Account of what Others have Written (which ſhews what help I have had from printed Books) I ſhall ſubjoyn my Acknowledgements, and Thanks to the Principal of my Friends, who have given me their Aſſiſtance in compiling ſome Parts of this Book. But their Names I ſhall not make more Publick than my own, being unwilling to be diſcovered my Self. In the Chap. of the Terms of Art, I owe much to the Aſſiſtance of Mr. *L. Br*.... a judicious Workman in *Fanchurch-ſtreet*, who drew me up a Scheme of the Clock-maker's Language. In the Hiſtory of the Modern Inventions, I have had (among ſome Others) the Aſſiſtance of the Ingenious Dr. *H*..... and Mr. *T*....: The former being the Author of ſome, and well acquainted with Others, of the Mechanical Inventions of that fertile

Reign

Reign of King *Charles* the IId; and the latter, actually concerned in all, or most of the late Inventions in Clock-work, by means of his famed Skill in that, and other Mechanical Operations.

There are some other Contrivances of this last Age (besides those I have mentioned) which I have passed over in Silence; because either they are only Branches, or Improvements of the Inventions I have taken Notice of, (such as several ways of Repeating-work, &c.) Or else, they only collaterally relate to Watch-work, as the Inventions of *Cutting-Engins* (which was Dr. *Hook's*) *Fusy-Engines*, and others, which were never thought of till towards the End of K. *Charles* the IId's Reign. To treat of all these, would swell my Book far beyond its intended Bounds; which I have already somewhat exceeded. I shall therefore commit this Task to some better Pen, hoping that no Person will take it amiss, that I have not mentioned his Inventions which I have been beholden to him for the Relation of.

For the Reasons last mentioned, I have also left out of my Book, a Chapter of the Art of making, and using many Sorts of Sodders, the Way of colouring Metals, &c. useful in the

Practice of Clock-work. This I had prepared for the sake of Mercurial Genlemen, but omitted printing it, and some other things, out of Charity to poor Apprentices and other Workmen, whose Purses I am unwilling my Volume should too much exceed.

If I have at any Time invaded the Workman's Province, it was not because I pretend to teach him his Trade; but either for Gentlemen's sakes, or when the Matter led me necessarily to it.

I have nothing more to add, but that I would have this little Treatise looked upon only as an Essay, which I hope will prompt some more able Undertaker to perform the Task better, especially in the Historical Part. For since Watch-work oweth so much to our Age, and Country, it is pity that it should not be remembred: especially when we cannot but lament the great Defect of History, about the Beginning and Improvements of this ingenious and useful Art.

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CONTENTS.

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THE

Artificial Clock-Maker.

Chap. I.

Of the Terms of Art, or Names by which the Parts of an Automaton *are called.*

IT is neceſſary that I ſhould ſhew the meaning of the Terms which Clock-makers uſe, that Gentlemen and others, unskilful in the Art, may know how to expreſs themſelves properly, in ſpeaking; and alſo underſtand what I ſhall ſay in the following Book.

I ſhall not trouble the Reader with a recital of every Name that doth occur, but only ſuch as I ſhall have occaſion to uſe in the following Diſcourſe, and ſome few others that offer themſelves, upon a tranſient View of a Piece of Work.

I begin with the more general Terms: As, the *Frame*; which is that which contains the Wheels, and the reſt of the Work. The *Pillars* and *Plates*, are what it chiefly conſiſts of.

Next for the *Main-Spring*, and its Appurtenances. That which the Spring lies in, is the *Spring-Box*: that which the Spring laps about, in the Middle of the Spring Box, is the *Spring-Arbour*; to which the Spring is hooked at one end. At the Top of the Spring-Arbour, is the *Endleſs-Screw*, and its Wheel; but in Spring-Clocks it is a *Ratchet-wheel* with its *Click* (that ſtops it.)

That which the main Spring draweth, and about which the Chain or String is wrapp'd, and which is commonly taper, is the *Fuſy*. In larger work, going with Weights, where it is cylindrical, it is called the *Barrel*: The ſmall Teeth at the Bottom of the Fuſy, or Barrel, that ſtop it in winding up, is the *Ratchet*. That which ſtops it when wound up, and is for that end driven up by the String, is the *Garde-gut*.

The Parts of a *Wheel* are, the *Hoop*, or *Rim*; the *Teeth*; the *Croſs*; and the *Collet*, or piece of Braſs, ſoddered on the Arbour, or Spindle, on which the Wheel is rivetted.

A *Pinion* is that little Wheel, which plays in the Teeth of the Wheel. Its Teeth (which are commonly 4, 5, 6, 8, *&c.*) are called *Leves*, not Teeth.

The Ends of the Spindle, are called *Pivots*: the Holes in which they run, *Pivot-holes.*

The guttered Wheel, with Iron Spikes at the bottom, in which the Line of ordinary Houſe-Clocks doth run, is called the *Pully.*

I need not ſpeak of the *Dial-Plate*, the *Hand*, *Screws*, *Wedges*, *Stops*, *&c.*

Thus much for general Names, which are common to all Parts of a Movement.

The moſt uſual Movements are *Watches* and *Clocks*. *Watches* ſtrictly taken, are all ſuch Movements as ſhew the Parts of Time: and *Clocks* are ſuch as publiſh it, by ſtriking on a Bell, *&c.* But commonly the Name of *Watches* is appropriated to ſuch as are carried in the Pocket; and that of Clocks to the larger Movements, whether they ſtrike the Hour or no. As for Watches which ſtrike the Hour, they are called *Pocket-Clocks.*

The Parts of a *Movement*, which I ſhall conſider, are the *Watch*, and *Clock-Parts.*

The *Watch-part* of a Movement is that which ſerveth to the meaſuring the

Hours. In which the firſt thing I ſhall conſider is the *Balance*; whoſe parts are, the *Rim*, which is the circular part of it; the *Verge*, is its Spindle; to which belong the two *Pallets*, or *Leves* which play in the Teeth of the Crown-Wheel; in Pocket Watches, that ſtrong Stud in which the lower Pivot of the Verge plays, and in the middle of which one Pivot of the Balance-Wheel plays, is called the *Pottance* vulgarly, I ſuppoſe for *Potence* (it being ſtrong) or *Portance*, as Dr. *Hook* calls it in his *Helioſcop*. p. 10. The bottom of this is called the *Foot*; the middle part (in which the Pivot of the Balance-wheel turns) is called the Noſe; the upper-part, the *Shoulder* of the Portance. The piece which covers the Balance, and in which the upper Pivot of the Balance plays, is the *Cock*. The ſmall Spring in the new Pocket-Watches underneath the Balance, is the *Regulator* or *Pendulum-Spring*.

The parts of a *Pendulum* are, the *Verge*, *Pallets*, and *Cocks*, as before. The *Ball* in long Pendulums, the *Bob* in ſhort ones, is the Weight at the bottom. The *Rod*, or *Wire*, is plain. The terms peculiar to the *Royal Swing*, are the *Pads*, which are the Pallets in others, and are fixed on the *Arbor*. The *Fork* is alſo fixed to the *Arbor*, and about 6 Inches below, catcheth hold on the Rod, at a flat piece of Brafs, called the *Flatt*, in which the lower end of the *Spring* is faftened.

The Names of the Wheels next follow. The *Crown-Wheel* in fmall pieces, and *Swing-Wheel* in Royal Pendulums, is that Wheel which drives the Balance, or Pendulum.

The *Contrate-Wheel*, is that Wheel in Pocket-Watches, and others, which is next to the Crown-Wheel, whofe Teeth and Hoop lie contrary to thofe of other Wheels; whence it hath its Name.

The *Great-Wheel*, or *Firft-Wheel*, is that which the Fufy, &c. immediately driveth. Next it, are the *Second-Wheel*, *Third-Wheel*, &c.

Next followeth the Work between the Frame and Dial-Plate. And firft, is the *Pinion* of *Report*; which is that Pinion, which is commonly fixed on the Arbor of the Great-Wheel, and in old Watches ufed to have commonly but four Leaves; which driveth the *Dial-Wheel*, and this carrieth about the *Hand*.

The laft part which I fhall fpeak of is the *Clock*, which is that part which ferveth to ftrike the Hours: In which I fhall

Firft fpeak of the *Great*, or *Firft-*

Wheel; which is that which the Weight or Spring firſt drives. In 16 or 30 Hour Clocks, this is commonly the *Pin-Wheel*; in 8 Day Pieces, the *Second Wheel* is commonly the *Pin-Wheel*. This Wheel thus with Pins is called the *Striking-Wheel*, or *Pin-Wheel*.

Next to this Striking-Wheel, followeth the *Detent-Wheel*, or *Hoop-Wheel*, it having a Hoop almoſt round it, in which is a Vacancy, at which the Clock locks.

The next is the *Third* or *Fourth-Wheel* (according as it is diſtant from the firſt-Wheel) called alſo the *Warning-Wheel*.

And laſtly is the *Flying-Pinion*, with a *Fly* or *Fan* to gather Air, and ſo bridle the Rapidity of the Clock's Motion.

Beſides theſe, there are the *Pinion* of *Report*, of which before, which driveth round the *Locking-Wheel*, called alſo the *Count-Wheel*, with 11 Notches in it commonly, unequally diſtant from one another, to make the Clock ſtrike the Hours of 1, 2, 3, *&c.*

Thus much for the Wheels of the Clock-part.

Beſides which there are the *Raſh*, or *Ratch*; which is that ſort of Wheel, of twelve large Fangs, that runneth concentrical to the Dial-Wheel, and ſerveth to lift up the Detents every Hour, and make the Clock ſtrike. The

The *Detents* are thoſe Stops, which by being lifted up, or let fall down, do lock and unlock the Clock in ſtriking.

The *Hammers* ſtrike the Bell: The *Hammer-tails* are what the Striking-pins draw back the Hammers by.

Latches are what lift up, and unlock the Work.

Catches are what hold by hooking, or catching hold of.

The *Lifting-pieces* do lift up, and unlock the Detents, in the Clock part.

The *Train* is the Number of Beats or Vibrations which the Watch maketh in an Hour, or any other certain time.

There are beſides theſe divers other Terms which the Clockmakers uſe in various Sorts of Pieces, as the *Snail*, or *Step-Wheel* in Repeating Clocks, the *Rack*, the *Safeguards*, the ſeveral *Levers*, *Lifters*, and *Detents*: But it would be tedious, and it is needleſs to mention the particulars.

For the better underſtanding theſe Terms of Art, and the Parts of a Clock, I have in *Fig.* 1. repreſented them to the Eye. In which, two diſtinct Parts may be obſerved, the *Watch*, and the *Clock-part*.

The Wheels, *&c.* on the right hand, is the *Watch-part*. They on the left, the *Clock-part*.

A. A. A. A. The upper *Plate* of the *Frame*; which you may imagine to be tranſparent (as of a Glaſs) to admit of a Proſpect of the Wheel-work underneath it.

B. B. B. The lower *Plate* of the *Frame*.

C. C. C. C. The *Pillars*.

D. D. The *Spring-Boxes* of the Watch, and Clock-part.

E. E. The *Great-Wheel* of each part.

F. F. The *Fuſy* of each part, about which the Chain, or String is wrapped.

g. g. g. g. g. g. g. The *Ratchet* of each part.

a. a. a. The *Hoop*, or *Rim* of the *Second-wheel*.

b. b. The *Croſs* thereof.

c. The *Pinion*.

H. The *Contrate-Wheel*.

I. The *Crown-Wheel*.

d. d. The upper and lower *Pevet* thereof.

K. A piece of Braſs, in which the *Pevet-hole* is, in which the *Pevet* d. playeth.

L. The *Pin-wheel*, with the *Striking-Pins* e. e. e. e. e.

M. The *Detent-wheel*.

N. The *Warning wheel*, or fourth Wheel.

O. The *Detent*.

P. The *Lifting-piece*.

Q. Q.

Q. Q. The *Fan*, and *Flying-Pinion*.
R. The *Bell*.
S. The *Hammer*.
T. The *Hammer-tails*.
V. V. The Chain, or String of the Watch and Clock.
x. The *Verge* or *Spindle* of the Balance, or Pendulum.
y. y. y. The *Rod* of the Pendulum.
z. The *Fork*.
2. The *Flatt*.
3. The *Great Ball*.
4. The *Corrector*, or *Regulator*; being a Contrivance of my own, of very great use to bring the Pendulum to its nice *Vibrations*.
5. 5. The *Pallets*.

CHAP. II.

The Art of Calculation.

SECT. I.

General preliminary Rules and Directions for Caculation.

§ 1. FOR the more clear understanding this Chapter it must be observed, that those *Automata* (whose

Calculation I chiefly intend) do by little Interstices, or Strokes, measure out longer Portions of Time. Thus the Strokes of the Balance of a Watch, do measure out Minutes, Hours, Days, *&c.*

Now to scatter those Strokes amongst *Wheels* and *Pinions*, and to *proportionate* them, so as to measure time regularly, is the Design of Calculation. For the clearer Discovery of which, it will be necessary to proceed leisurely, and gradually.

Oughtred of Autom. § 2. And in the first place, you are to know, that any Wheel being divided by its Pinion, shews how many *Turns* that Pinion hath to one Turn of that Wheel. Thus a Wheel of 60 Teeth driving a Pinion of 6, will turn round the Pinion 10 times in going round once, 6)60(10.

From the Fusy to the Balance the Wheels drive the Pinions; and consequently the Pinions run faster, or go more turns, than the Wheels they run in. But it is contrary, from the Great-wheel to the Dial-Wheel. Thus in the last example, the Wheel drives round the Pinion 10 times; but if the Pinion drave the Wheel, it must turn 10 times to drive the Wheel round once.

§ 3. Before I proceed further, I must shew how to write down the Wheels and Pinions. Which may be done

done either as Vulgar Fractions, or in the way of Division in Vulgar Arithmetick. For Ex. A Wheel of 60 moving a Pinion of 5, may be set down thus, $\frac{60}{5}$: or rather thus 5)60: where the uppermost Figure 60, or Numerator is the Wheel, the lowermost or Denominator, is the Pinion: or, in the latter example, the first Figure is the Pinion, the next without the Hook, is the Wheel.

The Number of Turns, which the Pinion hath in one Turn of the Wheel, is set without a hook on the right hand: as 5)60(12; *i. e.* a Pinion 5 playing in a Wheel of 60, moveth round 12 times in one Turn of the Wheel.

4)36(9
5)55(11
5)45(9
5)40(8

17

A whole Movement may be noted thus, $\frac{4}{36}$ $\frac{55}{5}$ $\frac{45}{5}$ $\frac{40}{8}$ 17 Notches in the Crown-Wheel. Or rather (because it will be easiest to mean Capacities) as you see here in the Margin: where the uppermost number above the line, is the Pinion of Report 4, the Dial-Wheel 36, and 9 turns of the Pin. of Report. The second Number (under the line) is 5 the Pinion, 55 is the Great-Wheel, and 11 turns of the Pinion it driveth. The third Numbers, are the Second-Wheel, *&c.* The fourth the Contrate-wheel, *&c.* And

And the single Number 17 under all, is the Number of the Crown-wheel.

§ 4. By the § 2 before, knowing the number of Turns, which any Pinion hath in one turn of the Wheel it worketh in, you may also find out how many Turns a Wheel or a Pinion hath, at a greater distance; as the Contrate-wheel, Crown-wheel, or &c. For it is but multiplying together the *Quotients*, and the Number produced is the Number of Turns. An Example will make what I say plain: let us chuse these 3 numbers here set down; the first of which

5)55(11
5)45(9
5)40(8

hath 11 Turns, the next 9, and the last 8. If you multiply 11 and 9, it produceth 99, for 9 times 11 is 99, that is in one Turn of the Wheel 55, there are 99 Turns of the second Pinion 5, or the Wheel 40, which runs concentrical, or on the same Arbour with the second Pinion 5. For as there are 11 Turns of the first Pinion 5, in one Turn of the Great-Wheel 55, or (which is the same) of the Second-Wheel 45, which is on the same Spindle with that Pinion 5; so there are 9 times 11 turns in the second Pinion 5, or Wheel 40 in one Turn of the Great-Wheel 55. If you

By the Quotients I commonly mean the number of Turns; which Number is set on the right hand, without the Hook, as is shewn in the last Paragraph: Which I note here now once for all.

you multiply 99 by the laſt Quotient 8 (that is, 8 times 99 is 792) it ſhews the number of Turns, which the third and laſt Pinion 5 hath. So that this third and laſt Pinion turns 792 times in one Turn of the firſt Wheel 55. Another Example will make it ſtill more plain. The example is in the Margin. The Turns are 10, 9, and 8. Theſe multiplied as before run thus, *viz.* 10 times 9 is 90, that is the Pinion 6 (which is the Pinion of the third Wheel 40, and runs in the ſecond Wheel 54) turns 90 times in one Turn of the firſt Wheel 80. This laſt product 90 being multiplied by 8, produces 720; that is, the Pin. 5 (which is the Pin. of the Crown-wheel 15) turns 720 times in one Turn of the firſt Wheel, of 80 teeth.

8)80(10
6)54(9
5)40(8
———
15

§ 5. We may now proceed to that, which is the very Ground-work of all; which is, not only to find out the Turns, but the Beats alſo of the Balance in thoſe Turns of the Wheels. By the laſt paragraph, having found out the number of Turns, which the Crown-wheel hath in one Turn of the Wheel you ſeek for, you muſt then multiply thoſe Turns of the Crown-wheel by its number of Notches, and this will give you half the number of Beats, in that

that one Turn of the wheel. Half the Number, I say, for the reasons in the following 6 §. For the Explication of what hath been said, we will take the example in the last §: the Crown-wheel there, has (as hath been said) 720 Turns to one Turn of the first Wheel: This Number multiplied by 15 (the Notches in the Crown-Wheel,) produceth 10800, which are half the number of Strokes of the Balance, in one Turn of the first wheel 80. The like may be done for any of the other Wheels; as the Wheel 54, or 40: but I shall not insist upon these, having said enough.

I shall give but one Example more, which will fully, and very plainly illustrate the whole matter.

4)32(8
———
5)55(11
5)45(9
5)40(8
———
17

The example is in the Margin, and 'tis of the old 16 hour Watches, wherein the Pinion of Report is 4, the Dial-wheel 32, the Great-wheel is 55, the Pinion of the second Wheel is 5, *&c.* the Number of Notches in the Crown-wheel are 17: the quotients, or Number of Turns in each, are 8, 11, 9, 8. All which being multiplied as before, make 6336: this Number multiplied by 17, produceth 107712; which last sum is half the number of Beats

in

in one Turn of the Dial-wheel. The half Number of Beats in one Turn of the Great-wheel, you will find to be 13464: For 8 times 17 is 136, which is the half Number of Beats in one Turn of the Contrate-wheel 40: and 9 times 136, is 1224, the half Beats in one Turn of the Second-wheel: and 11 times 1224, is 13464, the half Beats in one Turn of the Great-wheel 55. And 8 times this last, is 107712 before named. If you multiply this by the two Pallets, that is, double it, it is 215424, which is the Number of Beats in one Turn of the Dial-wheel, or 12 hours. If you would know how many Beats this Watch hath in an hour, 'tis but dividing the Beats in 12 hours, into 12 parts, and it gives 17952, which is called the Train of the Watch, or Beats in an hour. If you divide this into 60 parts, it gives 299 and a little more, for the Beats in a minute. And so you may go on to seconds and thirds if you please.

Thus I have delivered my Thoughts as plainly as I can, that I may be well understood; this being the very foundation of all the artificial part of Clock-work. And therefore let the young Practitioner exercise himself thoroughly in it, in more than one example.

If I have offended the more learned, quick-sighted Reader, by using many words;

words; my desire to instruct the most ignorant Artist, must plead my excuse.

Sir *J. Moor's* Math. Comp. 116. § 6. The Balance or Swing hath two strokes to every Tooth of the Crown-wheel. For each of the two Pallets hath its blow against each tooth of the Crown-wheel: wherefore a Pendulum that swings Seconds, hath its Crown-wheel only 30 teeth.

SECT. II.

The way to Calculate, or contrive the Numbers of a piece of Watch-work.

HAving in the last Section led on the Reader to a general knowledge of Calculation; I may now venture him further into the more obscure and useful parts of that Art: which I shall explain with all possible plainness, though less brevity than I could wish.

§ 1. Two Wheels and Pinions of different numbers may perform the same motion. As, a Wheel of 36 drives a Pinion of 4, all one as a Wheel of 45 drives a Pin. of 5; or as a Wheel of 90 drives a Pin. of 10. The turns of each are 9. Therefore

§ 2. In contriving a piece of work, you may make use of one Wheel and one

one Pinion or many Wheels and many Pinions, provided that the many Wheels and many Pinions have the same proportion that the one Wheel and one Pinion have. An example or two of which will make the matter plain. Suppose instead of a Wheel of 1440 Teeth (too large a Number for one Wheel) and a Pinion of 28 Leaves, you had rather make use of 3 wheels and Pinions: you may make use of 3 wheels of 36, 8, and 5, and three Pinions of 4, 7 and 1; which being multiplied together, continually make the two Sums, *viz.* 36 times 8 is 288, and 5 times that, is 1440. And 4, 7 and 1 so multiplyed, makes 28, the very Sums of the one Wheel, and one Pinion.

Or you may by § 1. make use of different Numbers, which will perform the same motion, although they reach not the same Numbers. As in the wheel 1440 and Pinion 28, there are $51\frac{3}{7}$ Turns. Now any Number of wheels and Pinions that will effect the same Number $51\frac{3}{7}$ Turns, will perform the same Motion as that one Wheel and one Pinion. Future examples will make all plain.

§ 3. In placing the Wheels and Pinions it matters not in what Order they are set; nor indeed which Pinion runs

in

in which Wheel. Only for beauty and convenience, they place them orderly according to their different Sizes and Numbers.

§ 4. If in breaking your Train into parcels (of which by and by) any of your Quotients ſhould not pleaſe you; or if you would alter any other two Numbers which are to be multiplied together, you may vary them by this Rule: Divide your two Numbers by any two other numbers which will meaſure them; and then multiply the Quotients by the alternate Diviſors, the Product of theſe two laſt Numbers found, ſhall be equal to the Product of the two Numbers firſt given. Thus if you would vary 36 times 8, divide theſe by any two numbers that will evenly meaſure them, as 36 by 4, and 8 by 1. The fourth part of 36 is 9, and 8 divided by 1 gives 8. Multiply 9 by 1. the product is 9; and 8 multiplyed by 4 produceth 32. So that for 36 times 8 you ſhall have found 32 times 9. The operation is in the Margin, that you may ſee, and apprehend it the better. Theſe Numbers are equal, *viz.* 36 times 8 is equal to 32 times 9; both producing 288. If you divide 36 by 6, and 8 by 2, and multiply as before is ſaid, you will have for

Oughtred Au'om. § 23.

9 8
36 × 8
4 1
32 × 9

36

36 times 8, 24 times 12, equal to 288 alſo.

If this Rule ſeem to the unskilful Reader hard to be underſtood, let him not be diſcouraged, becauſe he may do without it, although it may be of good uſe to him that would be a more compleat Artiſt.

§ 5. Becauſe in the following Paragraphs, I ſhall have frequent occaſion to uſe the Rule of Three, or Rule of Proportion, it will be neceſſary to ſhew the unskilful Reader how to work this noble Rule.

If you find 3 or 4 Numbers thus ſet, with 4 ſpots after the ſecond of them, 'tis the Rule of Proportion: as in this example, 2 . 4 :: 3 . 6. *i.e.* As 2 is to 4 :: So is 3 to 6.

The way to work this Rule, *viz.* by the 3 firſt numbers to find a fourth, is, to multiply the ſecond number and the third together, and divide their product by the firſt. Thus 4 times 3 is 12, which 12 divided by 2, gives 6; which is the Number ſought for, and ſtands in the fourth place

You will find the great uſe of this Rule hereafter; only take care to bear it in mind all along. But if there ſhould be occaſion for any farther Inſtructions in this *Rule of Three*, I refer the Reader to the Arithmeticians.

§ 6.

§ 6. To proceed. If in seeking for your Pinion of Report, or by any other means, you happen to have a Wheel and Pinion fall out with cross Numbers, too big to be cut in Wheels, and yet not to be altered by the former Rules, you may find out two Numbers of the same, or a near Proportion, by this following Rule, *viz.* As either of the
Id. Ib. Sect. 24. 2 numbers given, is to the other :: So is 360 to a fourth: Divide that fourth number, as also 360 by any Aliquot parts, as 4. 5. 6. 8. 9. 10. 12. 15. (each of which Numbers doth exactly measure 360) or by any one of those numbers that bringeth a quotient nearest to an integer (or whole Number.) Thus if you had these two Numbers, 147 the Wheel, and 170 the Pinion, which are too great to be cut in small Wheels, and yet can't be reduced into less, because they have no other common measure, but unity: say therefore according to the last paragraph, As 170 is to 147; or as 147 is to 170 :: So is 360 to a
See §. 4. fourth Number sought. In numbers thus, 170. 147 :: 360. 311. or 147. 170 :: 360. 416. Divide the fourth number and 360 by one of the foregoing numbers; as 311 and 360 by 6, it gives 52 and 60. In numbers 'tis thus.

6)311(52
360(60 Divide by 8 'tis thus, 8)311(39
360(45

If

If you divide 360 and 416 by 8, it will fall out exactly to be 45 and 52. 8)460(45 316(52
Wherefore for the two Numbers 147 and 170, you may take 52 and 60; or 39 and 45; or 45 and 52, or &c.

§ 7. I shall add but one Rule more before I come to the practice of what hath been laid down; which Rule will be of perpetual use, and consists of these five particulars.

1. *To find what number of Turns the Fusy will have*, thus: As the Beats of the Balance in one turn of the Great Wheel or Fusy (suppose 26928) to the Beats of the Balance in one hour (suppose 20196) :: So is the Continuance of the Watches going in hours (suppose 16) to the Number of the Turns of the Fusy 12. In numbers 'twill stand thus, 26928. 20196 :: 16. 12. By § 4. you may remember that you are to multiply 20196 by 16, the product is 323136. Divide this by 26928, and there will arise 12 in the Quotient, which must be placed in the fourth place, and is the *Number of Turns* which the *Fusy* hath.

Oughtred Sect. 18. Sir *J. Moor* Ibid. p. 109.

2. *By the Beats and Turns of the Fusy, to find how many Hours the Watch will go*, thus,

As the Beats of the Balance in one hour, are to the Beats in one Turn of the

the Fusy : : So is the Number of the Turns of the Fusy, to the Continuance of the Watch's going. In numbers thus,

20196. 26928 : : 12. 16.

3. *To find the Strokes of the Balance in one Turn of the Fusy*, say, As the Number of Turns of the Fusy, to the Continuance of the Watch's going in hours : : So are the Beats in one hour, to the Beats of one Turn of the Fusy. In numbers it is thus,

12. 16 : : 20196. 26928.

4. *To find the Beats of the Balance in an Hour*, say thus ; As the Hours of the Watches going, to the number of Turns of the Fusy : : So are the Beats in one Turn of the Fusy, to the Beats in an Hour. In numbers thus,

16. 12 : : 26928. 20196.

5. *To find what Quotient is to be laid upon the Pinion of Report*, say thus ; As the Beats in one Turn of the Great-wheel, to the Beats in an Hour : : So are the Hours of the Face of the Clock (*viz.* 12 or 24) to the Quotient of the Hour-wheel or Dial-wheel, divided by the Pinion of Report, *i. e.* the Number of Turns, which the Pinion of Report hath in one Turn of the Dial-wheel. In numbers thus,

26928. 20196 : : 12. 9.

Or rather (to avoid trouble) say thus, As the Hours of the Watch's going, are to to the Numbers of the Turns of the Fusy : : So are the Hours of the Face, to the Quotient of the Pinion of Report. In numbers thus, 16. 12 : : 12. 9. If the Hours of the Face be 24, the Quotient will be 18; thus, 16. 12 : : 24. 18.

N.B. This Rule may be made to serve to lay the Pin. of Report on any other Wheel thus; As the Beats in one T. of any wheel to the Beats in an Hour : : So are the Hours of the Face, or Dial-plate of the Watch, to the Quotient of the Dial-wheel divided by the Pinion of Report, fixed on the Spindle of the aforesaid Wheel.

§ 8. Having given a full account of all things necessary to the understanding the Art of Calculation, I shall now reduce what hath been said into practice, by shewing how to proceed, in Calculating a Piece of Watch-work.

The first thing you are to do, is to pitch upon your *Train*, or Beats of the Balance in an Hour : as, whether a swift Train, about 20000 beats (which is the usual Train of one of the old common 30 Hour Pocket-Watches) or a slower Train of about 16000 (the Train of the new Pendulum Pocket-Watches ;) or any other *Train*.

Having thus pitched upon your *Train*, you must next resolve upon the Number

ber of Turns you intend your Fuſy ſhall have, and alſo upon the number of Hours, you would have your Piece to go: As ſuppoſe 12 Turns; and to go 30 Hours, or 192 Hours (which is 8 days) or *&c.*

Theſe things being all ſoon determined; you next proceed to find out the Beats of the Balance, or Pendulum, in one Turn of the Fuſy, by the laſt § 6, part 3, *viz.* As the Turns of the Fuſy, to the Hours of the Watch's going:: So is the Train, to the number of Beats in one Turn of the Fuſy. In numbers thus, 12. 16 :: 20000. 26666. Which laſt number are the Beats in one Turn of the Fuſy, or Great-wheel; and (by Sect. I. § 5. of this Chap.) are equal to the Quotients of all the Wheels unto the Balance multiplied together. This Number therefore is to be broken into a convenient parcel of Quotients: which you are to do after this manner. Firſt, half your number of Beats, *viz.* 26666, for the reaſons in Sect. I. § 6. of this Chap. the half whereof is 13333. Next you are to pitch upon the number of your Crown-wheel, as ſuppoſe 17. Divide 13333 by 17, the Quotient will be 784 (or to ſpeak in the language of one that underſtands not Arithmetick, divide 13333 into 17 parts, and 784 will be one of them.) This 784 is the

the Number left for the Quotients (or Turns) of the rest of the Wheels and Pinions; which being too big for one or two Quotients, may be best broken into three. Chuse therefore 3 Numbers, which when multiplied all together continually will come nearest 784. As suppose you take 10, 9, and 9. Now 10 times 9 is 90; and 9 times 90 is 810, which is somewhat too much. You may therefore try again other numbers, as suppose 11, 9, and 8. These multiplied as the last, produce 792, which is as near as can be, and convenient Quotients also.

Thus you have contrived your Piece, from the Great-Wheel to the Balance. But the Numbers not falling out exactly according as you at first proposed, you must correct your Work thus. First, to find out the true number of Beats, in one Turn of the Fusy, you must multiply 792 aforesaid, (which is the true Product of all the Quotients you pitched upon,) by 17, the Notches of the Crown-wheel; the product of this is 13464, which is half the Number of true Beats in one Turn of the Fusy, by Sect. I. § 5. of this Chap. Then to find the true Number of Beats in an Hour, say by § 6. part 4. of this Sect. As the Hours of the Watch's going, *viz.* 16 : to the 12 Turns of the Fusy : : So is

13464 the half beats in one Turn of the Fusy, to 10098 the half beats in an Hour; the numbers will ſtand thus. 16. 12 :: 13464. 10098.

Then to know what Quotient is to be laid upon the Pinion of Report, ſay by § 6. part 5. of this Sect. As the Hours of the Watch's going, *viz.* 16, to the Turns of the Fuſy, *viz.* 12 :: So are the hours of the Dial-plate, *viz.* 12, to the Quotient of the Pinion of Report fixed on the Great-wheel. In numbers thus, 16. 12 :: 12. 9.

4)36(9
5)55(11
5)45(9
5)40(8
17

Having thus found out all your Quotients, 'tis eaſy to determine what numbers your Wheels ſhall have; for chuſe what numbers your Pinions ſhall have, and multiply the Pinions by their Quotients, and that produceth the number 3 for your Wheels, as you ſee in the Margin. Thus 4 is the number of your Pinion of Report, and 9 its quotient; therefore 4 times 9, which makes 36, is the number for the Dial-wheel. So the next Pinion being 5, and its quotient 11, this multiplied produces 55 for the Great-wheel. And the like of the reſt of the following numbers.

Thus, as plain as words can expreſs it, I have ſhewed how to calculate the number of a 16 hour Watch. § 8.

§ 8. This Watch may be made to go a longer time, by lessening the Train, and altering the Pinion of Report. Suppose you could conveniently slacken the Train to 16000, the half of which is 8000. Then say (by § 6. part 2. of this Sect.) As the halfed Train, or Beats in an hour, *viz.* 8000, to the Half Beats in one Turn of the Fusy, *viz.* 13464 : : So are the turns of the Fusy, *viz.* 12, to the hours of the Watch's going : in numbers thus, 8000. 13464 : : 12. 20. So that this Watch will go 20 hours. Oughtred Sect. 28.

Then for the Pinion of Report, say, by the same §, part 5, As (20 the Continuance ;) to 12 (the Turns of the Fusy) : : So are 12 (the Hours of the Face,) to 7, the quotient of the Pinion of Report. In numbers thus, 20. 12 : 12. 7.

4)28(7
———
5)55(11
5)45(9
5)40(8
———
17

The work is the same as before, as to the numbers ; only the Dial-wheel is but 28, because its quotient is altered to 7 ; as appears in the Margin, by the Scheme of the work.

§ 9. I shall give the Reader one example more, for the sake of shewing him the use of some of the foregoing Rules, not yet taken notice of in the former operations. Suppose you would give Numbers to a Watch of about 10000 Beats in an Hour, to have 12 Turns of the Fusy, to go 170 hours, and 17 Notches in the Crown-wheel.

This work is the same as in the last Example § 7. In short therefore thus, As the Turns 12: are to the Continuance 170 ; : So is the Train 10000, to 141666, which are the Beats in one Turn of the Fusy. The Numbers will stand thus, 12 : 170 : : 10000: 141666. Half this last is 70833. Divide this half into 17 parts, and 4167 will be for the Quotients. And because this Number is too big for 3 quotients, therefore chuse 4 : as suppose 10, 8, 8, and 6 $\frac{3}{5}$ (*i. e.* 6 and 3 fifths.) These multiplied together as before, and with 17, make 71808, which are Half the true Beats in one Turn of the Fusy. By this you are to find out your true Train first, saying in the former example, As 170: to 12 : : So 71808: to 5069 ; which last is the half of the true Train of your Watch. Then for the Pinion of Report, say, as 170: to 12 : : So 12 : to $\frac{144}{170}$, Which Fraction ariseth thus: If you multiply 12 by 12, it makes 144 ; and divide 144 by 170, you cannot ; but setting the 144 (the Dividend) over 170, (the Divisor) and there ariseth this Fraction $\frac{144}{170}$, which

which is a Wheel and Pinion; the lower is the Pinion of Report, and the upper is the Dial-wheel, according to Sect. 1. § 3. of this Chapter. Or (which perhaps will be more plain to the unlearned Reader) you may leave those two Numbers in their Divisional posture thus, 170) 144, which does express the Pinion and Wheel, in the way I have hitherto made use of. Sect. 1. § 3.

But to proceed. These Numbers being too big to be cut in small Wheels, may be varied, as you see a like example in § 6. of this Section, viz. say, as 144 is to 170: So is 360: to 425. Or as 170, to 144: So is 360: to 305. In numbers thus. 144:170::360:425. Or 170:144::360:305. Divide 360, and either of these two fourth and last Numbers by 4, 5, 6, 8, &c. (as is directed in the Rule last cited.) If you divide by 8, you will have for your numbers $\frac{144}{170}$ $\frac{45}{53}$ or $\frac{18}{45}$. If you divide by 15 (which will not bring it so near an Integer) you will have $\frac{24}{28}$ or $\frac{20}{24}$: which last are the numbers set down in the Margin; where the numbers of the whole movement are set down.

24)20($\frac{20}{24}$
6)60(10
6)48(8
5)40(8
5)33(6$\frac{3}{5}$
17

§ 10. Having ſaid enough, I think, concerning the Calculation of ordinary Watches, to ſhew the Hour of the Day: I ſhall next proceed to ſuch as ſhew Minutes and Seconds. The Proceſs whereof is thus; firſt, having reſolved upon your Beats in an Hour, you are next to find how many Beats there will be in a Minute, by dividing your deſigned Train into 60 Parts. And accordingly you are to find out ſuch proper Numbers for your Crown-wheel, and Quotients, as that the Minute-wheel ſhall go round once in an Hour, and the Seconds-wheel once in a Minute.

An Example will make all plain. Let us chuſe a Pendulum of 7 Inches length, which by the following Pendulum Table vibrates 142 Strokes in a Minute, and 8520 in an Hour. These Sums being Halved are 71, and 4260. Now the firſt Work to be done is to break this Half Number of Minutes 71 into good Proportions; which will fall as near as may be into one Quotient, and the Crown-wheel. Firſt, for the Crown-wheel; let it have 15 Notches. Divide 71 aforeſaid by this 15, the Quotient will be nearly 5. And ſo this firſt Work is done; for a Crown-wheel of 15, and a Wheel and Pinion,

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Sect. 1. § 6.

Pinion, whose Quotient is 5 (as in the Margin) will go round in a Minute, to carry a Hand to shew *Seconds*, if you please.

8)40(5	
15	

Next for a Hand to go round in an Hour to shew Minutes. Now because there are 60 Minutes in an Hour, 'tis but breaking 60 into two good Quotients (which may be 10 and 6, or 8 and 7 ½, or &c.) and the Work is done.

8)64(8	
8)60(7½	
8)40(5	
15	

Thus your Number 4260 is broken, as near as can be, into proper Numbers.

But because it does not fall out exactly into the above-mentioned Numbers, you must correct (as you were directed before) and find out the true Number of Beats in an Hour, by multiplying 15 by 5, which makes 75; and this by 60 makes 4500: which is the half of the true Train. Then to find out the Beats in one Turn of the Fusy, operate as before, *viz.* As the Number of Turns (16,) to the Continuance 192:: So is 4500 to 54000, which are half the Beats in one Turn of the Fusy. In Numbers thus, 16. 192:: 4500. 54000. This 54000, must be divided by 4500, which are the true Numbers already pitched upon, or Beats in

§ 6. Par. 3. § 7.

an Hour. The Quotient of this Division is 12, which being not too big for one single Quotient, needs not be divided into more. The Work will stand, as you see in the Margin.

9) 108(12
8) 64(8
8) 60($7\frac{1}{2}$
8) 40(5

15

As to the Hour-hand, the Great-wheel (which performs only one Revolution in 12 Turns of the Minute-wheel) will shew the Hour. Or rather you may order it to be done by the Minute-wheel, as shall be shewed hereafter.

§ 11. I shall add but one Example more, and so conclude this Section; and that is, to calculate the Numbers of a Piece whose Pendulum swings Seconds, to shew the Hour, Minutes, and Seconds, and to go 8 Days; which is the usual Performance of those Movements called *royal Pendulums* at this Day. First, cast up the Number of Seconds in 12 Hours (which are the Beats in one Turn of the Great-wheel.) These are 12 times 60 Minutes, and 60 times that, gives 43200, which are the Seconds in 12 Hours. Half this Number (for the Reasons before) is 21600. The Swing-wheel must needs be 30, to swing 60 Seconds in one of its Revolutions. Divide 21600 by it, and 720 is the Quotient, or Number left to be broken into Quotients.

Sir *J. Moor* ib. p. 116.

Quotients. Of these Quotients, the first must needs be 12 for the Great-wheel, which moves round once in 12 Hours. Divide 720 by 12, the Quotient is 60; which may be conveniently broken into two Quotients, as 10 and 6, or 5 and 12, or 8 and 7 $\frac{1}{2}$, which last is most convenient.

And if you take all the Pinions 8, the Work will stand as in the Margin.

8)96(12
8)64(8
8)60(7$\frac{1}{2}$
———
30

According to this Computation, the Great-wheel will go about once in 12 Hours, to shew the Hour, if you please: the Second-wheel once in an Hour, to shew the Minutes; and the Swing-wheel once in a Minute, to shew the Seconds.

Thus I have endeavoured with all possible Plainness, to unravel this most mysterious, as well as useful Part of Watch-work: In which, if I have offended the more learned Reader, by unartificial Terms, or Multitude of Words, I desire the Fault may be laid upon my earnest Intent to condescend to the meanest Capacity.

SECT. III.

To Calculate the Striking-part of a Clock.

HAving in the preceeding Section ſhew'd, as clearly as I could, the Way of Calculating Numbers for the *Watch-part*, I ſhall in this do the ſame for the *Clock*, or *Striking-part*. Which having never been treated before, I ſhall reduce to *as plain* Rules and Method as I can.

§ 1. Altho' this Part conſiſts of many Wheels and Pinions, yet Reſpect needs to be had only to the *Count-wheel*, *Striking-wheel*, and *Detent-wheel* which move round in this Proportion; the *Count-wheel* moveth round commonly once in 12, or 24 Hours. The *Detent-wheel* moves round every Stroke the Clock ſtriketh, ſometimes but once in two Strokes. From whence it follows,

1. That as many Pins as are in the Pin-wheel, ſo many Turns hath the Detent-wheel, in one Turn of the Pin-wheel. Or (which is the ſame) the Pins of the Pin-wheel are the Quotient of that Wheel, divided by the Pinion of the Detent-wheel. But if the Detent-wheel moveth but once round in two Strokes of the Clock, then the ſaid Quotient is but half the Number of Pins.

2. As many Turns of the Pin-wheel as are

are required to perform the Strokes of 12 Hours (which are 78) So many Turns must the Pinion of Report have, to turn round the Count-wheel once. Or thus: Divide 78 by the Number of Striking-pins, and the Quotient thereof shall be the Quotient for the Pinion of Report, and the Count-wheel. All this is, in Case the Pinion of Report be fixed to the Arbor of the Pin-wheel, as is very commonly done.

All this I take to be very plain: or if it be not, the Example in the Margin will clear all Difficulties. Here the Locking-wheel is 48, the Pinion of Report is 8, the Pin-wheel is 78, the Striking-pins are 13. And so of the rest. I need only to remark here, that 78 being divided by the 13 Pins, gives 6; which is the Quotient of the Pinion of Report; as was before hinted.

8)48(6
———
6)78(13 pins
6)60(10
6)48(8

As for the *Warning-wheel* and *Flying Pinion*, it matters little what Numbers they have, their Use being only to bridle the Rapidity of the Motion of the other Wheels.

Besides the last Observation, there are other Ways to find out the Pinion of Report, which will fall under the next §.

§ 2.

§ 2. These following Rules will be of great Use in this part of Calculation, *viz.*

Rule 1. *To find how many Strokes the Clock striketh in one Turn of the Fusy or Barrel.*

As the Number of Turns of the Great-wheel, or Fusy,

. To the Days of the Clock's Continuance;

: : So is the Number of Strokes in 24 Hours, *viz.* 156,

. To the Strokes in one Turn of the Fusy, or Great-wheel.

Rule 2. *To find how many Days the Clock will go.*

As the Number of Strokes in 24 Hours, which are 156,

. To the Strokes in one Turn of the Fusy or Great-wheel,

: : So are the Turns of the Fusy, or Great-wheel,

. To the Days of the Clock's Continuance, or going.

Rule 5. *To find the Number of Turns of the Fusy or Barrel.*

As the Strokes in one Turn of the Fusy,

. To the Strokes of 24 Hours, *viz.* 156,

: : So is the Clock's Continuance,

. To the Number of Turns of the Fusy, or Great-wheel.

These two last Rules are of no great Use

Use (as the first is) but may serve to correct your Work, if need be, when in breaking your Strokes into Quotients (of which presently) you cannot come near the true Number, but a good many Strokes are left remaining. In this case, by Rule 2. you may find whether the Continuance of your Clock be to your Mind, And by this Rule 3, you may enlarge or diminish the Number of Turns for this Purpose. The Praxis hereof will follow by and by.

The two following Rules are to find fit Numbers for the Pinion of Report, and the Locking-wheel, besides what is said before § 1. Inference 2.

Rule 4. *To fix the Pin. of Report on the Spindle of the Great-wheel.*

As the Number of Strokes in the Clock's Continuance, or in all its Turns of the Fusy,

. To the Turns of the Fusy,

: : So are the Strokes in 12 Hours, which are 78,

. To the Quotient of the Pinion of Report, fixed upon the Arbour of the Great-wheel.

But if you would fix it to any other Wheel, you may do it thus, as is before hinted, *viz.* § 1. *Inf.* 2.

Rule 5. First find out the Number of Strokes in one Turn of the Wheel you intend to fix your Pinion of Report upon

upon (which I ſhall ſhew you how to do in the following §.) Divide 78 by this Number, and the Number ariſing in the Quotient, is the Quotient of the Pinion of Report.

Or thus. Take the Number of Strokes in one Turn of the Wheel, for the Number of the Pinion of Report, and 78 for the Count (or Locking) wheel, and vary them to leſſer Numbers, by Sect. 2. § 5. of this Chapter.

The foregoing Rules, are of greateſt Uſe, in Clocks of a larger Continuance; altho' where they can be applyed, they will indifferently ſerve all. But the Rule following (which will ſerve larger Clocks too) I add chiefly for the Uſe of leſſer Pieces, whoſe Continuance is accounted by Hours.

Rule 6. This Rule is to find the Strokes in the Clock's Continuance, *viz*. As 12, is to 78 : : So are the Hours of the Clock's Continuance, to the Number of Strokes in that Time.

This Rule (I ſaid) may be made Uſe of for the largeſt Clock; but then you muſt be at the Trouble of reducing the Days into Hours. Whereas the ſhorteſt Way is to multiply the Strokes in one Turn of the Great-wheel, by the Number of Turns of the Fuſy. Thus in an 8 Day-piece, the Strokes in one Turn are 78. Theſe multiplied by 16, (the

(the Turns) produce 1248; which are the Strokes in the Clock's Continuance. If you work by the foregoing Rule, the Hours of 8 Days are 192. Then say, 12 78 : : 192. 1248.

§ 3. In this Paragraph, I shall shew the Use of the preceeding Rules, and by Example make all plain that might seem obscure in them.

I begin with small Pieces: of which but briefly. And first, having pitched upon the Number of Turns, and the Continuance of your Clock, you must find, by the last Rule, how many Strokes are in its Continuance. Then (if you make the Great-wheel the Pin-wheel) divide these Strokes by the Number of Turns, and you have the Number of Striking-pins. Or divide by the Number of Pins, and you have the Number of Turns.

Thus a Clock of 30 Hours, with 15 Turns of the Great-wheel, hath 195 Strokes. For by the last Rule, 12. 78 : : 30. 195. Divide 195 by 15, it gives 13 for the Striking-pins.

Or if you chuse 13 for your Number of Pins, and divide 195 by it, it gives 15, for the Number of Turns, as you see in the Margin.

15)195(13
13)195(15

As for the Pin. of Report, and the Rest of the Wheels, enough is said in the § 1.

But

But suppose you would calculate the Numbers of a Clock of much longer Continuance, which would necessitate you to make your Pin-wheel further distant from the Great-wheel, you are to proceed thus: Having resolved upon your Turns, you must find out the Number of Strokes in one Turn of the Great-wheel, or Fusy, by § 2. Rule 11 Thus in an 8 Day-piece, of 16 Turns, 16. 8 : : 156. 78. So in a Piece of 32 Days, and 16 Turns, 16. 32 : : 156. 312. (See the Operation of these Numbers in the Rule referred unto.) These Strokes so found out, are the Number which is to be broken into a convenient Parcel of Quotients, thus;

First resolve upon your Number of Striking-pins: divide the last named Number by it: the Quotient arising hence, is to be one, or more Quotients, for the Wheels and Pinions. As in the last Examples, divide 78 (the Number of Strokes in one Turn of the Fusy) by 8 (the usual Number of Pins in an 8 Day-piece) and the Quotient is $9\frac{3}{4}$; which is a Quotient little enough. So in the Month-piece: if you take your Pins 8, divide 312 (the Number of Strokes in one Turn of the Fusy) by it, the Quotient is 39. Which being too big for one, must be broken into two Quotients,

10)65(6½
8)48(6
6)48(8 pins

Quotients, for Wheels and Pinions, or as near as can be: which may be 7 and 5, or 6 and 6½. The latter is exactly 39, and may therefore stand; as you see in the Margin.

The Quotients being thus determined, and accordingly the Wheels and Pinions, as you see; the next Work is to find a Quotient for the Pinion of Report, to carry round the Count (or Locking) Wheel once in 12 Hours, or as you please. If you fix your Pinion of Report on the Great-wheel Arbour, you must operate by Rule 4, of the last Paragraph, as in the last Example of the Month-piece, by Rule 6 before, the Strokes in the Continuance of the Clocks going are 4992. Then by Rule 4. say, 4992. 16 : : 78 $\frac{4992}{1248}$; or thus, for a Pinion and Wheel 4992 (1248. The first of which two Numbers is the Pinion, the next is the Wheel. Which being too large, may be varied to $\frac{36}{9}$ or 36)9; or to $\frac{24}{6}$ or 24)6, by Sect. 2. § 6. before.

These Numbers being not the usual Numbers of a Month-piece, but only made use of by me, as better illustrating the foregoing Rules; I shall therefore, for the fuller Explication of what has been said, briefly touch upon the

Calculation

Calculation of the more usual Numbers. They commonly increase the Number of Striking-pins, and so make the Second-wheel the Striking-wheel. Suppose you take 24 Pins; divide 312 (the Number of Strokes in one Turn of the Fusy) by it, and the Quotient is 13.

8)104(13
6)72(12.24pins

Which is little enough for one Quotient; and may therefore stand as you see is done in the Margin: where the Quotient of the first Wheel is 13. In the second Wheel of 72 Teeth are the 24 Pins, although its Quotient is but 12, because the Hoop-wheel is double, and goes round but once in two Strokes of the Pin-wheel.

The Pinion of Report here, is the same with the last, if fixed upon the Arbour of the Great-wheel. But if you fix it on the Arbour of the Second, or Pin-wheel, its Quotient then is found by § 1. Infer. 2. or by § 2. Rule 5. before: *viz.* Divide 78 by 24, and the Number arising in the Quotient, is the Quotient of the Pinion of Report, which is $\frac{1}{4}$. The Pinion of Report then being 12. the Count-wheel will be 39, as in the Margin.

12)39(3$\frac{1}{4}$

To perfect the Reader in this Part of Calculation, I will finish this Section with

with the Calculation of a Year-piece of Clock-work. The Proceſs whereof is the ſame with the laſt, and therefore I may be more brief with this, except where I have not touched upon the foregoing Rules.

We will chuſe a Piece to go 395 Days with 16 Turns, and 26 Striking-pins. By § 2. Rule 1. there are 3851 Strokes in one Turn of the Great-wheel. For 16. 395 :: 156. 3851. This laſt Number divided by the 26 Pins, leaves 148 in the Quotient, to be broken into two or more Quotients, for Wheels and Pinions. Theſe Quotients may be 12 and 12; which multiplied, makes 144, which is as near as can well be to 148, without Fractions. The Work thus far contrived, will ſtand as you ſee in the Margin. Sect. 2. § 4.

10)120(12
8) 96(12
78 | 26 pins

Before you go any further, you may correct your Work, and ſee how near your Numbers come to what you propoſed at firſt, becauſe they did not fall out exact, and firſt, for the true Continuance of your Clock: *If you multiply* 12, 12, *and* 26 (i. e. *the Quotients and the Striking-pins*) *you have the true Number of Strokes, in one Turn of the Great-wheel*: Which, in this Example, make 3744. For 12 Times 12 is 144; and 26 Times

that,

that, is 3744. (This Direction I would have noted, and remembred, as a Rule useful at any Time to discover the Nature of any Piece of Clock-work.) Having thus the true Number of Strokes desired, by § 2. Rule 2. you may find the true Continuance to be only 384 Days. For 156 : 3744 : : 16 : 384. If this Continuance doth not please you, you may come nearer to your first proposed Number of 395 Days, by a small Increase of the Number of Turns, according to § 2. Rule 3. *viz.* by making your Turns almost 16½. For 3744. 156 : : 395. 16½. almost.

Thus much may serve for the Exercise of the young Practitioner; but he may, if he pleases, by the Help of Fractions, come up exactly to his Quotient 148, by taking 10 and 12⅓ for his two Quotients: In which Case, the Work will be as it stands in the Margin.

10)120(12
6) 74(12⅓
780 | 26 Pins

Lastly, For the Pinion of Report, if you fix it upon the Great-wheel, it will require an excessive Number: If you fix it upon the Pin-wheel (which is usual) then by § 2. Rule 5. the Quotient is 3; and the Pinion of Report being 13, the Count-wheel will be 39; as you see in the Margin.

13)39(3

But

But for the better exercising the Reader, let us fix it upon the Spindle of the Second-wheel 96. Its Quotient is 12; which multiplied by 26 (the Pins) produceth 312; which are the Strokes in one Turn of that Second-wheel. Then by § 2. Rule 5. divide 78 by 312. *i. e.* Set them as a Wheel and Pinion thus, 312)78, and vary them to lesser Numbers by Sect. 2. § 5.) *viz.* 36)9, or to 24)6 or the like, and the Work is done.

I think it needless to say any Thing of Pocket-Clocks, whose Calculation is the very same, with what goes before.

That the unlearned Reader may not think any Thing going before difficult, I need only to advise him, to look over the working of the Rule of Proportion, in Sect. 2. § 4. For I think all will be plain, if that be well understood.

SECT. IV.

Of Quarters and Chimes.

THIS being a Part of Clock-work, which was never before treated of, the Reader will expect I should say something about it; but because there is little, but what is purely mechanical in it, I shall say the less, and leave the Reader to his own Invention. § 1.

§ 1. The *Quarters* are generally a diſtinct Part from the Clock-part, which ſtriketh the Hour.

The *Striking-Wheel* may be the Firſt, Second, or *&c.* Wheel, according to your Clock's Continuance. Unto which Wheel you may fix the Pinion of Report.

The *Locking-Wheel* muſt be divided (as other Locking-Wheels) into 4, 8, or more unequal Parts, ſo as to ſtrike the Quarter, and lock at the firſt Notch; the Half-hour, and lock at the ſecond Notch, *&c.* And in doing this you may make it to chime the Quarters, or ſtrike them upon two Bells, or more.

'Tis uſual for the Pin-wheel, or the Locking-wheel, to unlock the Hour-part in theſe Clocks; which is eaſily done by ſome Jogg or Latch, at the End of the laſt Quarter, to lift up the Detents of the Hour-part.

If you would have your Clock ſtrike the Hour, at the Half-hour, as well as whole Hour, you muſt make the Locking-wheel of the Hour-part double: *i. e.* it muſt have two Notches of a Sort, to ſtrike 1, 2, 3, 4, *&c.* twice a piece.

§ 2. As for *Chimes*, I need ſay nothing of the Lifting-pieces and Detents, to lock and unlock; nor of the Wheels to bridle the Motion of the Barrel, that being

being purely mechanical. Only you are to obſerve, that the Barrel muſt be as long in turning round, as the Meaſure or Length of the Tune, or as you are in ſinging the Tune it is to play. As for the *Chime-Barrel*, it may be made up of certain Barrs, that run athwart it, with a convenient Number of Holes punched in them, to put the Pins in and out that are to draw each Hammer. By this means you may change the Tune, without changing the Barrel. This was the Way of the *Royal-Exchange* old Clock in *London*, and of others. In this caſe, either the Bars muſt be at the Diſtance of the quicker Time, as a Quaver, *&c*; which could not well be admitted of; or elſe at a wider Diſtance, as ſuppoſe of a Semibrief: And in this caſe, the Pins, or Nuts which draw up the Hammers, are ſome only of them to ſtand upright in their Holes, and others to bend off more or leſs, as ſuppoſe a Quarter, Half, or $\frac{3}{4}$ of that Diſtance between each Bar, according as the Notes are a $\frac{1}{4}$, $\frac{1}{2}$, or $\frac{3}{4}$ of a Semibrief, or the Diſtance between each Bar. Concerning the Reaſon of which, more by and by.

But the moſt uſual Way is, to have the Pins that draw the Hammers, fixed on the Barrel. For the placing of which Pins, you may make uſe of the Muſical

Musical Notes, or proceed by the Way of Changes on Bells, *viz.* 1, 2, 3, 4, *&c.* The first being far the better Way, I shall speak of that chiefly, especially because the Latter will fall in to be explained with it.

And first, you are to observe what is the Compass of your Tune, or how many Notes or Bells there are from the highest to the lowest; and accordingly you must divide your Barrel from End to End. Thus in the Examples following, each of those Tunes are 8 Notes in Compass; and accordingly the Barrel is divided into 8 Parts. These Divisions are struck round the Barrel, opposite to which are the Hammer-tails.

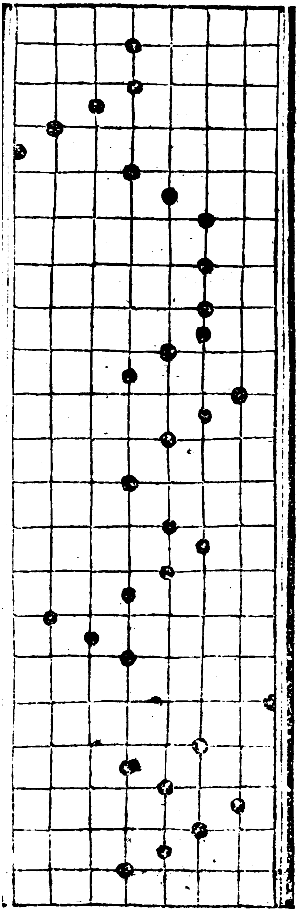
I speak here, as if there was only one Hammer to each Bell, that the Reader may more clearly apprehend what I am explaining. But when two Notes of the same Sound come together in a Tune, there must be two Hammers to that Bell, to strike it. So that if in all the Tunes you intend to chime, of 8 Notes Compass, there should happen to be such double Notes on every Bell, instead of 8, you must have 16 Hammers; and accordingly you must divide your Barrel, and strike 16 Strokes round it opposite to each Hammer-tail. Thus much for dividing your Barrel from End to End.

In

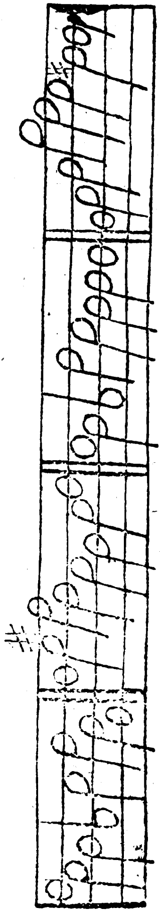
In the next place, you are to divide it (round about) into as many divisions, as there are musical Barrs, Semibriefs, Minums, *&c.* in your Tune. Thus the 100th Psalm-tune hath 20 Semibriefs; the Song-tune following, hath 24 Barrs of triple time: and accordingly their Barrels are divided. Each division therefore of the 100th Psalm Barrel is a Semibrief, and of the Song-tune 'tis three Crotchets. And therefore the intermediate Spaces serve for the shorter Notes: as, one third of a division, is a Crotchet, in the Song-tune. One half a division, is a Minum; and one quarter, a Crotchet, in the Psalm-tune. Thus the first note in the 100th Psalm, is a Semibrief, and accordingly on the Barrel, 'tis a whole division from 5 to 5. The second is a Minum, and therefore 6 is but a half a division from 5; and so of the rest. And so also for the Song-tune, which is shorter time: the two first Notes being Quavers, are distant from one another, and from the third Pin, but half a third part of one of the divisions, But the two next Pins (of the bell 3, 3.) being Crotchets, are distant so many third parts of a division. And the next Pin (of the bell 1) being a Minum, is distant from the following Pin (4) two thirds of a division.

A Table of Chimes to the 100 Psalm.

8 7 6 5 4 3 2 1



8 765 4321



The Musical Notes of Psalm 100.

The Musical Notes of

 The

From what hath been ſaid, you may conceive the Surface of a Chime-barrel to be repreſented in theſe Tables, as ſtretcheth out at length: or (to ſpeak plainer) that if you wrap either of theſe Tables round a Barrel, the Dots in the Table, will ſhew the Places of the Pins to be ſet on the Barrel.

You may obſerve in the Tables, that from the End of each Table to the Beginning, is the Diſtance of two, or near two Diviſions: which is for a Pauſe, between the End of the Tune, and its beginning to Chime again.

I need not ſay, that the Dots running about the Tables, are the Places of the Pins that are to draw the Hammers, and ſo play the Tune.

If you would have your Chimes compleat indeed, you ought to have a ſet of Bells, to the Gamut-notes; ſo as that each Bell having the true Sound of *Sol*, *La*, *Mi*, *Fa*, you may play any Tune, with its Flats and Sharps. Nay, you may by theſe means, play both the Baſs and Treble, with one Barrel.

If any Thing going before appears Gibberiſh, I can't help it, unleſs I ſhould here teach the skill of Muſick too.

As to ſetting a Tune upon the Chime-barrel from the Number of Bells, *viz.* 1, 2, 3, 4, I ſhall here give you a Specimen thereof.

The Tune called, Such command o'r my Fate, in Numbers.

775, 3; 3, 1, 4, 5, 6, 4, 4, 2.
4, 3, 2, 3, 4, 6, 3, 5, 7, 7, 7. ||
5, 6, 8, 8, 4, 4, 4 ; 3, 5, 4.
6, 5, 7, 5, 3 ; 41, 3, 5, 5, 5.
3, 3, 1, 3, 5. 554, 2, 4, 6.
4, 3 ; 23, 3 ; 53, 5, 7, 7, 7.

Note, In these Numbers, a Comma [,] signifies the Note before it, to be a Crotchet. A prick'd Comma, or Semi-colon [;] denoteth a prick'd Crotchet. And a Period [.] is a Minum. Where no Punctation is, those Notes are Quavers.

I shall only add further, that by setting the Names of your Bells at the Head of any Tune (as is done in the Tables before) you may easily transfer that Tune, to your Chime-barrel, without any great skill in Musick. But observe, that each Line in the Musick is three Notes distant ; *i. e.* there is a Note between each Line, as well as upon it : as is manifest by inspecting the Tables.

SECT.

SECT. 5.

To Calculate any of the Celestial Motions.

The Motions I here chiefly intend, are the Day of the Month, and Year, the Moon's Age, the Tides, the Motions of the Planets; and if you please, of their Secondaries or Moons, and of the Platonick Year, or Slow Motion of the Fixed Stars, *&c.*

§ 1. For the effecting these Motions in Watch-work, you may make them to depend upon the Work already in the Movement; or else measure them by the Beats of a Balance or Pendulum.

If the latter Way, you must however contrive a Piece (as before in Watch-work) to go a certain Time, with a certain Number of Turns.

But then to specify, or determine the Motion intended, you must proceed one of these two Ways: either,

1. Find how many Beats are in the Revolution. Divide these Beats by the Beats in one Turn of the Wheel, or Pinion, which you intend shall drive the intended Revolution: and the Quotient shall be the Number to perform the same. Which, if too big for one, may be broken into more Quotients. Thus, if you would re-

present the Synodical Revolution of the Moon, (which is 29 Days, 12 ¼ Hours) with a Pendulum that swings Seconds, the Movement to go 8 Days, with 16 Turns of the Fusy, and the Great-wheel to drive the Revolution, Divide 2551500 (the Beats in 29 Days 12 ¼ Hours) by 43200 (the Beats in one Turn of the Great-wheel) and you have 59 in the Quotient: which being too big for one, may be put into two Quotients. Or,

2. You may proceed as is directed before, in the Section of calculating Watch-work, *viz.* Chuse your Train, Turns of the Fusy, Continuance, &c. And then instead of finding a Quotient for the Pinion of Report, find a Number (which is all one as a Pin. of Report) to specificate your Revolution, by this following Rule.

Chap. ii. Sect. 2. § 7.

Rule. As the Beats in one Turn of the Great Wheel, or any other Wheel which you would have to drive the Revolution work : is to the Train : : So are the Hours of the Revolution you would perform : to the Quotient of that Revolution.

Thus to perform the Period of *Saturn* (which according to some, is 29 Years 183 Days) with a 16 Hour Watch, of 26928 Beats in one Turn of the Fusy, and 20196, the Train: the Quotient of the

Revolution

Revolution will be 193824. For as 26928, To 20196 : : So 258432 (the Hours in 29 y. and 183 d.) To 193824. Note here, that the Great-wheel Arbor-work is to drive the Revolution-work.

But if you would have the Revolution to be driven by the Dial-wheel, and the Work already in the Movement (which in Great Revolutions, is for the most Part, as nice as the last Way, and in which I intend to treat of the particular Motions) in this Case, I say, you must first know the *Days* of the Revolution. And because the Dial-Wheel commonly goeth round twice in a Day, therefore double the Number of the days in the Revolution, and you have the Number of Turns of the Dial-Wheel in that Time. This Number of Turns is what you are to break into a convenient Number of Quotients, for the Wheels and Pinions ; as shall be shewed in the following Examples.

§ 2. A Motion to shew the Day of the Month.

The Days in the largest Month are 31. These doubled are 62, which are the Turns of the Dial-Wheel, which may be broken into these two Quotients 15 ½ and 4 ; which multiplied together make 62. Therefore chusing your Wheels and Pinions, as hath been directed in the former Sections,

Oughtred. § 32.

your Work is done. The Wheels and Pinions may be, as you see done in the Margin. Or if a larger Pinion than one of 5 be Necessary, by Reason it is concentrick to a Wheel, you may take 10 for the Pinion, and 40 for the Wheel, as in the Margin.

4)62(15½
5)20(4

4)62(15½
10)40(4

The Work will lye thus in the Movement, *viz.* Fix your Pinion 10, concentrical to the Dial-wheel (or to turn Round with it upon the same Spindle.) This Pinion 10 drives the Wheel 40: which Wheel has the Pinion 4 in its Center, which carrieth about a Ring of 62 Teeth, divided on the Upperside into 31 Days.

Or, you may, without the Trouble of many Wheels, effect this Motion, *viz.* by a Ring divided into 30 or 31 Days, and as many Fangs or Teeth, like a Crown-wheel Teeth, which are caught and pushed forward once in 24 Hours by a Pin in a Wheel, that goeth round in that Time. This is the usual Way in the Royal Pendulums, and many other Watches; and therefore being common, I shall say no more of it.

Id Ib. § 33.

§ 3. *A Motion to shew the Age of the Moon.*

The Moon finisheth her Course, so as to overtake the Sun in 29 Days, and a little a little above an Half. This 29 $\frac{1}{2}$ Days (not regarding the small excess) makes 59 twelve Hours, or turns of the Dial-wheel, which is to be broken into convenient Quotients: which may be 5,9 and 10, as in the first Example; or 14 $\frac{3}{4}$ and 4, as in the second Example in the Margin.

10)59(5,9   4)59(14$\frac{3}{4}$
4)40(10   10)40(4

So that if you fix a Pinion of 10 concentrical with your Dial-wheel, to drive a Wheel of 40 (according to the last Example) which Wheel 40 drives a Pinion 4, it will carry about a Ring, or Wheel of 59 Teeth, once in 29$\frac{1}{2}$ Days. Which Ring may be divided into 29 $\frac{1}{2}$ Parts; or carry an Index to point to a Circle so divided.

§ 4. *A Motion to shew the Day of the Year, the Sun's place in the Ecliptick, Sun's Rising or Setting, or any other annual Motion of 365 Days.* Id. Ib.

The double of 365 is 730, the Turns of the Dial-wheel in an Year: which may be broken into these Quotients, *viz.* 18$\frac{1}{4}$ and 10, and 4, according to the first Example; or 18$\frac{1}{4}$, 8, and 5, according to the Second.

4)73(18$\frac{1}{4}$ 4)73(18$\frac{1}{4}$
4)40(10   4)32(8
5)20(4   4)20(5

So that a Pinion of 5 is to lead a Wheel of 20;

which again by a Pinion of 4, leadeth a Wh. of 40; which 3dly by a Pin. of 4, carrieth about a Wh. or Ring of 73, divided into the 12 Months, and their Days; or into the 12 Signs, and their Degrees; or into the Sun's Rising and Setting, &c. For the setting on of which last, you have a Table in Mr. Autom. § 35. *Oughtred's Opuscula*, or it may be done from any well calculated Almanack.

Id. Ib. § 37. § 5. *To shew the Tides at any Port.*

This is done without any other Trouble, than the Moon's Ring (before mentioned § 3.) to move round by a fixed Circle, divided into twice 12 Hours, and numbered the contrary way to the Age of the Moon.

To set this to go right, you must find out at what Point of the Compass the Moon makes full Sea, at the place you would have your Watch serve to Convert that Point into Hours, allowing for every Point North or S. lost, 45 min. of an Hour. Thus at *London-bridge* 'tis vulgarly thought to be high Tide, the Moon at N.E. and S. West, which are 4 Points from the N. and S. Or you may do thus: by Tide Tables, learn how many Hours from the Moon's Southing, 'tis High-water. Or thus; find at what Hour it is High-water, at the Full, or Change of the Moon: as at *London-bridge*, the full Tide is commonly reckoned to be 3

Hours

Hours from the Moon's Southing; or at 3 of Clock at the Full and Change. The Day of Conjunction, or New-Moon, with a little ſtud to point, being ſet to the Hour ſo found, will afterwards point to the Hour of full Tide.

This is the uſual way; but it being always in Motion, as the Tides are not, a better Way may be found out, *viz.* by cauſing a Wheel, or Ring to be moved forward, only twice a Day, and to keep Time (as near as can be) with Mr. *Flamſteed's* moſt correct Tables. But this I ſhall commit to the Readers contrivance, it being eaſie; and more of Curioſity than Uſe in it.

§ 6. *To Calculate Numbers, to ſhew the Motion of the Planets, the ſlow Motion of the fixed Stars,* &c.

Having ſaid enough before that may be applied here, and given Numbers in *Chap.* 10. which may be ſufficient to exerciſe, and inſtruct the Reader in this Matter, I ſhall not therefore trouble him or ſwell my Book with ſo many Words, as would be required to treat of theſe Motions diſtinctly, and compleatly.

Only thus much in general. Knowing the Years of any of theſe Revolutions, you may break this Number into Quotients; if you will make the Revolution to depend upon the Years Moti-

on;

on; which is already in the Movement, and described § 4. before. Or if you would have it depend upon the Dial-wheel, or upon the Beats of a Pendulum, enough is said before to direct in this Matter.

In all these slow Motions, you may somewhat shorten your Labour, by endless Screws to serve for Pinions, which are but as a Pinion of one Tooth.

Mat. Com. p. 117. Sir *Jonas Moor's* Account of his large Sphere going by Clock-work, will illustrate this Paragraph. In this Sphere, is a Motion of 17100 Years, for the Sun's *Apogeum*, performed by 6 Wheels, thus, as Sir *Jonas* relates it; 'For the 'Great-wheel fixed is 96, a Spindle-'wheel of 12 Bars turns round it 8 'Times in 24 Hours, that is, in 3 Hours; 'after these, there are four Wheels, 20, '73, 24, and 75, wrought by endless 'Screws that are in value but one; 'therefore 3, 10, 73, 24, and 75 mul-'tiplied together continually, pro-'duceth 7884000 Hours, which divid-'ed by 24 gives 328500 Days, equal 'to 900 Years. Now on the last Wheel '75 is a Pinion of 6, turning a great 'Wheel, that carrieth the *Apogeum* 'Number 114: and 114 divided by 6, 'gives 19 the Quotient: and 900 Times '19 is 17100 Years.

V. Sect. 1. § 4, 5.

Thus I have, with all the perspicu-ity

ity I could, led my Reader through the whole Art of Calculation, so much of it at least, that I hope he will be Master of it all; not only of those Motions, which I have particularly treated about, but of any other not mentioned: Such as the Revolution of the Dragon's Head and Tail, whereby the Eclipses of the Sun and Moon are found, the Revolution of the several Orbs, according to the *Ptolemaick* System, or of the Celestial Bodies themselves, according to better Systems, with many other such curious Performances, which have made the Sphere of *Archimedes* of old Famous: and since him, that of *William* of *Zeland*, and another of *Janellus Turrianus* of *Cremona*, mentioned by *Cardan*, and more lately those elaborate and curious Pieces of Mr. *Watson*, Mr. *Tompion*, and another very lately of Mr. *Rowley*; which goes by the Name of the *Orrery*. *De Sub.* ii. l. 17.

CHAP. III.

To alter Clock-work, or convert one Movement into another.

THis Chapter I design for the Use of such, as would convert old Balance Clocks into Pendulums, or would make any old Work serve for the

the Tryal of new Motions or would apply it to any other such like Use.

§ 1. To do this, you may draw a Scheme of your old Work: And so you will see what Quotients you have, and what you will want. To do all which, there are sufficient Instructions in the preceding Chapter. A few Instances will make all plain.

§ 2. Let us chuse, for Instance, an old Balance Watch to be turned into a Pendulum of 6 Inches. The old Work is, the Great-wheel 56, the Pinion 7; the next Wheel 54, the Pinion 6; the Crown-wheel 19, *&c.* The Scheme of this Work is in the Margin. The Quotients and Crown-wheel and 2 Pallets multiplied together continually; produce 2736, which are the Strokes of the Balance, in one Turn of the Great wheel, by Sect. I. § 4, 5 of the last Chapter. And by the Quotient of the Dial-wheel, (which is 12) it appears, that the Great-wheel goeth round once in an Hour. Or you may find the Beats in an Hour, by § 5, last cited. Having thus found the Beats in an Hour, of the Old-work, you must next find the Beats in an Hour of a 6 Inches Pendulum; which you may do by the Table in Chap. 5. § 4. following;

4)48(12
———
7)56(8
6)54)9
———
19

ing; according to which the Number is, 9204. Divide this by 2736, and you have the Quotient,

2736)9204(3 $\frac{2}{3}$

which is to be added to the Scheme of the old Work. This Quotient is 3 and near $\frac{2}{3}$ as you see in the Margin. But to avoid the trouble of Fractions, let us take it 3 $\frac{1}{2}$.

The Work thus altered, will stand as you see in the Margin, *viz.* a Pinion 6, and a Contrate-wheel 21, must be added.

4)48(12
———
7)56(8
6)54(9
6)21(3 $\frac{1}{2}$
—
19

According to this Way, the old Work will stand as before, only the Crown-wheel must be inverted.

§ 3. But because the Crown-wheel is too big for the Contrate-wheel (which is unseemly) therefore it will be best to make both the Contrate and Crown-wheels new; and increase the Number of the Contrate-wheel, but diminish that of the Crown-wheel. To do which, pitch upon some convenient Number for the Crown-wheel. Multiply all the Quotients, and this new Crown-wheel Number, as before; and divide 9204 by it. As suppose you pitch upon 11 for the Crown-wheel: If you multiply 8, 9 and 11, the product is 792; which multiplied by the 2 Pallets, makes

V. Sect. 1. § 6.

makes 1584, which are the Beats in one Turn of the Great-wheel, or in an Hour. Divide 9204 by it, and you have near 6 for the Quotient of your Contrate-wheel. The Work thus ordered, will stand as in the Margin.

4)48(12
7)56(8
6)54(9
6)36(6
——
11

If you would correct your Work, to find the true Number of Beats in an Hour, *&c.* you must proceed, as is shewn Sect. 2. § 7, and latter-end of § 8 of the last Chapter.

§ 4. But suppose you have a Mind to change the former old Watch, into a 30 Hour-piece, and to retain the old Balance-wheel (which may be often done: In this Case, you must add a Contrate-wheel, and alter the Pinion of Report. For the Contrate-wheel, chuse such a Quotient as will best suit with the Rest of your Work; and then multiply all your Quotients, Crown-wheel and 2 Pallets together, and so find the Number of Turns in the Great-wheel, as before. Then say by Sect. 2. § 7, Part 5. before, as the Beats in one Turn of the Great-wheel, to the Beats in an Hour: : So are the Hours of the Dial, to the Quotient of the Pinion of Report.

Thus in the old Work before; to the old Quotients 8, and 9, you may add another

another of 8, for the Contrate-wheel. Thoſe multiplied, as was now directed, make 21888, for the Beats in one Turn of the Great-wheel. And then for the Quotient of the Pinion of Report, ſay in Numbers thus, 21888. 9368 : :

12. 5. The Quotient for the Pinion of Report is ſomewhat more than 5, which overplus may be neglected; as you ſee by the Scheme of the whole work in the Margin.

6)30(5
7)56(8
6)54(9
6)48(8
—
19

If you deſire to know what Number of Turns the Fuſy muſt have in this Work; ſay by the laſt quoted §, Part 1, in Numbers thus, 21888. 9368 : : 30. 13 almoſt. So near 13 Turns will do.

If you would correct your Work, to know the exact Beats, *&c.* you are referred to Directions in the End of the laſt Paragraph.

But ſuppoſe in altering an old Watch, you would have it ſhew Minutes, as well as Hours; you may do it thus: Divide the Beats in one Turn of the Great-Wheel, by the Beats in an Hour; the Quotient will ſhew in how many Hours the Great-Wheel goeth round once. If the Beats in the Great-Wheel exceed the Train, you muſt chuſe your Minute-wheel firſt, and multiply it by the Quotient found; this will give the Pin.

Pin. of Report. But if the Train exceeds the Beats of the Great-wheel, you muſt chuſe the Pin. of Report and multiply the Quotient by it: the product is the Minute-wheel.

But it often falls out, that the Train and Beats of the Great-wheel will not exactly meaſure one another: if ſo, the beſt way is to Half the two Numbers as far as they will equally admit of Halfing; or divide them by ſome common Diviſor, and ſo having brought them to as ſmall Numbers as you can, you may ſuppoſe them to be a Wheel and Pinion, and reduce them to leſſer Numbers, by Chap. 2. Sect. 2. § 6. Thus ſuppoſe you would make the old Movement laſt mentioned, a Minute Watch: you may reduce the Numbers of the Great-wheel 21888, and the Train 9368, to a Pinion and Wheel 28) 12. by the Directions laſt cited. Which Pin. 28 being ſet upon the Spindle of the Gr. Wh. will drive a Wheel 12 round once in an Hour, to ſhew Minutes. If (as in the Movements in Ch. 10) you make this Wh. 12. drive another of 48; concentrical to which, is a Pin. 12, driving a Wheel 36 (which Wheel is concentrical with the Minute-wheel) this will carry a Hand round in 12 Hours. But in this Caſe, you muſt place the Pin. 28 on the

Spindle

Spindle of the Gr. Wh. ſo as to ſlide round ſtiffly, when you turn the Minute-hand to rectifie the Watch.

§ 5. I ſhall add but one Thing more, to what hath been ſaid in this Chapter, and that is to Change the ſtriking Part of this old Movement, into a 30-Hour Piece.

4)39(9¼
7)56(8 Pins
6)54(9
6)48(8

A Scheme of the old Work is in the Margin. And to alter it, the beſt way is, to double the Number of Striking Pins, making the 8, ſixteen Pins, and the Hoop of the Detent-wheel double, and the Pin-wheel may Strike two Strokes, in its going round once.

The greateſt Inconvenience here, will be to Bridle the Rapidity of the Strokes; which a Quotient of 2 alone added to the old Work, would be ſufficient for: But this being an inconvenient Number, 'twill be neceſſary to be content with the old Numbers, or make more Wheels and Pinions new, than may be thought worth the while.

If you would find what Number of Turns the Fuſy will require; you muſt find how many Strokes are in 30 Hours, by Sect. 3. § 2. R. 6. before. Theſe are 195; which divided by the 16 Pins, gives ſomewhat more than 12 Turns of the Fuſy.

Laſtly,

Laſtly, for the Pinion of Report, you muſt purſue the Directions in the laſt quoted place, R. 5.

5)24($\frac{7}{1}\frac{8}{6}$
7)56(8. 16 Pins.
6)54(9
6)48(8

The Work thus altered, will ſtand as in the Margin.

CHAP. IV.

To Size the Wheels and Pinions, or proportion them to each other, both Arithmetically and Mechanically.

§. 1 FOR the exact and eaſie moving of the Wheels and Pinions together, it is neceſſary that they ſhould fit each other, by having their Teeth and Leaves of the ſame wideneſs, or near of the ſame wideneſs. For many do make the Leaves of the Pinion narrower than the Teeth of its Wheel, by Reaſon of their running deep in each other; which is as if the Diameters of the Wheel and Pinion were leſs. But this I leave to thoſe whoſe Practice and Obſervations are greater than mine in theſe Matters.

§ 2. To make the Teeth of a Wheel and Pinion alike, the way *Arithmetically* is thus: Firſt you muſt find the Circumference of your Wheel and Pinion; which you may beſt do by the Rule of Three

Three (so often made use of before.) The Rule is thus, As 7 is to 22 :: so is the Diameter to the Circumference. Or more exactly thus, as 1, is to 3, 1416 :: So Diam. to Circum.

Suppose you have a Wheel of 2 Inches Diameter, and 60 Teeth, and would fit to it a Pinion of 6 Leaves. First 7. 22 :: 2. 6, 3. The Circumference of the Wheel, is then 6 Inches, and 3 Tenths of an Inch. Then say, as the Teeth of the Wheel to the Circumference of it :: So are the Leaves of the Pinion, to the Circumference thereof. In Numbers thus, 60. 6,3 :: 6. ,63. The Pinion then is 63 hundredth Parts of an Inch round. Sir *J. Moor* Mat. Com. R. 5.

Now to find the Diameter, 'tis but the Reverse of the former Rule, *viz.* As 22. to 7 :: So the Circumference to the Diameter. In Numbers thus, for the foregoing Pinion, 22. 7 :: 63. 2. The Diameter then of the Pinion must be two Tenths of an Inch, to fit the aforesaid Wheel of two Inches Diameter.

§ 3. But because this way may be difficult to Persons unacquainted with Decimal Arithmetick, which is very necessary here; therefore I shall set down a Way to do it *Mechanically*. Having drawn a Circle, divide it into as many Parts as you intend Leaves in the Pinion

Pinion you would Size. From two of these Points in the Circle, draw two or more Lines to the Center: to which apply two of the Teeth of your Wheel, guiding them up and down until they Touch at the same Width on these Radii or Lines. Mark where this Agreement is, and a small Circle drawn there, will represent the Circumference of the Pinion sought after.

CHAP. V.

Of PENDULUMS.

§ 1. AMong all known Motions, none measureth Time so regularly, as that of a *Pendulum*. But yet Watches govern'd hereby are not so Perfect, but that they are Subject to the Variations of Weather, Foulness, *&c.* And the shorter and lesser the Pendulum is, so much the more Subject such Watches are to these Annoyances.

As to the Cause and Degree of these Variations, the following Experiments will in some Measure discover, which I made upon my own Clock, that goes all the Year, with as great Exactness, as I believe any of the present Clocks are capable of. The Clock vibrates Seconds, the Ball of the usual Weight (about

bout 3 *l.*) with such a *Regulating Bob* underneath as is described § following, and is represented in Fig. 1. Num. 4.

This Clock having for some Years kept Time as well as could be expected, I hung upon its Weight an Addition of 6 Pound in *August* and *September* 1706, and in *July* and *August* 1707, and afterwards in *October* and *November* 1712. This increase of the Weight, although it made the Vibrations larger (as I found by an Index I have for that Purpose) yet were they the quicker, and made the Clock gain about 13 Seconds every Day; even in these warmer Months when all Pendulum Clocks are apt to go too slow, as much as in Winter they go too fast.

And from hence we may manifestly perceive what the Cause is of those Variations which the Weather, Foulness, &c. produce in the going of Clocks; and that is the Power of the Weight or Spring that drives the Work is increased or diminished thereby. Thus warm Weather (by attenuating the Oyl, &c.) and Cleaness, give the Weight or Spring their full Power, or Force. But Cold Winter Weather thickens the Oyl in the Pivot-holes, and also makes the Metal rigid, and indeed contracts it, as I find by Experiments on warmed, and frozen Iron. And Foulness in the

Oyl

Oyl makes it ſtiff and tenacious, like Bird-lime. All which, as it clogs the Work, ſo as ſometimes to ſtop the Clock's Motion; ſo it diminiſheth the Force of the Weight or Spring, and in effect is equivalent to the taking off ſo much Weight, or Strength.

This is the principal Cauſe of the Alterations in Pendulum-Clocks. Beſides which there are ſome leſſer Cauſes; as the Rarity and Denſity of the Air, which hath ſome Influence upon the Pendulum moving in it; as appears from Dr. *Derham*'s Experiments made on Pendulums in the Air-pump in *Philoſ. Tranſ.* Number 294. Alſo as moſt long Pendulums have commonly ſlender Rods, which may be obſerved to bend a little at the end of each Vibration; ſo the Cold or Warmth of the Weather, by making the Rod more rigid, or more flexible, makes ſome little Alteration in the Vibrations.

To remedy this laſt Inconvenience, I know a Watch-maker that makes his Pendulum-Rods thin, but broad at bottom next the Ball, and ſo tapers them up until they end in the Spring at top. This he cryed up to me as a wonderful Diſcovery, and kept it as a great *Noſtrum* and *Arcanum* for ſome time.

But

But for a general Remedy to all Inconveniences, one Way is, to make the Pendulum long, the Bob heavy, and to vibrate but a little way from its Settlement. Which is now the most usual way in *England.* The other is the Contrivance of the ingenious Mr. *Christian Huygens*, which is, to make the Upper-part of the Rod, play between two Cheek-parts of a Cycloid. Sir *Jonas Moor* says, that after some Time, and charge of Experiments, he believes this latter to be the better Way. And Mr. *Huygens* calls it *admirable.* Mat. Comp. Rule. 3.

If any desire to know how to make those Cycloidal Cheeks fit to all Pendulums, I refer him to the aforesaid Mr. *Huygens's* Book, because I can't shew how to do it, without the Trouble of Figures; and this Way is much ceased, since the Crown-wheel Method (to which it is chiefly proper) is swallowed up by the Royal Pendulums. *De Horal. Oscil.* p. 10, 11, 12.

§ 2. Another Thing to be remarked in Pendulums is, that the greater their Vibrations are, the slower they are. For if two isochrone Pendulums do move, one the Quadrant of a Circle, the other not above 3 or 4 Degrees, this latter shall move somewhat Quicker than the former. Which is one Reason, why small Crown-wheel Pendulums go faster in cold Weather, or when foul, than at other Times.

§ 3. For the Calculation of all Pendulums, it is necessary to fix upon some one, to be a Standard to the Rest. I pitch upon a Pend. to vibrate Seconds each Stroke.

Mr. *Huygens* lays down the Length of a Pend. to swing Seconds to be 3 Feet, 3 Inches, and 2 Tenths of an Inch (according to Sir *J. Moor's* Reduction of it to *English* Measure.) Ibid.

" The Honourable Lord *Bruncker* " (saith Sir *Jonas*) " and Mr. *Rook*, " found the Length to be 39. 25 Inches, " which a little exceeds the Other: " and maybe, was justened by Mr. *Huygens's* Rule for the Center of Oscilla- " tion. For *Mouton's* Pendulum, that " shall vibrate 132 Times in a Minute, " it will be found likewise 8.1 Inches " agreeing to 39.2 Inches *English*. " Therefore for certain 39.2 Inches " may be called the *Universal Measure*, " and relied on, to be the near Length " of a Pend. that shall swing Seconds " each Vibration. Ibid.

But forasmuch as the different Size of the Ball, will make some difference in the Length of this Standard Pendulum, therefore to make this Pend. an *Universal Measure*, to fit all Places and Ages, you must measure from the Point of

Suspension,

Suspension, to the Center of Oscillation. Which Center is found by this Rule, As the Length of the String from the Point of Suspension to the Center of a round Ball: is to the Semi-diameter of that Ball :: So is that Semi-diameter : to a 4th Number. Add two 5ths of that 4th Number, to the former Length, and you have the Center of Oscillation; and thereby the true Length of this *Standard Pendulum.*

Hugenius ubi supra p. 141. Sir *J. Moor* Ibid.

If it be desired to fit a Ball of a Triangular, Quadrangular, or any other Form to this Pend. the Center of Oscillation in any of these Bodies may be found in the last cited Book of Mr. *Huygens.*

If it be asked, What is the Meaning of the Center of Oscillation; the most intelligible Answer I can give an unskilful Reader is, That it is that Point of the Ball, at which if you imagine it divided into two Parts, by a Circle, whose Center is in the Point of Suspension, the Lower-part of the Ball shall be of the same Weight with the Upper.

§ 4. Having thus fixed a Standard, I shall next shew how from thence to find the Vibrations, or Lengths of all other Pendulums. Which is done by this Rule, *The Squares of the Vibrations, bear the same Proportion to each other, as their Lengths do.* And so contrarywise. Wherefore by the Number of Vibrations

Hugen. Moor. *ib.*

to find the Length of the Pendulum that will vibrate them, say, as the Square of those Vibrations, is to the Square of 60 (the Vibration of the Standard in a Minute) : : So is the Length of the Standard (*viz.* 39,2:) to the Length of the Pendulum sought.

If by the Length, you will find the Vibrations, it is the Reverse of the last Rule, *viz.* As the Length proposed : to the Standard (39,2) : : So is the Square of 60 (the Vibrations of the Standard): to the Square of the Vibrations sought.

Suppose for Example, you would know of what Length a Pend. is of, that Vibrates 153 Strokes in a Minute. The Square of 153 (*i. e.* 153 Times 153) is 23409. Say 23409. 3600 : : 392. 6. A Pend. then that vibrates 153 in a Minute, is about 6 Inches Long.

On the other Hand, if you would know how many Strokes a Pend. of 6 Inches hath in a Minute; say 6. 39,2 : : 3600. 23520. The Square-root whereof is 153, and somewhat more.

Note, because 141120 is always the Product of the two Middle-Terms multiplied together, therefore you need only to divide this Number by the Square of the Vibrations, it gives the Length sought: By the Length, it gives the Square of the Vibrations.

If you operate by the Logarithms, you

you will much contract your Labour. For if you seek the Length, it is but substracting the Logarithm of the Square of the Vibrations, out of the Logarithm of 141120, which is 5. 1495886, and the Remainder is the Logarithm of the Length sought.

If you seek the Vibrations, it is but Substracting out of the aforesaid Logarithm 5. 1495886, the Logarithm of the Length given, and Half the Residue is the Logarithm of the Vibrations required. The following Examples will illustrate each Particular.

To find the Length.

	Logarithms.
141120 ————————	5. 1945886
153 squared is 23409 or (which is the same Thing, and most ready) its Logarithm doubled is	4. 3693828
Length is more than 6 ——	0. 7802058

To find the Vibrations.

	Logarithms.
141120 ————————	5. 1495886
6 Inches long ————	0. 7781512
Square of the Vibr. ——	4. 3714374
Square root, or numb. of Vibr.	2. 1857187

is 153, and somewhat more.

According to the foregoing Directions, I have calculated the following Table, to Pendulums of various Lengths, and have therein ſhewed the Vibrations in a Minute and an Hour, from 1 to 100 Inches.

A Table of Swings in a Minute, and in an Hour, to Pendulums of ſeveral Lengths.

Pend. length in Inches	Vibrat. in a Minute	Vibrat. in an Hour.	Pend. length in Inches	Vibrat. in a Minute	Vibrat. in an Hour
1	375.7	22542	30	68.6	4116
2	265.6	15936			
3	218.9	13014	39.2	60.0	3600
4	187.8	11268			
5	168.0	10080	40	59.4	3564
6	153.3	9204	50	53.1	3186
7	142.0	8520	60	48.5	2910
8	132.8	7968	70	44.9	2694
9	125.2	7512	80	42.0	2520
10	118.8	7128	90	39.6	2376
20	84.0	5040	100	37.5	2250

The Uſe of this Table is manifeſt, and needs no Explication. As to the Decimals in the Column of Minute-Swings, I have added them for the ſake of calculating the Column of Hour-Swings; which would have been judged falſe

falſe without them, and would not have been exactly True without them.

§ 5. I have but one Thing more to add to this Chap. of Pendulums, and that is, *To Correct their Motion.*

The uſual Way is, to ſcrew up, or let down the Ball. In doing of which, a ſmall Alteration will make a conſiderable Variation of Time: as you will find by Calculation, according to the laſt Paragraph. To prevent the Inconvenience of ſcrewing the Ball too high, or low, Mr. *Smith* hath contrived a Table for dividing the Nut of a Pendulum Screw, ſo as to alter your Clock but a Second in a Day. But by Reaſon no Screw and Nut can be ſo made, as to be moſt exactly ſtraight and true, therefore it may happen, that inſtead of altering your Watch to your Mind, you may do quite contrary; as inſtead of letting the Ball down, you may raiſe it higher, by the falſe running of the Nut upon the Screw. *Horol. Diſquiſ.*

Conſidering this irremediable Inconvenience, I am of Opinion, that Mr. *Huygens's* way is much Better. His way is, to have a ſmall Weight or Bob, to ſlide up and down the Pend. Rod, above the Ball (which is immoveable.) But I would rather Adviſe, that the Ball be made to Screw up and down, to bring the Pend. pretty near its Gauge: and *De Centro Oſcil.* Prop. 23.

that this little Bob should serve only for more nice Corrections; as the Alteration of a Second, or &c. Which it will do better than the great Ball. For a whole Turn of this little Bob, will not affect the Motion of the Pend. so much as a small Alteration of the Great Ball.

The Directions Mr. *Huygens* gives about this little Corrector, is, that it should be Equal to the Weight of the Wire, or Rod of the Pend. or about a 5th Part of the Weight of the Great Ball, which he Appoints to be Three-pounds.

If the Reader hath a Mind to see what Alterations the sliding the Bob up and down will make in the Motion of the Pendulum, he may find a Table ingeniously calculated in the great Man's last cited Book. In which Table it may be observed, that a small Alteration of the Corrector towards the Lower-end of the Pend. doth make as great an Alteration of Time, as a greater raising or falling of it, doth make Higher. Thus the little Bob raised 7 Divisions of the Rod, from the Center of Oscillation, will alter the Watch 15 Seconds; raised 15.2 'twill alter it 30′. But whereas if it be raised to 154.3 Parts of the Rod, it will make the Watch go Faster 3 Minutes. 15 Seconds, the Watch shall be but 3′ 30″ Faster, if the Bob be raised

raised to 192, 6. So that here you have but 15″ Variation, by raising the Bob above 38 Parts; whereas Lower, you had the same Variation, when raised not above 7 or 8 Parts.

But I have found it to be a very commodious way, to put a small Bob of about 10 Ounces underneath the great Ball, (which is of 3, 4, or more Pounds Weight) to be screwed Higher or Lower, as Occasion is.

The Use of this little Ball, or *Corrector* is this; when you have brought the great Ball near its true Length, so that the Pendulum will keep Time pretty well, the Little Ball will bring it to a much greater Exactness, by Reason many of its Turns will no more influence the Motion of the Pendulum, than the smallest Alteration of the great Ball: So That if your Clock should in a Week, or a longer Time, err but a few Seconds, you may by screwing up, or letting down this Bob, or little Ball, *Fig.* 1. Nr. 4. correct even that minute Errour, and so bring your Clock to keep Time well all the Year, abating for the Alterations from Weather, *&c.* which I spake of.

If the Reader should have a Curiosity to know what Alterations the screwing up, or letting down the Great-Ball will Cause in 24 Hours of the Clock's going, this Table I calculated on purpose to shew him. Which will need but little Explication.

 Supposing

Pendul. Length.		Variation of Vibr.		
In.	Ten.	Min.	Sec	
38	0	22	33	
38	1	20	38	
38	2	18	43	
38	3	16	48	
38	4	14	55	
38	5	13	2	
38	6	11	9	
38	7	9	16	
38	8	7	25	Faster.
38	9	5	32	
39	0	3	42	
39	1	1	51	
39	2	00	00	
39	3	1	50	
39	4	3.	40	
39	5	5	29	
39	6	7	19	Slower.
39	7	9	7	
39	8	10	57	
39	9	12	42	
40	0	14	29	

Suppofing your Pendulum that vibrates Seconds to be 39 Inches and 2 Tenths, if you fhould fhorten it to 39 Inches, it would go 3′. 42″ Fafter than before: But if you fhould lengthen it to 39 Inches, 3 Tenths, it would go 1′. 50″ flower. And fo for the Reft of the Table.

If then the Great-Ball flides on a flat Piece of Brafs divided into Inches and Tenths, it will be eafy to difcern what Alterations will be caufed by the raifing or falling of it.

CHAP. VI.

The Antiquity, and general Hiftory of Watch, or Clock-work.

§ 1. IT is probable, that in all Ages, fome Inftruments or other have been ufed, for the meafuring of Time.

But

But the earlieſt we read of, is the *Dial* of *Ahaz.* Concerning which, little of certainty can be ſaid. The *Hebrew* Word *Maγaloth* doth properly ſignify Degrees, Steps, or Stairs, by which we aſcend to any Place. And ſo this Word *Maγaloth* is rendered *Ezek.* 40. 26. And accordingly the LXXII tranſlate the *Maγaloth* of *Ahaz*, by the Words Βαθμὺς and Ἀναβαθμὺς, *i. e. Steps* or *Aſcents.* The like doth the *Syriack*, *Arabick*, and other Verſions. 2 King 20. 11. Iſai. 38. 8.

Some pretend to give a Deſcription of this *Dial* of *Ahaz*: but it being meer Gueſſing, and little to my Purpoſe, I ſhall not trouble the Reader with the various Opinions about it.

Among the *Greeks* and *Romans*, there were two Ways chiefly uſed to meaſure their Hours. One was by *Clepſydræ*, or Hour-glaſſes. The other by the *Solaria* or Sun-dials. The Κλεψύδρα, ſay *Suidas* and *Phavorinus*, was Ὄργανον ἀστρολογικὸν ἐν ᾧ αἱ ὧραι μετρῶντ; *i. e. An Aſtronomical Inſtrument, by which the Hours were meaſured.* Alſo, *that it was a Veſſel, having a little Hole in the Bottom which was ſet in the Courts of Judicature, full of Water; by which the Lawyers pleaded.* This was, ſays *Phavorinus*, to prevent Babbling, that ſuch as ſpeak, ought to be Brief in their Speeches. Lexic. in verbo. ὧραι. In verbo κλεψύδρα.

As to the Invention of thoſe Water-watches (which were, no doubt, of

more

more common Use, than only in the Law-Courts) the Invention, I say of them, is attributed, by *Censorinus*, to *P. Cornelius Nasica*, the *Censor. Scipio Nasica*, *Pliny* calls him, and saith, *Primus aquâ divisit Horas æquè noctium ac dierum. Idq; Horologium sub tecto dicavit anno Urbis* 595. *i. e. Scipio Nasica was the first that by Water measured the Hours of the Night as well as the Day. And that Clock he dedicated within Doors in the Year U. C.* 595. which Time fell in about the Time of *Judas Maccabæus*, about 150 Years before our Blessed Saviour's Days.

De die Na. l. c. 23.

The other Way of Measuring the Hours, *viz.* with *Sun-dials*, seems, from *Pliny* and *Censorinus*, to have been an earlier invention than the Last. *Pliny* says, that "*Anaximenes Milesius*, the Scholar of "*Anaximander*, invented Dialing, and "was the first that shewed a Sun-dial "at *Lacedæmon*. *Vitruvius* calls him *Milesius Anaximander*. This *Anaximander* or *Anaximenes* was cotemporary with *Pythagoras*, says *Laertius*; and flourished about the Time of the Prophet *Daniel*.

Nat. Hist. l. 2. c. 76.

De Archit. l. 6. c. 48.

But enough of these antient Time-Engines, which are not very much to my Purpose, being not Pieces of Watch-work.

§ 2. I shall in the next Place take Notice of a few Horological Machines, that I have met with; which whether Pieces

Pieces of Clock-work, or not, I leave to the Reader's Judgement.

The firſt is that of *Dionyſius*, which *Plutarch* commends for a very magnificent, and illuſtrious Piece. But this might be only a well delineated Sun-Dial. In the Life of *Dion*.

Another Piece, is that of *Sapor* King of *Perſia*. Whether that *Sapor*, who was cotemporary with *Conſtantine the Great*, I know not. *Cardan* ſaith it was made of Glaſs; that the King could ſit in the Middle of it, and ſee its Stars Riſe and Set. But not finding whether this Sphere was moved by Clock-work, or whether it had any regular Motion, I ſhall ſay no more concerning it. *Euſeb. Vit. Conſt.* l. 3. *De Subtil.* l. 17.

The laſt Machine I ſhall mention in this Paragraph, is one I find deſcribed by *Vitruvius*. Which to me ſeems to be a Piece of Watch-Work, moved by an Equal influx of Water. *De Architect.* l. 9.

If the Reader will conſult the *French* Edition of *Vitruvius*, he will find there a fair Cut of it.

Among divers Feats which this Machine performed (as ſounding Trumpets, throwing Stones, *&c.*) one uſe of it was, to ſhow the Hours (which were unequal in that Age) through every Month of the Year. The Words of *Vitruvius* are, *Æqualiter influens aqua ſublevat Scaphum inverſum (quod ab artificibus Phellos*

Phellos sive Tympanum dicitur) in quo collocata regula, versatilia tympana denticulis æqualibus sunt perfecta. Qui denticuli alius alium impellentes, versationes modicas faciunt, ac motiones. Item aliæ Regulæ, aliaque Tympana ad eundem modum dentata, quæ una motione coacta, versando faciunt effectus, varietatesque motionum: in quibus moventur Sigilla, vertuntur Metæ, Calculi aut Tona projiciuntur, Buccinæ canunt, &c. *In his etiam, aut in columna, aut parastatica Horæ describuntur; quas Sigillum egrediens ab imo virgulæ, significat, in diem totum: quarum brevitates aut crescentias, cuneorum adjectus aut exemptus, in singulis diebus & mensibus, perficere cogit.*

The Inventor of this famous Machine, *Vitruvius* says, was one *Ctesibius*, a Barber's Son of *Alexandria*. Which *Ctesibius* flourished under *Ptolomy Euergetes*, says *Athenæus*, l. 4. And if so, he lived about 140 Years before our Saviour's Days; and might be cotemporary with *Archimedes*.

Vid. *Philand. not. in Vitruv.*

§ 3. Thus having given a small Account of the ancient Ways of measuring Time, it is Time to come closer to our Business, and say something more particularly of Watch and Clock-work. Which is thought to be a much younger Invention, than the forementioned Pieces; and to have had its Beginning in *Germany*, within less than these 200 Years. It

is

is very probable, that our Ballance-clocks or Watches, and ſome other *Automata*, might have their Beginning there; or that Watch and Clock-work (which had long been buried in Oblivion) might be revived there. But that Watch and Clock-work was the Invention of that Age purely, I utterly deny; having (beſides what goes before) two Inſtances to the contrary, of much earlier Date.

§ 4. The firſt Example is the *Sphere* of *Archimedes*; who lived about 200 Years before our Saviour's Days. There is no Mention of this Sphere in *Archimedes* his extant Works: but we have an Account of it in Others. *Cicero* ſpeaks of it more than once. In his 2d Book *De Natura Deorum*, are theſe Words; "*Archimedem arbitrantur plus valuiſſe in* "*imitandis Sphæræ converſionibus, quam* "*Naturam in efficiendis*, &c. *i. e. Thoſe fooliſh Philoſophers imagine, that* Archimedes *was able to do more in imitating the Motions of the Sphere, than Nature in effecting of them.* And in his *Tuſculane* Queſtions, the Collocutor, proving the Soul to be of a Divine Nature, argues from this Contrivance of *Archimedes*, and ſays, *Nam cum Archimedes Lunæ, Solis, quinque errantium motus in Sphæram illigavit, effecit.* &c. The Senſe is, that *Archimedes* contrived a Sphere, which ſhewed the Motion of the Moon, Sun, and five Planets. But

Lib. 1. 25. *Edit. Elzevir.*

Epigr. in Sphar. Archimed.

But the most accurate Description is that of *Claudian*, in these Words.

Jupiter in parvo cum cerneret æthera vitro,
Risit, & ad Superos talia dicta dedit:
Huccine mortalis progressa potentia curæ?
Jam meus in fragili luditur orbe labor.
Jura poli, rerumque fidem, legesq; Deorum
Ecce Syracusius transtulit arte Senex.
Inclusus variis famulatur Spiritus astris,
Et vivum certis motibus urget opus.
Percurrit proprium mentitus Signifer annum:
Et simulata novo Cynthia mense redit.
Jamq; suum volvens audax industria mundum
Gaudet, & humana Sidera mente regit.
Quid falso insontem tonitru Salmonea miror?
Æmula Naturæ parva reperta manus.

In English thus:

When Jove *espy'd in Glass his Heavens made,*
He smil'd, and to the other Gods thus said:
'Tis strange that human Art so far proceeds,
To ape in brittle Orbs my greatest Deeds.
The heavenly Motions, Nature's constant Course,
Lo! here old Archimede *to Art transfers.*
Th' inclosed Spirit here each Star doth drive;
And to the living Work sure Motions give.
The Sun in counterfeit his Year doth run,
And Cynthia *too her monthly Circle turn.*
Since now bold Man hath Worlds of's own de-(scry'd
He joys, and th' Stars by human Art can guide.

Why

Why should we so admire proud Salmons *cheats,*
When one poor Hand Nature's chief Work repeats?

From this Description it appeareth, that in this Sphere, the Sun, Moon and other Heavenly Bodies, had their proper Motion: and that this Motion was effected by some enclosed *Spirit.* What this *enclosed Spirit* was, I cannot tell, but suppose it to be Weights or Springs, with Wheels or Pullies, or some such means of Clock-work: Which being hidden from vulgar Eyes, might be taken (at least in a poetical Way) for some Angel, Spirit, or Divine Power; unless by Spirit here, you understand some aerious, subtiliz'd Liquor; or Vapours. But how this, or indeed any thing but Clock-work, could give such time and regular Motions, I am not able to guess.

§ 5. The next Instance I have met with of antient Clock-work, is that famous one in *Cicero,* which, among other irrefragable Arguments is brought in to prove, "That there is some in-"telligent, divine, and wise Being, "that inhabiteth, ruleth in, and is as "an Architect of so great a Work, as "the World is, as the Stoick expresseth "himself." His words (so far as they relate to my present Purpose) are these: *De Nat. Deor.* Lib. 2. § 34.

" *Cum*

"*Cum Solarium vel descriptum, aut ex* "*Aqua contemplere, intelligere declarari* "*horas arte, non casu*, &c." And a little after, *Quod si in Scythiam, aut in Britanniam, Sphæram aliquis tulerit hanc, quam nuper familiaris noster effecit Posidonius, cujus singulæ Conversiones idem efficiunt in Sole, & in Luna, & in quinque Stellis errantibus quod efficitur in cælo singulis diebus, & noctibus; quis in illa barbarie dubitet, quin ea Sphæra sit perfecta ratione?* The Summ of the Author's meaning is, "That there "were *Sun-dials* described, or drawn "[with Lines, after the Manner as our "Sun-dials are:] and some made with "Water (which were the *Clepsydræ*, "or Hour-glasses, before-mentioned.) "That *Posidonius* had lately contrived a "Sphere, whose Motions were the same "in the Sun, Moon, and 5 Planets in "the Sphere, as were performed in the "Heavens each Day and Night."

The Age wherein this Sphere was invented, was *Cicero's* Time, which was about 80 Years before our Saviour's Birth.

And that it was a Piece of *Clock-work*, is not (I think) to be doubted, if it be considered, that it kept Time with those Celestial Bodies, imitating both their annual, and diurnal Motions; as from the Description we may gather it did.

It may be questioned, whether those Machines were common or not: I believe

lieve they were Rarities then, as well as Mr. *Watson's* and Others are accounted now. But methinks it is hard to imagine, that so useful an Invention should not be reduced into common Use; it being Natural, and easie to apply it to the measuring of Hours (tho' unequal) especially in two such Ages, as those of *Archimedes* and *Tully* were, in which the liberal Arts so greatly flourished.

§ 6. After the Times last mentioned, *Barbarism* came on, and Arts and Sciences became neglected, so that little worth Remark is to be found till towards the 16th Century; and then Clock-work was revived, or wholly invented anew in *Germany*, as is generally thought, because the antient Pieces are *German* Work. But who was the Inventor, or in what Time, I cannot discover. Some think *Sever. Boethius* invented it long before about the Year 510.

But if it was not so early as *Boethius*, it might perhaps be in *Regiomantanus's* his Time, towards the Latter-end of the 14th Century. However it is very manifest, it was before *Cardan's* Time, because he speaketh of it, as a Thing common then. And He lived about 170 Years since. And at this very Day, there is a Stately Clock in his Majesties Palace at *Hampton-Court*, whose Inscription shews it to have been made in K.

Molyneaux, Scioth. Telescop. Ep. Dedic.

Henry

Hen. VIII's Time by one *N. O.* in the Year 1540; which for its Antiquity and good Contrivance I have given the Calliper of in Fig. 4, and ſhall ſay more of in Chap. 10.

Another Piece alſo I Remember I ſaw ſome Years ago, which was a Watch belonging to the ſame K. *Hen.* VIIIth, which went a Week. Probably it might be made by the ſame *N. O.*

§ 7. As to thoſe curious Contrivances in Clock-work, which perform ſtrange, ſurprizing Feats, I ſhall ſay little. Dr. *Heylin* tells us of a Famous Clock and Dial in the Cathedral Church of *Lunden* in *Denmark.* "In "the Dial (ſaith he) are to be ſeen "diſtinctly the Year, Month, Week-"day, and Hour of every Day through-"out the Year; with the Feaſts, "both moveable and fixed; together "with the Motion of the Sun and "Moon, and their Paſſages thro' each "Degree of the *Zodiack.* Then for "the Clock, it is ſo framed by artifi-"cial Engines, that whenſoever it is "to ſtrike, two Horſe-men encounter "one another, giving as many Blows "apiece, as the Bell ſounds Hours: "And on the opening of a Door, there "appeareth a Theatre, the Virgin "*Mary* on a Throne, with Chriſt in "her Arms, and the three Kings or

Heylin's *Coſmog.* l. 2.

" *Magi*

" *Magi* (with their ſeveral Trains)
" marching in Order, doing humble
" Reverence, and preſenting ſeverally
" their Gifts, two Trumpeters ſound-
" ing all the while, to adorn the Pomp
" of that Proceſſion."

To this I might add many more ſuch curious Performances; but I rather chuſe to refer the Reader to *Schottus*, where he may find a great Variety, to pleaſe him. *Magia Univerſ. P. 1. Proleg. & Magia Thaumaturg.*

CHAP. VII.

Of the Invention of Pendulum-Clocks.

§ 1. BEfore ever *Pendulums* were applied to *Watch-Work*, their Motion was made Uſe of for the more accurate meaſuring of Time in Obſervations, particularly ſuch as were Aſtronomical. The Famous *Tycho Brahe* is ſuppoſed to have made uſe of Them; but *Sturmius* ſaith, *Ricciolus primùm Pendula adhibuit ad tempora menſuranda. Eumq; ſecuti (etiamſi conatuum ejus ignari) Langrenus, Vendelinus, Merſennus, Kircherus, & alii quamplurimi. Automatis Horologiis applicavit Hugenius.* i. e. *Riccioli firſt made uſe of Pendulums*

Pendulums to measure Time: Whom Langrene, Wendeline, Mersenne, Kircher, and many others followed, although they were ignorant of his Practice. But Huygens *applied them to Clocks.* Sturm. Colleg. Curios. P. 1. Tent. 14.

And notwithstanding Divers have pretended to the Invention, yet Mr. *Christian Huygens* of *Zulichem* affirms he was the First that applied Pendulums to Clock-work, and gives very cogent Reasons for it.

Hor. Oscil. p 3. Edit. Paris. This excellent Invention, he says, he put first in Practice in the Year 1657: and in the following Year 1658, he printed a Delineation and Description of it.

Among them that have claimed the Honour of this Invention, the great *Galilæo* hath the most to be said on his Side. Dr. *John Joachim Becher* (who printed a Book when he was in *England*, entituled, *De Nova Temporis dimetiendi ratione Theoria*, &c. which he didicated to the *English* Royal Society, *Anno* 1680.) he, I say, tells us, "That the *Count Magalotti* "(the Great Duke of *Tuscany*'s Resident "at the Emperor's Court) told him the "whole History of these Pendulum "Clocks, and denied Mr. *Zulichem* to "be the Author of them. Also That "one *Treffler* (Clock-maker to the Fa-"ther of the then G. Duke of *Tuscany*)

related

"related to him the like Hiſtory: And "ſaid moreover, that he had made the "firſt Pend. Clock, at *Florence*, by the "command of the Great Duke, and by "the Directions of his Mathematician "*Galileus a Galilæo*; a Pattern of which "was brought into *Holland*. And fur-"ther he ſaith, that one *Caſpar Doms*, "a *Fleming*, and Mathematician to "*John Philip a Schonborn* (the late E-"lector of *Mentz*) told him that he "had ſeen at *Prague*, in the Time of "*Rudolphus* the Emperor, a Pend. "Clock, made by the Famous *Juſtus* "*Borgen*, Mechanick and Clock-ma-"ker to the Emperor: which Clock "the great *Tycho-Brahe* uſed in his "Aſtronomical Obſervations."

Thus far *Becher*. To which I may add, what is ſaid by the *Acadamie del Cimento*, *viz.* "It was thought good to apply "the Pendulum to the Movement of "the Clock: a Thing which *Galilæo* "firſt invented, and his Son *Vincenzio Ga-*"*lilei* put in Practice in the Year 1649.

Exper. made in the Acad. *del Cimento* tranſl. by Mr. *Waller* p. 12.

As to theſe Matters thus related by hearſay by *Becher*, and ſo expreſsly affirmed by the Academy, I have little to reply, but that Mr. *Huygens* (whom I take to have been a Man of as great Integrity, as Learning and Ingenuity) does expreſsly ſay, He was the Inventer, and that if *Galilæo* ever thought of any

Hugen. *ib.*

any such Thing, he never brought it to any Perfection. It is certain, that this Invention never flourished till Mr. *Huygens* set it Abroad.

§ 2. After Mr. *Huygens* had thus invented these Pendulum Watches, and caused several to be made in *Holland*, Mr. *Fromantil*, a *Dutch* Clock-maker, came over into *England*, and made the First that ever were made here; which was about the Year 1662. One of the first Pieces that was made in *England*, is now in *Gresham-Colledge*, given to that Honourable Society by the late eminent *Seth*, Lord Bishop of *Salisbury*: which is made exactly according to Mr. *Huygens's* Method.

§ 3. For several Years this way of Mr. *Huygens* was the only Method, *viz.* Crown-wheel Pendulums, to play between two cycloidal Cheeks, &c. But afterwards Mr. *W. Clement*, a *London* Clock-maker, contrived them (as Mr. *Smith* saith) to go with less Weight, an heavier Ball (if you please) and to Vibrate but a small Compass. Which is now the universal Method of the Royal Pendulums. But Dr. *Hook* denies Mr. *Clement* to have invented this; and says that it was his Invention, and that he caused a Piece of this Nature to be made, which he shewed before the

Horolog. Disquis. p. 3.

R. Society, ſoon after the Fire of *London.*

§ 4. The Uſe of theſe Pendulum Clocks Mr. *Huygens* ſetteth forth in ſeveral Inſtances. Particularly ; he giveth two Examples of their great Uſe at Sea, in diſcovering the Difference of Meridians, more exactly than any other Way : which he deduceth from the Obſervations of an *Engliſh*, and *French* Ship.

On Land, they were found very ſerviceable ; among other Uſes, particularly to theſe Two. 1. To meaſure the Time more exactly, and equally than the Sun. 2. To be (as Sir *Chriſtopher Wren* firſt propoſed) a perpetual, and univerſal Meaſure, or Standard, to which all Lengths may be reduced, and by which they may be judged of, in all Ages, and Countries. For (as our *Royal Society*, Mr. *Huygens*, and *Mountonus* have propoſed, after Sir *Chriſtopher Wren*) this *Horary foot*, or *Tripedal* length, which vibrateth Seconds, will fit all Ages and Places. But then Reſpect muſt be had to the Center of Oſcillation, which you have an Account of in Mr. *Huygens* his aforeſaid Book *de Horologio Oſcillatorio*, as hath before been ſaid.

§ 5. There is one Contrivance more of Pendulums, ſtill behind, *viz.* the

Circular Pendulum; which is mentioned by Mr. *Huygens* as his own, but is claimed by the late most ingenious Dr. *Hook* as really his. This Pend. doth not vibrate backward and forward, as those we have been speaking of do; but always round Round; the String being suspended above, at the tripedal Length, and the Ball fixed below, as suppose at the End of the Fly of a common Jack.

The Motion of this Circular Pend. is as regular, and much the same with those mentioned before: and was thus far made very useful in Astronomical Observations, by the said Dr. *Hook*, *viz.* To give warning at any Moment of its Circumgyration, either when it had turned but a Quarter, Half, or any lesser, or greater Part of its Circle. So that here you had Notice not only of a Second, but of the most minute Part of a Second of Time. You may find a Description of this Pendulum, and other Matters belonging to it, in Dr. *Hook's Lectiones Cutlerianæ: Animad. in Hevelii Mach. Cælest.* p. 60.

CHAP.

CHAP. VIII.

Of the Invention of those Pocket-Watches, commonly called Pendulum-Watches.

§ 1. THE Reason they are called *Pendulum-Watches*, is from the Regularity of their Strokes, and Motion, which were pretended to be not inferiour to those of a real Pendulum. This exactness is effected by the Government of a small Spiral Spring running Round the Upper-part of the Verge of the Ballance: which Spring I call the *Regulator*.

§ 2. The first Inventor hereof, was that ingenious and learned Member of our *R. Society*, the late Dr. *Hook*: who contrived various Ways of Regulation. One Way was with a Load-stone: another was with a tender straight Spring, one End whereof played backward and forward with the Balance. So that the Balance was to the Spring as the Bob of a Pendulum, and the little Spring, as the Rod thereof. And several other Contrivances he had besides of this Nature, as he assured me, and is manifest from divers Evidences.

§ 3. But the Invention which best anſwered Expectation, was at firſt, with two Balances: of which I have ſeen two Sorts, altho' there were ſeveral others. One Way was without Spiral Springs, the other with. They both agreed in this, that the outward Rims of both the Balances had a like Number of Teeth; which running in each other, cauſed each Balance to vibrate alike.

But as to the former of theſe, which had no Spiral Spring; the Verges of its Balance had each but one Pallet apiece, about the Middle of the Verge. The Crown-wheel lay (contrary to others) reverſed, in the middle of the Watch, in the Place, and after the Manner of the Contrate-wheel. The Teeth of this Crown-wheel, were cut after the Manner of Contrate-wheel Teeth, *viz.* lying upwards, but very wide apart, ſo as that the Pallets (which were about one Tenth of an Inch long, and narrow) might play in and out between each Tooth. The Verges of the two Balances, were ſet one on one Side, the other on the other Side of the Crown-wheel, ſo that the Pallets might play freely in its Teeth. And when the Crown-wheel in moving round, had delivered its ſelf of one Pallet, the other Pallet on the oppoſite Side, was drawn on to make its Beats, by means of of the Motion which the other Balance had given its Balance, (the two Balances moving one another, as hath been said in the Beginning of this Paragraph.) And so the same back again.

It may here be noted, That for the more clear Understanding of the last Contrivance, I have described the two Balances, as having Teeth on the edges of their Rims, running in one another. But the Contrivance was really thus; there was a small Wheel under each Balance, proportioned to the Width of the Crown-wheel. But the Balances were much larger. And so the Teeth of these two little foresaid Wheels or Balances, running in one another, moved the larger Balances above them, all one, as if these two great Balances had been toothed and played in each other.

§. 4. The other Way, with two Balances also, moving each other (as was said in the Beginning of the last §) had a Spiral Spring to each Balance, for its Regulator. In this Invention, only one Balance had the Pallets, as the common Balances have: And the Crown-wheel operated upon it, according to the usual Way. But then when this Balance vibrateth, it giveth the same Motion backward and forward to the other Balance, as hath been said.

The First of these two Ways was never prosecuted so far, as perhaps it deserved. And the Excellency of the latter is, that no Jirk, or the most confused Shake, can in the least alter its Vibrations. Which it will do in the best Pendulum Watch with one Balance now commonly used. For if you lay one of these Watches upon a Table, and by the Pendent jirk it backward and forward, you will put it into the greatest Hurry; whereas the last mentioned Watch, with two Balances, will be nothing affected with it. But notwithstanding this Inconvenience, yet the Watch with one Balance and one Spring (which was also Dr. *Hook's* Invention) prevailed, and grew common, being now the universal Mode: but of the other very few were ever made. The Reason hereof, I judge was the great Trouble and vast Niceness required in it, and perhaps a little Foulness in the Balance-Teeth may retard the Motion of the Balances. But the other is easier made, and performeth well enough, and in a Pocket is scarce Subject to the aforesaid Disorder, which is caused rather by a Turn, than a Shake.

§ 5. The Time of these Inventions was about the Year 1658, as appears (among other Evidence) from this Inscription,

ſcription, which I ſaw upon one of the aforeſaid double Balance-Watches preſented to King *Charles* II. *viz.* *Robert, Hook inven.* 1658. *T. Tompion fecit* 1675.

This Watch was wonderfully approved of by the King; and ſo the Invention grew into Reputation, and was much talked of at Home and Abroad. Particularly its Fame flew into *France*, from whence the *Dauphine* ſent for two; which that eminent Artiſt Mr. *Tompion* made for him.

§ 6. Dr. *Hook* had long before this, cauſed ſeveral Pieces of this Nature to be made, although they did not take till after 1675. However he had before ſo far proceeded herein, as to have a Patent (drawn, though not ſealed) for theſe and ſome other Contrivances, about Watches, in the Year 1660. But the Reaſon why that Patent did no further proceed, was ſome Diſagreement about ſome Articles in it, with ſome Noble Perſons who were concerned for the procuring it. The ſame ingenious *Dr.* had alſo a grant for a Patent for this laſt Way of Spring Watches in the Year 1675: but he omitted the taking it out, as thinking it not worth the while.

§ 7. After theſe Inventions of Dr. *Hook*, and (no doubt) after the Publication of Mr. *Huygens's* Book *de Horolog.*

Oscil. at *Paris* 1673 (for there is not a Word of this, though of several other Contrivances) after this I say, Mr. *Huygens's* Watch with a Spiral Spring came Abroad and made a great Noise in *England*, as if the Longitude could be now found. One of these the Lord *Bruncker* sent for out of *France*, (where Mr. *Huygens* had a Patent for them) which I have seen.

This Watch of Mr. *Huygens's* agreed with Dr. *Hook's*, in the Application of the Spring to the Balance: only Mr. *Huygens's* had a longer Spiral Spring, and the Pulses or Beats were much slower. That wherein it differs, is 1. The Verge hath a Pinion instead of Pallets; and a Contrate-wheel runs therein, and drives it round, more than one Turn. 2. The Pallets are on the Arbour of this Contrate-wheel. 3. Then followeth the Crown-wheel, &c. 4. The Balance, instead of turning scarce quite round (as Dr. *Hook's*) doth turn several Rounds every Vibration.

§ 8. As to the great Abilities of Mr. *Huygens*, no Man can doubt, that is acquainted with his Performances. But I have some Reason to doubt, whether his Fancy was not first set on Work by some Intelligence, he might have of Dr. *Hook's* Invention from Mr. *Oldenburgh*, or others his Correspondents here

here in *England*, although Mr. *Oldenburgh* vindicates himſelf againſt that charge in *Phil. Tran.* Nr. 118 and 129. But of this Controverſy ſee more in Mr. *Waller's Life of* Dr. *Hook.* p. 4.

But whether or no that ingenious Perſon doth owe any Thing herein to our ingenious Dr. *Hook*, it is however a very prety, and ingenious Contrivance; but Subject to ſome Defects: *viz.* When it ſtandeth ſtill, it will not vibrate, until it is ſet on vibrating: which though it be no Defect in a Pendulum-Clock, may be one in a Pocket-watch, which is expoſed to continual Jogs. Alſo, it doth ſomewhat vary in its Vibrations, making ſometimes longer, ſometimes ſhorter Turns, and ſo ſome ſlower, ſome quicker Vibrations.

I have ſeen ſome other Contrivances of this Sort, which I mention not, becauſe they are of a younger ſtanding. But theſe two (of Dr. *Hook* and Mr. *Huygens*) I have taken Notice of, becauſe they were the firſt that ever appeared in the World.

CHAP. IX.

The Invention of Repeating-Clocks.

1. THE *Clocks* I now shall speak of, are such as by pulling of a String, *&c.* do strike the Hour, Quarter, or Minute, at any Time of the Day and Night.

§ 2. These Clocks are a late Invention of one Mr. *Barlow*, of no longer Standing than the Latter-end of King *Charles* II, about the Year 1676.

This ingenious Contrivance (scarce so much as thought of before) soon took Air, and being talked of among the *London* Artists, set their Heads to Work; who presently contrived several Ways to effect such a Performance. And hence arose the different Ways of *Repeating-work*, which so early might be observed to be about the Town, every Man almost practising, according to his own Invention.

§ 3. This Invention was practised chiefly, if not only, in larger Movements, till King *James* II's Reign: At which Time it was transferred into Pocket-Clocks. But there being some little contest concerning the Author hereof,

hereof, I shall relate the bare Matter of Fact; leaving the Reader to his own Judgement.

About the Latter-end of King *James* II's Reign, Mr. *Barlow* (the ingenious Inventor before mentioned) contrived to put his Invention into Pocket-watches; and endeavoured (with the Lord Chief Justice *Allebone*, and some others) to get a Patent for it. And in order to it, he set Mr. *Tompion*, the Famous Artist, to work upon it: who accordingly made a Piece according to his Directions.

Mr. *Quare* (an ingenious Watch-maker in *London*) had some Years before been thinking of the like Invention: But not bringing it to Perfection, he laid by the Thoughts of it, until the Talk of Mr. *Barlow's* Patent revived his former Thoughts; which he then brought to Effect. This being known among the Watch-makers, they all pressed him to endeavour to hinder Mr. *Barlow's* Patent. And accordingly Applications were made at Court, and a Watch of each Invention, produced before the King and Council. The King upon Trial of each of them, was pleased to give the Preference to Mr. *Quare's*; of which Notice was given soon after, in the Gazette.

The

The Difference between these two Inventions was, Mr. *Barlow's* was made to Repeat by pushing in two Pieces on each Side the Watch-box: One of which Repeated the Hour, the other the Quarter. Mr. *Quare's* was made to Repeat, by a Pin that Stuck out near the Pendant, which being thrust in (as now it is done by thrusting in the Pendant) did Repeat both the Hour, and Quarter, with the same thrust.

It would (I think) be very frivolous, to speak of the various Contrivances, and Methods of Repeating work, and the Inventers of them; and therefore I shall say nothing of them.

CHAP. X.

Numbers for several Sorts of Movements.

ALthough I have before given such plain Directions, as may, I hope, accomplish a young Practitioner in the Art of Calculation; yet it may be very convenient to set down some Numbers fit for several Movements; partly to be as Examples to exercise the Young Reader: And partly, to serve such, who want Leisure or Understanding to attain to the Art of Calculation.

§ I.

§ 1. But first it may be requisite, to shew the usual Way of Watch-makers writing down their Numbers, because it is somewhat Different from that more artificial Way which I directed to in Ch. 2, and which I have all along made Use of in this Book.

Their way representeth the Wheel and Pinion, on the same Spindle; not as they play in one another. Thus the Numbers of an old House-watch, of 12 Hours, they write down thus.

My Way:	The Watch-maker's Way.
4)48	48
7)56	56——4
6)54	54——7
19	19——6

According to my Way, the Pin. of Report [4] drives the Dial-wheel [48 :] the Pinion [7] plays in the Great-wheel [56] &c. But according to the other Way, the Dial-wheel stands alone ; the Great-wheel hath the Pinion of Report on the same Arbour : the Wheel [54] hath the Pin : [7] and the Crown-wheel [19] the Pin : [6] on the same Spindles.

This latter Way (although very inconvenient in Calculation) representeth a Piece of Work handsomely enough, and somewhat naturally.

§ 2.

§ 2. Numbers of an 8 Day Piece, with 16 Turns of the Barrel, the Pend. vibrates Seconds, and shews Minutes, Seconds, &c.

The Watch part.	The Clock part.
8)96	8)78
8)60—48)48—6)72	6)48 8 Pins.
7)56	6)48
—	6)48
30	

In the Watch-part, the Wheel 60 is the Minute-wheel, which is set in the middle of the Clock, that its Spindle may go through the middle of the Dial-plate to carry the Minute-hand.

Also on this Spindle is a Wheel 48, which driveth another Wheel of 48, which last hath a Pinion 6, which driveth round the Wheel 72 in 12 Hours. Note here two Things: 1. That the two Wheels 48, are of no other Use, but to set the Pinion 6 at a convenient Distance from the Minute-wheel, to drive the Wheel 72, which is concentrical with the Minute-wheel. For a Pinion 6 driving a Wheel 72, would be sufficient, if the Minute-hand and Hour-hand had two different Centers. 2. These Numbers, 60—48)48—6)72, set thus, ought (according to the last §) be thus read, *viz.* The Wheel 60, hath another Wheel 48 on the same Spindle; Which Wheel 48 divideth (playeth in,

or

or turns round) another Wheel 48; which hath a Pinion 6 Concentrical with it: Which Pinion driveth, or divideth a Wheel of 72. For a Line parting two Numbers (as 60——48) denoteth those two Numbers to be Concentrical, or to be placed upon the same Spindle: And when two Numbers have a Hook between them (as 48) 48) it signifies one to run in the other, as hath before been hinted.

In the Striking-part, there are 8 Pins on the Second-wheel 48. The Count-wheel may be fixed unto the Great-wheel, which goeth round once in 12 Hours.

§ 3. A Piece of 32 Days, with 16, or 12 Turns both Parts: the Watch sheweth Hours, Minutes, and Seconds; and the Pendulum vibrateth Seconds.

The Watch-part.

With 16 Turns.	With 12 Turns.
16)96	12)96
9)72	9)72
8)60--48)48--6)72	8)60--48)48-6)72
7)56	7)56
——	——
30	30

Or

Or thus with 16 Turns.

12)72
8)64
8)60
7)56

—

30

The Striking-part.

With 16 Turns.		With 12 Turns.	
10)130		8(128	
8)96	24 Pins. / 12)39	8)104	26 Pins. / 8)24
6)72 Double hoop		8)96 Double hoop	
6)60		8)80	

The Pinion of Report is fixed on the End of the Arbour of the Pin-wheel. This Pinion in the First is 12, the Count-wheel 39; thus, 12)39. Or it may be 8)26. In the latter (with 12 Turns) it may be 6)18, or 8)24.

§ 4. *A Two Month Piece*, of 64 Days; with 16 Turns; Pend. vibrateth Seconds, and sheweth Minutes, Seconds, *&c.*

Watch-part.	Clock-part.	
9)90	10)80	
8)76	10)65	
8)60--48)48--6)72	9)54	12 Pins. / —8)52
7)56		
—	5)60 Double hoop	
30	5)50	

Here

Here the third Wheel is the Pin-wheel, which also carrieth the Pinion of Report 8, driving the Count-wheel 52.

Or thus.

Watch-part.	Clock-part.
8)80	6)144
8)76	6)78 { 26 Pins. —— 8)24
8)60--48)48--6)72	
7)56	6)72 Double-hoop
——	6)60
30	

§ 5. A Piece of 13 Weeks, with Pendulum, Turns, and Motions, as before.

The Watch-part.

8)96 Or Thus	6)72
8)88	6)66
8)60--48)48-6)72	6)48--48)48--6)72
7)56	6)45
——	——
30	30

The Clock-part.

8)72 Or thus.	5)145
8)64—37)30	6)90 { —30 pins —24)62
8)48—12 Pins	
6)48 Double hoop	6)72
5)40	6)60

§ 6. A *Seven Month* Piece, with Turns, Pendulum, and Motions, as before.

The

The Watch.	The Clock.
8)60	8)96
8)56	8)88——27)12
8)48	8)64——16 Pins.
6)45--48)48--6)72	6)48 Double hoop
5)40	6)48
——	
30	

§ 7. *A Year Piece*, of 384 Days, with Turns, Pendulum, and Motions, as before.

The Watch.	The Clock.
12)108	10)120
9)72	8)96——36)9
8)64	6)78 26 Pins.
8)60--48)48--6)72	6)72 Double hoop
7)56	6)60
——	
30	

If you had rather have the Pinion of Report, on the Spindle of the Pin-wheel it must be 13)39.

§ 8. A Piece of 30 Hours, Pend. about 6 Inches.

The Watch.	The Clock.
12)48	8)48
——	——
6)78	6)78 13 Pins.
6)60	6)60
6)42	6)48
——	
15	

§ 9. A piece of 8 Days, with 16 Turns, *Pendulum*

Pendulum about 6 Inches, to ſhew Minutes, Seconds, *&c.*

The Watch
8)96
8)64—48)48—6)72
8)60
8)40 The Seconds Wheel. § 2.

15

The Clock may be the ſame with the 8 Day Piece before.

§ 10. A *Month Piece* of 32 Days, with Pendulum, Turns, and Motions, as the laſt.

The Watch.
8)64
8)48
6)48—48)48—6)72
6)45
6)30 Seconds Wheel.

15

The Clotk may have the ſame Numbers, as the Clock § 3.

§ 11. A *Year Piece* of 384 Days with Pendulum, Turns, *&c.* as the laſt.

The Watch part.
10)90
8)64
7)56
6)48—48)48—6)72
6)45
6)30 Seconds Wheel.

15

Or thus, with a Wheel leſs, not to ſhew Minutes and Seconds.

8)96
6)72—36)9
6)66
6)60
6)54

In the latter of these two Numbers, the Pinion of report is 36, on the Second Wheel. The Dial Wheel is 9.

The *Clock-part* may have the same Numbers, as the Year-piece before § 7.

§ 12. An 8 *Day* Piece, to shew the Hour and Minute, *Pend.* about 3 *Inches* long.

6)96	The Clock may have the
8)64—6)72	same Numbers, as the 8
7)49	Day-piece before § 2.
6)36	

19

Automata shewing the Motion of the Celestial Bodies.

§ 1 Numbers for the Motion of the *Sun* and *Moon.* See before in Chap. 2. Sect. 5. § 3, 4.

§ 2. Numbers to shew the Revolution of the Planet *Saturn*, which consists of 10759 Days.

On the Dial-wheel.	If you would make it
5)69	depend upon a Wheel
4)52	going round in a Year
4)48	thus, 10)59 or thus,
4)40	6)30
	4)118

Note, The lowermost Pinion in these, and the following Numbers, is to be fixed concentrical to the Wheel, which is to drive

drive the Motion, *viz.* the Dial-wheel, Year-wheel, or *&c.*

And it is further to be noted that the Dial-wheel is here supposed to move round once in 12 Hours.

§ 3. Numbers for the Planet *Jupiter*, whose Revolution is 4332 ½ Days. On the Dial-wheel.

4)48 Or thus, on the Year-wheel.
4)40 6)71
4)36
4)32

Note here, That the two last Numbers of *Saturn*, may be the two first of *Jupiter* also.

By the Permission of my ingenious Friend Mr. *Flamsteed*, I here insert a Description of Mr. *Olaus Romer*, the *French* King's Mathematician's Instrument, to represent the Motion of *Jupiter's Satellites*; a Copy of which he sent to Mr. *Flamsteed* in 1679, and is from his own Draught represented in Fig. 2.

Upon an Axis (which turns Round once in 7 Days) are four Wheels fixed: one of 87 Teeth, a Second of 63; the Third 42; and the Last 28 Teeth. On another Axis run 4 other Wheels (or Pinions you may call them) which are driven by the aforesaid Wheels. The first is a Wheel, or Pinion of 22 Leaves driven by the Wheel 87, which carrieth Round the first Satellite. The Second

cond is 32, driven by the Wheel 63, which carrieth round the second Satellite. The third hath 43 Leaves, driven by the Wheel 42, which carrieth the third Satellite. And lastly, is the Pinion 67, driven by the Wheel 28, which carrieth round the fourth Satellite.

On the first Axis is an Index, that pointeth to a Circle divided into 168 Parts, which are the Hours in seven Days.

On the other Axis all the Pinions run concentrically, by means of their being hollow in the Middle.

But the whole Contrivance will be best understood by an Inspection of the Figure. In which

A. B. is the Upper-plate of the Instrument.

C. D. The Lower-plate.

K. L. The *Axis*, or *Spindle*, on which four Wheels are fixed, and turn round with it, and with the Hand L. once in 7 Days. E. F. G. H. are the *Sockets*, or hollow *Arbours* of 4 Wheels running concentrically.

The hollow Arbour H. carrieth round the *First-Satellite* p. and belongeth to the Wheel or Pinion 22, before mentioned.

The hollow Arbour G. carrieth round the *Second-Satellite* q. and belongeth to the

the Wheel 32, which is driven by the Wheel 63. And the like of the *Arbours* F. and E.

Within all these hollow Arbors is another fixed one included, on the Top of which is the Ball (I) representing the Planet *Jupiter*: round which the *Satellites* move, represented by the little Balls p. ſ. t. q. Or the Spindle with the Ball (I) may be made to turn round once in 9 Hours, 56 Minutes, to ſhew the Motion of *Jupiter* on its own Axis.

This *Satellite-Inſtrument* may be added to a Clock, by cauſing the Great-wheel or Dial-wheel to drive round the Arbor K. L. once in 7 Days. To do which there are ſufficient Directions given in the preceeding Book, and therefore needeth not to be inſiſted on here.

This Inſtrument may be of good Uſe to ſuch as make Obſervations of the Eclipſes of *Jupiter's Satellites* either by Sea or Land, to give them Notice of the Appulſes of every Satellite to *Jupiter's* Shadow. For which Purpoſe it might be convenient to place a Black or Blew Plate of the Width of *Jupiter's* Diameter; behind which the Satellites paſſing, will repreſent the Immerſions and Emerſions of each Satellite and the Times when they happen.

§ 4.

4. Numbers for *Mars*, whose Revolution is 687 Days nearly.

On the Dial-wheel.

4)48 The two last Numbers of *Saturn* may be the two first of *Mars* also.
4)40
4)46

§ 5. Numbers for *Venus* whose Revolution is in $224\frac{1}{2}$ Days.

On the Dial wheel.

4)32 *Note*, The last Number of *Jupiter* may be the first of *Venus*.
4)32
4)28

§ 6. Numbers for *Mercury*, whose Revolution is near 88 Days.

On the Dial-wheel.

4)64
4)44

§ 7. Numbers to represent the Motion of the *Dragon's Head* and *Tail*, (near 19 Years) to shew the *Eclipses* of the Sun and Moon.

On the Dial-wheel. On the Year-wheel.

4)48 4)76
4)40 *Note*, the two last Numbers of *Saturn* may be the two First of this on the Dial-wheel.
4)44
4)42

As to the placing these several Motions on the Dial-plate, I shall leave it wholly to the Workman's Contrivance. Only to assist him a little therein, I shall

ſhall, for the Rarity thereof, preſent the Reader with a ſhort Account of the *Hampton-Court Clock* before mentioned, made A. D. 1540; which ſhews the Time of the Day, and the Motion of the Sun and Moon through all the Degrees of the Zodiack, together with the Matters depending thereon; as the Day of the Month, the Sun and Moon's Place in the Zodiack, Moon's Southing, *&c.*

To ſhew how compleatly (for that Age) the Wheel-work is laid under the Moving-part of the Dial-plate, I have given the Callibre thereof in Fig. 4. which repreſents the ſeveral Wheels and Pinions only, which lye under the Dial-plate, and drive the ſeveral Motions in this Manner. In the Center of all, both the Dial-plate and its Wheel-work is placed on a fixed Arbour, which hath a Pinion of 8 on the End of it, which drives both the Solar and Lunar Motions, by means of a large Wheel of 288 Teeth turning round upon it once in 24 Hours; which large Wheel is driven round by a Pinion of 12 fixed on the Arbor of the Great-wheel within the Clock, which turneth round once in an Hour. The Wheel 288 thus turning round in 24 Hours, carries about with it the Wheel 37 and its Pinion of 7 Leaves, as alſo the other pricked Wheel, and its

Pinion, on the other ſide. The Pinion 7 of the Wheel 37 drives another Wheel of 45 Teeth, which carries round the Moon's Ring or Circle. On the oppoſite ſide the aforeſaid Pinion 8 drives round the pricked Wheel, whoſe Pinion drives a Wheel of 29 Teeth, whoſe Pinion of 12 Leaves drives round the Wheel 132 that carries the Sun round, and the Zodiacal Matters.

Theſe were the Numbers of the Wheel-work remaining in the Year 1711. But the pricked Wheel and Pinion was taken out formerly, I ſuppoſe by ſome ignorant Workman that was not able otherwiſe to amend the Clock: but were ſupplied, and the whole Movement repaired lately by that ſkilfull Artiſt Mr. *Lang. Bradley* in *Fanchurch-ſtreet*, *London*.

Numbers for Pocket-Watches.

§ 1. A Watch to go 8 *Days*, with 12 Turns, to ſhew Minutes and Seconds; the Train 16000.

6)96
6)48——12)48——12)36.
6)45 On the Wheel [42] is the Se-
6)42 conds Hand placed, and on the
19 Wheel [48] the Minute Hand.

§ 2. Another of the ſame, without Minutes and Seconds, to go with only 8 Turns.

20)10

---

6)66
6)60
5)50
5)45

19

§ 3. A Pocket-watch of 32 Hours, with 8 Turns, to shew Minutes and Seconds, Train as the last.

12)48
6)48——12)48——12)36
6)45——Seconds Hand.

19

If this Crown-wheel be too large, you may use these Numbers, *viz.*

12)48
6)48
6)45
6)48 Seconds Hand.

15

§ 4. The usual Numbers of 30 Hours Pendulum Watches, with 8 Turns, to shew the Hour and Minute,

12)48
6)54——12)48——12)36
6)48
6)45

15

§ 5. The

§ 5. The usual Numbers of the old 30 Hours Pocket-watches.

With 5 Wheels.	With 4 Wheels.
10)30	6)32
———	———
7)63	6)66
6)42	5)50
6)36	5)45
6)32	———
———	17
15	

If any of the Numbers of the preceeding Wheels and Pinions should not please the Reader, he may easily correct them to his Mind, by the Instructions in the foregoing Part of the Book. The Way in short is this: Divide the Wheel by the Pinion, and so find the Number of Turns according to the Chap. 2. Sect. 1. § 2. Multiply the Pinion you like better, by this Number of Turns, and the Product is the Wheel. Thus in the 8 Day Pocket-watch § 1, if you think the Great-wheel too large, you may make it instead of 6)96(16, thus, *viz.* 5)80 (16 : *i. e.* chusing the Pinion only 5, and multiplying it by 16 (the Turns) the Wheel will be 80.

CHAP.

CHAP. XI.

Of the Government of Chronometers, *with Tables for that and other Uses in Watch-work.*

HAving led the Reader through moſt of the uſeful Matters relating to *Clock-Work*, to compleat him the more therein, I ſhall preſent him with ſome Inſtruments for the adjuſting his *Chronometers*, and ſome Tables that will be of great Uſe either in *Calculation*, or *Time-keeping.*

Of the Equation of Natural Days.

In Order to the adjuſting of Chronometrical Inſtruments, it is neceſſary to be underſtood, that the Day's of the Year are not all equal, but ſome are longer, ſome ſhorter; ſo that if a Clock was ſo nicely adjuſted, as to agree exactly with the Sun at the years End, as well as it did at the Beginning, yet would it vary at other Times. The Reaſon of which, is partly the *Eccentricity* of the Earth's Orb, by which means its Motion therein is unequal; and partly the Obliquity of the Ecliptick, by which means it comes to paſs that all Parts of the Ecliptick and Equator come not to the Meridian of any Place at one and the ſame Time; and therefore although we ſhould ſuppoſe the Earth to move equal Arches of the Ecliptick in equal Times all the Year round, yet would it come to the Meridian with unequal Arches of the Equator, by whoſe equal Revolutions the *Equal Time* is meaſured.

In meaſuring therefore of Time by the Sun, there are two Sorts thereof, the *Equal*, wherein all Days are of the ſame Length; and the *Apparent Time*, which is that which is ſhewn by Sun-Dials, &c. The Variations of which two Sorts of Time may be ſeen in the following Tables for every Day of the Year nearly enough, although the Tables are run out a few Seconds at this Preſent; which I began to correct, but found the Errour ſo little, that I thought it not worth ſo great Labour to proceed much in it.

For theſe Tables (which I examined by the Originals) the Reader, as well as my ſelf, is obliged to that great Aſtronomer Mr. *Flamſteed*, who was the firſt Man that fully demonſtrated and cleared this Inequality of Natural Days, and brought it to a certainty, although others, even *Ptolemy* himſelf had a partial Notion of it.

These

A TABL[E …]736, being Leap-Year.

1736	Jan. (Clock too Fast.)		Feb. (Clock too Fast.)		t.	Octob. (Clock too Slow.)		Nov. (Clock too Slow.)		Dec. (Clock too Slow. / Clock too Fast.)		1736
	M	S	M	S	S	M	S	M	S	M	S	
1	8	46	14	4	04	13	34	15	30	5	34	1
2	9	09	14	4	25	13	48	15	21	5	05	2
3	9	32	14	4	45	14	01	15	11	4	36	3
4	9	54	14	4	06	14	14	15	00	4	06	4
5	10	15	14	4	27	14	26	14	48	3	36	5
6	10	36	14	3	48	14	38	14	36	3	06	6
7	10	56	14	3	09	14	49	14	23	2	36	7
8	11	15	14	2	30	14	59	14	09	2	06	8
9	11	33	14	2	51	15	09	13	54	1	36	9
10	11	50	14	1	12	15	19	13	39	1	06	10
11	12	07	14	0	33	15	28	13	23	0	36	11
12	12	23	13	5	54	15	36	13	06	0	06	12
13	12	38	13	4	14	15	43	12	48	F	24	13
14	12	52	13	3	34	15	49	12	29	0	54	14
15	13	06	13	2	54	15	55	12	09	1	24	15
16	13	19	13	1	14	16	00	11	49	1	53	16
17	13	31	13	0	34	16	04	11	28	2	22	17
18	13	42	12	5	54	16	07	11	07	2	51	18
19	13	52	12	4	14	16	09	10	45	3	20	19
20	14	01	12	3	33	16	10	10	22	3	49	20
21	14	10	12	2	51	16	11	9	58	4	18	21
22	14	18	12	0	09	16	12	9	34	4	46	22
23	14	25	11	5	27	16	12	9	09	5	14	23
24	14	31	11	3	44	16	11	8	43	5	41	24
25	14	36	11	2	01	16	09	8	17	5	08	25
26	14	40	11	0	18	16	06	7	51	6	35	26
27	14	44	10	5	34	16	02	7	25	7	02	27
28	14	49	10	3	50	15	57	6	58	7	28	28
29	14	49	10	1	05	15	51	6	30	7	53	29
30	14	50			20	15	45	6	02	8	17	30
31	14	50				15	38			8	40	31

A TABLE being the Third Year

1735	Jan. M	Jan. S	Feb. M	Feb. S	Octob. M	Octob. S	Nov. M	Nov. S	Dec. M	Dec. S	1735
1	8	52	14	0	13	23	15	36	5	54	1
2	9	15	14	1	13	38	15	28	5	25	2
3	9	37	14	2	13	52	15	19	4	56	3
4	9	59	14	3	14	05	15	08	4	27	4
5	10	20	14	4	14	18	14	57	3	58	5
6	10	41	14	5	14	30	14	45	3	29	6
7	11	00	14	5	14	41	14	32	2	59	7
8	11	18	14	6	14	52	14	19	2	29	8
9	11	36	14	7	15	02	14	05	1	59	9
10	11	53	14	8	15	12	13	50	1	29	10
11	12	10	14	9	15	21	13	34	0	59	11
12	12	26	13	0	15	29	13	17	0	29	12
13	12	41	13	0	15	37	13	00	F	01	13
14	12	55	13	0	15	44	12	42	0	31	14
15	13	08	13	0	15	50	12	23	1	02	15
16	13	21	13	0	15	55	12	04	1	32	16
17	13	32	13	0	16	00	11	44	2	01	17
18	13	43	12	0	16	04	11	23	2	32	18
19	13	53	12	9	16	07	11	01	3	01	19
20	14	02	12	8	16	09	10	38	3	30	20
21	14	10	12	7	16	11	10	15	3	59	21
22	14	18	12	5	16	12	9	51	4	28	22
23	14	25	11	3	16	12	9	27	4	56	23
24	14	31	11	1	16	11	9	02	5	23	24
25	14	36	11	9	16	09	8	36	5	50	25
26	14	40	11	6	16	07	8	10	6	17	26
27	14	43	10	2	16	04	7	44	6	43	27
28	14	45	10	8	16	00	7	10	7	09	28
29	14	47		3	15	55	6	50	7	34	29
30	14	48		8	15	49	6	20	7	59	30
31	14	49			15	43			8	20	31

Jan.: Clock too Fast. — Feb.: C… too Fast — Octob.: Clock too Slow. — Nov.: Clock too Slow. — Dec.: too Slow. / Clock / Clock too Fast.

S	M	S	H				
[illegible]	4	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]
70	4	22	0	[illegible]	[illegible]	[illegible]	[illegible]
05	4	09	0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4	09	0	[illegible]	[illegible]	[illegible]	[illegible]
03	4	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]
02	4	[illegible]	0	[illegible]	[illegible]	09	[illegible]
08	4	21	0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	3	09	1	[illegible]	[illegible]	18	[illegible]
[illegible]	[illegible]	19	1	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	3	32	1	[illegible]	[illegible]	11	[illegible]
49	3	45	1	[illegible]	6	[illegible]	[illegible]
[illegible]	3	57	1	[illegible]	6	[illegible]	[illegible]
[illegible]	3	09	2	[illegible]	6	[illegible]	[illegible]
[illegible]	3	20	2	[illegible]	6	25	[illegible]
[illegible]	3	30	2	[illegible]	[illegible]	15	[illegible]
[illegible]	3	[illegible]	2	5	[illegible]	[illegible]	[illegible]
[illegible]	3	49	2	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	14	[illegible]
[illegible]	2	07	3	[illegible]	4	[illegible]	[illegible]
[illegible]	2	15	[illegible]	[illegible]	4	15	[illegible]
41	2	[illegible]	[illegible]	[illegible]	3	10	[illegible]
[illegible]	2	[illegible]	[illegible]	[illegible]	3	[illegible]	1
[illegible]	2	35	[illegible]	1	[illegible]	[illegible]	1
[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]
[illegible]	1	53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]

A TABL being the *first Year after*

1733	Jan. M	Jan. S	M	S	Octob. M	Octob. S	Nov. M	Nov. S	Dec. M	Dec. S	1733
1	9	03	1	9	13	30	15	32	5	41	1
2	9	26	1	0	13	44	15	23	5	12 Slow.	2
3	9	48	1	1	13	58	15	13	4	43	3
4	10	09	1	2	14	11	15	02	4	14	4
5	10	30	1	3	14	23	14	51	3	44	5
6	10	50	1	4	14	35	14	39	3	14	6
7	11	09	1	5	14	47	14	26	2	44 too	7
8	11	27 Fast.		6	14	58 Slow.	14	12 Slow.	2	14	8
9	11	45		7	15	08	13	58	1	44 Clock	9
10	12	02		8	15	18	13	43	1	14	10
11	12	18		8	15	27	13	26	0	44	11
12	12	34		8	15	35	13	09	0	14	12
13	12	48		9	15	42	12	52	F	17	13
14	13	02		9	15	48	12	33	0	47	14
15	13	15		9	15	53	12	14	1	17	15
16	13	27		9	15	58	11	54	1	47	16
17	13	38		9	16	02	11	33	2	17	17
18	13	48 too		9	16	06 too	11	12 too	2	47 Fast.	18
19	13	58		9	16	09	10	50	3	16	19
20	14	07		8	16	11	10	28	3	48	20
21	14	15		5	16	12	10	05	4	14	21
22	14	22		5	16	13	9	40	4	42	22
23	14	28		3	16	12	9	15	5	09 too	23
24	14	33		1	16	11	8	50	5	36	24
25	14	38		8	16	09	8	24	6	03	25
26	14	42		5	16	07	7	58	6	30	26
27	14	45		1	16	04	7	32	6	57	27
28	14	47 Clock		6	15	59 Clock	7	05 Clock	7	23 Clock	28
29	14	48		1	15	53	6	38	7	48	29
30	14	49		6	15	47	6	10	8	12	30
31	14	48			15	40			8	30	31

A TABLE *of* … *g the Second Year*

1734	Jan. M	Jan. S	Feb. M	Feb. S
	Clock too Fast.		Clock too Fast.	
1	8	58	14	48
2	9	21	14	47
3	9	43	14	45
4	10	05	14	42
5	10	26	14	38
6	10	45	14	33
7	11	04	14	28
8	11	22	14	22
9	11	40	14	16
10	11	57	14	09
11	12	14	14	01
12	12	30	13	52
13	12	44	13	43
14	12	58	13	34
15	13	11	13	24
16	13	23	13	13
17	13	35	13	02
18	13	46	12	50
19	13	56	12	37
20	14	05	12	25
21	14	13	12	12
22	14	20	11	58
23	14	26	11	43
24	14	32	11	28
25	14	37	11	13
26	14	41	10	58
27	14	44	10	42
28	14	46	10	25
29	14	48		
30	14	49		
31	14	49		

S (partial)	Nov. M	Nov. S	Dec. M	Dec. S	1734
	Clock too Slow.		Clock too Slow. / Clock too Fast.		
7	15	34	5	48	1
0	15	26	5	19	2
5	15	16	4	50	3
8	15	05	4	21	4
0	14	54	3	51	5
2	14	42	3	21	6
3	14	30	2	51	7
3	14	16	2	21	8
3	14	01	1	51	9
3	13	46	1	21	10
2	13	30	0	51	11
1	13	13	0	21	12
9	12	55	F 0	09	13
5	12	37	0	39	14
1	12	18	1	09	15
0	11	59	1	39	16
0	11	39	2	09	17
4	11	18	2	38	18
7	10	56	3	07	19
9	10	33	3	36	20
1	10	10	4	05	21
3	9	46	4	34	22
2	9	21	5	02	23
1	8	56	5	29	24
9	8	30	5	56	25
6	8	04	6	23	26
3	7	38	6	50	27
9	7	11	7	16	28
4	6	44	7	41	29
8	6	16	8	05	30
1			8	29	31

These Tables need but little Explication. If you would keep your Watch to the *Middle* or *Equal Motion* of the Sun, it muſt go ſo many Minutes and Seconds faſter or ſlower than the Sun-Dial, as the Tables ſhew. But if you would keep your Watch to go by the Sun-Dial; you may conclude it goes well, if it looſeth or gaineth every Day, ſo many Seconds as you will find in the Table. Thus (for Example) *Jan.* 1. in *Leap-year*, the Watch ought to be 8 min. 47 Sec. faſter than the Sun-Dial: on *Jan.* 2. it ought to be 9′ 10″, *&c.* If you would know on the ſame Days, whether your Watch goes well, when kept to go by the Sun-Dial if ſet on *Jan.* 1. it hath gained on *Jan.* 2. as much as 8′ 47″ wanteth of 9′-10″. *viz.* 23″ you may conclude your Watch goes well. Otherwiſe you muſt ſcrew up, or let down the *Ball* or *Corrector*, until it loſeth, or gaineth according to the Equation Tables.

The Tables will ſerve for many Years, being made for *Biſſextile*, and the 3 Years following. Therefore, knowing the Year, you may find what Table you are to uſe all that Year, whether Leap-year, or any after it.

By Reaſon of the Refractions, or ſome Errour in the Sun-Dial, it may be convenient to compare, or ſet your Watch

Watch at ſome certain Hour of the Day. Noon is a good Time for it, if you have a nice *Meridian-line*, or any Way to ſee when the Sun is exactly South, becauſe the Time of the Day is not at all then varied by the Refractions, in Dials that caſt a Shade.

Having conſidered the Equation of Time, I ſhall next ſhew ſome Ways of finding it. The Way to do it by taking the Altitudes of the Sun, and fixed Stars, I ſhall paſs by, although it be one of the ſureſt Methods, becauſe it would be neceſſary for me to launch out into Trigonometry, &c. for it. But I ſhall lay down ſome other Methods that may be ſufficient for the Purpoſe. And the firſt ſhall be

To find a Meridian-Line.

This will be of good Uſe becauſe it may happen that we may be at a Place, where there is no Sun-Dial, or not one to be relied upon; or indeed where we have a good one, it may be very uſeful to have a *Meridian-Line*. For the finding of which there are divers Ways, but I ſhall ſhew only two.

The firſt is, draw one or more Circles on ſome Plain, as on the Bottom of a

Southern

Southern Window. (Or you may make the Center on the Southern edge of the Window, and draw only half Circles.) Hang up a Thread and Plumbet exactly over, or in the Center of the Circles. By a Bead or two sliding up and down the Thread, mark out exactly the Points of the Circles, touched by the Shade of the Beads in some of the Morning Hours (the longer before Noon the better.) In the Afternoon when the same Shade of the Beads toucheth the Circles, mark that Point, or Points also. A line drawn through the Center, and in the Middle, between these two Points in the Circle, is the Meridian-line, or nearly so.

If you can't hang up a Plumbet, a Pin set exactly upright will do the Matter.

Another and better Way, is by the *Pole-Star*, when it is exactly upon the Meridian. Or if but near so, the Errour will not be great.

You may find the Time when the Pole-star comes to the Meridian, by substracting the Suns Right Ascension from the right Ascension of the Pole-Star, and turning the Remainder into Hours, Minutes and Seconds, allowing to every Degree four Minutes of Time, whereby you will have the Apparent Time, when the Pole-Star comes on the Meridian above the Pole. I scarce need

to

to observe, that the Time when it comes under the Pole is 12 Hours distant.

You may shorten your Labour by using Tables of the Sun's Right Ascension in Time, which you may find in Sir *J. Moor's Mathem. Compendium*, and other Books.

Note, If the *Sun's* R. Ascension exceed the *Pole-Star's* R. A. you must add 24 Hours to the Pole-star's R. A. and then substract. The right Ascension of the Pole-star is determined by Mr *Flamsteed* 0h 33′. 44″ of Time in the Year 1690, and the increase of its R. Ascension 1′. 16″ of Time in 10 Years. Therefore this present Year 1731 its true R. Ascension is 0h 38′ 55″ of Time.

If the unlearned Reader should think this way difficult, he may see when the *Pole-Star* comes near the Meridian, by hanging up a Line and Plumbet, and observing when the first Star in the *Great-Bear's* Tail, next her Rump, comes under the Line on one Side of the Pole, or when the Plumb-line nearly approacheth the Star in *Cassiopeia's* Knee on the other Side of the Pole.

When the *Pole-star* is found to be on the Meridian, if you hang up two Strings with Plumbets, between the *Pole-star* and your Eye, this will be a *Meridian-line*, to see when the Sun comes to the Meridian. Or you may do it with a

Crevis

Crevis between two Boards, or Plates of Metal, almost touching one another.

But much the best Way which I have yet thought of, and which is exceedingly Nice, is with the Instrument, Fig. 3. which is thus made. At each End of a Board, or rather small flat Iron-bar (A. B.) fix two upright Sights: one with a very small Hole (a. b) to look through to the Sun; the other (c. d) with a large Hole, to look at the Pole-star. Not far from the Sights, on the same Bar, fix two Arms (C.D, C.D) to bend off, so as to be out of the Way of the Sights, when you look through them. On the Top of these Arms, place a small Rod of Iron or Wood, to turn with a joint at D. which Rod is to bear the Plumb-lines (E. F.) and to turn backward and forward, so as to bring the Plumb-lines to the Sights at any Time. Place this Instrument on a Pedestal (G. H.) to turn round on it stiffly.

Your Instrument being thus prepar'd, Plant it in some convenient Place, where you may see the Pole-star, by Night, and the Sun by Day. When the Pole-star is on the Meridian, look thro' the Sight with the bigger Hole, and turn the Whole Instrument about until you see the opposite Plumb-line intersect the Pole-star. Take care at the same Time, that the Plumb-lines hang so as to interſect the Sights. Your Inſtrument, thus placed, ſtandeth nicely on the Meridian, ſo as to ſee when either Sun, Moon or Stars come thereon.

When you look by Night, it is neceſſary that a Candle ſhould ſhine on the Plumb-line, that you may ſee it.

If you look at the Sun, you muſt guard your Eye againſt the Sun-beams with a coloured Glaſs, or one blackened with the ſmoke of a Candle.

I had almoſt forgotten, to ſay that it Matters not much what Length the Bottom-piece, A. B. is of (but the longer the better) provided that the Plumb-lines are high enough to ſee the Pole-ſtar, and the Sun in the Summer Solſtice, or any time of the Year. If the Bottom-piece be 2 Feet long, the Plumb-lines had need to be near 4 Feet.

This Inſtrument is very ſerviceable to ſeveral Purpoſes; particularly 1. To ſee the *Southing* of the Sun, or Moon: which you may do with great exactneſs. You may ſee nicely when the very edge of the Sun or Moon toucheth the Meridian, and whilſt all their Body is paſſing it.

2. You may ſee what Stars are, at any Time, on the Meridian, either Northward or Southward, and ſo find the Hour of the Night. To do which when any Star is on the Meridian, Subſtract

tract the Right Aſcenſion of the Sun from the R. Aſc. of the Star, the Remainder is the Hour of the Night, when turned into Time.

3. You may with all exactneſs continue your Meridian-line for many Miles, if you pleaſe, by looking through either Sight, and ſeeing what Objects the Plumb-lines interſect.

4. If you would be ſtill more nice, you may apply a *Teleſcope* to this *Meridian Inſtrument*, by placing, for the Eye-glaſs, a convex Glaſs, of a convenient *Focus*, at a due Diſtance between the Plumb-line and either Sight, ſo as thro' the Sight to ſee the Plumb-line through the Convex glaſs (or Eye-glaſs.) And at a convenient Diſtance from the Inſtrument, place another Convex-glaſs for the Object-glaſs.

5. If I am not much miſtaken this *Meridian Inſtrument* may as well (and being made Teleſcopulous) much better ſerve the Deſign of trying whether the Meridian differeth or not; which ſome have experimented with more Trouble and Expence than this Inſtruments comes to.

6. This Inſtrument is very eaſily brought to the Meridian. For whether it ſtands upright, aſide, or any other way, ſtill the Plumb-lines may be brought eaſily to their due Place.

7. This Instrument is prepared with little Cost or Trouble; it may be carried from Place to Place; or imitated where-ever there is Occasion to correct either Sun-Dial or Watch.

This Instrument may be found improved by Mr. *Derham* in the *Philosoph. Trans.* Nr. 291, together with a Cut shewing when the Pole-star comes to the Meridian.

I would present the unskilful Reader with a Table of the Appulses of the Pole-star to the Meridian; but it will hold for so little a Time true, that it is not worth the while.

The Way to govern a Clock by the Fixed Stars.

Monf. la Hire in his *Tabulæ Astron.* hath given us two Tables of the Difference between the Solar and Sydereal Day. The latter and most correct of which is this following.

A Table

A Table shewing how much the Solar is longer than the Sydereal Day.

Re.	M S T	Re.	H M S T
1	3. 55.53	16	1. 2. 54. 11
2	7. 51.46	17	1. 6. 50. 4
3	11. 47.40	18	1. 10. 45. 58
4	15. 43.33	19	1. 14. 41. 51
5	19. 39.26	20	1. 18. 37. 44
6	23. 35.19	21	1. 22. 33. 37
7	27. 31.12	22	1. 26. 29. 30
8	31. 27. 6	23	1. 30. 25. 24
9	35. 22.59	24	1. 34. 21. 17
10	39. 18.52	25	1. 38. 17. 10
11	43. 14.45	26	1. 42. 18. 3
12	47. 10.38	27	1. 46. 8. 56
13	51. 6. 32	28	1. 50. 4. 50
14	55. 2. 25	29	1. 54. 0. 43
15	58. 58.18	30	1. 57. 56. 36

Explanation of the Table.

This Table ſhews how much the Sidereal goeth faſter than the Solar Day, in any Number of Nights for a Month: So that obſerving by your Watch the nice Time when any fixed Star cometh to the Meridian, or any other Point of the Heavens: if after one Revolution of that ſame Star to the ſame Point, your Watch goeth 3′ 56″ ſlower than the Star; or after two Nights 7′, 51″; or 16 Nights, 1 Hour 2′. 54″, &c. then doth your Watch keep Time rightly with the mean Motion of the Sun. If it varieth from the Table, you must alter the Length of your Pendulum to make it so keep Time.

For observing the Time when the Star cometh again to the same Point of the Heavens, you may make Use of your Meridian Instrument last described; or if you would be more exact and nice, you may make Use of a Telescope, such as is used for the Sights of Quadrants, &c. which consists commonly of an Object, and an Eye-glass, with Cross-hairs in the common Focus of both Glasses. Having observed with this Telescope the Transit of any fixed Star Cross the Hairs, leave the Telescope in that Position until as many Revolutions of the Star are past, as you are minded to take Notice of.

Of the Time of the Day shewn by Sun-Dials.

Forasmuch as by the Refractions the Sun appears higher than really he is, therefore all the Sun-Dials which shew the Hour by the Sun's Height, go not exactly true. The Quantity of which is shewn in this Table.

A TABLE

A TABLE shewing the Variations made in the true Hour of the Day, by the Refraction of the Sun in the Equator, and both the Solstices.

Sun's alti-tude Deg.	Sun's Refra-ction. ′ ″	Variation at the N. Solstice. ′	″	Variation at the E-quator. ′	″	Variation at the S. Solstice. ′	″
0	33.00	4	34	3	32	4	38
1	23.00	2	34	2	28	3	19
2	17.00	2	24	1	49	2	31
3	13.30	1	46	1	27	2	3
4	11.30	1	29	1	12	1	40
5	9.30	1	12	1	1	1	33
6	7.30	0	56	0	49	1	17
7	7.00	0	52	0	44	1	16
8	6.00	0	43	0	39	1	8
9	5.00	0	36	0	34	1	2
10	4.40	0	25	0	29	1	2

Remarks upon the Table.

The Refractions, although in the Table they are the same, yet do differ at different Seasons of the Year, nay perhaps, according to the different Temperature of the Air sometimes, in the same Day. Thus Mr. *Flamsteed* found the Refractions in *February* very different from those in *April*: and it is observed, that the Refractions are commonly greater, when the *Mercury* is higher in the Barometer.

The Table therefore doth not ſhew what the Refractions always are, but only about the middle Quantity of them at every Degree, of the 10 firſt of the Sun's Altitude. And accordingly I have calculated the Variations thereby made in the Hour of the Day.

Theſe Variations of the Hour are greater or leſſer, according as the Angle of the Sun's diurnal Motion is Acuter with the Horizon. The Reaſon is plain; becauſe as the Sun appears by Refraction higher than really he is; ſo that falſe Height doth affect the Hours in Winter, more than the Summer half Year.

There is no Ray indeed of the Sun, but what cometh refracted to a Sundial, and conſequently, there is no Dial but what goeth more or leſs falſe (except at Noon in Dials that caſt a Shade, where the Refraction makes no Variation.) But the Refraction decreaſeth apace, as the Sun gets higher, and cauſeth a Variation of not above half a Minute at 10 Degrees of the Sun's Altitude; except when the Sun is in, or near the Southern Tropick. Nearer than half a Minute, few common Sundials ſhew the Time. And therefore I have calculated my Table to only 10 Degrees. The

The Table needs little Explication. For having the Sun's Height, you have against it, in the next Column, the Refraction: and in the 3 next the Alterations of the Hour, at 3 Times of the Year. Taking therefore by a Quadrant the Sun's Altitude, and observing at the same Time, the Hour of the Day by a Sun-dial; by the Table, you see how many Minutes, and Seconds, the Dial is too fast, or too slow. As at the Sun-rising a Sun-dial is too fast, or too slow, 4'. 34', about *June* 11, and 3'. 32'', about *Mar.* 10. and *Sept.* 12, and 4', 38'', about *Dec.* 11.

A Table of the Parts of Time.

Since in Calculation there is frequent Occasion to make Use of the Parts of Time, I have added the following Table, which at one View exhibits the Parts of Time, without any troublesome Operations of Reduction.

Seconds.						
60	Minutes					
3600	60	Hours				
86400	1440	24	Day			
604800	10080	168	7	Week		
2592000	43200	720	30	4	Month	
31556940	525949	8765	365¼	52		Year

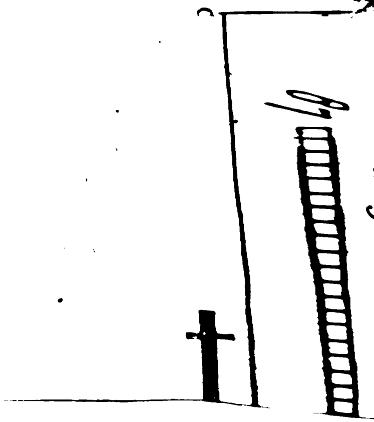
This

This Table is easily understood. For in the Concurrence of the Squares is the Quantity of the Time set over, or against each Square. As for Example; in a Minute are 60 Seconds: in an Hour are 60 Minutes, and 3600 Seconds: in a Year are 31555 &c. Seconds, 525 &c. Minutes, &c. So that if we would readily see what Number of Seconds are in a Year (for Instance,) under *Seconds*, and against *Year*, is the Number sought. And so of the Rest.

But here it is to be noted that the Seconds, Minutes, and Hours in an Year are the true Numbers, according to the before commended Mr. *Flamsteed's* Determination of the Length of the Year, *viz.* That the Year is 365 Days 5 Hours 49 Minutes, and no Seconds.

If you would know any Number, where an odd Number is to be added, as the Seconds in a Month and one Day, add the Seconds in a Month, and the Seconds in a Day together, and the Sum is the Number sought, which is 2678400. And so for the Rest.

The END.



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