

15772-93

15772-93

73

*Delivered the 12<sup>th</sup> day of May  
1763.*

*...mility,  
...on the  
...Watch  
...; and  
...those  
...t -  
...forgive  
...or so  
...e to  
...king,  
...ples  
...ructed  
...full  
...ne of  
...ting  
...stedp*



To  
The King's Most Excellent Majesty

Most Gracious Sovereign!

Permit me, with the greatest humility,  
to lay at your feet the following Remarks, on the  
most probable means of bringing Clock and Watch  
Work to their long wished for State of perfection; and  
declaring that no motives less pressing than those  
hereafter mentioned, together with the firmest  
confidence in Your Majesty's readiness to forgive  
the imperfections that must attend them in so  
premature a State; could have induced me to  
hope for Royal Protection to an Undertaking,  
which, tho' it may contain the true Principles  
on which Clocks and Watches may be constructed  
with the greatest advantages, must require full  
Illustrations to overcome prejudice, and become of  
universal utility. But my motives for putting  
them in writing, before they were properly  
digested



digested and illustrated, will, I hope with  
Your Majesty, plead my excuse for presuming  
to offer them in so imperfect a State. And should  
those my weak endeavours of improvement meet  
with Royal Approbation, it will inspire me  
with the most ardent desire of meriting so great  
an Honor, and testify my most unfeigned Gratitude,  
by explaining, and illustrating those Remarks, so as  
to become of universal utility; as well as, by confirming  
them in practice, and giving all the light in my  
power towards the improvements that are wanting,  
and may be made in execution as well as in  
Principle.

I am, with the most unfeigned Zeal,

Your Majesty's  
most dutiful Subject

Wm. Camming

15774

Having lately been informed  
that I was named one of those, to whom  
Mr. Harrison of Red Lion Square was to  
communicate the improvements he had  
made towards measuring Time at Sea;  
And not doubting that among the many  
improvements, that in so many years  
Application, a Person of his known abilities  
must have made, some, at least, of a footmark,  
of mine, towards the improvement of Clocks and  
Watches may be found to coincide; I thought  
it therefore necessary to put my sentiments  
on that head in Writing, before those improve-  
ments were made known to me; that I might, by  
this means, be enabled hereafter to distinguish  
and ascertain, my own thoughts from those of  
Mr. Harrison



Mr. Harrison, not chusing, on any pretence,  
to assume a merit to which I had no right; or  
be deprived of the privilege of ever mentioning  
any Thought as my own, after his Principles  
were disclosed to me. I have therefore, in  
justice to both Parties, wrote out the following  
Remarks, that Mr. Harrison may, if he  
chuses, sign or seal each Page, to prevent any  
future addition, that he may apprehend.

By which means these few Sheets will  
serve equally to prevent my assuming  
any undue Praise, as to secure to me  
what cannot be denied my Right.

And I have reason to hope, that, if the  
following Remarks are found to contain  
any improvement, however short of  
Mr. Harrisons, I shall not be  
Thought

15775

thought overpaid in being acknowledged  
their Author.



*Remarks on the best manner of  
constructing Watches; deduced from an  
examination of a Pendulum Clock:  
by Alexander Cumming. 7 April 1763.*

*As Clocks are now deemed the  
Standard for measuring equal Time,  
inasmuch that a Clock, executed with little  
care, will measure Time better than any  
Watch constructed on the common principles  
as hitherto laid down: We are naturally directed  
to a minute enquiry into the cause or causes  
of this excellency in Clocks.*

*I shall therefore begin with the  
Pendulum, which let be considered as detached  
from the Clock, in which case it has the following  
properties.*



1. .... That, if once put in motion, it would ever continue to vibrate, if the friction of its suspension and the resistance of the Air did not tend to destroy its Motion.

2. .... That, if it did continue its motion without diminution, and the influences of heat and cold were removed, it would always vibrate equal Arches, and in equal times.

3. .... That two Pendulums of equal length, though unequal weight, will perform their vibrations in equal times; and those seem to me the properties of the Pendulum to which Clocks owe their Superiority to Watches.

And have their Rise from the Effects of Gravitation, and the natural tendency of

15777

of Matter to retain its acquired State of Rest or Motion: and in the Pendulum, those two properties of Matter do so exactly ballance each other that they may be properly termed Action & Reaction: or rather, Gravitation does, by means of the vis viva, counter-act itself.

Now that we have considered the principal Properties of the Pendulum, let us suppose, that such, be secured against the influences of heat and cold, and so suspended, in an exhausted Receiver, that it shall vibrate without friction; if once put in motion, it would ever continue to vibrate without increase or diminution, and all those Vibrations would be performed in equal times.

And



And if a train of Wheels could be applied so as to number those vibrations, without any how influencing them, we should obtain a Time-measurer that might answer the Theory of a Philosopher; but as this method seems impracticable, let us enquire how the same Advantage may be otherwise acquired.

In order to which; the influence of Heat and Cold may be remedied, by the Application of Gridiron or Mahogany Pendulum Rods; or by any judicious opposition of the Expansion in Metals.

The effects of the different resistances of the Air, may be counteracted by the application of Cycloidal Checks, made of a Metal not liable to rust, as far as possible from

from Elasticity, and so fixed, as neither to alter their place or position. The Pendulum Spring should be slender, so as to apply close to the Checks; or rather, the Pendulum should be suspended by two narrow Springs, at a distance from each other, and each bearing half the weight.

But as the resistance of the Air & the friction of the Suspension both tend to destroy the vibration of a Pendulum, a train of Wheels must be applied to maintain its motion; which gives rise to the following inconveniences.

- 1<sup>st</sup>..... The Inequalities arising from the action of Wheels on Pinions, will render the moving Power unequal, in the different parts of their action.
- 2<sup>d</sup>..... The different states of fluidity in the Oil



Oil applied, will also tend to vary the moving Power, or impetus of the Wheels on the Pendulum.

3. .... The manner of applying the impetus of the Wheels to the Pendulum is so erroneous as to distort its natural tendency, and that, more, or less, as the moving Power varies. Whoever compares the Dead-Beat in Clocks to the common Scapements, will, I presume, discover in the former, a tendency to retard the natural motion of the Pendulum; and in the latter to accelerate it.

And though this has not yet been proved by experiment, I doubt not of being able soon to support the Assertion.

In order therefore to give the Pendulum, as much as possible, its natural Properties,

when

when applied to a Clock, it becomes necessary to remove the foregoing inconveniencies; of which in order:

1. .... The action of Wheels on Pinions may be rendered sufficiently equal by applying Rollers to the Leaves of the Pinions: or by disengaging all the Wheels from the Pendulum except the one which immediately applies the impetus to the Wheels: and lastly by encreasing the number of Teeth in the Wheels and Pinions.

2. .... As to the different States of fluidity of the Oil, it is proper to observe, that the smaller the acting Power, the greater proportion will those accidental inequalities bear to it. And though in large Machines the application of Oil may be rendered

unnecessary



unnecessary. I apprehend that the above  
remark will be very serviceable in Watches,  
though fitted with the best Jewels.

3<sup>d</sup> ..... It has already been observed, that  
Pendulums of equal lengths, though  
unequal weight, would vibrate in equal  
times; And this affords a most excellent  
hint for the best method of applying the  
impetus of the Wheels to the Pendulum:  
namely that its action may exactly  
co-incide with the effects of Gravitation  
on the weight of the Pendulum; in which  
case any increase, or diminution in the  
moving Power would have no other  
effect, than encreasing or diminishing  
the weight of the Pendulum would have:  
which, by the third property of the Pendulum  
would not alter the times of Vibration.

From all that has been said, it plainly  
appears, that it is the Pendulum only, that  
has the natural tendency to measure the  
time, by its equal vibrations; and that the  
Wheels, only serve to maintain its motion,  
and number the Vibrations.

And that the motion of a Pendulum is  
naturally regular, but apt to be disturbed  
by the application of Wheels; which suggests,  
that the moving Power should bear but a  
small proportion to the momentum of the  
Pendulum; though in all cases, superior  
to the accidental variations that arise from  
the Oil &c.

But from the manner that is proposed  
of applying the impetus of the Wheels  
to the Pendulum, together with the properties  
of the



12  
but shall, with cheerfulness, hereafter  
contribute all in my power, towards  
the improvement of Clock and Watch  
works, provided that those equally concerned  
do the like. —

Having examined the Principles  
that, I apprehend, will procure the best  
performance in Clocks, I shall next endeavour  
to point out the Means of procuring the  
same advantages in Watches; and the  
reasons why, any Watch constructed  
on the common Principles, could not  
measure time equal to the meanest Clock  
with a Royal Pendulum. In order to  
which, it will be necessary to point out  
the chief Articles in which Watches differ  
from Clocks; viz.<sup>d</sup>

- 1<sup>st</sup>..... Clocks are immovable; and Watches  
portable.
- 2<sup>d</sup>..... Clocks are moved by Weights; and  
Watches by Springs.
- 3<sup>d</sup>..... Clocks are regulated by a Pendulum;  
and Watches by a Ballance & Spiral Spring.

It now becomes necessary to consider  
what inconveniencies Watches are liable to  
from those differences in their construction  
from that of Clocks: and the first in order  
is:

- 1<sup>st</sup>..... That Ballances are influenced by any  
external motion of the Watch, that happens  
in the direction of their Vibrations; and  
such influence is in the proportion that  
such external motion bears to the velocity  
of the Ballance: from which it is evident



that the influence of external motion is in a reciprocal proportion to the velocity of the Ballance.

This suggests a Method for partly correcting the evil, and one more consideration will remove it to such a degree as will render its effect scarce sensible at Sea.

It is to be observed, that curvilinear motions only influence the Ballance; and that, more or less, as they deviate from a straight Line.

By which it appears, that a Watch is much more disturbed in the pocket than on board a Ship, particularly when the Ballance vibrates parallell to the Decks.

But the chief Article here to be observed is, that if a Watch be so plac'd in a Ship, that it shall vibrate in the direction of the Ship's  
greatest

greatest Motion; and if only one Vibration of the Ballance is performed during one Roll, or motion of the Ship, that vibration will be influenced in the proportion above mentioned, but if two Vibrations are performed, the one corrects the other, and for the same reason, if any <sup>equal</sup> number of vibrations are performed (suppose 100) during one motion of the Ship, the one half of them are as much accelerated as the other is retarded, and consequently the whole performed in the same time they would, if no external motion influenced them.

From which it appears, that it is the odd vibration only, that is influenced, in point of measuring time; and that only, in the proportion above mentioned. And the velocity may be acquired, either by increasing the  
Diameter



Diameter of the Ballance, or the number of its Beats; the latter is to be preferred, so far as Materials can be procured that will stand the necessary degree of motion.

Here it may not be improper to observe, that the most proper part of a Ship to lay a Watch in, is near its center of Gravity.

Let it be further observed concerning Ballances, that those, which when at rest, are least liable to begin their vibrations by any external motion, are least influenced by such motion, after their vibrations are begun.

The Propriety of this remark will appear more evident, if we consider how little the impetus of the wheels in a clock will remove the Pendulum from its point of Rest, and that no external motion influences the Pendulum. —

I am apt to think, that the above Remarks properly applied may, in a sufficient degree, remedy the influence of external motion on watches; but in making Ballances, their matter should be, as much as possible, removed to their extreme Circumference, because their weight near the Center tends to endanger the Pivots and increase friction, without having any considerable effect in the vibration. And the Metal that is found least liable to expansion, magnetic attraction and Rust are fittest for this purpose.

Two Ballances vibrating in contrary directions and at equal distances from the Centre of Magnitude of the Watch, would wholly remedy the influence of external motion; But the difficulty of connecting them properly, renders one Ballance and a quick train, much preferable.

And



And though Watches are apt to alter their measure of time with their position; the causes of such alterations, do not properly belong to the Theory, as they arise wholly from inaccuracy in the Execution. I shall therefore only observe, that in order to adjust a Watch for all Positions, it must be tried in six capital ones, of which all others are compounded.

Having thus far obviated the influence of external motion, I now proceed to the second inconvenience.

2<sup>d</sup> . . . . . The imperfection of Watch main Springs seem to arise from, their too great length, and equality of thickness; but if made thinner towards the inner end, and to act with fewer Coils, their action might be rendered progressive from their external to their internal end.

AND

And the application of Oil rendered unnecessary; in which case, a Fusee properly adjusted, would always act uniformly, allowing for the influence of heat and Cold on the Spring, which will be fully remedied by the application of the Cycloid.

Now let us compare the Ballance and its Spring to a Pendulum; and enquire how far the former does, or may be made, to possess the properties of the latter.

A Pendulum can never rest but when its Center of Gravity is immediately below its point of suspension; and if by any means, the Center of Gravity be removed from its point of rest, the Action of Gravity will bring it back to the same point; by which means, it acquires a degree of motion that

will



will carry it as far beyond; and thus the vibrations are performed by means of Gravitation and the vis viva.

In this respect the Spiral Spring of the Ballance (or rather its action) resembles the action of Gravity on the Pendulum; and the Ballance has the inherent property of retaining its acquired motion; by which means the vibrations of the Ballance are performed; and since the spiral spring, does, by means of the Ballance, counter-act itself, it cannot be denied that its action and reaction are as equal as those of the Pendulum; by which means, it has the same natural tendency to perform its vibrations in equal times. And if a Ballance Spring could be made perfectly elastic, and so formed  
and

and applied, that, on the least motion of the Ballance, all its parts would have an equal tendency to bend: and that it would not incline the Ballance more to any one side than the other; but on the contrary suspend it in such a manner as to remove, as much as possible, the friction that would arise from its own weight, I am ready to believe that if all the shake could be removed from the Pivots, its vibrations, would very nearly approach the natural regularity of the Pendulum.

The only article in which the nature of the Ballance may seem to differ from that of the Pendulum is, that though increase or diminution in the weight of the Pendulum will not alter the times of its vibration, yet an increase or diminution  
in



in the weight of the Ballance, or the strength of its Spring, will tend to accelerate or retard its vibrations. But here, it should be observed, that, in the Pendulum, the influence of Gravitation and the Vis viva are inseparably connected, which is not the case in the Ballance. And if the weight of the Ballance, and the strength of its Spring were increased or diminished, in the same proportion, it would be found, that Ballances, as well as Pendulums of different weights would perform their vibrations in equal times. From all which it is evident that Ballances possess all the natural properties of the Pendulum, and are governed by the same Laws; and that the greatest part of the imperfections that have hitherto attended their

their performance, has been owing to a want of due attention to their natural properties, and the imperfections of execution; which latter will be very difficult to remove.

I must also observe, that, in one respect, the Ballance has the Advantage of the Pendulum, as not being influenced by the change of Latitude, which imperfection is inseparable from the Pendulum. —

And as it is the Vibrations of the Ballance only, that tends to measure time in Watches, the wheels serving only to maintain its motion, it must be carefully observed, that its momentum should have the same superiority over the impetus of the Wheels, as Pendulums have in Clocks; in order that the Ballance may command the wheels; they not it. —



It would be thought very absurd in the most ignorant Clock-maker, to make the Impetus of the wheels equal to the Action of Gravity on the Pendulum; but it is the constant Practice, in Watch-making to have the impetus of the Wheels on the Ballance equal, if not superior to the resistance of the Pendulum Spring: this is proved by watches beginning their own motion, when by any means it has been discontinued.

And though I doubt not, that M<sup>r</sup>. Harrison has made many great improvements in his Time-keeper, I am ready to think, that his having discovered this universal Error, must be the greatest step towards procuring a steady performance.

Would not any person versant in  
the

the principles of Clock-work, be surpris'd to hear, that a Clock should measure time well, having no weight / or Bob / to its Pendulum; yet I dare venture to assert, that the Pendulum Rod only has more the Command of the Wheels in a Clock, than a Ballance has in a Watch. What improvement then may be expected in Watches, by giving the momentum of the Ballance the proper superiority over the impetus of the Wheels!

Having thus compared the natural properties of the Ballance to those of a Pendulum, and, I hope, pointed out the reasons why the performance of the Ballance has hitherto been so very inferior to that of the Pendulum. I shall next endeavour to suggest the means by which the natural  
tendency



tendency of the Ballance may be preserved,  
and consequently the performance of Watches  
made nearly to approach to that of Clocks,  
even in their most perfect State.

In order to which, it is necessary to  
remove the following inconveniencies. viz.

- 1.<sup>st</sup> ..... The inequalities arising from the action  
of Wheels on Pinions.
- 2.<sup>d</sup> ..... The different states of fluidity of the Oil.
- 3.<sup>d</sup> ..... The manner of applying the impetus  
of the Wheels to the Ballance.
- 4.<sup>th</sup> ..... The influence of Heat and Cold.
- 5.<sup>th</sup> ..... That the Ballance, as well as the  
Pendulum, will tend to perform its unequal  
vibrations in unequal times.

The first of those inconveniencies may  
be remedied in Watches, as in Clocks:

and

and though the two first methods, may  
seem ingenious, I am of opinion that high  
numbered Pinions will answer better in  
practice, as their inequalities of Action  
diminish with the versed Sines of their Angles.

The Second, may be sufficiently removed,  
by a judicious application of Jewels to the  
Pivots: and always observing that the  
moving Power have a sufficient superiority  
over those accidental variations. —

In answer to the Third; let the impetus  
of the Wheels be so applied, that its action  
may coincide, with the natural tendency  
of the Ballance; which will give the same  
advantage as in Clocks.

To remove the Fourth: A judicious  
opposition of the Expansion of Metals, must  
be



be applied to the Ballance Spring; which must not only counteract the Expansion of the Spring, but also that of the Ballance; and this naturally suggests a method for adjusting those Expansions.

In Answer to the Fifth, and last: all the properties of the Cycloidal Clocks may be applied to the Ballance; by which means, its vibrations, whether long or short, will be performed in equal times. But the Curve which gives this property to the Ballance, will deviate as much from the true Cycloid, as the resistance of the Pendulum Spring does from the action of Gravity on a Pendulum; this is also applicable to the Pallets.

N. B. The application of the  
Cycloid

Cycloid to the Ballance, will wholly remove any part of the First and Second inconveniences that may yet remain: And the very intention of the Cycloid points out a method of adjusting that Curve truly, by the application of different moving Powers. And tho' the Cases of a Watch, may seem to have no concern in the measuring of time, in some circumstances their weight is an advantage, and never hurtful to the Watch's performance.

Having now, I hope, performed my proposed Task of pointing out not only the Causes of the irregularities that have  
hitherto



hitherto attended the performance of Watches, but also the means by which Pendulum Clocks may be brought to the highest Perfection; and all their properties applied to Watches; I have only now to add, that, though I have only treated of the Theory, and even that, without such Illustrations as may by many be thought necessary, I have reason to hope, that if those few Remarks should ever appear in publick, that proper allowance will be made for the Imperfections that must attend an abortive production; in which, though no mention is made of the Practice, I have, in every part, had it, so much in view, that I could undertake to execute every Article that

I

I have mentioned as practicable, if the expence that must attend the making proper Engines, and scarcity of proper hands for such a Work, were not too great a discouragement for any one who considers the matter in its full extent. And though I doubt not, that under proper regulations, those improvements may become of general utility, I apprehend that the application and expence that will, at least for a time, be necessary, will dissuade any Mechanick who is equal to the task, from attempting so great an undertaking, unless it becomes a Publick Concern.

But as I have already mentioned the only motives that have induced me to put my Sentiments in writing, I beg leave

here



here to observe, that the high Opinion  
 I have of Mr. Harrison's Abilities, and  
 a firm persuasion that the above Remarks  
 are founded on the established Principles  
 of Philosophy, induce me to think, that  
 those my Sentiments will, at least in  
 part, coincide with his, if so, I deserve  
 no more praise, than having been in  
 close pursuit of him, in establishing  
 the Principles of Clock and Watch Work:  
 that I have thought of, what probably,  
 he has executed. Should my Sentiments  
 differ from his, my comfort is, that  
 they are not more Theorems: And that,  
 without any addition to the above  
 Principles, I doubt not of being able  
 to construct and execute a Watch, much  
 superior

superior to any that has yet appeared in  
 Publick. I cannot however omit this  
 opportunity of expressing my happiness  
 in the Success and encouragement of a  
 Person whose natural Abilities and  
 Application I have so high an opinion;  
 and declaring, that if any merit is found  
 in the foregoing Remarks, it was not with  
 any intention to detract from his, that  
 I committed them to writing, but in  
 hopes that sometime hereafter they might  
 be the means of my being allowed capable  
 of thinking for myself, as well as conceiving  
 what I was told. I do here also express  
 my just sense of the honor done me in  
 being named one of those, to whom an  
 Improvement so valuable to the Publick  
 was



was to be communicated; and assuring  
those who have done me that honor,  
that I shall give all the Application  
in my power, towards getting thoroughly  
acquainted with an affair, on the success  
of which may depend the safety of so  
many valuable Lives.

Wm<sup>d</sup> Cumming

The Introduction to those Remarks  
as well as the conclusion, were by me read  
+ to M<sup>r</sup> John Harrison on the Ninth day  
of April 1763 in presence of the Right  
Honble the Earl of Dunmore and M<sup>r</sup>  
Harrison Junior; that he might then  
sign each Page for the purposes before  
mentioned: which was declined until  
the manner of making his discovery  
was agreed on by him and the Commissioners  
appointed by Act of Parliament for that  
purpose.

I am therefore induced, contrary to  
my first intention to lodge with the  
Secretary of the Royal Society an exact  
Duplicate, signed and sealed / even in  
this



this imperfect State) to prevent any  
Dispute or Inconvenience that  
might attend any such further  
Refusal on M<sup>r</sup> Harrison's part,  
or long delay on mine. —

Alex<sup>r</sup> Cumming



A number of blank pages follow  
and have not been photographed.



