

LXXXVIII. *A Letter of Mr. James Short, F. R. S. to the Royal Society, concerning the Inventor of the Contrivance in the Pendulum of a Clock, to prevent the Irregularities of its Motion by Heat and Cold.*

Gentlemen,

Read Nov. 9, 1752. **T**HE subject of conversation of late having often turn'd upon that ingenious contrivance in the pendulum of a clock, to prevent the inequalities in its motion, arising from its different lengths, in different seasons of the year, by the effects of heat and cold; and it having been often asked, who was the inventor of it, I have therefore thought proper to draw up the following historical account of it: And as this account contains nothing but matters of fact, supported by the best authorities, I hope it will be acceptable to this Society. I am

Your most obedient humble servant,

J. Short.

**S**OON after the invention of pendulum-clocks (justly ascribed to the celebrated Mr. Huygens), it was found, that they were liable to considerable inequalities in their motion; which were imagined to arise from the pendulum, in its vibrations, describing an arc of a circle; and, consequently, that the larger vibrations must be slower than the shorter ones.

ones. In order to remedy this imperfection, the same Mr. Huygens wrote a treatise, called *Horologium oscillatorium* (a piece of geometry, which does honour to the last century), in which he demonstrates, from the properties of the cycloid, that the vibrations of a pendulum, moving in a cycloid, would be perform'd in equal times, even tho' the vibrations were unequal. Pendulums therefore were made to vibrate in a cycloid; but great inequalities were still observ'd in the motion of clocks.

We do not read of any attempts, after this, to regulate the motion of clocks, till the year 1726, when Mr. George Graham deliver'd into the Royal Society a paper, which is publish'd in the *Phil. Trans.* N<sup>o</sup> 392, in which he says, that it having been apprehended, that the inequalities in the motion of clocks arose from a change of length in the pendulum, by the influences of heat and cold, he, about the year 1715, made several trials, in order to discover, whether there was any considerable difference of expansion between brass, steel, iron, silver, &c. when expos'd to the same degrees of heat; conceiving, that it would not be very difficult, by making use of two sorts of metals differing considerably in their degrees of expansion and contraction, to remedy, in great measure, the irregularities, to which common pendulums are subject. He says also, that, from the experiments he then made, he found their differences so small, as gave him no hopes of succeeding that way, which made him leave off prosecuting this affair any more at that time: That, some time after, having observed an extraordinary degree of expansion, by heat, in quicksilver, he thought of a proper manner

manner of applying a column of it to the pendulum of a clock, in order to prevent the inequalities arising from its different lengths by the effects of heat and cold; which succeeded accordingly, and is what is now called Mr. Graham's quicksilver-pendulum.

Mr. Graham, in the same paper, takes notice, that, tho' the pendulum of a clock was to remain invariable, yet there would still be some irregularities in the motion of the clock, arising from the friction of the different parts of the clockwork, and from the different degrees of foulness.

In the year 1725, Mr. John Harrison, of Barrow in Lincolnshire, made several experiments upon wires of different metals, in order to find their different degrees of expansion and contraction: For he thought, that, by a proper combination of wires of two different metals, differing considerably in their expansion and contraction, he might be enabled to keep the centre of oscillation of a pendulum always at the same distance from the point of suspension. In consequence of these experiments, he made a pendulum, consisting of one steel wire, at the end of which is the bob or weight, and, on each side of this wire, four wires alternately brass and steel, so disposed and contrived, as to raise the pendulum the same quantity as it is lengthen'd by heat, and to let down the pendulum in the same proportion as it is raised by cold. He made also a drawing of a clock, in which the wheels are disposed in a different manner from those then in use; which drawing I have seen, signed by himself in the year 1725. Two of these clocks with pendulums, as described above, were finished in the year 1726. In these clocks Mr. Harrison has made  
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a particular sort of pallets, so as to be almost intirely free from friction; for tho' he had thus happily succeeded in his contrivance to prevent the inequalities in the motion of the clock, arising from the different lengths of the pendulum by the effects of heat and cold, yet he found there were considerable errors still remaining, occasion'd by the friction of the pallets, as in the common way. He has also suspended the pendulum upon the wall of the house, intirely independent of the clock and clock-case: For he had observed considerable alterations in the going of the clock, when the pendulum is suspended as in the common manner. His pendulum vibrates in an arc of about 15 degrees, with a bob of about three pounds, between cycloidal checks, which he himself found were necessary, tho' he had never heard of M. Huygens's book, till after he had made them. He has also disposed the force of his pendulum-wheel upon the pendulum, by his sort of pallets, in such a manner, that the vibrations of the pendulum will not be affected by the different resistance of the air. Upon the whole, this clock is made in such a manner, as to be almost intirely free from friction; in consequence of which he uses no oil, and therefore there is no necessity ever to clean the clock. When he settled in London, he sent for one of these clocks from the country, and set it up in his house in Orange-street, in the year 1739, where it has stood ever since, and in all that time has never varied above one minute from the truth. He can depend upon it to a second in a month.

About the year 1729, Mr. Harrison made his first machine for measuring time at sea, in which he has likewise

likewise applied this combination of wires of brass and steel, to prevent any alterations by heat and cold. In the year 1726, he went on board one of His Majesty's ships of war with this machine to Lisbon, and returned, where this machine was seen by every curious and ingenious person, who were pleased to go to his house. Since that time, he has made two more of these machines or clocks for keeping time at sea, in both which he has likewise this provision, to prevent the effects of heat and cold.

An account of these curious machines, and of the many ingenious contrivances which Mr. Harrison has made use of in them, for answering their intended purpose, and also an account of the success of his voyage to Lisbon, and back again, is contained in an excellent speech of our worthy President Martin Folkes, Esq; upon his delivering to Mr. Harrison the gold medal of Sir Godfrey Copley; which speech is inserted in the minutes of the Society in the year 1749.

Mr. John Shelton, who was the principal person employed by Mr. Graham in the making of astronomical clocks, informs me, that Mr. Graham, in the year 1737, made a pendulum consisting of three bars, *viz.* one of steel, between two of brass, and that the steel bar acted upon a lever, so as to raise the pendulum, when lengthened by heat, and to let it down, when shortened by cold. This lever, which is very strong, rests upon a roller; which roller is made moveable, so as to adjust the arms of the lever to their true proportion. The whole was made to be as free from friction, as possible, in such a construction. Mr. Graham made observations, by transits of

the fixed stars, of the motion of the clock with this sort of pendulum, and from the experience of several years (during which the clock was kept constantly going) he found, that the clock was liable to sudden starts and jerks in its motion. Of this he informed Dr. Bradley, Mr. Blis, myself, and several other gentlemen. This clock still remains in Mr. Graham's house, in the possession of his executors.

I have been informed, that one Mr. Frotheringham, a quaker, of Lincolnshire, caused a pendulum to be made, consisting of two bars, one of brass, and the other of steel, fasten'd together by screws, with levers to raise or let down the bob; and that these levers were placed above the bob. This clock I have seen, and was told by the maker, Mr. John Berridge, that the pendulum of it was made in the year 1738, or 1739, and that the dial-plate of it was engraved at Mr. Sisson's house in the year 1738: and this clock is in the possession of Mrs. Gibson, in Newgate-street, who has had it ever since the year 1739.

In the *Hist. of the Royal Acad. of Sciences at Paris*, for the year 1741, there is a memoire of M. Cassini, in which he describes several sorts of pendulums for clocks, compounded of bars of brass and steel, and applies a lever to raise or let down the bob of the pendulum, by the expansion or contraction of the bar of brass. He has also given us, in the same memoire, a problem for finding the proportion, which the two arms of the lever should have, to answer the intended purpose; and also a demonstration of it.

In June, 1752, Mr. John Ellicott gave in to the Royal Society a paper, containing the description of a pendulum, consisting of two bars, one of brass, and the other of iron, fastened together by screws, with two levers in the bob of the pendulum, so contrived, as to raise and let down the bob, by the expansion and contraction of the brass bar; and also to adjust the arms of the levers to their true proportion\*. He says, that he first thought of these methods of applying bars of brass and iron to prevent the irregularities of a clock, arising from the different lengths of the pendulum, by the effects of heat and cold, in the year 1732; and that he put this his thought in execution in the year 1738.

In the year 1743, I bought a clock of Mr. Graham, which he had kept going for two years before. This clock has a pendulum, compounded of wires of brass and steel, in the manner of Mr. Harrison's combination. It has also a provision in the bob, to adjust the wires, in case they happen to be too long. When I first took notice of this contrivance or provision in the bob, I asked Mr. Graham the reason of it; who told me, that, having observed some inequalities in the motion of the clock, he imagined, that they arose from the wires being somewhat too long; and there-

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\* He has also given us in the same paper another construction of a pendulum to prevent the effects of heat and cold, consisting of two bars, one of brass, and the other of iron; the brass bar acting upon a lever, at the end of which is fastened the pendulum, the whole so constructed and contrived, as to raise the pendulum, when it is lengthened by heat, and to let it down, when shortened by cold.

fore added this contrivance, to adjust the length of the wires ; but that, when he had done this, he found inequalities still remaining; and therefore justly concluded, that they arose from the difference in the friction of the different parts of the clockwork, occasioned by the differences in the fluidity of the oil, &c.

From what has been said above, it appears, that the improvement of clocks, by a contrivance to prevent their inequalities arising from the different lengths of the pendulum, in different seasons of the year, by the effects of heat and cold, was first thought of, and executed, by Mr. George Graham ; and that the application of wires or bars of two metals, which have different degrees of expansion or contraction, to prevent the same inequalities, was also first thought of by Mr. Graham, and first executed by Mr. John Harrison, without the least knowledge of what Mr. Graham had done before him.

LXXXIX. *A Letter from Mr. Henry Eeles, to the Royal Society, concerning the Cause of Thunder.*

Gentlemen,

Lismore, Ireland, June 18,  
1752.

Read Nov. 7, 1752. **T**HE greatest men of most ages having thought it worth the while to inquire, what was the cause of thunder ; and the world seeming to acquiesce in an hypothesis subscrib'd by some great modern names, it must appear presumptuous in me, to offer you some thoughts for a theory intirely new .(at least it is so to me) unless I can shew, that the former hypotheses are ill-grounded,