Ferguson's Paradox ~ The Solution

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The following is an extract from "Wheelwright of the Heavens - the Life and Work of James Ferguson, FRS" by John R. Millburn

Before leaving this subject, it is appropriate that one of Ferguson's orrery-type models should be mentioned, namely, the Mechanical Paradox. Although this was a straightforward piece of mechanical hardware, it owed its origin to a theological discussion. Ferguson related the story in a very long letter to a friend, the Rev Mr Cooper of Glass, Banffshire, written many years later. The original letter does not appear to have survived, but Henderson printed it in full from a copy said to be in Ferguson's own hand; it had previously been printed in the Horological Journal for 1858. The essence of the story was as follows. One evening Ferguson went to a weekly gathering (probably a dining or drinking club), where one of the other people present, a watchmaker, 'began to hold forth against a Trinity of persons in the God-head, wondering at the impudence of the person who broached such an absurd doctrine'. Ferguson, who was sitting just opposite to him, 'gave him a severe frowning look', whereupon the watchmaker asked his opinion concerning the Trinity. Ferguson suggested that they should talk about the watchmaker's business instead, and asked him whether he understood how one gear wheel turned another. 'I hope I do, said he'.

Then, said I, suppose you make one wheel as thick as other three, and cut teeth in them all, and then put the three thin wheels all loose on one axis, and set the thick wheel to them, so that its teeth may take into those of the three thin ones; now turn the thick wheel round: how must it turn the others? Says he, your question is almost an affront to common sense; for everyone who knows anything of the matter must know that, turn the thick wheel which way you will, all the other three must be turned the contrary way by it. Sir, said I, I believe you think so. Think! says he, it is beyond a thought - it is a demonstration that they must. Sir, said I, I would not have you be too sure, lest you possibly be mistaken; and now what would you say if I should say that, turn the thick wheel whichever way you will, it shall turn one of the thin wheels the same way, the other the contrary way, and the third no way at all. Says he, I would say there was
never anything proposed that could be more absurd, as being not only above reason, but contrary thereto. Very well, says I. Now, Sir, is there anything in your ideas more absurd about the received doctrine of the Trinity than in this proposition of mine? There is not, said he; and if I could believe the one, I should believe the other too.

Ferguson then said that he could make such a machine, and would bring it along to show to the assembled company the following week. He did so, and asked the watchmaker to explain it. The watchmaker turned it to and fro, took it to pieces and put it back together again, and confessed that he was thoroughly perplexed. 'The thing is not only above all reason, but it is even contrary to all mechanical principles'.

For shame, Sir, said I, ask me not how it is, for it is a simpler machine than any clock or watch that you ever made or mended; and if you may be so easily non-plused by so simple a thing in your own way of business, no wonder you should be so about the Trinity; but learn from this not for the future to reckon every thing absurd and impossible that you cannot comprehend.

The wheelwork of Ferguson's 'Mechanical Paradox', as it came to be called, was a simplified version of the arrangement commonly employed in orreries to produce parallel motion by three equal gears, plus a slow advance or regression. Some years later, he converted his basic model into an orrery, in which the three motions represented the parallelism of the Earth's axis, the advance of the Moon's apogee, and the regression of its nodes. In 1764 he published a tract describing it, illustrated by an engraving. This version of the model was shown to the Royal Society on 21 November 1765. The original model presumably consisted of the two parallel plates and wheelwork, without the Sun ball, Earth ball, and the orbit rings seen at the right-hand side of the plate; it must, however, have had some way of showing the relative movements of the three thin gears, so the latter were probably mounted on coaxial tubes carrying individual pointers above the upper plate. The date of its conception is uncertain, but was probably around 1750.....
Anyone who has followed the arguments in Chapter 4 on whether or not the Moon rotates, will realize that the Mechanical Paradox is concerned with matters of definition: It is, of course, quite true, as the watchmaker claimed, that two spur gears meshing with each other must turn 'in opposite directions'. In Ferguson's device, the thick wheel necessarily turned all the three thin wheels in the opposite direction, relative to the plates between which the wheels were mounted; but the arrangement of the wheelwork as a whole was such that it could only be put into motion by turning the plates themselves round a central fixed gear. One of the thin gears, having the same number of teeth as the thick one (and the central fixed gear below the Sun), remained parallel with itself, i.e. it turned 'no way at all'; the other two, having slightly more and slightly fewer teeth, exhibited a slow advance and regression respectively in comparison with the 'parallel' gear.

My Model

The above extract explains the operation of the "paradox". I was sufficiently interested when I first saw it to construct a model for myself.

The major difficulty in construction is that the 3 thin wheels are all the same diameter, but have different tooth counts, so it is not possible to mesh them all perfectly with the thick wheel. In Ferguson's drawing of the later orrery, he made the thick wheel of variable diameter, like three wheels fixed together.
In the earlier model it was a single wheel, but the wheels were made of soft wood to take up any uneven meshing.

I made the model of brass, and found that it works well with slight adjustment of the tooth shapes. The circular base is perspex.
I hope this is all clear. It might be thought to be a complete waste of time, but it was a good exercise in wheel cutting when I needed the practice, and it gave an insight into James Ferguson, a fascinating character who was influential in the 18th century scientific world. If you have bothered to read this far, it has obviously done something for you too!
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