Galileo and Scientific History

The Leaning Tower and Other Stories

By Prof. A. S. Eve, F.R.S.

GOOD stories are apt to survive by their very fitness. In old age they may lose their savour because they are deemed legendary, but it is not well to part too lightly with old friends. The three best stories about Galileo are all under suspicion—the swinging lamp, the leaning tower, and "eppur si muove". I am sufficiently naïve to believe that all these three stories may have an underlying basis of fact.

The Swinging Lamp

There is a familiar story of Galileo (in 1581) timing with his pulse the swings of a hanging lamp in the Cathedral at Pisa and finding that the period was independent of the amplitude. The beautiful bronze lamp of Maestro Possenti which hung (and still hangs) from the roof of the nave is pointed out as the lamp which Galileo observed. J. J. Fahie, in his "Galileo, his Life and Work", adds to the story this critical footnote :

"Whether this be only a pretty fable, like that of Newton and the apple, cannot now be decided, but it is at least certain that Possenti's lamp was not the one that Galileo observed, since it was not made until 1587, and was only hung in its present place on the 20th December in that year."

Nevertheless, Galileo early invented a small pendulum, adjustable in length, wherewith to measure the rate of the beats of the human pulse. This was used by physicians, and drawings and descriptions of four different forms of such *pulsilogia* were published in 1607 by Santorio, professor of medicine at Padua.

The Leaning Tower

The last assault on the tower has been made by Prof. Lane Cooper in his interesting book "Aristotle, Galileo and the Tower of Pisa", which recently received a full and able review by Dr. R. T. Gunther in NATURE[1]. It is not necessary to recapitulate the whole case, but it is sufficient to state that Galileo's last pupil and first biographer, Viviani, told the story in his life of the master (1654) only thirteen years after his death. In 1832 J. E. Drinkwater told the same story in his "Life of Galileo". Referring to the Aristotelians, he wrote :

"Galileo repeated his experiments in their presence from the famous leaning tower of Pisa ; and with the sound of the simultaneously falling weights still ringing in their ears, they could persist in gravely maintaining that a weight of ten pounds would reach the ground in a tenth part of the time taken by one of a single pound, because they were able to quote chapter and verse in which Aristotle assures them that such is the fact."

Prof. Lane Cooper claims that there is no contemporary evidence of this story and that Galileo never mentions such an experiment in any of his works. The remarkable thing is that Prof. Lane Cooper does not quote, or even refer to, the most important passage bearing on this subject. He quotes correctly (on page 51) page 64 of Crew and de Salvio's translation of Galileo's "Dialogues of Two New Sciences", but he does not notice at all the relevant passages two pages earlier.

These are the words that he does quote (p. 64) :

"*Salviati*

"Aristotle says that 'an iron ball of one hundred pounds falling from a height of one hundred cubits reaches the ground before a one pound ball has fallen a single cubit !' I say that they arrive at the same time. You find, on making the experiment, that the larger outstrips the smaller by two finger breadths, that is, when the larger has reached the ground, the other is short of it by two finger breadths ; now you would not hide behind those two fingers the ninety-nine cubits of Aristotle."

Prof. Lane Cooper points out in his book (p. 51) that "the speaker is not Galileo, but 'Salviati' who to some extent represents Galileo, *as 'Sagredi' does also* [my italics]—'Simplicio' is an Aristotelian man of straw who fares ill in the argument, and whose name recalls the faithful sixth-century commentator on the treatise, De Caelo."

The following is the interesting and important passage in Crew and de Salvio's translation (p. 62) of the Dialogue which is ignored by Prof. Lane Cooper. Note well that Sagredi "who to some extent represents Galileo" distinctly used the words "I, who have made the test".

"*Simplicio*

"So far as I can remember Aristotle inveighs against the ancient view that a vacuum is a necessary prerequisite for motion and that the latter could not occur without the former. . . . Aristotle shows that it is precisely the phenomenon of motion, as we shall see, which renders untenable the idea of a vacuum. His method is to divide the argument into two parts. He first supposes bodies of different weights to move

in the same medium, then supposes one and the same body to move in different media. In the first case, he supposes bodies of different weights to move in one and the same medium with different speeds which stand to one another in the same ratio as the weights; so that for example a body which is ten times as heavy as another will move ten times as rapidly as the other. In the second case, he assumes that the speeds of one and the same body moving in different media are in inverse ratio to the densities of these media; thus, for instance, if the density of water were ten times that of air, the speed in air would be ten times greater than in water. From this second supposition he shows that, since the tenuity of a vacuum differs infinitely from that of any medium filled with matter however rare, any body which moves in a plenum through a certain space in a certain time ought to move through a vacuum instantaneously; but instantaneous motion is an impossibility, it is therefore impossible that a vacuum should be produced by motion."

This seems to be an honest attempt by Galileo to express the views of Aristotle (see Lane Cooper, p. 40), but it is not certain that the *void* of Aristotle and the *vacuum* of to-day mean the same kind of emptiness! However that may be, the dialogue continues:

"*Salviati*

"The argument is, as you see, *ad hominem*, that is, it is directed against those who thought the vacuum prerequisite for motion. Now if I admit the argument to be conclusive and concede also that motion cannot take place in a vacuum, the assumption of a vacuum considered absolutely and without reference to motion, is not thereby invalidated. But to tell you what the ancients might possibly have replied and in order better to understand just how conclusive Aristotle's demonstration is, we may, in my opinion, deny both of his assumptions. And as to the first, I greatly doubt that Aristotle ever tested by experiment whether it be true that two stones, one weighing ten times as much as the other, if allowed to fall at the same instant, from the height, say, of one hundred cubits, would so differ in speed that when the heavier had reached the ground, the other would not have fallen more than ten cubits."

"*Simplicio*

"His language would seem to indicate that he had tried the experiment, because he says: *We see the heavier*; now the word *see* shows that he had made the experiment.

"*Sagredo*

"But I, Simplicio, *who have made the test*" [my italics] "can assure you that a cannon ball weighing one or two hundred pounds or even more, will not reach the ground by as much as a span ahead of a musket ball weighing only half-a-pound, provided both are dropped from a height of 200 cubits."

It is certainly disconcerting to find Sagredo altering the height from 100 to 200 cubits. One hundred cubits, or bracchia, would mean about 58½ metres, while the height of the leaning tower is said to be 54 metres. Nevertheless, this definite claim, written by Galileo himself, published in the Dialogue in 1638, before Renieri made his experiments from the tower in 1641, seems to give some basis for the story told by Viviani. Weight may also be given to the words, duly quoted by Lane Cooper, written in Galileo's manuscript "De Motu" about 1590, in turn consulted by Viviani in 1654, but not published until the nineteenth century. The passage is this:

"If two stones were flung at the same moment from a high tower one stone twice the size of the other who would believe that when the smaller was half-way down the largest had already reached the ground?"

No doubt Lane Cooper is correct in saying that Galileo was flogging a dead horse, and that many had already attacked the rash statement of Aristotle, stated thus by Lane Cooper (p. 40):

"Bodies in the same medium with unequal weights, alike in other respects, move faster over an equal space and in the ratio which their magnitudes bear to each other."

There is another passage (p. 64) from Aristotle's "De Caelo", very suggestive of his erroneous view of falling bodies:

"The downward movement of a mass of gold or lead or of any other body endowed with weight is quicker in proportion to its size."

It may well be that Galileo had to confute not Aristotle, but his followers in Italy.

To sum up: it is not unlikely that Viviani founded his story about the Leaning Tower of Pisa on traditional information linked up with the specific claim that Galileo placed in the mouth of Sagredo in the "Dialogue of Two New Sciences". At the same time, our gratitude is due to Prof. Lane Cooper for showing that definite historical evidence is lacking.

EPPUR SI MUOVE

The traditional story is that no sooner had Galileo recanted before the Inquisition than he exclaimed: "It moves nevertheless."

Such a remark made audibly before the Holy Office, after his abjuration, would doubtless have led him quickly to a dungeon or even the stake. It would have been rash to whisper such a remark even to a faithful friend. For many years this story, started by Giuseppi Baretti about 1757, was therefore regarded as legendary.

However, J. J. Fahie in his exquisite "Memorials of Galileo Galilei 1564–1642" shows that these words were connected with Galileo from a much earlier date. A strange discovery, made in 1911, strongly indicates that the famous remark was recorded in a curious manner only a few years after Galileo's death.

It is well known that the Archbishop of Siena was a good friend to Galileo, who lived with him for some time after his condemnation as "vehemently suspected of heresy". Now the archbishop had a soldier brother, General Piccolomini, who served in Italy, Austria, Spain and Flanders. It is supposed that he asked Murillo in Spain to paint a portrait of his famous fellow-countryman Galileo, and the general may have shown some earlier picture to the artist for the purpose of the portrait.

In due course the Spanish portrait came into the hands of Mr. Jules Van Belle of Roulers, who found that the portrait had been framed in such fashion as to hide a heretical portion depicting the earth going round the sun, together with other astronomical symbols connected with the discoveries of Galileo, who is shown in a dungeon as the main figure with a nail in his hand, scratching the heretical figures on the wall. The date on the picture is deciphered as 1646, the signature is perhaps that of Murillo, and under the largest astronomical figure appear the words:

E PUR SI MUOVE.

[1] NATURE, **136**, 6, July 6 (1935).

Coal Production and Utilisation*

THE report of the Fuel Research Board for the year ending March 31, 1935, is timely, coming just when the difficulties of the coal industries are again forced upon public notice by the restiveness of labour in the mining community. Here is an industry equipped and staffed for a production of coal greatly in excess of current requirements. The industry itself seems to have lacked prevision of the results of the natural trend of events. It has sunk large new pits as though consumption would continue the expansion of pre-War days. Then an abundant export market existed and wasteful consumption at home offered tempting opportunities to secure economy by attention to more efficient consumption. Indeed, this economy was enjoined by the Ministry of Reconstruction at the end of the Great War, as an aim to be sought by national action. Consumers have grasped at the economies to be secured by better technique in fuel consumption, and the report gives clear illustrations by quoting figures covering the reign of King George.

"Despite increasing industrial prosperity and rising population the consumption of coal in Great Britain has fallen from 180 million tons a year in 1910 to 165 million tons in 1934. It is sometimes said that this fall is due to the replacement of coal by oil but the report shows that this is largely erroneous and the decrease is due mainly to the increased efficiency of practically every process for which coal is used.

"In 1910 about 4½ million tons of coal were required to produce 2,500 million units of electricity, while for the 16,100 million units generated by authorised undertakings in 1934 only 11·4 million tons were necessary. If the efficiency of production of electrical power had remained the same, 29 million tons of coal would have been used in 1934."

Collieries themselves have greatly improved the efficiency of coal-getting by mechanisation and its preparation for the market by methods of cleaning.

"The coke-oven industry is closely associated with the iron and steel industries, whose coal requirements have fallen by some 15 million tons a year. A considerable proportion of this is due to reduction in the amount of pig iron produced, but it is claimed by the British Iron and Steel Federation that since 1923, largely from the application of the results of research, £4,500,000 per annum has been saved in the cost of fuel. This figure indicates broadly that about 6 million tons less coal were necessary in 1934 than would otherwise have been the case."

It is generally recognised that the organisation of distribution has lagged behind. Production capacity in excess of needs and free competition both by individuals and districts produced marketing conditions favouring the buyer, and the working miners have suffered from loss of employment and reduced earnings. Few would wish to deny them an improved livelihood; but this can only be gained by an increased return for coal sold, because wages constitute the major item in the cost of raising coal. The coal industry itself seeks to increase consumption by any and every method, regardless of its desirability on other grounds. In fact, to judge by its spokesmen, it has a "raw coal mentality". One may cite a north of England mining borough which insists on equipping its municipal houses with wash boilers fired with coal rather than with gas. Moreover, the industry itself apparently envisages that the increased price shall not be got from raw coal burnt in the domestic fire. This does not accord with the view advanced in the report that "there is an ever increasing movement to regard coal as raised from the mine as a raw material which must be processed before it is offered for sale". It is to be hoped that this

* Department of Scientific and Industrial Research. Report of the Fuel Research Board for the Year ended 31st March, 1935; with Report of the Director of Fuel Research. Pp. xi+188+11 plates. London H.M. Stationery Office, 1935.) 3*s*. 6*d*. net.