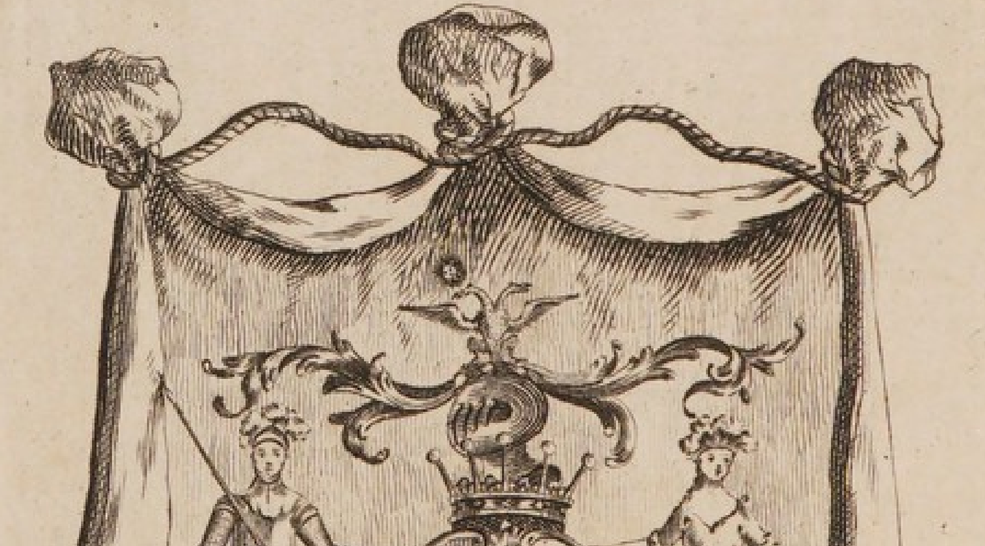
I BIDE MY TIME
John Earl of Loudoun.

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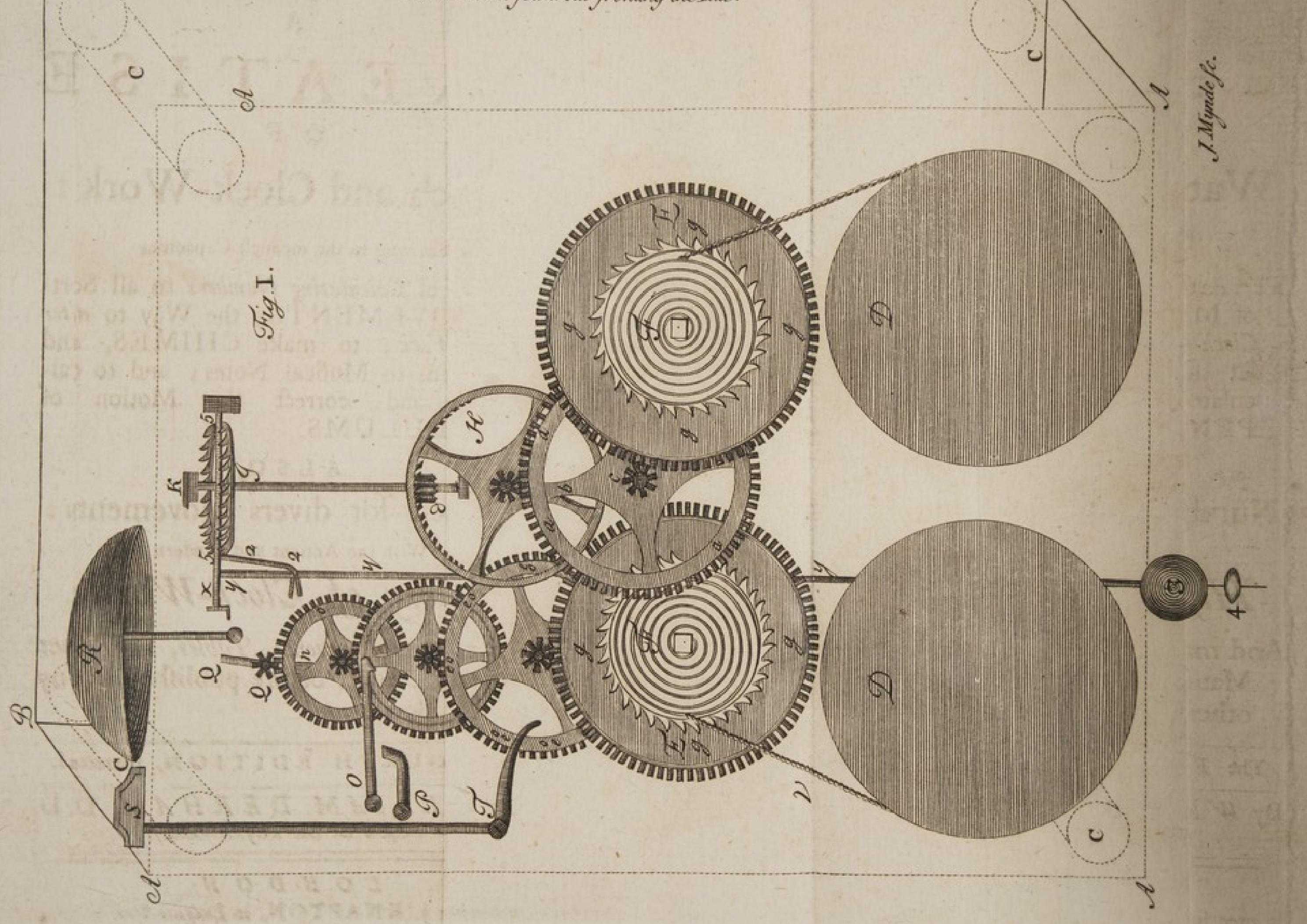


THE
Artificial Clock-Maker.
A
TREATISE
OF
Watch and Clock-Work:

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, corrected.

By *WILLIAM DERHAM*, D.D.
Fellow of the Royal Society.

LONDON:
Printed for J. KNAPTON, in *Ludgate-Street*. 1759.

TO THE
READER,
Concerning the Third Edition.

ALTHOUGH 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 third 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 Apprentices, but also among many Gentlemen and others, that delight in Mechanical Studies and Exercises: to whom it hath been an innocent and virtuous 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 itſelf, 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 PREFACE.

THE following Book was at firſt drawn up in a rude Manner, only to pleaſe myſelf, and divert the vacant Hours of a ſolitary country Life. But it is now publiſhed, purely in hopes of it's 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 virtuous) Sport of leiſure Hours; I think myſelf excuſable to God and the World, for the Expence of ſo much Time, in 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 (although 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

publiſh this Book, *viz.* Becauſe no Body, that I know of, hath prevented 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 Inventor of Automatical Computation.

But altho' 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 *Horological Dialogues*, in 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 *Jonas Moor*, with some Additions of his own; which you have in his *Math. Compend.* and since him, by Mr *Leybourne*, 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

added ſeveral other Things of my own: particularly the Calculation of the Clock-Part, *&c.* which I myſelf have reduced to Rules. And to name no 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 preceding Account of what others have written (which ſhews what help I have had from printed Books) I ſhall ſubjoin my Acknowledgments and Thanks to the principal of my Friends, who have given me their Aſſiſtance in compiling ſome Parts of this Book. In the Chapter of the Terms of Art, I owe much to the Aſſiſtance of Mr *Langley Bradley* a judicious Workman in *Fenchurch-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 *Hook* and Mr *Tompion*: The former

former being the Author of ſome, and well acquainted with others, of the Mechanical Inventions of that fertile Reign of King *Charles* II. 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-Engines*, (which was Dr *Hook*'s) *Fuſy-Engines*, and and others, which were never thought of 'till towards the End of King *Charles* the II's Reign. To treat of all theſe, would ſwell my Book far beyond it's 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 Gentlemen, 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 pretended 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, 'tis pity that it ſhould not be remembered: eſpecially when we cannot but lament the great Defect of Hiſtory, about the Beginning and Improvements of this ingenious and uſeful Art.

THE CONTENTS.

CHAP.

The

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 it's 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-Arbor*; to which the Spring is hooked at one end. At the top of the Spring-Arbor, is the *Endleſs-Screw*, and it's Wheel: but in Spring-Clocks it is a *Ratchet-wheel* with it's *Click* (that ſtops it).

That which the Main-Spring draweth, and about which the Chain or String is wrapped, 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 *Gardegut*.

The parts of a *Wheel* are, the *Hoop*, or *Rim:* the *Teeth:* the *Croſs:* and the *Collet*, or piece of Braſs, ſoddered on the Arbor,

Arbor, or Spindle, on which the Wheel is riveted.

A *Pinion* is that little Wheel, which plays in the Teeth of the Wheel. It's 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 Clock 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 *Ballance*: whoſe parts are, the *Rim*, which is the circular part of it: the *Verge*, is it's 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 Ballance-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 Ballance-wheel turns) is called the Noſe; the upper-part, the *Shoulder* of the Portance. The piece which covers the Ballance, and in which the upper Pivot of the Ballance plays, is the *Cock*. The ſmall Spring in the new Pocket-Watches underneath the Ballance, 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

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 Braſs, called the *Flatt*, in which the lower end of the *Spring* is faſtened.

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

The *Contrate Wheel*, is that Wheel in Pocket-Watches, and others, which is next to the Crown-Wheel, whoſe Teeth and Hoop lie contrary to thoſe of other Wheels: whence it hath it's Name.

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

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

The laſt part which I ſhall ſpeak of is the *Clock*, which is that part which ſerveth to ſtrike the hours: In which I ſhall

Firſt ſpeak of the *Great*, or *Firſt-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

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 *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 *Safegards*, 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 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. The *Fan*, and *Flying-Pinion.*

R. The *Bell.*

S. The *Hammer.*

T. The *Hammertails.*

V. V. The Chain, or String of the Watch and Clock.

x. The *Verge* or *Spindle* of the Ballance, 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 it's nice *Vibrations.*

5. 5. The *Pallets.*

CHAP. II.

The Art of Calculation.

SECT. I.

General preliminary Rules and Directions for Calculation.

§. 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 Ballance 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.

§. 2. And in the firſt place, you are to know, that any Wheel being divided by it's Pinion *, ſhews how many *turns* that Pinion

* *Oughtred* of Autom.

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 Ballance 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 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 upper most 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, $\frac{4}{36}$ $\frac{55}{5}$ $\frac{45}{5}$ $\frac{40}{5}$ 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 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

* By the Quotients, I commonly mean the number of Turns; which number is ſet on the right hand, without the

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 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 Arbor 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 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

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

the hook, as is shewn in the last Paragraph: Which I note here now once for all.

8)80(10
6)54(9
5)40(8
———
15

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 Pinion 5 (which is the Pin of the Crown-Wheel 15) turns 720 times in one Turn of the firſt Wheel, of 80 teeth.

§. 5. We may now proceed to that, which is the very Groundwork of all; which is, not only to find out the Turns, but the Beats alſo of the Ballance 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 it's number of Notches, and this will give you half the number of Beats, in 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-

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 Ballance, 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. 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 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

4)32(8

---

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

17

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; my deſire to inſtruct the moſt

ignorant

ignorant Artist, must plead my excuse.

§. 6. The Ballance or Swing hath two strokes to every tooth of the Crown-Wheel *. For each of the two Pallets hath it's blow against each tooth of the Crown-Wheel: wherefore a Pendulum that swings Seconds, hath it's 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, tho' 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 Pinion of 5; or as a Wheel of 90

* Sir *J. Moor*'s Math. Comp. p. 116.

drives a Pinion 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 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 3 Pinions: you may make uſe of 3 Wheels of 36, 8, and 5, and 3 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 multiplied, 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 affect the ſame Number 51 $\frac{3}{7}$ Turns, will perform the ſame

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 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 multiplyed 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 Pro-

* Oughtred, Autom. §. 23.

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

9 8
36 × 8
4 1
———
32 × 9

If this Rule ſeem to the unſkilful Reader hard to be underſtood, let him not be diſcouraged, becauſe he may do without it, altho' 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 four 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. 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 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

* Id. ibid. Sect. 24.

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

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*

* See Sect. 4.

1. *To find what Number of Turns the Fusy will have*, thus *: As the Beats of the Ballance in one turn of the great Wheel or Fusy (suppose 26928) to the Beats of the Ballance in one Hour (suppose 20196) : : So is the Continuance of the Watch's going in Hours (suppose 16) to the Number of the Turns of the Fusy 12. In Numbers it will 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.

2. *By the Beats and Turns of the Fusy, to find how may Hours the Watch will go:* Thus,

As the Beats of the Ballance in one Hour, are to the Beats in one Turn of 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 Ballance in in one Turn of the Fusy:* say, As the Number of Turns of the Fusy, to the Con-

* *Oughtred*, Sect. 18. Sir *J. Moor*, ibid. p. 109.

tinuance 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 Ballance in an Hour:* ſay thus, As the Hours of the Watch's 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 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

the Hours of the Face be 24, the Quotient will be 18; thus, 16. 12 :: 24. 18.

N. B. This Rule may be made ſerve to lay the Pinion of Report on any other Wheel thus, As the Beats in one Turn 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 Ballance 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 of Turns you intend your Fuſy ſhall have,

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 Ballance, 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 Ballance 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 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 Ballance. 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

Number of Beats in an Hour, ſay by §. 6. part 4. of this Section. 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 Section. 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 it's Quotient; therefore 4 times 9, which makes 36, is the Number for the Dial-Wheel.

Wheel. So the next Pinion being 5, and it's 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. 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.

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.

* *Oughtred,* Sect. 28.

The

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 it's 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,

before, and with 17, maketh 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 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.

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

* Sect. 1. §. 3.

	As 144 is to 170 :: So is
24)20($\frac{20}{24}$	360 to 425. Or As 170
———	to 144 :: So is 360 to 305.
6)60(10	In Numbers thus, 144.
6)48(8	170 :: 360. 425. Or 170.
5)40(8	144 :: 360. 305. Divide
5)33(6$\frac{3}{5}$	360, and either of these
———	two fourth and last Num-
17	bers 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 $\frac{38}{45}$. 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.

§. 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 design-ed Train into 60 Parts. And according-ly you are to find out such proper Num-bers for your Crown-Wheel, and Quo-

tients,

tients, 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, 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)64(8
8)60(7½
8)40(5
———
15

* Ch. V. § 4. † Sect. 1. §. 6.

6, or 8 and 7 $\frac{1}{2}$, or *&c.*) and the Work is done.

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 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

* §. 6. Par. 3. §. 7.

forms 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 it's Revolutions. Divide 21600 by it, and 720 is the Quotient, or Number left to be broken into 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 Quo-

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

tients, 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 preceding 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

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 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 Section.

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

Rule

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 3. *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 (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 Pinion of Report on the Spindle of the great Wheel.

As the Number of Strokes in the Clock's Continuance, or in all it's 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 Arbor of the great Wheel,

But

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

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

* §. 1. Inf. 2.

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 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 preceding 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 it's 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

ber 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 Pinion of Report, and the reſt of the Wheels, enough is ſaid in §. 1.

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 1. 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 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, for Wheels and Pinions, or as near as can be: which may be 7 and 5, or 6 and $6\frac{1}{2}$. The latter is exactly 39, and may therefore ſtand: as you ſee in the Margin.

10)65($6\frac{1}{2}$
8)48(6
6)48(8 pins

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.

please. If you fix your Pinion of Report on the great Wheel-Arbor, 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 Clock's 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 Nnmbers 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 of the more useful 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. Which is little enough for one Quotient; and may therefore stand as you see is done in the Margin:

8) 104(13
6) 72(12.24 pins

where

where the Quotient of the firſt Wheel is 13. In the ſecond Wheel of 72 Teeth, are the 24 Pins, altho' it's 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 Arbor of the great Wheel. But if you fix it on the Arbor of the ſecond, or Pin-Wheel, it's 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 $3\frac{1}{4}$. 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 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 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.

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, 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

* Sect. 2. §. 4.

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 16 $\frac{1}{2}$. For 3744. 156 :: 395. 16 $\frac{1}{2}$ 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 12 and 12 $\frac{1}{3}$ for his two Quotients: in which Caſe, the Work will be as it ſtands in the Margin.

10)120(12
6) 74(12$\frac{1}{3}$
78 | 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 for the better exerciſing the Reader, let us fix it upon the Spindle of the ſecond

ſecond Wheel 96. It's 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. 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

and unlock; nor of the Wheels to bridle the Motion of the Barrel, that 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 Bars, 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 beat 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 quarter, half, or $\frac{3}{4}$ of a Semibrief, or the Diſtance between each Bar. Concerning ths 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 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

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 the next place, you are to divide it (round about) into as many Diviſions, as there are muſical Bars, 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.

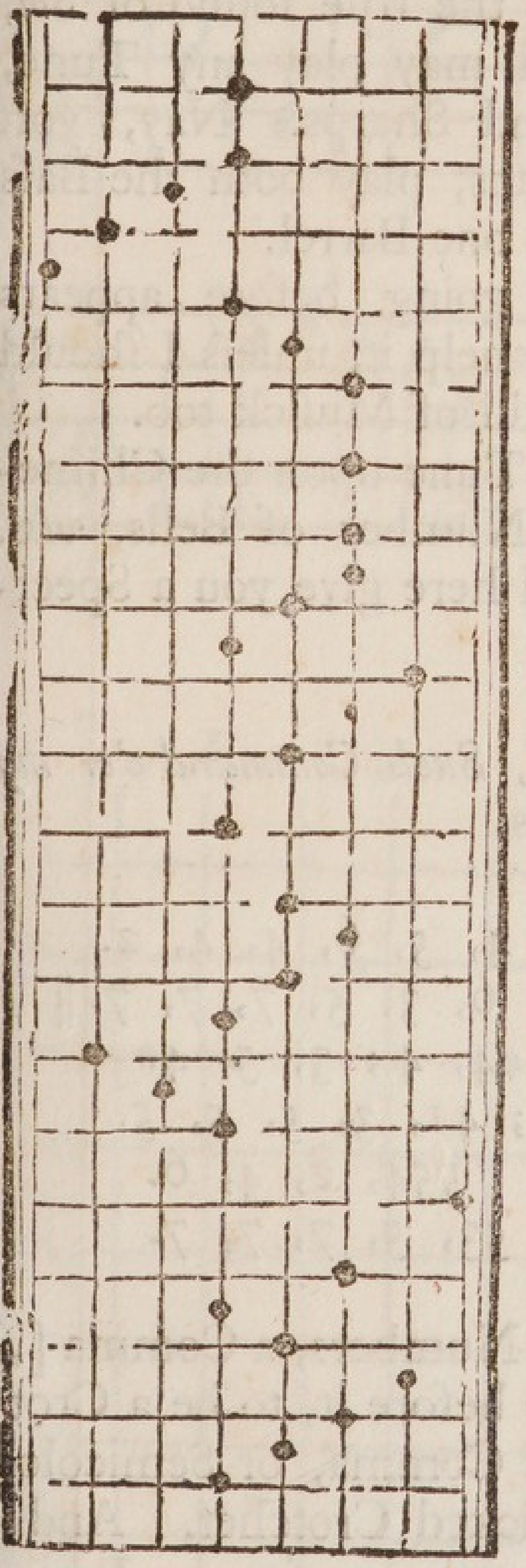
From what hath been ſaid, you may conceive the ſurface of a Chime-Barrel to be repreſented in theſe Tables, as ſtretcheth out at length: or (to ſpeak plainer) that if you wrap either of theſe Tables round a Barrel, the Dots in the Table, will ſhew the Places of the Pins to be ſet on the Barrel.

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 it's 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.

A Table of Chimes to the 100 Psalm.

8 7 6 5 4 3 2 1



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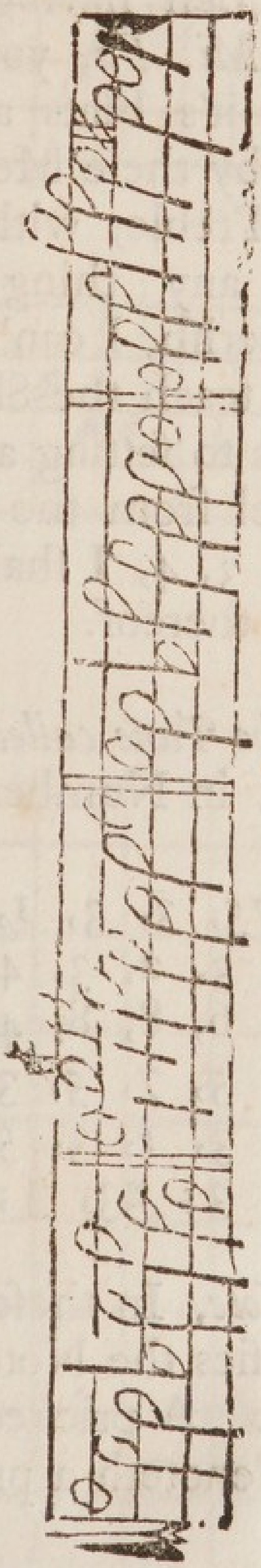


The Musical Notes of Psalm 100.

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 it's 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.

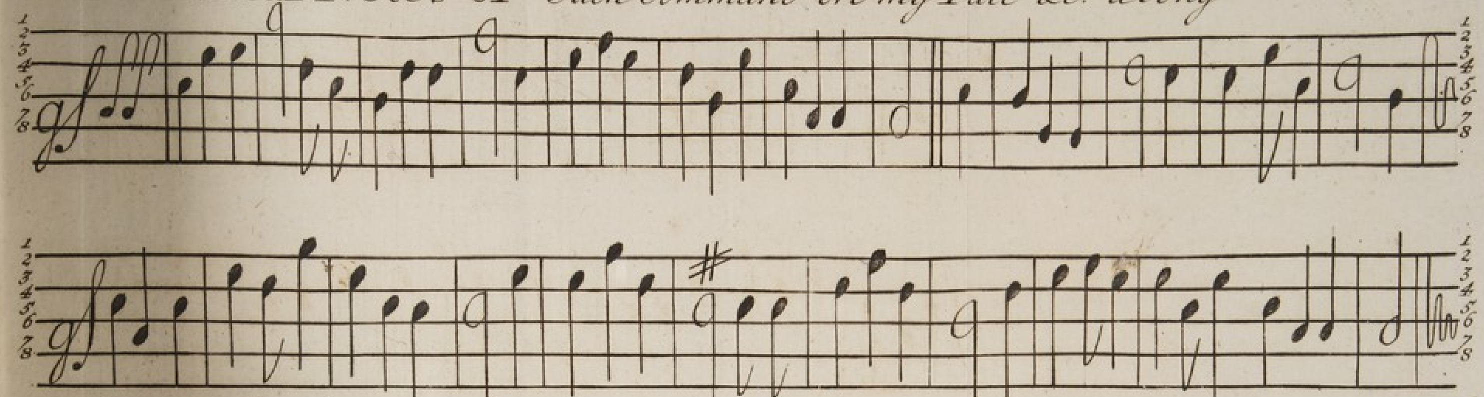
The Tune called, Such Command o'er my Fate, in Numbers.

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.

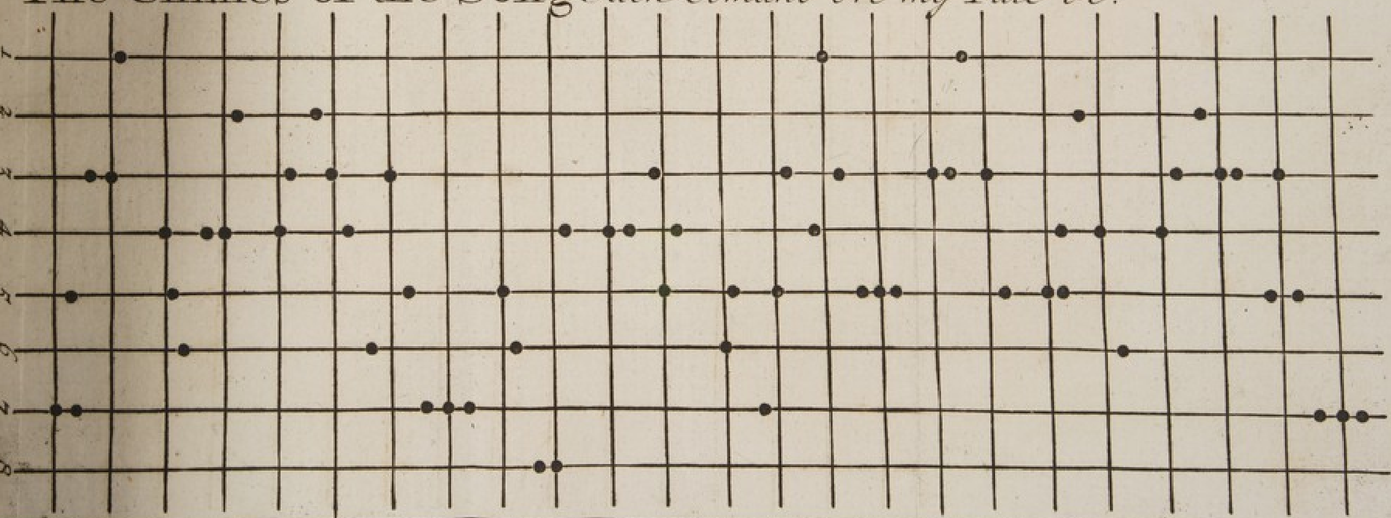
Note, In theſe Numbers, a Comma [,] ſignifies the Note before it, to be a Crotchet. A pricked Comma, or Semicolon [;] denoteth a pricked Crotchet. And a Period

fronting page 56.

The Musical Notes of *Such Command o're my Fate &c. a Song*



The Chimes of the Song. *Such Comand o're my Fate &c.*



I. Senex sculp.

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. V.

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 Ballance or Pendulum.

If

If the latter way, you muſt however contrive a Piece (as before in Watch-Work) to go a certain Time, with 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 repreſent the Synodical Revolution of the Moon, (which is 29 Days, 12 $\frac{3}{4}$ 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 $\frac{3}{4}$ Hours) by 43200 (the Beats in one Turn of the great Wheel) and you will 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,

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 Pinion of Report) to specificate your Revolution, by this following Rule.

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 will be 193824. For as 26928, To 20196 : : So 258432 (the Hours in 29 Years and 183 Days) 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

* Chap. II. Sect. 2. §. 7.

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 $15\frac{1}{2}$ and 4; which multiplied together make 62. Therefore chuſing your Wheels and Pinions, as hath been directed in the former Sections, 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

4)62($15\frac{1}{2}$
5)20(4

* Oughtred, §. 32.

a Wheel, you may take 10 for the Pinion, and 40 for the Wheel, as in the Margin.

4)62(15½
10)40(4

The Work will lie 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 it's center, which carrieth about a Ring of 62 Teeth, divided on the upper side 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.

§. 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 above an half. This 29 ½ Days (not regarding the small excess) makes 59 twelve Hours, or Turns of the Dial-Wheel,

* Id. ibid. §. 33.

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. 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.

10)59(5.9	4)59(14$\frac{3}{4}$
4)40(10	10)40(4

§. 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* *.

The double of 365 is 730, the Turns of the Dial-Wheel in a 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. So that a Pinion of

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

* Id. ibid.

of 5 is to lead a Wheel of 20; which again by a Pinion of 4, leadeth a Wheel of 40; which 3dly by a Pinion of 4, carrieth about a Wheel 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 *Oughtred's* *Opuscula* *, or it may be done from any well calculated Almanack.

§. 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 South lost, 45 Minutes of an Hour. Thus at *London-Bridge* 'tis vulgarly thought to be high Tide, the Moon at North East and South West, which are 4 Points from the North and South. Or you may do thus: by Tide-Tables,

* Autom. §. 35. Id. ibid. § 37.

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 from the Moon's Southing; or at 3 o'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 Reader's contrivance, it being eaſy; 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.* X. 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 Year's Motion; 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.

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 *Apogæum*, 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 4 Wheels, 20, 73, " 24, and 75, wrought by endless Screws " that are in Value but one; therefore

* Mat. Comp p. 117.

" 3, 10, 73, 24, and 75, multiplied toge-
" ther continually, produceth 7884000
" Hours *, which divided by 24 gives
" 3285000 Days, equal to 900 Years.
" Now on the laſt Wheel 75 is a Pinion
" of 6, turning a great Wheel, that car-
" rieth the *Apogæum* Number 114: and
" and 114 divided by 6, gives 19 the
" Quotient: and 900 times 19 is 17100
" Years."

Thus I have, with all the perſpicuity 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

* V. Sect. 1. §. 4, 5. † De Sub. il. l. 17.

elaborate and curious Pieces of Mr *Watſon*, Mr *Tompion*, and another very lately of Mr *Rowley*.

CHAP. III.

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

THIS Chapter I deſign for the uſe ſuch, as would convert old Ballance Clocks into Pendulums, or would make any old Work ſerve for 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 Ballance 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.

4)48(12
7)56(8
6)54(9
19

The Quotients and Crown-Wheel, and two Pallets multiplied together continually; produce 2736, which are the Strokes of the Ballance, 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. V. §. 4. following; according to which the Number is, 9204. Divide this by 2736, and you have the Quotient,

2736)9204($3\frac{2}{5}$

which is to be added to the Scheme of the old Work. This Quotient is 3 and near $\frac{2}{5}$ as you see in the Margin. But to avoid the trouble of Fractions, let us take it 3 $\frac{1}{2}$.

The

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

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

4)48(12
———
7)56)8
6)54(9
6)21(3 ½
—
19

§. 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 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 the Contrate-

 Wheel.

* V. Sect. 1. §. 6.

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 Ballance 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 v. 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 of 8, for the Contrate-Wheel. Thoſe multiplied, as was now directed, make 21888, for the Beats in one Turn of 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 Section, Part 1, in Numbers thus, 21888.9368 : : 30.13 almoſt. So that 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 Pinion of Report. But if the Train exceeds the Beats of the great Wheel, you muſt chuſe the Pinion 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. II. 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 Pinion 28 being ſet upon the Spindle of the great Wheel, will drive a Wheel 12 round once in an Hour, to ſhew Minutes. If (as in the Movements in Chap. X.) you make this Wheel 12. drive another of 48; concentrical to which, is a Pinion 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 Pinion 28 on the Spindle of the great Wheel ſo as to ſlide round ſtiffly, when you turn the Minute-Hand to rectify 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.

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, that the Pin-Wheel may ſtrike two Strokes, in it's going round once.

4)39(9 $\frac{1}{4}$

---

7)56(8 pins
6)54(9
6)48(8

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, it will be neceſſary to be content with the old Numbers, or make more Wheels and Pinions new, than may be thought worth the while.

If

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

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

5)24($\frac{7}{1}\frac{8}{6}$
———
7)56(8.16 pins
6)54(9
6)48(8

CHAP. IV.

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

§. 1. FOR the exact and eaſy 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

rower than the Teeth of it's 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 (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.

Now

* 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 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 'till 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 governed 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 3 *lb.*) with ſuch a *Regulating Bob* underneath as is deſcribed §. following, and is repreſented in Fig. 1. Numb. 4.

This Clock having for ſome Years kept time as well as could be expected, I hung upon it's Weight an Addition of

6 Pound

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 Cleanneſs, 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 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

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 my Experiments made on Pendulums in the Air-Pump, in *Philoſophical Transactions*, 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 'till 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 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 it's 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*.

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.

§. 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

* Mat. Comp. Rule 3.

† De Horol. Oſcil. p. 10, 11, 12.

Wheel Pendulums go faster in cold Weather, or when foul, than at other times.

§. 3. For the Calculation of all Pendulums, 'tis necessary to fix upon some one, to be as a standard to the rest. I pitch upon a Pendulum to vibrate Seconds each stroke.

Mr *Huygens* lays down the length of a Pendulum 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) *.

" The Honourable Lord *Brouncker*, " (saith Sir *Jonas* †) and Mr *Rook*, found " the length to be 39.25 Inches, which " a little exceeds the other: and may be, " was justened by Mr *Huygens*'s Rule " for the Center of Oscillation. 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 Pendulum that shall " swing Seconds each Vibration."

But forasmuch as the different Size of the Ball, will make some Difference in

 the

* Ibid. † Ibid.

the length of this ſtandard Pendulum, therefore to make this Pendulum an *Univerſal Meaſure*, to fit all Places and Ages, you muſt meaſure from the Point of 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*.

If it be deſired to fit a Ball of a Triangular, Quadrangular, or any other form to this Pendulum, 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.

* Huygenius, ubi ſupra, p. 141. Sir J. Moor, ibid.

§. 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 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 Vibrations 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, 'tis 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 Pendulum 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 Pendulum then that vibrates 153 in a Minute, is about 6 Inches long.

* Huygens, Moor, ibid.

On the other Hand, if you would know how many ſtrokes a Pendulum 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 will much contract your Labour. For if you ſeek the length, 'tis 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

To find the Length.

	Logarithms.
141120 ———————	5.1945886
153 ſquared is 23409 or (which is the ſame thing, and moſt ready) it's 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 Vibrations——	4.3714374
Square Root, or Number of Vibrations is 153, and ſomewhat more.	2.1857187

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	216,9	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 without them, and would not have been exactly true without them.

§. 5. I have but one thing more to add to this Chapter of Pendulums, and that is, *To correct their Motion.*

The

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 ſtrait 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.

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 Pendulum 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 Pendulum pretty near it's guage: and that this little Bob ſhould ſerve only for more nice Corrections; as the alteration

* Horol. Diſquiſ. † De Centro Oſcil. Prop. 23.

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 Pendulum 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 Pendulum, or about a 50th 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 Pendulum, 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 Seconds. 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

Minutes

Minutes 30 Seconds faſter, if the Bob be raiſed to 192,6. So that here you have but 15 Seconds 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 of 3 or 4 *lb.* 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 it's 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 it's 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. No. 4. correct even that Minute error, 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, 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.

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

Suppoſing your Pendulum that vibrates Seconds to be 39 Inches and 2 Tenths, if you ſhould ſhorten it to 39 Inches, it would go 3 Minutes 42 Seconds faſter than before: But if you ſhould lengthen it to 39 Inches 3 Tenths, it would go 1 Minute 50 Seconds ſlower. And ſo for the reſt of the Table.

If then the great Ball ſlides on a flat Piece of Braſs divided into Inches and Tenths, it will be eaſy to diſcern what Alterations will be cauſed by the raiſing or falling of it.

CHAP.

CHAP. VI.

The Antiquity and general Hiſtory of Watch or Clock-Work.

§. 1. IT is probable that in all Ages, ſome Inſtruments or other have been uſed for the meaſuring of Time. 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.* xl. 26. And accordingly the LXXII tranſlate the *Maγaloth* of *Ahaz*, by the Words Βαθμὲς and Ἀναβαθμὲς, *i. e. Steps*, or *Aſcents*. The like doth the *Syriack*, *Arabick*, and other Verſions.

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

* 2 Kings xx. 11. Iſaiah xxxviii. 8.

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 Κλεψιύδρα, say *Suidas* * and *Phavorinus*, was Ὄργανον ἀστρολογικὸν ἐν ᾧ αἱ ὧραι μετροῦνται; *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.

As to the Invention of those Water-Watches (which were, no doubt, of 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. Idque 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*

* Lexic. in verbo ὧραι. † In verbo κλεψύδρα.
|| De die Nat. c. 23.

Year U. C. 595. which time fell in about the time of *Judas Maccabæus*, about 150 Years before our bleſſed Saviour's Days.

The other way of meaſuring the Hours 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 Dialling, and "was the firſt that ſhewed a Sun-Dial "at *Lacedæmon*." *Vitruvius* † calls him *Mileſius Anaximander*. This *Anaximander*, or *Anaximenes*, was contemporary with *Pythagoras*, ſays *Laërtius*; and flouriſhed about the time of the Prophet *Daniel*.

But enough of theſe ancient 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 of Clock-Work, or not, I leave to the Reader's Jugdment.

The firſt is that of *Dionyſius*, which *Plutarch* || commends for a very magnificent and illuſtrious Piece. But this might

* Nat. Hiſt. l. 2. c. 76. † De Archit l. 6. c. 48.
|| In the Life of Dion.

might be only a well delineated Sun-Dial.

Another Piece, is that of *Sapor* King of *Perſia* *. Whether that *Sapor*, who was contemporary 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 it's 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.

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.

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 ſhew the Hours (which were unequal in that Age) through every Month of of the Year. The Words of *Vitruvius* are, *Æqualiter influens aqua ſublevat ſcaphum inverſum (quod ab artificibus phellos ſive*

* Euſeb. Vit. Conſt. l. 3. De Subtil. l. 17.
† De Architect. l. 9. c. 9.

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 moventer ſigilla, vertuntur metæ, calculi aut tonà 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 Inventer 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 contemporary with *Archimedes*.

§. 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

* Vide Philand. not. in Vitruv.

Which is thought to be a much younger Invention, than the forementioned Pieces; and to have had it's beginning in *Germany*, within leſs than theſe 200 Years. It 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 *Tuſculan* * Queſtions,

* Lib. 1. 25. edit. Elzevir.

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 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, legeſque 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.

* Epigr. in Sphær. Archimed.

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 do run,
And Cynthia *too her monthly Circle turn.*
Since now bold man hath Worlds of's own deſcry'd
He joys, and th' Stars by human Art can guide.
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 for ſome Angel, Spirit, or Divine Power; unleſs by Spirit here, you underſtand ſome

ſome aërial ſubtilized Liquor, or Vapours. But how this, or indeed any thing but Clock-Work, could give ſuch true and regular Motions, I am not able to gueſs.

§. 5. The next Inſtance I have met with of ancient Clock-Work, is that famous one in *Cicero* *, which, among other irrefragable Arguments is brought in to prove, "That there is ſome intel-"ligent, 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: "*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 efficiant 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 ſum of the Author's meaning is, "That there "were *Sun-Dials* deſcribed, or drawn

* De Nat. Deor. Lib. ii. §. 34.

[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 five Planets, 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 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 eaſy to apply it to the meaſuring of Hours (though 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 XVIth Century; and then Clock-Work was revived, or wholly invented anew in *Germany*, as is generally thought, becauſe the ancient Pieces are *German* Work. But who was the Inventor, or in what time, I cannot diſcover. Some think *Sever. Boëthius* invented it long before about the Year 510 *.

But if it was not ſo early as *Boëthius*, it might perhaps be in *Regiomantanus*'s Time, towards the latter end of the XIVth 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 Majeſty's Palace at *Hampton-Court*, whoſe Inſcription ſhews it to have been been made in King *Henry* VIII's Time by one *N. O.* in the Year 1540; which for it's Antiquity and good Contrivance I have given the Calliper of

 in

* Molyneaux, Scioth. Teleſcop. Ep. Dedic.

in Fig. 4, and ſhall ſay more of in Chap. X.

Another Piece alſo I remember I ſaw ſome Years ago, which was a Watch belonging to the ſame King *Henry* VIII, 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 throughout the Year; with the " Feaſts, both moveable and fixed; together with the Motion of the Sun " and Moon, and their paſſage thro' each " Degree of the Zodiack. Then for the " Clock, it is ſo framed by artificial Engines, that whenſoever it is to ſtrike, " two Horſemen 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 *Magi* (with their ſeveral " Trains) marching in order, doing hum-

" ble

"ble 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.

✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠✠

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. Eumque ſecuti (etiamſi conatuum ejus ignari) Langrenus, Vendelinus, Merſennus, Kircherus,*

* Heylin's Coſmog. L. ii. † Magia Univerſ. P. 1. Proleg. & Magia Thaumaturg.

cherus, & alii quamplurimi. Automatis Horologiis applicavit Hugenius. i. e. *Riccioli first made use of 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. Curiof. 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.

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.

Amongst them that have claimed the honour of this Invention, the great *Galileo* hath the most to be said on his side. Dr *John Joachim Becher* (who printed a Book when he was in *England*, intituled, *De Nova Temporis dimetiendi ratione Theoria*, &c. which he dedicated to the *English* Royal Society, *Anno* 1680.) he, I say, tell us, " That the Count *Magalotti* (the " Grand Duke of *Tuscany*'s Resident at " the

* Hor. Oscil. p. 3. Edit. Paris.

" 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 Grand Duke of *Tuſca-*
" *ny*) related to him the like Hiſtory:
" And ſaid moreover, that he had made
" the firſt Pendulum-Clock at *Florence*,
" by the command of the Grand Duke,
" and by the Directions of his Mathe-
" matician *Galileus à Galilæo*; a pattern
" of which was brought into *Holland*."
And further he ſaith, " that one *Caſpar*
" *Doms*, a *Fleming*, and Mathematician
" to *John Philip à Schonborn* (the late
" Elector of *Mentz*) told him, that he
" had ſeen at *Prague*, in the time of
" *Rudolphus* the Emperor, a Pendulum-
" Clock, made by the famous *Juſtus*
" *Borgen*, Mechanick and Clock-Maker
" to the Emperor: which Clock the
" Great *Tycho Brahe* uſed in his Aſtro-
" nomical 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

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

" of the Clock: a thing which *Galilæo* " first invented, and his Son *Vincenzio* " *Galilei* put in Practice in the Year " 1649."

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 Inventor, and that if *Galilæo* ever thought of 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 the possession of the Royal Society, given to that Honourable Body by the late eminent *Seth*, Lord Bishop of *Salisbury*: which is made exactly according to Mr *Huygens*'s Method.

§. 3.

* Huygens, ibid.

§. 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 *William 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 *Royal 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)

* Horolog. Diſquiſ. p. 3.

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*'s 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 Pendulum doth not vibrate backward and forward, as those we have been speaking of do; but always round; the String being suspended above, as 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 Pendulum is as regular, and much the same with those mentioned before: and was thus far made very useful in Astronomical Observations,

Obſervations, by the ſaid Dr *Hook*, *viz.* To give warning at any Moment of it's Circumgyration, either when it had turned but a Quarter, Half, or any leſſer, or greater Part of it's 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. 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 inferior 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.

§. 2. The firſt Inventor hereof, was that ingenious and learned Member of our *Royal Society*, the late Dr *Hook*: who contrived various ways of Regulation. One way was with a Load-Stone: another was with a tender ſtrait Spring, one end whereof played backward and forward with the Ballance. So that the Ballance 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 Ballances: of which I have ſeen two ſorts, although 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 Ballances had a like number of Teeth; which running in each other, cauſed each Ballance to vibrate alike.

But as to the former of theſe, which had no ſpiral Spring; the Verges of it's Ballance 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 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 Ballances, were ſet one on one ſide, the other on the other ſide of the Crown-Wheel, ſo that the Pallets might play freely in it's Teeth. And when the Crown-Wheel in moving round, had delivered itſelf of one Pallet, the other Pallet on the oppoſite ſide, was drawn on to make it's Beats, by means of the Motion which the other Ballance had given it's Ballance (the two Ballances 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 Ballances, 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 Ballance, proportioned to the width of the

Crown-

Crown-Wheel. But the Ballances were much larger. And ſo the Teeth of theſe two little foreſaid Wheels or Ballances, running in one another, moved the larger Ballances above them, all one, as if theſe two great Ballances had been toothed and played in each other.

§. 4. The other way, with two Ballances alſo, moving each other (as was ſaid in the beginning of the laſt Section) had a ſpiral Spring to each Ballance, for it's Regulator. In this Invention, only one Ballance had the Pallets, as the common Ballances have: And the Crown-Wheel operated upon it, according to the uſual way. But then when this Ballance vibrateth, it giveth the ſame Motion backward and forward to the other Ballance, 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 it's Vibrations. Which it will do in the beſt Pendulum-Watch with one Ballance 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

mentioned Watch, with two Ballances, will be nothing affected with it. But notwithſtanding this Inconvenience, yet the Watch with one Ballance 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 Ballance-Teeth may retard the Motion of the Ballances. But the other is eaſier made, and performeth well enough, and 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, upon one of the aforeſaid double Ballance 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 it's Fame flew into *France*, from whence the Dauphin 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 Doctor 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 *Brouncker* ſent for out of 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 Ballance: 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 Arbor of this Contrate-Wheel. 3. Then followeth the Crown-Wheel, *&c.* 4. The Ballance, 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 *Oldenburg*, or others his Correſpondents here in *England*, although Mr *Oldenburgh* vindicates himſelf againſt that charge in *Philoſophical Tranſactions*, No. 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 pretty and ingenious Contrivance, but ſubject to ſome Defects: *viz.* When it ſtandeth ſtill, it will not vibrate, 'till 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 Joggs. Alſo, it doth ſomewhat vary in it's 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,

ter, 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, I ſhall relate the bare Matter of Fact, leaving the Reader to his own Judgment.

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 Watchmaker 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, 'till 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 tryal 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 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 'tis done by thruſting in the Pendant) did repeat

both

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 Inventors 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.

§. 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 Chap. II. 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-makers way.
4)48	48
7)56	56——4
6)54	54——7
19	19——6

According to my way, the Pinion 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 Arbor: the Wheel [54] hath the Pinion [7] and the Crown-Wheel [19] the Pinion [6] on the ſame Spindles.

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

§. 2. Numbers of an eight Day-Piece, with 16 Turns of the Barrel, the Pendulum vibrates Seconds, and ſhews Minutes, Seconds, *&c.*

The

The Watch Part.	The Clock Part.
8)96	8)78
8)60--48)48--6)72	6)48 8 pins.
7)56	6)48
30	6)48

In the Watch Part, the Wheel 60 is the Minute-Wheel, which is ſet in the middle of the Clock, that it's 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 Section) be thus read, *viz.* The Wheel 60, hath another Wheel 48 on the ſame Spindle; which

Wheel

Wheel 48 divideth (playeth in, 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 the end of the Arbor 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; Pendulum vibrateth Seconds, and ſheweth Minutes, Seconds, *&c.*

Watch

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 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	6)72 Double hoop.
7)56	6)60
30	

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

The

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

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

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

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, Pendulum 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

§. 9. A Piece of 8 Days, with 16 Turns, Pendulum about 6 Inches, to ſhew Minutes, Seconds, &c.

The Watch.	The Clock may be
8)96	the ſame with
8)64—48)48—6)72	the 8 Day-Piece
8)60	before, §. 2.
8)40 The Seconds-Wheel.	
15	

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

The Watch.	The Clock may
8)64	have the ſame
8)48	Numbers, as
6)48—48)48—6)72	the Clock §. 3.
6)45	
6)30 Seconds-Wheel.	
15	

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

The

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
19

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 eight Day-Piece, to ſhew the Hour and Minute, Pendulum about 3 Inches long.

6)96
8)64—6)72
7)49
6)36
19

The Clock may have the ſame Numbers, as the eight Day-Piece before §. 2.

Automata ſhewing the Motion of the Celeſtial Bodies.

§. 1. Numbers for the Motion of the *Sun* and *Moon*. See before in Chap. II. 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 depend upon a Wheel going round in a Year
5)69	
4)52	
4)48	thus, 10)59 / 6)30 or thus,
4)40	4)118

Note, The lowermoſt Pinion in theſe, and the following Numbers, is to be fixed concentrical to the Wheel, which is to 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 $\frac{1}{2}$ 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 is 32, driven by the Wheel 63, which carrieth round the ſecond Satellite. The

third

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 ſeven Days. E. F. G. H. are the *Sockets*, or hollow *Arbors* of 4 Wheels running concentrically.

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

The hollow Arbor G. carrieth round the *Second Satellite* ſ. and belongeth to the Wheel 32, which is driven by the

Wheel 63. And the like of the *Arbors* 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 it's 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 preceding 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 Blue 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*, whofe Revolution is 687 Days nearly.

On the Dial-Wheel.

4)48	The two laft Numbers of *Saturn* may be the two firft of *Mars* alfo.
4)40	
4)46	

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

On the Dial-Wheel.

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

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

On the Dial-Wheel.

4)64
4)44

§. 7. Numbers to reprefent the Motion of the *Dragon*'s-*Head* and *Tail*, (near 19 Years) to fhew the *Eclipfes* of the Sun and Moon.

On the Dial-Wheel.	On the Year-Wheel.
	4)76
4)48	Note, the two laſt Numbers
4)40	of *Saturn* may be the two
4)44	firſt of this on the Dial-
4)42	Wheel.

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, 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 lie under the Dial-Plate, and drive the ſeveral Motions in this Manner. In the Center of all, both the Dial-Plate and it's Wheel-Work is placed on a fixed Arbor, 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 it's Pinion of 7 Leaves, as alſo the other pricked Wheel, and it's 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 ſkilful Artiſt Mr *Langley Bradley* in *Fenchurch-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 Seconds
6)42 Hand placed, and on the Wheel
19 [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

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 uſual Numbers of the old 30 Hours Pocket-Watches.

With

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 preceding 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 Chap. II. 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 Days 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 Year's 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 it's 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

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 Arcs 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 Error 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 myſelf, 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

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 by the Letters F. or S. But if you would keep your Watch to go by the Sun-Dial, you may conclude it goes well, if it loſeth or gaineth every Day, ſo many Seconds as you will find in the Table. Thus (for Example) *Jan* 1. in in *Leap-Year*, the Watch ought to be 4 Minutes faſter than the Sun-Dial: on *Jan.* 2. it ought to be 4 Minutes 28 Seconds, *&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 4 Minutes want of 4 Minutes 28 Seconds, *viz.* 28 Seconds, you may conclude your Watch goes well. Otherwiſe you muſt ſcrew up, or let down the *Ball* or *Corrector*, 'till it loſeth or gaineth according to the Equation Tables *.

* Mr *Flamſteed*'s Tables having run out a few Seconds in Dr *Derham*'s time, and more ſince: The Tables in this Edition are computed for the preſent Time, to the mean Noon of every Day, for the Meridian of *Greenwich* Obſervatory, and are adapted to the New Style. And the Letters F. or S. denote faſter or ſlower.

The Biſſextile

The Bissextile or Leap Year.												
Days	Jan.		Feb.		March		April		May		June	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4 F.	0	14 F.	6	12 F.	36	3 F.	47	3 S.	14	2 S.	39
2	4	28	14	13	12	23	3	29	3	21	2	29
3	4	56	14	20	12	10	3	10	3	28	2	20
4	5	24	14	26	11	56	2	52	3	34	2	10
5	5	51	14	31	11	42	2	35	3	40	2	0
6	6 F.	18	14 F.	35	11 F.	28	2 F.	17	3 S.	45	1 S.	49
7	6	44	14	39	11	13	1	59	3	49	1	38
8	7	10	14	41	10	57	1	42	3	53	1	27
9	7	35	14	43	10	41	1	25	3	56	1	15
10	7	59	14	44	10	25	1	8	3	59	1	3
11	8 F.	23	14 F.	44	10 F.	9	0 F.	52	4 S.	1	0 S.	51
12	8	47	14	44	9	52	0	36	4	2	0	39
13	9	10	14	43	9	35	0	20	4	3	0	27
14	9	32	14	41	9	18	0	5	4	4	0	15
15	9	53	14	38	9	1	0 S.	10	4	4	0	2
16	10 F.	14	14 F.	34	8 F.	43	0 S.	25	4 S.	3	0 F.	11
17	10	35	14	30	8	25	0	40	4	1	0	24
18	10	54	14	25	8	7	0	54	3	59	0	36
19	11	13	14	19	7	49	1	7	3	57	0	49
20	11	31	14	13	7	31	1	20	3	54	1	2
21	11 F.	48	14 F.	6	7 F.	12	1 S.	33	3 S.	51	1 F.	15
22	12	5	13	58	6	53	1	45	3	47	1	28
23	12	21	13	50	6	35	1	57	3	42	1	41
24	12	36	13	41	6	16	2	8	3	37	1	54
25	12	50	13	32	5	57	2	19	3	31	2	7
26	13 F.	3	13 F.	22	5 F.	38	2 S.	30	3 S.	25	2 F.	19
27	13	15	13	11	5	19	2	40	3	18	2	32
28	13	27	13	0	5	1	2	49	3	11	2	44
29	13	38	12	48	4	42	2	58	3	4	2	56
30	13	48			4	24	3	6	2	56	3	8
31	13 F.	57			4 F.	5			2 S.	47		

The

The Bissextile or Leap Year.												
Days	July		Aug.		Sept.		Oct.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	F.19	5	F.47	0	S.27	10	S.33	16	S.12	10	S.18
2	3	30	5	43	0	46	10	51	16	12	9	55
3	3	41	5	38	1	5	11	9	16	12	9	30
4	3	52	5	33	1	24	11	27	16	11	9	6
5	4	3	5	28	1	44	11	45	16	8	8	40
6	4	F.13	5	F.21	2	S. 4	12	S. 2	16	S. 5	8	S.14
7	4	23	5	14	2	24	12	19	16	1	7	48
8	4	32	5	7	2	44	12	35	15	56	7	21
9	4	41	4	59	3	4	12	51	15	51	6	54
10	4	49	4	50	3	25	13	6	15	44	6	26
11	4	F.57	4	F.40	3	S.46	13	S.21	15	S.37	5	S.58
12	5	5	4	30	4	6	13	36	15	28	5	29
13	5	12	4	20	4	27	13	50	15	19	5	1
14	5	19	4	9	4	48	14	3	15	6	4	32
15	5	25	3	57	5	9	14	16	14	59	4	2
16	5	F.31	3	F.46	5	S.30	14	S.28	14	S.47	3	S.33
17	5	36	3	34	5	51	14	39	14	35	3	3
18	5	41	3	21	6	12	14	50	14	21	2	34
19	5	45	3	7	6	33	15	1	14	7	2	4
20	5	49	2	53	6	53	15	11	13	52	1	34
21	5	F.52	2	F.39	7	S.14	15	S.20	13	S.36	1	S. 4
22	5	54	2	24	7	35	15	28	13	20	0	33
23	5	56	2	9	7	55	15	36	13	3	0	4
24	5	58	1	53	8	16	15	23	12	45	0	F.26
25	5	58	1	37	8	36	15	49	12	26	0	56
26	5	F.59	1	F.20	8	S.56	15	S.54	12	S. 7	1	F.26
27	5	58	1	3	9	16	15	59	11	46	1	56
28	5	57	0	46	9	36	16	4	11	25	2	26
29	5	56	0	28	9	55	16	7	11	3	2	55
30	5	54	0	10	10	14	16	9	10	41	3	24
31	5	F.51	0	S. 8			16	S.11			3	F.53

The first after Leap Year.

Days	Jan.		Feb.		March		April		May		June	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4F.	21	14F.	11	12F.	39	3F.	52	3S.	12	2S.	41
2	4	49	14	18	12	27	3	33	3	20	2	32
3	5	16	14	24	12	14	3	15	3	26	2	23
4	5	43	14	30	12	0	2	57	3	33	2	13
5	6	10	14	34	11	46	2	39	3	38	2	2
6	6F.	37	14F.	38	11F.	32	2F.	21	3S.	43	1S.	52
7	7	3	14	41	11	17	2	4	3	48	1	41
8	7	28	14	43	11	2	1	47	3	52	1	30
9	7	53	14	44	10	46	1	30	3	55	1	19
10	8	17	14	44	10	30	1	13	3	58	1	7
11	8F.	41	14F.	44	10F.	13	0F.	56	4S.	0	0S.	55
12	9	4	14	44	9	57	0	40	4	2	0	43
13	9	26	14	42	9	40	0	24	4	3	0	30
14	9	48	14	39	9	23	0	9	4	4	0	18
15	10	9	14	35	9	6	0S.	6	4	4	0	5
16	10F.	30	14F.	31	8F.	48	0S.	21	4S.	3	0F.	7
17	10	49	14	26	8	30	0	36	4	2	0	20
18	11	8	14	21	8	12	0	50	4	0	0	33
19	11	26	14	15	7	54	1	4	3	58	0	46
20	11	44	14	8	7	36	1	17	3	55	0	59
21	12F.	1	14F.	1	7F.	17	1S.	30	3S.	52	1F.	12
22	12	17	13	53	6	59	1	42	3	48	1	25
23	12	32	13	44	6	40	1	54	3	43	1	38
24	12	46	13	34	6	21	2	6	3	38	1	50
25	13	0	13	26	6	3	2	17	3	33	2	3
26	13F.	12	13F.	14	5F.	44	2S.	27	3S.	27	2F.	16
27	13	24	13	2	5	25	2	37	3	20	2	28
28	13	35	12	51	5	6	2	47	3	13	2	40
29	13	46			4	47	2	56	3	6	2	53
30	13	55			4	29	3	4	2	58	3	4
31	14F.	4			4F.	10			2S.	50		

The

The first after Leap Year.												
Days	July		Aug.		Sept.		Oct.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	F.16	5	F.48	0	S.22	10	S.28	16	S.12	10	S.24
2	3	28	5	45	0	41	10	46	16	13	10	1
3	3	39	5	40	1	0	11	5	16	12	9	37
4	3	50	5	35	1	19	11	23	16	11	9	12
5	4	0	5	29	1	38	11	40	16	9	8	47
6	4	F.10	5	F.23	1	S.58	11	S.58	16	S. 6	8	S.21
7	4	20	5	16	2	18	12	14	16	2	7	55
8	4	30	5	9	2	38	12	31	15	57	7	28
9	4	39	5	1	2	59	12	47	15	52	7	1
10	4	47	4	52	3	19	13	2	15	46	6	34
11	4	F.56	4	F.43	3	S.40	13	S.17	15	S.39	6	S. 6
12	5	3	4	34	4	1	13	32	15	31	5	37
13	5	11	4	24	4	21	13	46	15	22	5	9
14	5	18	4	13	4	42	13	59	15	12	4	40
15	5	24	4	1	5	3	14	12	15	1	4	11
16	5	F.30	3	F.49	5	S.24	14	S.26	14	S.50	3	S.41
17	5	35	3	37	5	45	14	36	14	38	3	11
18	5	40	3	24	6	6	14	48	14	25	2	41
19	5	44	3	11	6	27	14	58	14	11	2	11
20	5	48	2	57	6	48	15	8	13	56	1	41
21	5	F.51	2	F.43	7	S. 9	15	S.17	13	S.41	1	S.11
22	5	54	2	28	7	29	15	26	13	24	0	41
23	5	56	2	13	7	50	15	34	13	7	0	11
24	5	58	1	57	8	10	15	41	12	50	0	F.19
25	5	58	1	41	8	31	15	47	12	31	0	49
26	5	F.59	1	F.25	8	S.51	15	S.53	12	S.12	1	F.18
27	5	59	1	8	9	11	15	58	11	51	1	48
28	5	58	0	51	9	30	16	2	11	31	2	18
29	5	56	0	33	9	49	16	6	11	9	2	47
30	5	54	0	15	10	0	16	9	10	47	3	16
31	5	F.52	0	S. 3			16	S.11			3	F.45

The ſecond after Leap Year.												
Days	Jan.		Feb.		March		April		May		June	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4F.	14	14F.	9	12F.	42	3F.	56	3S.	10	2S.	43
2	4	42	14	17	12	30	3	38	3	18	2	34
3	5	10	14	23	12	17	3	19	3	25	2	25
4	5	37	14	28	12	3	3	1	3	31	2	15
5	6	4	14	33	11	49	2	43	3	37	2	5
6	6F.	30	14F.	37	11F.	35	2F.	26	3S.	42	1S.	54
7	6	56	14	40	11	20	2	8	3	47	1	44
8	7	22	14	42	11	5	1	51	3	51	1	33
9	7	47	14	44	10	50	1	34	3	54	1	21
10	8	11	14	44	10	34	1	17	3	57	1	10
11	8F.	35	14F.	44	10F.	18	1F.	0	4S.	0	0S.	58
12	8	58	14	43	10	1	0	44	4	2	0	46
13	9	21	14	42	9	44	0	28	4	3	0	33
14	9	43	14	39	9	27	0	12	4	4	0	21
15	10	4	14	36	9	10	0S.	3	4	4	0	8
16	10F.	25	14F.	32	8F.	52	0S.	18	4S.	3	0F.	4
17	10	45	14	28	8	34	0	32	4	2	0	17
18	11	4	14	22	8	16	0	47	4	1	0	30
19	11	22	14	16	7	58	1	0	3	58	0	43
20	11	40	14	10	7	40	1	14	3	56	0	56
21	11F.	57	14F.	3	7F.	22	1S.	27	3S.	52	1F.	9
22	12	13	13	55	7	3	1	39	3	49	1	22
23	12	28	13	46	6	44	1	51	3	44	1	34
24	12	43	13	37	6	26	2	3	3	40	1	47
25	12	56	13	27	6	7	2	14	3	34	2	0
26	13F.	9	13F.	17	5F.	48	2S.	25	3S.	28	2F.	13
27	13	21	13	6	5	29	2	35	3	22	2	25
28	13	33	12	54	5	11	2	45	3	15	2	37
29	13	43			4	52	2	54	3	8	2	50
30	13	53			4	33	3	2	3	0	3	2
31	14F.	1			4F.	15			2S.	52		

The second after Leap Year.												
Days	July		Aug.		Sept.		Oct.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3 F.	13	5 F.	49	0 S.	17	10 S.	23	16 S.	12	10 S.	30
2	3	25	5	45	0	36	10	42	16	12	10	7
3	3	36	5	41	0	55	11	0	16	12	9	43
4	3	47	5	36	1	14	11	18	16	11	9	18
5	3	58	5	31	1	34	11	36	16	9	8	53
6	4 F.	8	5 F.	25	1 S.	53	11 S.	53	16 S.	6	8 S.	28
7	4	18	5	18	2	13	12	10	16	3	8	1
8	4	27	5	11	2	34	12	27	15	59	7	35
9	4	36	5	3	2	54	12	43	15	53	7	8
10	4	45	4	54	3	14	12	59	15	47	6	40
11	4 F.	53	4 F.	45	3 S.	35	13 S.	14	15 S.	40	6 S.	12
12	5	1	4	36	3	56	13	28	15	32	5	44
13	5	9	4	26	4	16	13	42	15	24	5	16
14	5	16	4	15	4	37	13	56	15	14	4	47
15	5	22	4	4	4	58	14	9	15	4	4	18
16	5 F.	28	3 F.	52	5 S.	19	14 S.	22	14 S.	53	3 S.	48
17	5	34	3	40	5	40	14	34	14	41	3	19
18	5	39	3	27	6	1	14	45	14	28	2	49
19	5	43	3	14	6	22	14	56	14	14	2	19
20	5	47	3	0	6	43	15	6	14	0	1	49
21	5 F.	50	2 F.	46	7 S.	4	15 S.	15	13 S.	44	1 S.	19
22	5	53	2	31	7	24	15	24	13	28	0	49
23	5	55	2	16	7	45	15	32	13	11	0	19
24	5	57	2	1	8	5	15	39	12	54	0 F.	11
25	5	58	1	45	8	26	15	46	12	35	0	41
26	5 F.	59	1 F.	29	8 S.	46	15 S.	52	12 S.	16	1 F.	11
27	5	59	1	12	9	6	15	57	11	56	1	41
28	5	58	0	55	9	25	16	2	11	36	2	11
29	5	57	0	37	9	45	16	5	11	14	2	40
30	5	55	0	19	10	4	16	8	10	52	3	9
31	5 F.	52	0 F.	1			16 S.	11			3 F.	38

The third after Leap Year.

Days	Jan. M.	Jan. S.	Feb. M.	Feb. S.	March M.	March S.	April M.	April S.	May M.	May S.	June M.	June S.
1	4 F.	7	14 F.	7	12 F.	45	4 F.	1	3 S.	8	2 S.	45
2	4	35	14	15	12	33	3	42	3	16	2	36
3	5	3	14	21	12	20	3	24	3	23	2	27
4	5	30	14	27	12	7	3	6	3	29	2	17
5	5	57	14	32	11	53	2	48	3	35	2	7
6	6 F.	24	14 F.	36	11 F.	39	2 F.	30	3 S.	41	1 S.	57
7	6	50	14	39	11	24	2	12	3	46	1	46
8	7	16	14	42	11	9	1	55	3	50	1	35
9	7	41	14	44	10	54	1	38	3	54	1	24
10	8	5	14	44	10	38	1	21	3	57	1	12
11	8 F.	29	14 F.	44	10 F.	21	1 F.	4	3 S.	59	1 S.	1
12	8	52	14	43	10	5	0	48	4	1	0	49
13	9	15	14	42	9	48	0	32	4	3	0	36
14	9	37	14	40	9	31	0	16	4	4	0	24
15	9	59	14	37	9	14	0	1	4	4	0	12
16	10 F.	20	14 F.	33	8 F.	57	0 S.	14	4 S.	3	0 F.	1
17	10	40	14	29	8	39	0	29	4	2	0	14
18	10	59	14	24	8	21	0	43	4	1	0	27
19	11	17	14	18	8	3	0	57	3	59	0	40
20	11	35	14	12	7	44	1	10	3	56	0	53
21	11 F.	52	14 F.	4	7 F.	26	1 S.	23	3 S.	53	1 F.	6
22	12	9	13	57	7	8	1	36	3	50	1	18
23	12	24	13	48	6	49	1	48	3	46	1	31
24	12	39	13	39	6	30	2	0	3	41	1	44
25	12	53	13	29	6	12	2	12	3	36	1	57
26	13 F.	6	13 F.	19	5 F.	53	2 S.	22	3 S.	30	2 F.	10
27	13	18	13	8	5	34	2	32	3	24	2	22
28	13	30	12	57	5	15	2	42	3	17	2	35
29	13	40			4	56	2	51	3	10	2	47
30	13	50			4	38	3	0	3	2	2	59
31	13 F.	59			4 F.	19			2 S.	54		

The third after Leap Year.						
Days	July M. S.	Aug. M. S.	Sept. M. S.	Oct. M. S.	Nov. M. S.	Dec. M. S.
1	3 F. 11	5 F. 50	0 S. 13	10 S. 19	16 S. 11	10 S. 35
2	3 22	5 46	0 31	10 37	16 12	10 12
3	3 33	5 42	0 50	10 56	16 12	9 48
4	3 44	5 37	1 10	11 14	16 11	9 24
5	3 55	5 32	1 29	11 32	16 10	8 59
6	4 F. 5	5 F. 26	1 S. 49	11 S. 49	16 S. 7	8 S. 34
7	4 15	5 19	2 9	12 6	16 4	8 8
8	4 25	5 12	2 29	12 23	16 0	7 41
9	4 34	5 5	2 49	12 39	15 55	7 14
10	4 43	4 56	3 9	12 55	15 49	6 47
11	4 F. 51	4 F. 48	3 S. 30	13 S. 10	15 S. 42	6 S. 19
12	4 59	4 38	3 51	13 25	15 34	5 51
13	5 7	4 28	4 11	13 39	15 26	5 23
14	5 14	4 18	4 32	13 53	15 17	4 54
15	5 21	4 6	4 53	14 6	15 6	4 25
16	5 F. 27	3 F. 55	5 S. 14	14 S. 19	14 S. 55	3 S. 56
17	5 32	3 43	5 35	14 31	14 44	3 26
18	5 37	3 30	5 56	14 42	14 31	2 56
19	5 42	3 17	6 17	14 53	14 18	2 26
20	5 46	3 4	6 38	15 3	14 4	1 56
21	5 F. 50	2 F. 50	6 S. 59	15 S. 13	13 S. 48	1 S. 26
22	5 53	2 35	7 19	15 22	13 32	0 56
23	5 55	2 20	7 40	15 30	13 16	0 26
24	5 57	2 5	8 0	15 38	12 58	0 F. 4
25	5 58	1 49	8 21	15 45	12 40	0 34
26	5 F. 59	1 F. 33	8 S 41	15 S. 51	12 S. 21	1 F. 4
27	5 59	1 16	9 1	15 56	12 1	1 34
28	5 58	0 59	9 21	16 1	11 41	2 3
29	5 57	0 42	9 40	16 5	11 20	2 33
30	5 55	0 24	10 0	16 8	10 58	3 2
31	5 F. 53	0 F. 6		16 S. 10		3 F. 31

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By Reaſon of the Refractions, or ſome Error in the Sun-Dial, it may be convenient to compare, or ſet, your 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, The second after Leap Year.

Days	July M.	July S.	Aug. M.	Aug. S.	Sept. M.	Sept. S.	Oct. M.	Oct. S.	Nov. M.	Nov. S.	Dec. M.	Dec. S.
1	3 F.	13	5 F.	49	0 S.	17	10 S.	23	16 S.	12	10 S.	30
2	3	25	5	45	0	36	10	42	16	12	10	7
3	3	36	5	41	0	55	11	0	16	12	9	43
4	3	47	5	36	1	14	11	18	16	11	9	18
5	3	58	5	31	1	34	11	36	16	9	8	53
6	4 F.	8	5 F.	25	1 S.	53	11 S.	53	16 S.	6	8 S.	28
7	4	18	5	18	2	13	12	10	16	3	8	1
8	4	27	5	11	2	34	12	27	15	59	7	35
9	4	36	5	3	2	54	12	43	15	53	7	8
10	4	45	4	54	3	14	12	59	15	47	6	40
11	4 F.	53	4 F.	45	3 S.	35	13 S.	14	15 S.	40	6 S.	12
12	5	1	4	36	3	56	13	28	15	32	5	44
13	5	9	4	26	4	16	13	42	15	24	5	16
14	5	16	4	15	4	37	13	56	15	14	4	47
15	5	22	4	4	4	58	14	9	15	4	4	18
16	5 F.	28	3 F.	52	5 S.	19	14 S.	22	14 S.	53	3 S.	48
17	5	34	3	40	5	40	14	34	14	41	3	19
18	5	39	3	27	6	1	14	45	14	28	2	49
19	5	43	3	14	6	22	14	56	14	14	2	19
20	5	47	3	0	6	43	15	6	14	0	1	49
21	5 F.	50	2 F.	46	7 S.	4	15 S.	15	13 S.	44	1 S.	19
22	5	53	2	31	7	24	15	24	13	28	0	49
23	5	55	2	16	7	45	15	32	13	11	0	19
24	5	57	2	1	8	5	15	39	12	54	0 F.	11
25	5	58	1	45	8	26	15	46	12	35	0	41
26	5 F.	59	1 F.	29	8 S.	46	15 S.	52	12 S.	16	1 F.	11
27	5	59	1	12	9	6	15	57	11	56	1	41
28	5	58	0	55	9	25	16	2	11	36	2	11
29	5	57	0	37	9	45	16	5	11	14	2	40
30	5	55	0	19	10	4	16	8	10	52	3	9
31	5 F.	52	0 F.	1			16 S.	11			3 F.	38

The

The third after Leap Year.

Days	Jan. M.	S.	Feb. M.	S.	March M.	S.	April M.	S.	May M.	S.	June M.	S.
1	4 F.	7	14 F.	7	12 F.	45	4 F.	1	3 S.	8	2 S.	45
2	4	35	14	15	12	33	3	42	3	16	2	36
3	5	3	14	21	12	20	3	24	3	23	2	27
4	5	30	14	27	12	7	3	6	3	29	2	17
5	5	57	14	32	11	53	2	48	3	35	2	7
6	6 F.	24	14 F.	36	11 F.	39	2 F.	30	3 S.	41	1 S.	57
7	6	50	14	39	11	24	2	12	3	46	1	46
8	7	16	14	42	11	9	1	55	3	50	1	35
9	7	41	14	44	10	54	1	38	3	54	1	24
10	8	5	14	44	10	38	1	21	3	57	1	12
11	8 F.	29	14 F.	44	10 F.	21	1 F.	4	3 S.	59	1 S.	1
12	8	52	14	43	10	5	0	48	4	1	0	49
13	9	15	14	42	9	48	0	32	4	3	0	36
14	9	37	14	40	9	31	0	16	4	4	0	24
15	9	59	14	37	9	14	0	1	4	4	0	12
16	10 F.	20	14 F.	33	8 F.	57	0 S.	14	4 S.	3	0 F.	1
17	10	40	14	29	8	39	0	29	4	2	0	14
18	10	59	14	24	8	21	0	43	4	1	0	27
19	11	17	14	18	8	3	0	57	3	59	0	40
20	11	35	14	12	7	44	1	10	3	56	0	53
21	11 F.	52	14 F.	4	7 F.	26	1 S.	23	3 S.	53	1 F.	6
22	12	9	13	57	7	8	1	36	3	50	1	18
23	12	24	13	48	6	49	1	48	3	46	1	31
24	12	39	13	39	6	30	2	0	3	41	1	44
25	12	53	13	29	6	12	2	12	3	36	1	57
26	13 F.	6	13 F.	19	5 F.	53	2 S.	22	3 S.	30	2 F.	10
27	13	18	13	8	5	34	2	32	3	24	2	22
28	13	30	12	57	5	15	2	42	3	17	2	35
29	13	40			4	56	2	51	3	10	2	47
30	13	50			4	38	3	0	3	2	2	59
31	13 F.	59			4 F.	19			2 S.	54		

The

The third after Leap Year.

Days	July M.	July S.	Aug. M.	Aug. S.	Sept. M.	Sept. S.	Oct. M.	Oct. S.	Nov. M.	Nov. S.	Dec. M.	Dec. S.
1	3 F.	11	5 F.	50	0 S.	13	10 S.	19	16 S.	11	10 S.	35
2	3	22	5	46	0	31	10	37	16	12	10	12
3	3	33	5	42	0	50	10	56	16	12	9	48
4	3	44	5	37	1	10	11	14	16	11	9	24
5	3	55	5	32	1	29	11	32	16	10	8	59
6	4 F.	5	5 F.	26	1 S.	49	11 S.	49	16 S.	7	8 S.	34
7	4	15	5	19	2	9	12	6	16	4	8	8
8	4	25	5	12	2	29	12	23	16	0	7	41
9	4	34	5	5	2	49	12	39	15	55	7	14
10	4	43	4	56	3	9	12	55	15	49	6	47
11	4 F.	51	4 F.	48	3 S.	30	13 S.	10	15 S.	42	6 S.	19
12	4	59	4	38	3	51	13	25	15	34	5	51
13	5	7	4	28	4	11	13	39	15	26	5	23
14	5	14	4	18	4	32	13	53	15	17	4	54
15	5	21	4	6	4	53	14	6	15	6	4	25
16	5 F.	27	3 F.	55	5 S.	14	14 S.	19	14 S.	55	3 S.	56
17	5	32	3	43	5	35	14	31	14	44	3	26
18	5	37	3	30	5	56	14	42	14	31	2	56
19	5	42	3	17	6	17	14	53	14	18	2	26
20	5	46	3	4	6	38	15	3	14	4	1	56
21	5 F.	50	2 F.	50	6 S.	59	15 S.	13	13 S.	48	1 S.	26
22	5	53	2	35	7	19	15	22	13	32	0	56
23	5	55	2	20	7	40	15	30	13	16	0	26
24	5	57	2	5	8	0	15	38	12	58	0 F.	4
25	5	58	1	49	8	21	15	45	12	40	0	34
26	5 F.	59	1 F.	33	8 S.	41	15 S.	51	12 S.	21	1 F.	4
27	5	59	1	16	9	1	15	56	12	1	1	34
28	5	58	0	59	9	21	16	1	11	41	2	3
29	5	57	0	42	9	40	16	5	11	20	2	33
30	5	55	0	24	10	0	16	8	10	58	3	2
31	5 F.	53	0 F.	6			16 S.	10			3 F.	31

The

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

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 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 Plummet, 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 Error will not be great.

You may find the time when the Pole-Star comes to the Meridian, by ſubſtracting the Sun's 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 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 *Mathematical Compendium*, and other Books.

Note, If the *Sun*'s Right Aſcenſion exceeds the *Pole-Star*'s Right Aſcenſion, you muſt add 24 Hours to the Pole-Star's Right Aſcenſion, and then ſubſtract. The Right Aſcenſion of the Pole-Star is determined by Mr *Flamſteed* 33 Minutes 44 Seconds of Time in the Year 1690, and the Increaſe of it's Right Aſcenſion 1 Minute 16 Seconds of Time in 10 Years. Therefore this preſent Year 1714 it's true Right Aſcenſion is 36 Minutes 46 Seconds of Time.

If

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 Plummet, 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 Plummets, 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 Crevice 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 larger 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 prepared, 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 through the Sight with the bigger hole, and turn the whole Inſtrument about 'till you ſee 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, 'tis 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

with a coloured Glaſs, or one blackened with the Smoak 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, ſubtract the Right Aſcenſion of the Sun from the Right Aſcenſion 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 through 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 Inſtrument 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 wherever there is occaſion to correct either Sun-Dial or Watch.

This Inſtrument may be found improved in the *Philoſophical Tranſactions*, No. 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.

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

A Table

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

Rev.	M.	S.	T.	Rev.	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 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 Minutes 56 Seconds ſlower than the Star; or after two Nights 7 Minutes 51 Seconds; or 16 Nights, 1 Hour 2 Minutes 54 Seconds, *&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 'till as many Revolutions of the Star are paſt, as you are minded to take notice of.

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 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 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.	Sun's Re-fraction.		Variation at the N. Solſtice.		Variation at the Equator.		Variation at the S. Solſtice.	
Deg.	M.	S.	M.	S.	M.	S.	M.	S.
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

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 Sun-Dial, 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 Sun-Dials shew the Time. And therefore I have calculated my Table to only 10 Degrees.

The Table needs but little Explication. For having the Sun's height, you have against it, in the next Column, the Refraction: and in the three next the alterations of the Hour, at three 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 Minutes 34 Seconds, about *June* 11, and 3 Minutes 32 Seconds about *March* 10, and *Septem-*

ber 12; and 4 Minutes 38 Seconds about *December* 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	Days			
604800	10080	168	7	Weeks		
2592000	43200	720	30	4	Months	
31556940	525949	8765	365¼	52	12	Year

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 31556940 Seconds, 525949 Minutes, &c. So that if we would readily ſee what Number of Seconds are in a Year (for Inſtance) under *Seconds*, and againſt

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 a Year are the true Numbers, according to the beforecommended 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.

Place this to fold out at the End of ye Book