

AN EXPLANATION OF MY WATCH OR TIMEKEEPER FOR THE LONGITUDE AND
AS WITH A VIEW OF OTHER TIMEKEEPERS VIZ OF SUCH AS HAVE HITHERTO
BEEN PRODUCED IN THE WORLD AND AS FARTHER WITH SOME HISTORICAL
ACCOUNT COINCIDENT TO MY PROCEDURE

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By Figure 1st may be seen that there will be a draught or force communicated to the circumference or teeth of the 2nd wheel, from a given force or weight acting at a certain distance from the centre of the 1st wheel.

But this moving force, viz at the 2nd wheel (and as to be understood under its diminution from the force given to the 1st wheel) will be rendered unequable or inconstant to itself by the difference that will by times happen in the Friction at the pevetts etc. of those two wheels.

And from Figure 2nd it fairly appears that the same force or draught at the circumference of the second wheel, as being continuing the same in diameter as in figure 1st (but the diameter of the 1st wheel and pinion being doubled) in there had as Figure 1st. And that without any more than 1/0 of the pressure at the teeth of the 1st wheel, as also consequently without any more than 1/2 the pressure upon the pivots of the 2nd wheel: therefore it must as a subsequent be with much less than 1/0 the Friction or uncertainty of obstruction in moving because the pevetts of the 2nd wheel not only be smaller but as far more than double the number of teeth may be in the 1st wheel, as also in the pinion because the teeth may be much weaker or finer and with the conspiring, will not only (as from the double radius of the 1st wheel) be abated to half, but withal, of the spaces of the teeth in the circumferences of the said wheel and pinion, and the which versed lines (or as may be styled evanescents of the arches of space, or the distances from the syzgia) will be lessened nearly according to the squares of the same spaces.

And it is to be understood that the same preheminece in harmony is to be extended throughout all, as following in the next place betwixt the 2nd wheel and the 3rd wheel and so on.

Hence in a watch to some degree of the pivots of the wheels may not be required to be so thick as in a smaller watch, or if in the most advantageous construction as touching from largeness more force etc. they be required to be as thick, it may still be much better since then the effect of a far greater force be still for the better be had i.e. to a far greater certainty in itself as being still freer from the incumbrance of friction viz in comparison to the said force acquired (for the feebler force is in itself the more alteration or alterations will happen therein i.e. at the end of upshot, as here implied of a number of things concerned) and therefore it may hence be infered that nature never bespoke a little watch, whatever our whims or fancies may have suggested, produced or required, and tho I have here as from a small one made a foundation of reasoning for a larger and when as it hath never heretofore been found that a very large watch according to the principles upon which they are made, performed so well as a lesser, but as that to happened be retaining what workmen think or seem to them to be proportion, as making without grounds the pivots etc. of a small watch the standard (and especially them of the balance as better to be perceived hereafter) my foundation for reasoning (as touching this point) is therefore right.

But still in my longitude watch that is not all as touching this matter for notwithstanding the freeness or more than common certainty in force as above and that as pretty well to be bore with as below, yet there is still a rectitude of the same at the wheel next to the balance wheel viz as properly thereby a larger controller or corrector of the force for the said wheel so as by which means that wheel or the contrate wheel becomes as it were the first mover concerned in the measuring of time and that with an equal force whereby to act, upon the pinion of the balance wheel itself, for by the means here, mentioned the force wherewith that wheel is to act is exactly there measured out and the over plus as intimated be at more or less as may sometimes be occasioned by inequalities in draught from the main spring and fusee, and as the best from the force being handed as it were through all the rest of the wheels as hath been treated of and tho in that point much better than common and even as from them all so be bore with, providing as hereafter the figure of the pallats be or can be always rightly acquired, yet still I say, the over plus be it more or less (but as implying it in the contrivance always to be) is thrown off to turn a wheel and fly

the which is done 8 times in a minute and that at all the most (as the matter is contrived) without any sensible incumbrance the said contrate wheel.

So consequently chiefly (as to be regarded) without any sensible difference ever to attend the same.

Now in such watches as hitherto common, the force of the balance wheel has about the quarter part of the command of the balance; for it is allowed, as a general rule among workmen, that the ballance without its spring must take about 1 vibration in the time in which it is to take 2, so I know that according to the thoughts of some or even of most of them, it is imagined that the said ballance wheels has or rather along with it all the rest of the wheels have to half command of the balance, but however it is much better than so since to make a thing more with twice the velocity (and without considering any resistance from the air) requires the force to be made up four times, as much, but notwithstanding in this case tis still bad enough i.e. was it intended or from thence to be in anywise pretended to touch the affair of Longitude as being without any proper counter-poise so as to ballance that to any sufficient equality, viz, when the said quarter part of the force is or becomes less in itself at sometimes than at others, and when as a consequent of what has been illustrated and to augment the matter, the less the watch (I am here meaning among pocket watches) the more inconstant or unequable in it self will the 4th part of that force command be and so consequently, the more unstable the performance of the watch.

But what is or ought indeed to be very surprising, did not custom or usage make it familiar or confirm the matter that this 4th part of the command of the balance and the which can even put the balance in motion from rest, is, that it does not as yet, occasion the balance to vibrate much farther than what it generally does or is found to do, for it is, seldom found to vibrate farther than 5/8th the circle, but commonly (as the matter is managed) not so far.

To this is to be answered that through this force is or must be able, as with respect to the ballance spring to set the balance in motion from

rest notwithstanding its incumbrance from friction in comparison to its smallness viz, in a little watch as treated of above, but as being still farther incumbered with the friction attending the balance itself together with the sluggishness, as hitherto of the balance spring is or must be the occasion (as will in the force) a perpetual motion might be gained, but on the contrary, it is always (as 3 beans in a bladder) the same.

Now hence or from what has been explained, is it to be expected in a cylinder watch to be any considerable space of time and that without either its adjusting plate being altered or its ballance wheels applied with oil i.e. so as to excel or vie with other common watches when equally as well executed) unless it could be said that more friction with less ponderosity of Balance, and with, as it were, a secondary or counter ballance wheel as proving there a hinderance to the sudden violence of the wedge like motion of the said wheel upon the ballance can make it better, the which must consequently be a very imperfect action, especially at such a distance from the centre of the ballance as those required.

Whereas it is only from that means, improperness of the said action and friction that the force is so far lost as not to carry a ballance, or rather, as more properly speaking, as not to admit of being governed by a balance equal to that of the other and when having as here strongly implied, the more occasion for it, for was it, or could it be naturally otherwise, as touching all these properties, it would then be naturally something else and consequently better than what it is.

And the same as touching imperfectness might be said of a pendulum clock with a little vibration and (considering the nature of the thing) so fully as great a degree, was not the bob even as it were immensely heavy. (So therefore, as towards that it is generally heavy enough or even much too heavy as with regard to what it and the clock is commonly supported from) viz of the wedge like power or thrust of the pendulum wheel there and at so great a distance from the centre of the pendulum as then coherent to such smallness of vibration.

But here it may be notified that according to the most general opinion it is thought that hence arises and excellency and that chiefly through the

esteem of Mr. Graham, viz in that a small force at the pendulum wheels (not considering the steepings of the slope or scaping of the pallats and as together with their length) will keep the pendulum in motion.

Now this is without taking any notice of what the difference in freeness or clamminess there, viz as with respect to that small force, at such a length of pallats may as with regard in inequality, in such small vibrations do, save only, at first sight it must be insofar evident as that a heavy bob must be required.

I say this latter circumstance or those latter circumstances (viz of freeness or clamminess etc.) are not fairly taken into the question, but that from the former there is deemed an excellency and that chiefly as above through the choice and judgement of Mr. Graham.

Well, granting this to be or if it be an excellency then it must be better to enhance or augment it i.e. to carry it farther, and the farther, or more so still the better, so it must be the best for the pallats to be at least as long as the pendulum i.e. in effect for the action of the pendulum wheel to be at or upon the bob itself, for then certainly a very small force or even an unfortunately small force with a steepness of pallat will do; but now at last it must be fairly left for anybody to ask, where is hardly the pendulum at all and be the bob ever so heavy?

Nay in a church or turret clock upon this principle i.e. as with this wedge like action and smallness of vibration and only so far as done or produced to the world by Mr. Graham (viz with no more length of pallats as in proportion to the wheel etc. nor steepness of shape than what he did) the vibrations of the pendulum will even be pretty much effected by the different weight of the rope as the weight grows lower and lower, and pretty much affected from the discharging of the striking part and as farther withal with the demonstrably nonsensical dead beat for were the vibrations in some degree or proper measure bigger, the which would certainly be much better (not meaning as without a cycloid to be large) then a suitable recoiling from the disposition of the pendulum wheel and pallats alone as acquired from proper experiments might in some measure or even in pretty good measure stand in lieu of a cycloid (tho still as from the common manner of scaping, not to be understood to come up to a great degree of exactness that is, the recoiling must be in some correspondently greater

and greater degree, the farther it goes and that as with, or as on course as with a greater impulse towards the motion of the pendulum to be impressed upon it at the beginning of each of its descents, than must or ought to be towards the latter end of each of its ascents, for as touching the matter or the dominion which the pendulum ought to have over the wheels, it ought to be considered from the nature of vibrations and as together from the causes from whence they are produced or maintained, that a pendulum bob of 3 pound weight and vibrating in an arch of 12 degrees will have the same dominion over the wheels or differences in friction among them as a bob of 48 pounds when only vibrating in an arch of 3 degrees, and as then or therein with the differences in friction at the pallets, at so great a distance from the centre of suspension of the pendulum as might be coincident to such small vibrations, and even still, it is moreover to be understood that this would only prove to be the case as with respect to equality or exacting in going for a long time, if the differences in such small vibrations of a long pendulum, from the manner as commonly maintained could be adjusted by the application of a cycloid the which (in itself) could not be (so small a portion thereof being then to be in use) was the greater of such vibrations, as from the nature of what has been shewn always found slower or to take up as they naturally ought to do, somewhat more time than when smaller, whereas, from the cleanness, or foulness of the clock or from a touch of oil being given to the pendulum wheel etc. the contrary is oft times found to be fact, the which I have heard Mr. Graham acknowledge and Dr. Bradley affirm, and indeed considering the meanness or lowness of such principles as hath been illustrated, it would be very surprising had not custom made it familiar to see a man get us such a clock and in pointing out the time; and even in books to direct.

But nevertheless or notwithstanding what has been or can be said, it is, however, a brave, easy, sleepy way to deal with the pendulum and so as whereby from its nature to except something from it.

Be it so; yet still or again it cannot, as at the same time be said to be any other than as it were a heartless dead or cowardly way, viz as in comparison to the so managing it as whereby it shall be obliged to do its best or not be prevented from so doing, but instead, that, as on the other hand, may be declared as an exceedingly great engagement and notwithstanding Mr. Hygen's demonstration of the cycloid (for with respect to the application thereof it is better without his demonstration than with it as I shall show)

but still surely not too great for a true hearted English Mechanick to encounter with or to the Honor of the nation to be forbore; and here it may be improper to remark that I from being a Ringer (or taking a hint therefrom) and made use of an artificial cycloid (but had no name for it) some years before I had so much as heard of Mr. Hygen's name and not in the least at a loss for that since a demonstration of the natural cycloid can be of no service in the affair for no spring at the top of a pendulum whereby the pendulum can be suspended could ever properly submit to such an application as the top or tops of such curves would make without being in danger; yea even in immediate danger of braking, therefore some other curvature must be to the purpose and the which can be so as even thereby to preserve the spring from braking.

Nor is Mr. Hygen's demonstration any further true in itself than by supposing the pendulum to move by itself i.e. without any force from the wheels of a clock and consequently in vacuo, whereas the contrary effects must be in themselves, and can upon a proper foundation be taken in: Mr. Hygen's demonstration must also farther suppose, not only the pendulum to keep always its same length, but as above implies the spring at the top to be without strength (See Appendix A)

to no better performance as also to publish so foolishly in magazines and News Papers as if no better things were ever possible to be expected and that, because Mr. Graham neither discovered nor practiced upon such principles as whereby my better or more perfect things were ever likely to be attained but, as nevertheless his clock (though as properly speaking neither pendulums nor Ballance, but as rather in effect, from the smallness of the vibration etc. as mongrels between two) to be styled Astronomical and the folly in his watches proportionally extold; there not being indeed (and as with my gridiron pendulum and notwithstanding what has been shewn) any better Astronomical clocks as yet (though had enough) mine only to be expected; but mine is a clock which cannot easily be removed.

But now it is to be observed that one of my longitude watches and the which can still more easily be removed, will hereafter do much better for Astronomical Observations abroad, should there be thought occasion than one of Mr. Graham's clocks; but indeed, at the time or times of observation it will require an assistant to count or read the watch, whereas to the purpose

or as in the most true light, and when all things are brought to the greatest perfection and as so to be acquired by the easiest methods, and as setting aside my friends proceedings, viz Mr. Graham's as not the most properly adapted to the purpose or at least not to such farther purpose as hereafter to be required but as therefore otherwise proceeding and that as it were in a contrary direction, viz according to my examples, and though as therein demonstrable to be far more agreeable to the Harmony of Nature (as is to be perceived by this explication) yet still as so, it is certain that all the clockmakers or every clockmaker will not as thence be rightly able to accomplish an astronomical clock, or perfectly continuing Regulator, neither consequently, as by some surmised, every watch maker a Longitude watch; but notwithstanding, as with respect to the watches there is no doubt to the least if proper care be taken but that (after some time) there may always be a sufficient supply, and therefore to proceed).

In my watch or Timekeeper for the Longitude, the balance wheel has but about 1/80 part of the command of the Ballance, but that as in great measure from its largeness, the said 80th part because for greater in itself that the 4th part is, on other watches, inasmuch, that to continue to a certainty (though not to be presumed as quite to eternity) no diamond pallats and with the balance wheel of steel, quite hard.

No Longitude watch, but as still with respect to the force, or momentum of the Ballance but 1/80 part thereof, so consequently from the great strength of the balance spring, and, as I order the matter, with its briskness of elasticity, the which I may now properly term, the great power or strength of artificial gravity (and that as will appear by and by to far surpass in effect that of Natural) the said 1/80 part can but hardly stir the balance so far from rest (if standing) as the wheels of a clock can (then) stir the pendulum i.e. not only meaning as in comparison to the angle that each one, after set a going plays, or is to play but as more correspondently considering the space through which each one has to pass in each second of time the which in my watch (with its artificial gravity) is more than 2/3 the circle, five times in a second whereas in the pendulum when as hath been weakly thought to be best perfection it is but (in that time) a small arch or space but that the force of the balance wheel in my watch as with respect to the whole momentum of the balance bears but the 80th part, is plain as followeth for by the force of the said balance wheel the ballance

without its spring (or artificial gravity) will almost or even very nearly require 2 seconds of time wherein to perform 1 vibration, whereas with its spring (or Artificial Gravity) it fetches 10 vibrations in that space of time. Nay with its spring alone, i.e. without the wheels, it will move or is to move as fast as with the force from the wheels and that from or by reason of the declivity on the back of each pallet when the wheels act (as of which below) now was the balance, when without its spring to be quite 2 seconds in fetching 1 vibration it would then require the force to be made up by the said spring 100 times as much, and that in order to fetch 10 vibrations in the same time)i.e. the force then required must be as the square of 10) and as that is so nearly the case, I may safely say, the ballance wheel has not however above the 1/80 part of the command of the balance and consequently the balance spring all the rest.

But as farther to this, it may in other words be notified that as from the construction of the pallets, together with the briskness (or perfections) of elasticity in the balance spring the motion of the balance is by no means languished (that being an idle property whether in pendulums or balances) but exceedingly brisk, yes so as thence to become from its coherent diameter and weight (and as required velocity) of far greater momentum as with regard to its dominion over the wheels than ever was known in the world before, nay, as almost (as with respect to a watch) infinitely more, I may therefore, as with assurance pronounce it a consequent indeed! and that as farther, from the performance of the watch, as thoroughly speaking, the virtues of the same.

But still, they say a watch is but or can but be a watch and that Mr. Ellicott has tried what a watch will do and that the performance of mine, though nearly to truth itself must be altogether a deception.

But now it is farther to be observed that as touching the nature of balances, was my watch to have been regulated by a ballance of but half the diameter of what it has, and as still to have had the same dominion over all the wheels, it would have been of 8 times the solidity it now it, since it must have been (as I found from experience) 4 times as heavy as what it is*

*(That is that the weight of the balances must or ought to be diversely as the squares of their diameter. Now this discovery happened with other

things to fall in my way the which all the learning hitherto the world could never, or at least would hardly ever have exhibited: and from hence may be observed a great, but common inadvertaning, or rather dark incapacity of workmen as notifying the weight of a balance more than its diameter, when as the latter is in effect of far more than double the consequences of the former, and on which account Mr. Graham's example proved a very bad pattern to the misapprehension of the world as may be observed from my Description of the Nature of Ballances.

would have been increased, as its pivots and since withal then must, have then been thicker, dumpy, shaggy work, sure: but as it is and in proportion to the nearness to the centre of which the wheel acts and as with its artificial gravity, it is fairly demonstrable that it is in effect a much longer pendulum than when by such length of pallats as betwixt the 14th and 15th part of the pendulum itself, as according to Mr. Graham's way swings, or rather creeps seconds, yea, every so far then exceeding, without any farther, as about 2 to 1; whereas there is, farther, of great importance to be added, the great power, dominion or advantage arising from the great difference of velocity therein.

As now as still farther with respect to this my timekeeper; what would become of its balance, as with the greatness of elasticity there is in the balance spring, was the force of the balance wheel (if possible, as under the same condition in all other respects) to be made up so great as to bear 1/4 part of the command of the ballance?

Why, it would occasion it to vibrate perhaps about 3 times round every stroke of beat, could there be, or as supposing a provision for it so to do* and that still 5

*(I fancy not more, or it might be not so much the resistance from the air being according to the square of the velocity; and the which as so and in so far as it does vibrate is of great service in the affair: Its radius being 11/8th inch; its weight without its spindle or any brass in the middle betwixt 28 and 29 grains; and it is to be remarked that its 3 crosses are but smallish and the round part in the middle, but little, so the most of its weight is in its rim.)

such strokes or beats in 1 second of time, but then it would not go so well by far, since the force from the wheels or from the balance wheel would have so much to do in the matter, but still much better than when from a very feeble force as is the case in common watches; but to return to what it does do, and that as from the properest cause, and as communicated to it in the best manner (viz according to my direction and industry that I think is ever likely to be) viz to the $\frac{2}{3}$ + the circle 5 times in a second; it is certain for the worse that no natural gravity of a pendulum, as in the long pendulum way can occasion it to move with such swiftness (or power) in such clocks as in the said way can properly be described (viz to the swiftness of 24 inches in 1 second of time, and even as without any returns therein, viz in the time whereas my balance has 5) until indeed it comes to the length of about 13 foot; and was a pendulum to be put in execution so short as to vibrate $\frac{2}{3}$ the circle 5 times in a second it would be good for nothing, since neither by a cycloid nor by any other means (as I think I may make bold to say) could difference in such vibrations be regulated, and as when, moreover, in the pendulums falling each time so far, viz as about $\frac{1}{3}$ the circle; would be created about 4 times its weight upon its pivots (or upon one of its pivots) as it passes by the bottom; hence Artificial Gravity is better in itself than natural, for as in other works, it is plain that no such large vibrations of a pendulum, as natural, and as is or may be coincident to Artificial, can be regulated or adjusted and as when moreover in the Artificial, be the vibrations of any bigness so ever, there is only, or as simply the weight of the ballance to be suspended throughout the whole of each, nay, in the horizontal position its weight can but occasion little friction at most, therefore again, artificial gravity must be better than natural though the world has been “croggleing” and defaming it for so long a time; but why should it be thought strange that Artificial Gravity (as I have termed it) should be better than natural, for cannot an Artificial magnet be stronger than a natural one? But yet or notwithstanding there may indeed be said to be a preference in the pendulum, viz when applied to a clock upon my principles, and as in a great respect of my sort of materials as whence jointly (besides to a great truth in going) never to want cleaning when as the watch by times may* the which indeed in the clock is absolutely

*(But (as touching such a watch) it is to be understood when taken in pieces to be cleaned, that the very next day will be fit for its duty).

necessary to be the case, since a long time may even be required so as thoroughly to adjust it (at least if without the help of another clock of the same kind as best when already adjusted for, if from nothing but celestial observations alone it would be, considering to what nicety it will bear, and may from other help be brought to, it would be, I say almost, nay I may say altogether an endless undertaking) the which in the watch by the help of such a clock and as meaning in winter time or coldish weather can be short, and the reason for that is that nature so offering itself there, as that different causes can be separated as below; but still, in a pendulum and when upon the best foundation as here intimated, as also then from the strictest or ablest adjusting, the performance may be hard and so as to continue for a long time to less than 6 seconds in a year; whereas from artificial gravity, and upon such a foundation as can properly be the case in a watch made portable to carry on ship-board, and to which thing it can most properly be adapted it must, nay even beyond all expectations or methods whatever as touching exactness in Longitude, be looked upon as very well when to a second or two in a week, and that is what can from thence to the said purpose of Longitude be had; and therefore as so and as even with looking upon it as if not intended as primarily for that purpose, yet it ought still, as from its performance so be looked upon as a far greater curiosity than all the British Museum, for there are no other things, or natural things in the said Museum but what may elsewhere, or in several places of the world be seen whereas in my watch, there is, from all the world a hidden piece of nature or mechanism but as chiefly to be notified from the learned part thereof, a thing, thought to be quite out of the course of nature produced or brought to light; but indeed, should darkness be permitted to over-shadow it again, it might stand but a very bad chance of ever hereafter truly appearing.

And it may be proper to show, notwithstanding all unreasonableness as in our mechanical world, and therefore as not degrading it, because (through mistrust and ignorance) it cannot help it, that as my watch has been a voyage, and the which proved a very rough one, and though as not completed according to my acquired skill in the matter, yet even still in such a voyage, by performing the same it did, or would have done on shore (viz, in such variations in position as it so roughly met withal) it came within the nearest limit proposed by Parliament, and that in taking the whole voyage both out and in, when as in case of such great or uncommon roughness and that from my having had a little more time (viz as touching this my new invented timekeeper) tis now far better than it was before, tho as still to my knowledge, not to

be said to be so far completed, as to the purpose it is capable of bearing; but however as touching the matter, should such a watch hereafter be made, there can be no nonsensical necessity to go to sea to try it, since that would but be a trying of that one watch foolishly there, and not of others that the same it does or that anyone may hereafter do, and under such proper experiments made at hand, as most always be tried, to know whether or not all about the balance be right, the same it, or any other one respectively will or must do at sea, had not any experience there been had about it; but however (as above) that has sufficiently, or even severely there been tried and found to agree with such, demonstration and consequently with experiments made at land, the only indeed that can, or is necessary to be made, viz, in order to turn off, or try the thing true for its use, and that hereafter by such persons as must be rightly furnished and qualified for it; but it may be remarked that one person (but it must be a workman) so prepared might try, and in some measure adjust i.e. accomplish the adjustive providing that watches could come to him in such order as so to be done by, and indeed, was there to a Royal Observatory furnished with such a person, and with such a clock as spoken of above, it would certainly do as much good or be of greater than that at Greenwich*

*But this I fancy will hardly take, but that rather on the contrary, any workman, who may hereafter be able to furnish himself with such a clock will think himself the properest person to adjust or complete his own watches.)

it not being possible to bring such watches to their greatest perfection, or to what they will bear or are capable of bearing, and that is so nearly the truth itself, at least not in any reasonable time, without the help of such a clock as whose motion is as good as quite invariable, and that because it must for some time or as chiefly be necessary, was no farther wanting, that every 3 hours on the day times the performance of the watch be observed thereby to 1/10 second or less, the which being I speak from experience, very predictable to be done, since the observations are not like to Astronomical Observations, but each may be dwelt upon (or examined into) for the space of two minutes or more.

But here as in consequence of what has been shewn, it may not be amiss to remark, that one of my watches in perfection, would do much better to try or adjust others by than such a clock as what at present is called a regulator,

and consequently better, as well as at the same time to be attended with much less trouble to go anywhere abroad, should there hereafter be occasion to make Astronomical Observations, and not (as withal) wanting any adjusting to a different Longitude.

But perhaps in the whole it may still be thought there is or may be some difficulty in turning off such watches as being of such sublimity as even the great Sir Isaac Newton did not or could not discover the least glimpse of* be it so: it is then to be answered that in

*(But here, as by the by, it may seem somewhat strange viz according to such drift as was in my affair carried on (or rather as according to arbitrary designs therein) that Mr. Newton was not obliged to make all the mathematical and philosophical part of the world fully as sagacious as himself or to speak to God Almighty so to do before any significant notice could or might be taken of, his labours; whereas still, of all the things he had done there were none of so great utility as my watch and I believe it will hereafter be acknowledged that none of the Liberal Arts in the world (or what are so called) ever as heretofore produced anything superior to the foundation or principles of such a mechanical machine: but still not that I would be understood to disparage anything that Sir Isaac did).

any other way whatever, purposing to find the longitude there will be difficulty and if attended with a great deal of labour with figures, and wherein it may be no wonder by times to miss a figure and as when happening under the most favourable circumstances (viz as when the time at the ship can even as it all i.e. with any true exactness, or safety as this, neither (as intimated) to be had with any such frequency, therefore this must be by far the most preferable; *and since withal as well as once

*(For certainly that must be the best method, which easily offers itself so as whereby to be observed nearest to the truth, and that upon any, or every day when the sun and the horizon can be seen, no other phenomena to the watch being wanting.)

for all (in any one and the same watch) the difficulty here (if such it may be termed) is to overcome in quietness at land and never afterwards to be attended with any trouble or difficulty, when a ship is in tossing by the raging of the sea, so therefore to proceed.

(MS Appendix D)

It is to be understood that after a many experiments whereby to find out or ascertain as above, the greatest dominion in that a ballance could possibly have, or the means I say whereby the greatest power possible could be given it over the wheels, or as more properly speaking over any inequality in the draught from the wheels etc. I at last (and with the fronts of the ballance wheel teeth quite upright) acquired in the Figure and proportion of pallats accordingly as here represented by the drawings A and B as drawn correspondently to my two (Appendix D ends) different sizes of watches for the Longitude (viz one so as may be put in the pocket (not what I should think it the most proper for the purpose always to keep it there) the other larger and doubtless better of which large one all hitherto has been treated and experienced but in this point it is to be understood that the dimensions by drawings are just 10 times as much as what is represented by them i.e. or 100 times in area; and where in the first place the largest circle in each figure represents according to the said dimensions the bigness of the balance wheel as taken from out to out, to which the circle described by the radius or edges of the pallats is bearing in diameter $1/7$ part, taking the said wheel at a little less than from out to out and here it is to be understood the wheel to have 15 teeth and so (as found in consequence) this radius of pallats to be about $1/3$ tooth: the little circle to which the dotted lines from 24^{th} of the great circle (viz from 0.1234) make tangents is in radius about $1/4$ of that described by the edge of the pallats and represents the thickness of the balance spindle of the places upon which each pallat is fixed, and where the wheel passes or must pass closely by, save only in the lesser figure with a little allowance (as obliged for the worse) it being hardly convenient to make the spindle there so small and the which aforementioned dotted lines represent the plains or directions of the extremity of the balance wheel teeth, at such corresponding portions of the over turn of the pallats as by the said lines, from the figures as above are represented; the virtue of which over turn as from the declivity on the back of each pallat must even at first sight be very obvious as with respect to a different draught from the wheels

*(And now (in the watch) as touching to page 41 this interline following)

*(for as thence it is to be understood that if the balance at any time

may receive somewhat a greater impulse from the balance wheel, that can only occasion it to play somewhat farther, but, by means of which declivity not the vibrations to be performed in less time than as if not so, or as when so permitted from lightness of the air; or if both should so happen at the time (as the limit will never be very great) it is still but all one providing the declivity be rightly acquired, but to which acquisition (as well as in the greater respect below) Cambridge and Oxford education could make no assistance. Now the radius of which declivity (or curvature) viz as here described is about $\frac{3}{5}$ the radius of the pallets and with its centre of the spindle as may be perceived in the figures; and at the same distance from the centre of the spindle, viz at the $\frac{2}{5}$ the radius of what the edge of the pallets describe is a dotted circle to which the plain or front of each pallet must make a tangent nay this circle must be about the radius whether the centres of the declivities be to be in it or not, for from my experiments, and the which, from the pains I took about the matter, I am sure may be relied on, may be observed as followeth; and from whence withal it is very apparent that no demonstration could have anything to do in the matter or what was there to be sought after, viz, as touching what must be the best figure, pitch or situation of or for the front of each pallet, and in its best proportion as with respect to the wheel or teeth thereof and as together with the position of the fronts of the said teeth so as whereby to be given or maintained and that with a swift velocity as a consequent from the rate of 5 vibrations in a second and from a describing or fetching each time and angle or compass of 248 degrees, and as with the rim of the balance from its radius and as hath just been intimated from such short periods of time for its returns and as therein against the air's resistance, to pass through the space of 24 inches in 1 second of time; I say to give a solution, as touching the pallets or the action of the wheel thereupon that so whereby (under the circumstances here recited) the greatest vibrations of a balance of a given weight, and as above implied of a given diameter, shall be maintained from the smallest or from a given force; such a solution being beyond the reach of any demonstration whatever, so consequently must be both out of the latitude and longitude of Cambridge and Oxford* therefore the whole of the matter, and that as a

*(Yet Professors from thence, reverend men, must needs be showing themselves something by raising poor dijections in what they knew nothing, save only a weak smattering about heat and cold: i.e. only so far as to mention that such a provision ought to be, not what in reality must be, that

being a matter quite out of their sphere, though at the same time they must pretend to dislike or distrust it).

very material step and as here to be done in the first place (nothing being done to the purpose before in the World), was only to be acquired from experience, or according to the assertions of some, from such chances as might happen to fall out therein.

But to return, perhaps the radius of the curvative of declivity on the back of each pallat, may be required to be somewhat greater or less, i.e. so as the descent about the dotted line from number 2 (as in chiefly there, to the purpose to be ascertained) may be somewhat more or less, that being only (accordingly as here described and so far as I am able to do or say at present) somewhat steeper than as in my watch already executed, and wherein I afterwards found (as under proper experiment) was wanting so to be; or it may perhaps require each pallat (as in some other curve mathematically speaking) to be a little plumper towards the extremity or outward edge, so as the descent about that place was still be rather steeper as must hereafter, from farther experience be confirmed or brought to perfection, demonstration having nothing to do in this part of the matter any more than as in the other above, save only so far as that there be a declivity, not the Figure or proportion of its descent, so there was scarcely a probability that there should be exactly hit at first, unless chance had so far been pleased to favour me as that it might, as some have made bold to say, that all my things are nothing else but chance, I being of no capacity or learning so neither, as withal, anything that I could write to be understood; as chiefly Lord Morten; but to proceed, as in this point it could not be known what was done until some other things were first brought to their state of perfection, and the which as still could not be judged when so, without the diamond pallats themselves in some measure towards that state, so I say it was almost impossible that this declivity should be brought to its best at first*and as diamond is so very hard as whereupon or whence to try

*(The thing I may now as from experience affirm, that it must be the best when 'tis as much as it can most properly be, viz about the place above mentioned and there withal to be as from the centre of the balance, as the breadth of the pallats, upon the other more ground or previous account will rightly permit it to be).

experiments, and moreover, such experiments tedious and costly and unless of diamond would be nothing so I say again if not in this point impossible, yet it might have been very hard for me to have tried farther (as well as perhaps to the other loss of the thing to the nation) whether my time and money would have proved sufficient, this first essay to have carried me through for if not so it would have proved the last essay.

*(MS Appendix F)

I.E. As with respect to my attempting the matter in the compass and figure of a large watch, viz of about 5 inches diameter from out to out of its case, and that from the experience I had in my greater machines; the which, or drift therein was consequently to be, or to turn off a far more portable thing than my other machines, and the which I thank God (that to the good of mankind) is now so near in its whole construction as to do its business well, and not the effect of chance as according to Lord Morton.)

Now according to the result of the dimensions above, the ballance must vibrate fully $\frac{1}{4}$ the circle to let the pallets scape or interchange; and at its vibrating $\frac{1}{2}$ of the circle the overturn of the pallets will begin; and the most convenient force from the balance wheel must be such as to occasion the ballance to vibrate above $\frac{1}{12}$ the circle more each way, i.e. to come nearer the points, the whole vibration in the horizontal position is best to be maintained at about 10 degrees above $\frac{2}{3}$ the circle, viz the whole, (in that position) to be about 250 degrees; and then the effect of this force upon the balance as in comparison to that of the balance spring, and as jointly therewith, will prove to be no more than about $\frac{1}{80}$ part of the whole as treated of above.

Note, that space betwixt the balance and the cock, as also that space under the balance must not be less than $\frac{3}{100}$ of inch for if less, the air will too much resist the motion of the balance, or rather, as with respect to the matter, will not rightly (as below) do its duty, or permit of what is right therein.

Now, I suppose it will be allowed by all that if a pendulum or a balance would move by itself i.e. without any force, or as not requiring any force from the draught of the wheels etc, and that with a brisk, rapid, or lively

motion it would go true; I say (whether in a pendulum or balance) with a brisk, by no means languid motion; for it is certain that the motion of Comets when in their Aphelion i.e. when their motion is the most languid it is the most liable to uncertainty a variation.

And now I affirm, from experience that from the proportion and disposition of the ballance wheel and pallats as above, that the greatest vibration of a balance, and as with properness of radius, and weightness therein, so as jointly from which, together with briskness in the balance spring and so as thence withal to be attended or to meet with properness of resistance from the air, and that as implies from properness of velocity, as being much better than such vibrations of a balance, as must be maintained from the draught of wheels etc. be chiefly so limited, than as it were by friction alone as in the common feeble cases I say from the proportion and disposition of the balance wheel and pallats as above, there is the liveliest or the most powerful motion of the balance to be had or maintained from a given force, or rather from such a force as may, can, or ought most properly be given, an acquisition indeed of a very material consequence as being in nature the very soul of the thing (viz as from the ballance receiving as little of its motion from the wheels and as having so much of it as it were in itself, as being from its own, spring, or as in other words from artificial gravity) and as being withal as in consequence attended with the least effects of friction at the pallats, and obstruction from weights in the balance wheel.

*(Where note withal, that the ballance wheel may be thin and light, since from the nature or pre-ordained agreement of the said wheel (as of steel quite hard) and pallats (as of diamond) there will not be any wearing; but as this could not rightly be known before the trial the balance of my watch was best too heavy; and here note withal that it must be best for the contrate wheel to be also as light as can conveniently be.)

Indeed a many experiments and they very tedious and costly ones I found were absolutely necessary to be tried about it; (but still or as notwithstanding my skill and industry, I was by Lord Morten deemed a pick pocket) but how far from this must what they call a cylinder watch be? For was my Longitude watch a cylinder watch and was its balance to be the same in diameter it is, and to fetch as many vibrations in the same time, and they to be as large as they now were, it would not allow of above, may

I am very sure not of so much as 1/6 part of the weightiness of ballance it now has nay rather, as pretending to the properties above recited, I may venture to say it could not be at all* and that because the vibrations, and as when

*(Whence according to such a backward improvement, such a timekeeper as my watch must for ever have been debarred from the world.)

at the best, would be to be maintained by a very improper power or action as hath above been shewn (see MS P10&11) but as farther touching the matter, I may say withal from such an action as pretty much resembles, and that both in likeness and nature the latch of a door, where sometimes the door will hardly shut unless the end of the said latch be touch with oil, a poor matter indeed!

Nay, in fact as touching the affair of a watch, the biggest nonsense (in the whole) that ever was introduced into the world, as being no foundation, whereupon to expect any steadfastness, for any length of time, whatever might therefore be at first expected or embraced; but still as there was nothing done to the purpose anyway but even at the best were only as it were in embryo, viz in comparison to what the truth or as might for the truth be required so it took the effects of its chance amongst the rest, and made it through the blind opinion of the world, somewhat the worse for any, whether little or great John Harrison etc. to follow or come after my worthy friend renowned George Graham.

By Figure C is represented the action of the balance wheel as applied in its vertical manner to the pallats wherein the white teeth and pallat are to be looked upon as the upper and the hatched (as driving the other way) the lower and as the pallat etc. are in this figure represented in the same proportion as laid down above, so accordingly in still the same proportion is the extremity of the balance here described; and whence many be see, even by ocular demonstration that this is in effect (and though in this figure the representation for the lesser watch) a longer pendulum than Mr. Graham's in swinging seconds, and, whereas farther, this balance is to fetch 6 large vibrations in a second; (note to be farther this at A P119 in Appendix).

Now it has all along been supposed from principles of reasoning, that greater or less vibrations of a ballance as from the power of a spring

thereunto applied, must be performed exactly in the same time; not was I ever thoroughly able, under such circumstances as attended my larger machines to say or affirm anything to the contrary, but only from thence had great reason to suspect it; whereas from the qualities attending my watch I can affirm that that is not strictly true; but still reasoning came not much short in the matter, nor perhaps had not at all, supposing the air to have been out of the question, yet as notwithstanding in what I am now sure it was deficient (as in the medium of air) proved of so small harm to me; but now the truth is, that greater vibrations of a ballance so acted upon as here above and as occasioned to continue to move in air and as without any flour or power, as otherwise attending (i.e. when according to my principles there is no improperness of action at the pallats etc.) are naturally performed in somewhat less time than when smaller, viz contrary to the nature of the pendulum, nay indeed by some more late experiments in the thing and from whereas I was farther able to observe the matter, it might be more so than seems just here above to be intimated and so as more especially or as according to what I have observed, done or improved in the ballance, it must be regulated as in the pendulum viz by some natural or supernatural event and the which (according to my discovery and application I now denominate as a reciprocal cycloid: but it is an easier matter to put the same in execution than it is to put the other to a pendulum though at the same time none can be most surprised if I tell them that I went through a strange depart to find it.

(MS Appendix A)

But here it may not be improper to observe under what deception Mr. Graham was in, concerning this matter, and the which also (at that time) strongly occasioned me to acquiesce in the same opinion. He showed me from experience, in a balance of (as I remember) about 4 inches or somewhat more in diameter and as simple in itself save only its spring, and moving vertically, i.e. with its axis horizontal upon friction rolls, for this balance at first set to vibrate the whole arch, would for the time it was ceasing (or approaching to rest) perform each of its vibrations exactly in the same time, or exactly in a second of time as was to be observed by a clock which stood by: now this proved the matter to be quite the contrary to what he then imagined it to prove, and to what I also then acquiesced in, for as at first viz, when the vibrations were large, they would and did

cease faster by much (from the Airs Resistance) then when they became smaller, yet still (under that circumstances were formed in, or took up the same time, whereas had there been an uniform force applied, so as to have kept the large vibration from ceasing they would (each one) have been performed in less time as is fairly to be perceived as followeth.

Supposing a vibration of one hundred part of the circle (i.e. $3 \frac{6}{10}$ degrees) to be maintained in air be a certain small force, then as vibration of the whole circle could not or cannot be maintained in air with any less than a 100 times a 100 equal 1000 times that force, it cannot be unreasonable to suppose but that such vibrations must be performed in less time; but here (as by the by) it may not be improper to remark that the great force must be better than the small one, as being to be rendered more constant to itself.

In the drawings of my timekeeper for the Longitude its ballance spring is represented in its due or full proportion, and as with my metalline thermometer applied thereunto; and in the same figure is also represented the moveable figure of the root of the said thermometer as also of that of the outer end or root of the ballance spring and each of which in two respects, one sliding the other as correspondently respecting a centre or centres; and by the same drawing it is to be observed, that after a little portion of such curvature of the spring as is to be supposed to suit the range of the thermometer, and the which upon the draught is described by a radius of about $\frac{3}{4}$ the length of the thermometer as being nearly suitable to what may be required for that purpose, viz, from the thermometer bending by heat or cold, I say after that little portion of curvature, the rest as remaining part of the spring (viz from thence to the end) goes away nearly straight (though not quite so) and at a right angle to the temperate degree of the thermometer as in may be seen in the draughts and about the midway betwixt the thermometer and what may be called the stud (or somewhat father from the stud) is applied what I call the Reciprocal Cycloid as of which hereafter but it must be best for the end of the spring as when leaning with its proper pressure against the said cycloid (and is in supposing with the watch standing) to be about the shape in which it appears in the draught, that is, so to be understood, as when without that leaning, to be naturally, from the pin of the cycloid to the end more straight if not rather curving the other way.

Now from that part of the spring going from the thermometer to the stud in manner as above shown, the root or basis of the said spring thereby becomes firmer in itself and, consequently, must thereby better tend towards truth in the going of the watch than if it went concentric to the centre of the ballance as common, for (to the purpose) I know from experience that this conspires in some measure towards making the ballance to vibrate faster from a given force.

But this is not all for what this shape in that part of the spring is designed but that chiefly as followeth.

It is to be observed that the Reciprocal Cycloid has its application only to one side of the spring, viz, to that side, towards the upright, or as may be called parallel line which passes through the centre of the ballance and that the spring as hereafter to be understood, is only to depart from it at a good deal later, or after the middle of the vibration and that as (only can be) with respect to but on way of the ballances vibrating; but what I am here about to shew is that was this part of the spring to be otherwise curved, than what it may be said as here to be* (or as what is here to be shown, i.e. meaning that the radius of which part as expressed in the draught to be 5 ½ inch may perhaps be less, that not being at my drawing of which acquired from experience, the end of the spring in my first watch not being in that shape, I not understanding it than viz (in the making of which) so to be necessary or so to be required, but the matter must be, that when, with the balance cock off, that then by depressing and elevating in a few degrees alternatively that side of the watch where the spring barrel or pendant is, that then I say, that part of the spring, not thereby in the least to be found to alter its figure, viz by the leaning of the balance each way, for should it do so, then, as in the watches) going with its face upwards, but not quite horizontal, but with the pendant a little elevated or depressed, as supposing about 6 degrees, then I say, was this part of the balance spring to be more sensibly or otherwise curved than what, as by the draught is represented or as is here shown, there would then be an occasion, through the little shake that the balance pevet must have in its jewel hole, to make the said spring depart (as mathematically speaking) a little sooner or later from the cycloid, and thence occasion a small variation, as is the case in my first watch.

Note, the two pins in the thermometer which compare of the notch for

the spring, must be tempered steel, for brass will not continue to bear the pressure of the spring; and it is to be understood that the spring is to be so closely confined between the said pins as only to be so far sure, that by the bending of the spring or the going of the watch, that (I say) the spring never touch both the pins at once, i.e. measuring as at the extremities of the vibrations* (and the reciprocal cycloid (as termed above) must be best, as mathematically speaking, to be made of brass; but the reason for it so to be is not worth any further notifying, because the demonstration would not only be tedious but useless; but it must be very thin (as about 0.03 of 1/4 inch) with a bit at the end wherein to drill a hole for such alike (tempered) steel pin as one of them of the thermometer).

And now the balance spring must be turned up into its figure before it be hardened, and to be let in the fire for hardening it must be laid in a pan (turned up) of thinnish plate-iron and as bound between two pieces of the same material (but thinner) crossed out into ribs, and each with an angle or edge towards the spring (that the water in quenching may have freer access) and with borders left about their extremities somewhat broader than the ribs, but the whole so light as only to make sure of going speedily into the water, the which the spring alone would not make sure of doing (the water, as best, to be set before the fire a little beforehand); and as the spring by hardening will fly out of order more or less, so it must after hardening be confined in a groove cut in a bit of plate iron prepared beforehand, and to which it will submit (tho hard) without danger of breaking and then, after being well oiled or moistened with oil it must be immersed in a mixture of lead and pewter just melted viz 17 of lead to 1 of pewter, the which as found from diverse experiments will both give it the most elastic temper and also bring it to its figure again, but if it should not happen to be quite right as touch its figure in the thermometer place as spoken of above, and as of which more hereafter, it must be put in another plate or groove, adapted on purpose and in the same manner be oiled and immersed again, nay it may be so done by a second or a third time etc. should there be occasion, taking care that the mixture of metal as stirred about and seamed with a bit of bath be never made hotter than just melted; then it must (with care) be rubbed to its thickness or strength as in its figure and that with a convenient bit of brass and oil-stone powder as resting upon a bit of wood prepared for the purpose and as thereby (I say) to its strength as found by short trials from the going of the watch, as perhaps at first from 3 or 4 minutes each, but

making sure the spring be put each time (or always) firm in the collet, and as with respect to its crink or elbow as nearly as possible at the same place or distance therefrom, for the farther that is out or off the collet the greater or stronger will be the effect of the spring and so may occasion deception in its ribbing or bringing down to its required strength if not in this point carefully observed*

(*The shape of which collet being best to be as in the draught. And here it may not be amiss to remark that as the said collet must be best to consist of as little weight as may be properly possible, so its centre hole as thence not to be too wide, but rather to have little notches for its going on, or slipping over the frames of the pallets; and note also, its hole for the spring wedging must be square).

and for the first trying of the said spring it is to be understood that one of the pins in the thermometer may be somewhat too small, so when the spring is come to its thickness it may be taken out and the hole broadened a little and a thicker pin put in, in order to bring the watch to its straightness as above: and it is to be understood that the spring is to be a little tapering or so tapering that all its turning work regular as the balance vibration.

Now it is to be understood that by the great strength of the balance spring, and as with the watch Horizontal the balance spindle without the cock must stand quite upright as to be acquired from the moveable roots of the thermometer and balance spring; and then, as the said balance spring is so strong, the balance may be set vibrating.

*(Viz by moving the watch first, one way then the other as horizontal (but each but a little) and so in keeping with the balance to lead it for a few vibrations. This being also (as here by the by) the way to set the watch a going (viz, often first wound up) if at any time it should be let go down, and then to be done differently (as just shown) without opening the watch [p.28].

*(As also it may here as further be observed, that the watch must never (as at other time) be turned or twisted hastily about in the plain of the dial plate (i.e. in the plain in which the vibrations of the balance are performed) but as otherwise, when to be wound up, or at any time to be taken in the hand, such turning or twisting as necessary must be resolved into two other sort of turnings, viz in one respect, as if upon two pivots, the one at the pendant the other at the opposite or 6 o'clock side, and in another as

if upon hinges at 12 or 6, 9 or 3 etc. and still the slower the moving the better which ever of them be first (but I do not mean extremely slow) I say it must so be minded in such a watch, although as happening from the poorness or meanness as used in common watches or as rather from the suitable weakness of their construction (viz weakness from whence to expect truth in going) that such a matter (nor as hereafter spoken of viz, at the end of a note P.78) needs not in them to be regarded: Not but that this watch may be turned about slowly in the plain of the ballance the virtue of which consisting or ought to consist of as followeth: viz as primarily in freeness from friction in their action and as therein coincidentally to a large vibration and that as with the force from the wheel whereby the pendulum is to be kept in motion to act upon it (as taken in a mean) at but about 4/10 inch from the centre of the spindle or arbor of the pallats or (as I here mean as the same thing) from the centre or suspension of the pendulum itself (viz in a pendulum that swings seconds) though from the draught as spoken of below it may seem to be at a great deal farther distance if not right understood and then as secondarily from the pendulum receiving as from the said pallats (and as in taking the result of the action of one with that of the other) a considerably greater impulse for the maintenance of its vibration against the airs resistance in each or every of the ascents (viz from its lowest point to where the pallats interchange) than in its descents; and as thus from such force at the pendulum wheel, as to occasion the pendulum to vibrate about 1½ degree on each side, over and above what would barely permit the pallats to interchange, the which at the pendulum end (in a compound pendulum swinging seconds) will be on each side above an inch;* for from the

*(And here it may not be amiss to observe, that the angle of vibration will be means of the weight of the wires on which the pendulum is composed, or as in other words by means of the weight of the upper part thereof (as thence occasioning the pendulum to bend near its top or near the bottom of its spring) will, I say, cause a greater angle to be required at the bottom of the pendulum, so as whereby to suffer the pallats to interchange, than is represented by the drawings, consequently the whole vibration must or will also, according to that result be enlarged.)

nature of such pallats as here explained, and as I have confirmed from experience, and as best to be observed in or from my last design of a pendulum clock, and as together therefrom the size of the pendulum wheel,

number of its teeth and all other things pertaining thereto, and as withal to be understood, as in my other clock, the axis of spindle of the pallats to move upon edges of brass, in polished notches of glass (tho, as yet the clock unfinished, viz at the drawing up of these writings, and that through, as ought to have been thought unnecessary hindrances) that from or with this portion of recoiling viz in the $1\frac{1}{2}$ degrees after the interchange of the pallats, or as may often happen, or keep happening, in some degree to be more or less, viz from alterations in the pendulum road, by difference densities of the air etc. but yet the which as together from such the other or continued virtue or virtues of the pallats, as just here above treated of and wherein it is as thence to be observed in the recoiling that the farther it is occasioned to extend, a greater abatement of force will attend whence I say that from somewhat at any time a bigger or lesser force at the pendulum wheel and that the clock will not, as implying with a cycloid, be occasioned to go either faster or slower, on that account or on these accounts, whereas if that was not the case or was not the foundations as here described the said cycloid could never to be so ordered as rightly to do its duty* hence I infer, that if not as chiefly from a

*But here it may be asked whether Cambridge or Oxford education was ever likely to have taught this? As knowing about as much thereof this matter or of such a foundation as in this treatise described for the Longitude or as I may say of such the most properly perfect, convenient or surest foundation for that purpose (viz before I made it known or as from time to time exhibited it to the World) as the blind Priest in the Jewish Sanbedrim, did about what sort of a King Jesus Christ was to be though that concern was the highest piece of His Divinity, and tho this of late years has proved the highest search pertaining to these Reverend gentlemen's study, and still or at last, not only to know nothing of it, but would hardly be persuaded to hear anything about it (viz about the most easy, sure, or properest foundation for the Longitude) and yet or as notwithstanding I must be perversely judged and handled by them (viz the Reverend, Professors from Cambridge and Oxford) as being not only appointed to be my mastery but as with a full design (though not to be supposed through ignorance, but only for the love of money) to quite over set the thing, and that by a scheme attended with several uncertainties and difficulties and but seldom to be put in practice and only by particular persons and as then with a great deal of labour attending as perhaps as when at the best, viz when from the distance of the moon as taken from the sun, of 3 or 4 hours work perhaps,

as when from a star of about that space of time only that be done or practicable at all and therefore (as or be rendered practicable at all, and therefore as from the nature of the thing) 2 in the whole not to be depended on since in which as aforesaid there must be a great deal of difficulty as well as uncertainty and as moreover and liable to mistakes therein.

but not so far as a 1/4 the circle lest the pallats or one of the pallats catch hold of the wheel (if the wheel be in) and in which vibrating (and as with the turn of the spring moving regular, and that as partly from the length and turn of the same as described in the draught, as well as therein from properness of taper: and as together with the other due length as there represented of what may be demonstrated as the straight part of the spring, although in that part somewhat otherwise required, viz as for the best application of the thermometer etc. as already notified) it is to be observed that the pivot of the balance will stand as still, or nearly as still as if it was guided by the cock and vibrating will continue for a pretty long time.

Now the thermometer is to be filed or drawfiled (and that with a sharp smooth file and without any farther polishing) to its thickness from experiences of the watches going and in the horizontal position (and that as in itself to an equal thickness) and as in the experiments with the duty of the cycloid as hereafter, as also with the ballance as equally weighted from the callipers (and as then, viz in the weighting without its spring and collet) as it possibly can*;

*But here it is to be understood that cold weather is best for the purpose because different degrees of heat for observations of 3 hours each may properly be made so far as may be necessary by means of fire of the day time (and as to be observed by a thermometer laid in the place or receptacle along with the watch, and as so observing never to heat the watch farther than properly be from nature, and that the watch be turned at some shorter but equal intervals of time as each hour and half the opposite side towards the fire, viz the pendant to and from) beginning at or commencing from half an hour after 7 in the morning as I have hitherto done, and (taking the fire out at half an hour after 4) in the night it will be cold.)

and the said thermometer is to be left in direction from each time of its filing and as that it may not only pass through its centre or that centre at about 7/8 the length of the thermometer from whence the watch is to be

adjusted for fast and slow in general as hereafter, but as withal to be imagined would be about straight when the medium is about temperate, for here it is to be understood that from its filing it will always become crooked viz convex on the brass side, so must be bent discreetly with the fingers as much or rather more the other way and when set back again to where it is to be left, and that as again so as may not only be imagined to pass through the centre above spoken of but still withal to be about straight when the medium is about temperate: but here it is to be remarked that when the plates composing the thermometer are first put together (and with brass rivets) the brass side must then be a pretty deal concave, because by or from these after filings the said brass side will stretch out more in length than the steel side, and so, if not a good deal concave at first, would be more unwilling to be rectified; and here it must likewise be remarked that after filing, setting or bending of the thermometer, that I say, before it be put to the watch, it must, as the most handy, safest and readiest way be laid upon the palm of one hand and be covered with the other (but not so there with to touch it) so that it may become as warm as the hands (not forgetting withal that they be clean hands, or as in cold weather it may be laid upon one hand and held before the fire) and then laid upon a mass of lead to cool, and so by repeating this three or four times it will be fit to be tried in the watch, for otherwise it will not be stable to the truth at first, but will alter or vary for some time and here it may likewise be very proper farther to be remarked, that if the thermometer should happen by this filing or drawfiling as here above, to be taken rather too thin, i.e. to overdo in a small measure what it ought to do, then a slight rub upon its edge with a burnster will bring it back again, but it must be best to take care that this be not wanting, at least but in a very small degree.

But here I must let to be understood that I found from experience something contrary to my expectation, and that as followeth; I did imagine that as the ballance spring is much smaller or of less substance in itself than the thermometer that it would therefore, sooner feel the effects of heat and cold than the said thermometer, and accordingly made the covering or defence for it, very thin whereas from experience the contrary was really fact, viz that the thermometer was sooner touched or affected with the changes and increases of Heat and Cold than the ballance spring, and ought therefore, instead of a very thin to have a thicker covering*;

*Or rather the thermometer to have been a little thicker in itself and consequently longer as is here in length represented, viz in this

present drawing.)

for hence, it certainly was fact that the watch would go rather faster whilst the warmth of each day, or warmth by fire was increasing, than when decreasing viz as under a proper or uniform way of trying as from turning the watch half round (horizontal position) every hour and half.

And this was the contrary to what I did expect, but as experience showed, and that very steadily, that this was the case, I think the solution is not difficult, but must be because brass is more penetrable than steel and so more quickly received the impressions of heat and cold, and as of course withal, that side of the thermometer being of brass from whence this effect could be so produced, whereas the balance spring is of steel and of a high temper; (take this note on P.135 at A).

*(But indeed the balance itself as in this matter here above may be said to compare viz from its being of far more substance in its rim than the ballance spring or even of more substance than the thermometer, and consequently to be more late than either in feeling the effects of heat and cold; but to this it is to be answered that what the balance can alter in its bigness by heat or cold, or the effects of such therein is, or will ever be but very small in comparison to what must arise from the difference thereby in the strength of the balance spring, and in the bending of the thermometer).

But my not knowing this event beforehand (or its being unknown to the world) and its coming contrary to my expectation, proved (by tedious experiments, through mistakes in the matter) a great deal of trouble to me in adjusting my watch; hence the brass wires in compound pendulums ought to be thicker than the steel ones

*(But it must be implied that the spring at the top of the pendulum be as short as it well can i.e. as short as the cycloid will well permit it to be; the which spring (though as touching its strength as a spring must be very immaterial) must be made of good brass well hammered or rather of gold alloyed with copper well hammered not of steel when with a cycloid; but still as the said spring must have some length, and be very thin, it must as farther be implied that the wires of pendulum be not (in general) thick but on the contrary as small as they well may be, as also the bob (viz from its top to bottom) not to be greater in diameter.)

(but indeed this cannot much matter as touching such clocks as hitherto commonly put to) but it does not bespeake that the brass side of a thermometer for a watch ought to be so but however it is not proper to be thinner.

Now by my watch, besides what I have already spoke of the following experiments can be made, viz, that from changes or increases of heat, as by fire on the day time and with windows opposite to the chimney and the watch laid (horizontal position) upon a table about the midway betwixt if then the root of its thermometer be towards the fire, the watch will go somewhat faster than if vice versa; or as cold increases in the night from the external air without the windows and the watch lying as before, the effect upon it will be the same, save only in what it may in each case be varied, viz in somewhat a greater or less proportion, accordingly as the changes themselves in that respect may be; or if there be not fire and the watch lying still the same way, if therein warmth increases in the room from warmth of the external air without the windows, the effect upon the watch for during that increase will be the reverse of the other, but these matters and as must in particular that chief one as first above mentioned are to be understood in a very small degree, and this last in the smallest, but none seldom more than 1/10 second in 3 hours.

Now from these experiments is fairly shown how little the wheels of my watch have to do in the matter of measuring time i.e. as I may say in other words with the regularity or motion of the balance although that same motion is maintained by them, hence I may say, of so nice a texture is this my watch or time keeper for the Longitude at sea, as to discover differences in the warmth or coldness of a room in so short a space as in the length of its thermometer, a nicer longitude than the other!

But it is to be understood that this could never have been assuredly known had not my pendulum clock been first in being; though the said pendulum clock is yet deficient in comparison to what may hereafter be made upon the same principles and now, though the notch or space between the pins of the thermometer is to be straight as above, yet the spring with the ballance at rest, and as still meaning in the horizontal position with the cock off, must touch neither of the said pins, nor ought it to be as mathematically speaking, exactly in the middle betwixt them, but rather nearest the inner pinion (viz that

pin towards the centre of the watch) and more especially or precisely so towards the colder part of the range of the thermometer, as must be observed with a glass that magnifies pretty much (as of an inch focus or nearly so short) and by the application of a small bit of wood to the end of the thermometer so as to spring it a little each way viz in such measure to quantity as may be most proper*

*(But here it may be proper to notify that as the whole range of the thermometer by heat and cold is no more than about 1/16 or 1/15 inch, so consequently by this sort of bending or springing for so little a way will but be hardly mathematically different to what will be produced or described by nature, and as from the thermometer being all of a thickness.

And note, when I say with the balance at rest, I mean that the wheel is not so much as to touch it, as may (in the horizontal position) be examined by occasioning the balance to vibrate a little way with the cock off, as then letting the wheel stand still.

But here it must also be very proper to be remarked that before the cock be (at any time) taken off, that the force of the wheels or of the balance wheel (as in common watches) be secured the which is here to be done by drawing the fly wheel back (and as required one whole turn) after the watch being first made to stand by touching the balance and that after a few beats from one of its runnings or windings up, and there to be secured by the lock of the detent, and it is then to be examined as already intimated that the balance wheel be clear of the balance.

And here it must also be very proper farther to be remarked that after the cock is (at any time) put on again, that before ever the balance be set a going, or be occasioned to vibrate much, that the said detent be first discharged, or else harm may attend the matter; as that by one of the pallets catching hold of the wheel may occasion its frame to twist upon the spindle or if not so (or as from the pallet frames being too firm or fast fixed upon the spindle) worse as then by the violent power of the balance to break off the pallet: and for the same reason great care must be taken that the second hand never be touched (as by any accident whatever) when the watch is a going, because from that the same mischief may happen.

Now in these points common watches will ever have the advantage over such watches as these, for they are commonly so harmless or innocent as not at all to be hurt by such occasion.

And the spring in this so to be found or to be occasioned as thus to suit the range of the thermometer and as when at the same time leaning against the reciprocal cycloid; and that leaning must be such, as that when the balance as with the cock on, is turned that way as to occasion the turns of the spring to come closer and consequently that part of the spring which leans against the said cycloid to depart from it, as occasioned by the intercourse of the thermometer; so I say (and as to be notified but one way) that this departing, and so as when from experience, to have if required the greatest effect, must begin to be when the balance is moved (viz with a thin slip of wood or ivory with a bit standing up to take hold of one of its crosses by the rim, and as I say, with the cock) somewhere about $1/8$ of the circle rest, the which by the by, tho not as I think a material remark, happens to be (when the watch is going) somewhere about the interchange of the pallats, for there, as just above mentioned from experience is (so far as I have hitherto been able to judge) whereabouts it will have the greatest influence of all (if so to be required) for was the said cycloid to be set or ordered as whence one would think it ought to do somewhat more.

I found it would begin to do less and so as on course, do less and less until nothing at all save only (as withal and to be understood) to its more and more tending to faster in general, but nothing at all as with respect to its design, viz, the adjusting of different vibrations; but indeed I cannot strictly tell what portion of the circle ought to be, before this, departure must begin because this first time I had not the end of the spring as here described but only somewhat, or rather pretty much towards it, viz towards as it were going off in the tangent; but hence I think where the place, or portion of vibration is as with respect to the whole, or rather distance from the middle so as thence by the springs departing from the cycloid to have or produce the greatest effect (supposing it to be required) and withal how long the straight part of the said spring ought and as with regard to the whole, as best for the purpose, to be as well as in what direction and of what strength that part of the spring ought to be in respect to the rest is again what no Seminary or College of Learning could ever foretell or have foretold or produced no, nor even so much as that such a cycloid (if any wise practicable) should at all be wanting, and that as in supposing withal, the wheels and the

air resistance to the ballance, to have to do in the matter as my thought with indefatigable labours in every respect have done!

But here to return; it must consequently by this departure of the spring as not being in the middle of the vibration but a good deal later, so be ordered as that the greater the vibration the more it will be affected thereby, or rendered in some measure slower than it would otherwise naturally be*

*(But all this must be with supposing the outer end of the spring to be of such a strength as with respect to the rest; as whence the cycloid may not only prove capable of doing its duty, but that withal the thickness of the thermometer, as with regard to its length, may likewise be required to be about what may be found or esteemed as the most convenient.)

And this I find to suit the nature of the thing (as a fundamental of the contrivance) quite right:

*(Consequently better than could have been, had such a departure been to have been, or would have admitted to have been both ways, and then to have begun sooner or nearer the middle of each vibration; besides in the way that it is part, a greater equality is thereby occasioned or as thence ascertained in the ballance spring, the said spring being otherwise stronger when its turns by the ballances vibrating come closer together than when by the same cause thrown out, as may be observed by my third (or larger machine) for it made to stand, the stroke which is upon one of its balances, whereby to observe the vibrations will not stand exactly in the middle between the extremities of the same, but this matter is not very material).

Whereas I had an endless trouble with a small part of my third machine the which (according to my contrivance then) I found to be necessary towards this matter, but never could thereby rightly conquer it.

Now here it may be fairly seen that if my contrivances or inventions be be as some have affirmed all chance, then it is certain that chance and the Dictates of Reason must only be two different names for any the same thing.

Now I have shown above in what manner or to what strictness or nicety the ballance spring and as with the ballance at rest, must in the place or range of the thermometer suit thereto, for it not so it is to be notified as followeth; viz that as (according to my discovery) there be to be used what I call Reciprocal Cycloid, then the farther the spring is of the inner pin of the thermometer in any part of its range the faster the watch will go at that place, and the reason for it is, because by that means the spring will be later before it departs from the cycloid, whereas, if there be not the cycloid, as I know from a many experiments in my third machine, the effect will be quite the contrary, viz the nearer the spring is to the said inner pin in any place of the range of the thermometer (and as still under the same circumference of the ballance at rest) the faster at that place the watch will go.

Hence the thermometer may be adjusted to a nicety and that is by so ordering the range of the spring (and as when to be understood with the cycloid) as whence for instance if the thermometer does not do enough the inner pin may as thence become rather farther from the spring when warm than when cold, and vice versa, but as this is a little diverse to what has been treated above, or as it were a making one fault to mend another, so it must still be necessary to take such care, in bringing the thermometer to its thickness, as that this adjusting may be required to be but very small, if at all; but hence it may be asked how far short of this? Or rather how well adapted to the purpose was Mr. Ellicott's provisions for heat and cold?

And as when at the same time no one member of the Royal Society to spy any faults but the President (Lord Macclesfield) even to speak in favour of it, whereas, according to what is here advanced, it was not much better than quite repugnant to the matter; well might a watch be still a watch, nay it certainly then would be worse than an ordinary watch, was its foundation (as from the wheels etc) ever so good; no commendation save to English skill therein!

After the thermometer is exactly bought to do its duty as above (viz from experience of the watches going in the horizontal position, and in different degrees of Heat and Cold, and with the cycloid as above spoken of or intimated) then it must be examined how nearly the ballance, as left from

the callipers may be in equilibria, the which will not be found, if proper care there (as at first) be taken to be a many seconds out, no not in any position in 24 hours' time, not but that observations of 3 hours each will, and especially at first be most convenient for the purpose and also sufficient*

*(But here it may be proper to notify that in equalling the balance in the callipers that the side of the balance which is to be upwards when the watch is vertical with 12 o' clock or pendant upwards, must be rather heavier than the opposite, and that because of the weight of the thermometer as the attending towards fastness.)

And it is to be observed that when the balance is brought so correct as that 12 up and 6 up are found to be alike, as also 3 up and 9 up respectively, so and though each one, or neither one of these (as now reduced into to) may not exactly correspond with the horizontal position, yet the ballance is then so nearly an equilibrium in itself as ought to be, and the matter is or must be as followeth.

As 1st. If the watch goes faster when vertical with 12 up or 6 up then when horizontal, but meaning to lean a little backwards (for reason hereafter p.92) shews that the descent of each pallat is not steep enough viz about the place of the dotted line from no.2 as above treated of: Now the reason for this is, that as the ballance will have rather more force when its spindle is upright then when horizontal, and the which difference in force is then wanting more to be balanced by the greatness of curvature, or virtue of quicker descent, viz about that place upon the back of each pallat as above spoken of.

And 2nd. If, as under the same course of trying the watch be found to go slower when vertical with 3 up or 9 up then when horizontal, shews that the cycloid does not do enough (the vibration of the ballance being the less than in the horizontal position) and so as in brief these two paragraphs (so far) take in the whole that is in this point required; for as touching the first paragraph it is to be observed that the lighter the ballance wheel upon the account the retreated, the less the difference, whereas, therin, is also included any difference in the fore of the said wheel that may otherwise happen for, as principally it is to be observed that with the ballance spring having so much dominion or so great a power in the matter as I have shewn, as

well as by what means I so acquired it, viz by the tedious experimental, costly pick pocket, unskilful chance method (according to Lord Merton) as treated of above, that I have only here been speaking of small, small variation which may happen from the greatest extremes in position, as perhaps of 3 or 4 (4 or 5 deleted) seconds in 24 hours, but it may as still be better if such extremes in position be never strictly adhered to, but as chiefly horizontal (with each of such positions, and even still sufficient from observations of 3 hours if well observed by a proper apparatus; but here it may be proper to remark, that if there be no running part so as whereby that part the which by the said running part becomes the more simple for the measuring of time is to be wound up or supplied with new force several times in a minute, then it must, as to the purpose be necessary to ascertain from the watch's going in the horizontal position (viz in any one and the same watch, that is meaning as with the continuance of the same mainspring etc.) what must be allowed in vertical positions in each 3 hours respectively, beginning from the winding up (i.e. in or for each of the first four 3es and as on the day time, then the latter 12 for all the night, but as a preparative thereto, it must as first be made sure that the watch goes exactly the same, as in the same horizontal positions in different degrees of Heat and Cold in the first 3 hours of its fusee) tho these differences, as from a good mainspring and fusee rightly adapted, and as together with properness of wheel work, but as more particularly from a right acquisition of the pallats, and then as secondarily from the virtue of the cycloid will ever be but, small, yea so as perhaps such observations to be but scarcely needful to be made at all; for it may be notified that if there be not that running part, then a balance of the same diameter and in the same size of watch, and as with the same number of beats and largeness of vibration, may be heavier by some grams; so whether, through right management in all respects the watch may not come up to the same goodness I cannot well tell, tho I think as the best it hardly will; and here it may not be improper to notify that as notwithstanding what trouble or care may ever be required to get the pallats to their shape, viz, after that is rightly known, and as from proper methods whereby to be tried as also together with what belongs to their setting, yet they must even (was it upon no other account) be said to be the cheapest pallats of all, because (as of diamond) they will scarce ever be worn at all, neither the wheel; whereas the wheel, as well as the pallats so far as hitherto common, and as essentially speaking can hardly be said to hold a month.

And here it may be proper as farther to be remarked, that if the watch in such positions towards 23 up and 6 up, should be found so as to go a second or two a day faster than in their positions towards 3 up and 9 up, and as also then to be understood, somewhat faster than in the horizontal there would never be any error as thence to become of harm, and that because, from the nature of the most proper placing or fixing the watch in the ship, viz with the front of its box being towards the head or stern, and the pendant of the watch either towards or from the front of the same or rather alternatively with respect to that direction (and with always the dial plate upwards) as one day with the pendant towards the head of the ship, the other towards the stern for then (I say) the pitching of the ship will so well ballance for the slowness then arising from such declivities or reclinations as may happen, or be suffered to happen from the ships lying on one side, as that no error in the whole may ever as thence be material, and note, as in this case especially a little marble may be put in a receptacle or cistern made upon the box lid of about 3 inches square, that so by the rolling of which therein, the box may at any time be so rectified as that by the tossing of the ship in general, the marble may as thence keep rolling, viz side way, as well as from the pitching the watch to be understood to lie parallel to the Box (See P 142).

*(And here it may not be improper to observe and through as above in the horizontal position) that, as the motion of the balance is so very swift, the yawing of the ship or her tacking about cannot in the least effect its motion, for it is to be understood that unless it could be said that the ship could instantaneously begin any yaw, or as the same thing, could alter instantaneously in the direction of her course with such celerity as presently and comparatively here to be spoken of or notified or (as in other words) could with the same instantaneous swiftness (or differences) make any alteration (whether so as to become either faster or slower) in or from any circular motion she may already have at any time acquired, whereas at the same time such alteration or change (though sometimes or oft times to be esteemed as violent) may ever be looked upon at the most as but little or slow, viz when taken as with respect to so small a distance from any centre or motion as the radius of the balance (viz about 1 1/8 inch) that is (as to be understood) unless the ship could begin to vary in her course, viz at each or any time (I say begin such her variations, as only in the case to be notified) in or from these circumstances as here above, respectively more quick than the

balance if standing (or at rest) would want, from its artificial gravity to vibrate, she cannot in the least affect its motion, or disturb it from rest, whereas if she could, or as supposing that she can (as but small) the irregularity thence arising as taking the contrary effects one time with another must or could ever but be in a very immaterial degree.

But as the ship will continuously keep altering the place in which the balance may be said to vibrate, and as must especially so, or in a greatest degree by her pitching and rolling upon a rough sea than upon a smooth, and as the balance from its diameter and quickness in motion must at any time be unwilling to be altered in or from the said plane, there must therefore, and especially in rough weather be somewhat more friction occasioned at its pivots than if it kept always the same horizontal position, and thereby consequently the vibrations of the balance to become somewhat less and, as the result of the matter, the motion of the watch as thence somewhat slower was not the consequence prevented, or naturally taken in by the reciprocal cycloid as above, so hence or from the whole no irregularity or at least any material; but still or as notwithstanding, that instead of these trifling concerns of slight disturbances I have here shown, as ever to be from the ship, the searoy reasonings of Scholar Ludlam etc. will speak of the watch as if thence to be in danger of being made stand).

But to go back for a little to page 49; I have there said that the balance must not on account of the air, have any less spances above and below its run than $3/100$ inch; but what I am here about to remark is, that supposing the ballance as this to have, besides its own thickness $6/100$ inch to move in, yet if it was not then so to be put upon its spindle as to be exactly in the middle of that space i.e. (with so allowing for end way shake) that, whether the watch lies with its dial plate upwards or with its back upwards, the interchangeable spaces as so becoming under the balance be exactly the same, otherwise when the straightest space is under the balance whichever it happens to be, the watch would go somewhat slower, and that as according to the difference of the said lower spaces (but this is here meaning without the cycloid, consequently then, as otherwise designed a great deal too slow in general), therefore, as in supposing this to be known, it must be best to make sure that when the back is upwards, that the lowest space be then rather straighter than when the dial plate is upwards, i.e. considering the end way shake that they be both alike with the said dial plate upwards for then the

cycloid may even from the two horizontal positions (viz from the dial plate upwards and back upwards) be pretty well confirmed, was there no other means as better for its adjusting, but in anywise, it must be understood as with supposing the pallets to be right, in the first place, and with no less room (in the whole) for the ballance than as above; and the ballance spring (as being very strong in itself) must also as best, be supposed to lie very flat i.e. not to have any tendency towards making the balance go upwards or downwards from its fastening in the stud for if so it will have something to do in this matter of face up and back up viz, but its thence occasioning the friction to be more or less at the end of the balance pivots.

Hence it may be understood that was there to be a pretty deal more room for the said balance to move in, the which would be very inconvenient in other respects, what I have here above treated of would vanish; and so it may likewise be perceived that in my lesser watch, where the diameter of the ballance is not so great, and tho more vibrations in the time, yet there need not as thence to be quite so much room; but still on the other hand, was there to be no more room than as hitherto common, and the balance not to be in the middle or best of it, I have learnt from some experiments not to be surprised if the watch went more than a minute difference betwixt face up and back up (i.e. from the two horizontal positions) and consequently no cycloid etc. to prove a remedy to it, nor scarcely any towards it.

Now whether the resistance from the air, as here in my balance moving with such great celerity, and as with its returns or directions thereof changing (for still the better) in such short intervals of time, I say whether this difference be as thence from the crosses of the balance or from the rim, it matters not, since the fact is here material and not the cause, but however, there is great reason to judge it to be as chiefly from the rim, and upon the same subject as hath just here been treated, it is to be reasoned about adjusting the cycloid of a pendulum (viz as happening partly from the resistance or as more particularly from difference in the resistance of the air, and partly from the manner by which the motion of the pendulum is maintained against it, yet still in the whole, vastly unnecessary that that resistance as from a great vibration be; for was not that to be the case, viz when the pallets as it were, without friction, as well as when otherwise agreeably adapted to the purpose, there neither would nor could be any proper limitation to the variations) but as proving in this adjusting in a much more

difficult degree than as in the balance above, and as even not to be done at all if things be not so ordered, or as that the pallats, as there in chief do not do their duty right, as now indeed hitherto have done, then of my pendulum clock only to be expected and they but hardly so and that for want of experience when the clock was made, there being none to the purpose before in the world, that if not as chiefly from a proper construction of the pallats and as when from properness of foundation from the wheel work, and as together from firmness or suspension of the pendulum from a wall (i.e. as quite independent of the clock its case wainscat, or any word whatever the case if self though situated upon the floor, being also to be separately sustained from the said wall, as still independently of wainscat) neither the cycloid nor gridiron should ever be rightly adjusted, nor would it then signify much if they could since deficiencies in these other respects would assuredly be able, yea more than sufficiently able to spoil or prevent exactness in the matter, viz as touching a nice mensuration of time and that as meaning with respect to the diversity of times, and for a long time, as even (after the adjusting is completed, and as in supposing the clock not to be removed) for a hundred or two hundred years without any cleaning (viz as upon my materials and construction) and that to the nicety of a $\frac{1}{4}$ second or less in a month, or perhaps as taking any year throughout to less than 2 seconds supposing without the clock to stand in a pretty temperate place, and the case to be very good and close, as that no dust or cobwebs may get or increase upon the pendulum.

(Now I have said above, as with respect to pendulum that a bob of 3 pound weight describing an arch of 12 degrees will be equal in power for the regulating a clock, as a bob of 48 pound describing an arch of 3 degrees when as, equality in the cases may seem to be in bobs of 3 pound and 12 pound, but it is to be understood that the 12 degrees or somewhat more (i.e. critically speaking, the descents of the chords of such the two arches of 6 degrees or of somewhat more as must be described on each side the perpendicular) must be maintained against the airs resistance from the action of the wheel as applied at but the distance from the centre of suspension of the pendulum that must or will be in the other, and then it must be as bobs of 3 and 48, viz as in keeping to the same manner of acting or scaping; and herein as a great point in the matter it is to be understood, that it is not the greatness or smallness of force from the wheel at what distance so ever applied from the centre of the pallats as may reciprocally be required that can alter the case,

providing it could be truly constant to itself because for greater or lesser vibrations there must be forces accordingly adapted, but the which as inconstant ought to be disposed of (and that from the shape of the pallats) that so as not only to prevent irregularity to the pendulum which may

(But as the result of the shape required is shewn pages 124 and 125, I think it is not necessary to say anything here about it).

arise from difference therein when (and as best) the whole force is pretty great in itself but also at the same time (and as then with a cycloid) to prevent irregularity which may arise from difference in the air's resistance; or even if the bob was very light and with a small vibration and the force as still to be notified accordingly thereto but withal to be constant or regular in itself from the wheel or wheels (whereas it would then be the most irregular) it ought still to do the same; but now as it is certain that that would not be the case (and that without notifying the great deficiency or the greatness or irregularity there would then be in the draught or force from the wheels viz as in proportion to the whole) it must be certain that irregularity must chiefly arise from mutable differences in the scaping i.e. from differences in the sliding, rubbing, sticking or damming of the pallats in their application to the wheel and as thence to be more or less affecting or disturbing the truth of the pendulum motion, according to the distance at which the same is from the centre of the pallats or that of the pendulum suspension and as in consequence thereof the more so by far in a little vibration than in a greater one, as well as at the same time (viz is a small vibration) to be in some measure augmented, or made worse by the conspiring irregularity from the weakness or unstableness of the draught of the wheels, whence as in my invention of pallats, wherein is not only comprehended what is above spoken of viz as touching the shape or disposed of the force of the wheel (and as in manifest by the drawing) but as thence withal a great vibration is maintained at no more purchase over the pendulum, viz from the wheel or wheels than about the 1/4 part of the distance from its centre that Mr. Graham's small vibration is maintained viz without the taking in his wedge like power (as above P.12) and as moreover (at that small distance) with but about, or at most with no more than the 120th part of the friction that would be according any greatness of force or draught from the wheels (and still the which force of draught as above implied to be then in itself the more regular) as he himself in each respect, allowed to me to be fact upon my

explanation (and so must everybody else who is, or may be able to understand this reasoning or demonstration) therefore as thence, and as with a cycloid properly adapted (the which indeed can only be as thence) as well as with my provision for heat and cold (as in both respects to be adjusted upon the foundation above) what truth therefore ought to be expected from the swing of a pendulum when in such a perfect state? i.e. when all things are rightly adapted for the purpose.

That the force given by the pendulum wheel to the pendulum whereby its motion must be maintained against the air's resistance, ought (as when with a cycloid) to be greater in its ascents than in its descent, and even the greatest in the latter part of each ascent, viz as when the nearer and nearer it approaches the interchange of the pallets, as also the least in the beginning of each descent is demonstrable as followeth.

Supposing a pendulum and such as will keep its certain length in different degrees of heat and cold to move in a cycloid, and as then to be set swinging (but upon a firm foundation) in vacuo and as there without the help of the wheels of a clock, to continue to perform some certain number of its vibrations, or each vibration, mathematically exact in some certain space or spaces of time.

And then, let it be supposed the same pendulum (as at the same length, and as with the same cycloid and firmness of suspension) to be put to the wheels of a clock, and as thence to have its motion maintained against the air's resistance: and as first let it be supposed the pendulum wheel (as from the shape of the pallets) only, to act upon the pendulum in each of its descents, and if you please, the strongest at the beginning of each; now it is certain that each vibration would then be performed in less time than before, for the pendulum must (as thence) have acquired a quicker velocity when got to its lowest point, than as when in vacuo or otherwise it would never go up against the air's resistance (on the other side) so far a from whence it fell: and again (from the shape or other shape of the pallets) let it be supposed the pendulum wheel to act upon the pendulum only in its ascents; now it is certain that this would have a contrary effect to the other, since the pendulum in its following through the air's resistance would not have so quick a velocity at its lowest point as when in vacuo, and so, as wanting on the other side it be helped up (and still against the air's resistance) and as most

(if you please as above so to suppose it) towards the latter end of each ascent it must consequently, in each vibration, take up more time than as supposed in vacuo: hence an equality to what it would do in vacuo (as under the circumstances there supposed) may be acquired from the shape of the pallets, or as more properly (or perfectly) from something equivalent thereto and that as with a proper recoiling, and as moreover, or as together, with which without any possible friction, as according to my construction of pallets is done; and surely, it ought not to be looked upon as a wonder, or to be distrusted that a thing, which is in the whole built upon so much necessary thought, should go truer than what is built as it were upon no thought, a sleepy or indifferent one excepted.

But has been treated of here above, viz as touching the pallets, may be otherwise illustrated as in the following propositions, where two of which may be said to be coherent but not to be practicable.

As first. A force to be communicated to the pendulum exactly according to the resistance of the air, and that in all parts or different velocities of the vibration, and in different densities of air, and the which must consequently be without any recoiling or lying dead. Not to be done.

Secondly. A force to be given uniform in itself throughout the whole of each vibration, but greater or less according to different densities of the air, and not according to different states of oil at the pallets (viz as touching freeness or clamminess there) and the which must still consequently be without any recoiling or lying dead. Not to be done.

But now thirdly and the which may be done (or is what I have done) viz the force of the pendulum wheel to be so disposed of by the construction of the pallets (and as thence without any sensible friction, or at least at all times without any sensible difference in the friction) so as a much greater impulse may be impressed upon the pendulum towards the latter end of each or every one of its ascents, than at the beginning of each or every of its descents, yea so much greater as to bear with, or truly to ballance the acceleration, or rather as more properly speaking the hastening arising from a proper recoiling as must be when (and that in a right proportion) the said hastening power will thereby become less and less, the greater that space or quantity of the vibration, as occupied in the said part of recoiling ever at any time

happens to be; for this (as these) as I found from experience (and as implied with the vibration large) can be ordered as that truly to take in (whenever it may so happen) both a different force from the wheel and a different resistance from the air, as well as at the same time to be truly adapted to either of which above. And it is to be observed that if this be not the case; then (to the point of truth) no cycloid can take place.

And now (in the watch) as touching fast and slow in general, but in which respect it is to be supposed as nearly right all this while, viz from the rubbing of the ballance spring, though every time the thermometer is taken out to be filed, it may, or will be different therein and that from what may be said each time to be the general direction of the thermometer, and the which was not, as every time then to be so much regarded, but now, or at least it is so to be set or directed from experience of the watches going (and in the horizontal position) as best to be chosen, and the which, as is to be understood must be after the cycloid is so adjusted as (in the first place) to do its duty right, for then it is to be understood of what has been done that the direction of the thermometer, as upon its centre, or the centre as mentioned above, and as passing through the same, must, or at least may be virtue of a fine screw, and as together from as much length or lever (in effect) as can conveniently be, or the compass of the watch will permit, must, I say, or at least thence as may (and with but little trouble be so set, directed or adjusted as that the watch (with respect to mean solar time) may perform to less than a second a day.

And now, it only remains to be remarked as followeth, viz that when the balance is to be taken out, as for the watch at proper times to be cleaned (as well as upon the several occasions at first) the end of the ballance spring must not be unwedged, but the stud must always come away with it, the spring in the first place then as well as at first of all being to be suspended from its leaning against the cycloid, as perhaps in quantity about half as much space as its departing from the said cycloid will be by the vibrating of the balance (but this quantity may best be acquired from experience, if found towards it at all) and the same suspension must then be by a prop or setter as adjoined to the said stud; now this is to be done (if wanted) for fear of any regaining of strength in the spring, as after once a flagging, and consequently as thence, as well as at first without such proper care taking, would require some time to be spent, or taken up in such flagging, or as now, in any after case in coming too again; but as this, or from which means, in putting the ballance spring and stud in again, the

watch will go the very same, as ever wanting, after once all is right, to be made go faster or slower; but here it may not be improper to remark, that when the stud is so raised up as that its steady pins are out of their holes, that a bit of wood be put under it, left, as the balance is taking out they catch in their holes and endanger the spring.

And now, as one thing more towards the purpose it is to be observed that there is such a provision to the follower (or guide) of the ballance wheel, as that whereby it must always go in to a certain place and not to be put any farther, neither to be varied the least in position.

So now by these writings and drawings I have fully discovered all the principles upon which my watch or timekeeper is constructed, and whereby indeed it far excels all that I myself could, as previously think or imagine, and that through prejudice of such timekeepers as hitherto made or produced in the world; and I hereby thank Almighty God that I have lived so long, as in some measure to complete it (viz as already to a higher degree than was ever as from more length of time to be expected) and as thence to draw up this description of it, the which as from experience, is much better that what is otherwise could have been: and I think I may make bold to say that there is neither any other mechanical nor mathematical thing in the world that is more beautiful, or curious in texture than this my watch or timekeeper for the Longitude, neither, as in comparison thereof to be of greater utility: and certainly its performance ought to afford a much more welcome surprise, than when, upon the discovery of the properties of a right-angled triangle, Pythagoras thought proper to sacrifice a hundred oxey; whereas now on the contrary, instead of such a transport as that (as upon so good a result of 35 years close application and as at last to be accomplished in the form of a large watch, and as also after a very dangerous return of my sone from Jamaica) it was, for my ingenuity, or for so far an accomplishment of the design thought proper by Lord Morton some that for the residue of my life I ought to be made a slave; but that was found a matter quite repugnant to a free nation, viz to a nation where ingenuity the best to grow and flourish, and wherein I hope to the honour of the same, my watch (or such timekeeper) will hereafter be brought to the greatest perfection of which such the most excellent or rather (as I may say) such the most notable discovery is capable; and consequently as thence to have the Longitude to a far greater degree of exactness than ever as heretofore could seem possible or as in the least

degree credible to be imagined yea even in long voyages (i.e. anywhere betwixt such nations as must be in such voyages) to nearly the truth, itself and that and every day any day when observation by the sun can be had and as thence with such facility as only as it were from one operation of trigonometry.