Salviati. This we have already examined at length by showing that all terrestrial events from which it is ordinarily held that the earth stands still and the sun and fixed stars are moving would necessarily appear the same to us if the earth moved and the others stood still. Among all sublunary things it is only in the element of water (as something which is very vast and is not joined and linked with the terrestrial globe as are all its solid parts, but is rather, because of its fluidity, free and separate and a law unto itself) that we may recognize some trace of indication of the earth's behavior in regard to motion and rest. After having many times examined for myself the effects and events, partly seen and partly heard from other people, which are observed in the movements of the water; after, moreover, having read and listened to the great follies which many people have put forth as causes of these events, I have arrived at two conclusions which were not lightly to be drawn and granted. Certain necessary assumptions having been made, these are that if the terrestrial globe were immovable, the ebb and flow of the oceans could not occur naturally; and that when we confer upon the globe the movements just assigned to it [earlier in the *Dialogue*], the seas are necessarily subjected to an ebb and flow agreeing in all respects with what is to be observed in them.

Sagredo. The proposition is crucial, both in itself and in what follows as a consequence; therefore I shall be so much the more attentive in listening to its explanation and verification.

Salviati. In questions of natural science like this one at hand, a knowledge of effects is what leads to an investigation and discovery of the causes. Without this, ours would be a blind journey, or one even more uncertain than that; for we should not know where we wanted to come out, whereas the blind at least know where they wish to arrive. Hence before all else it is necessary to have a knowledge of the effects whose causes we are seeking.

Galileo, *Dialogue*, Day Four, p. 484

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Re-examining Galileo's Theory of Tides

PAOLO PALMIERI

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according to the hypotheses of the Newtonian equilibrium theory, where there is no need for a dynamic response of water, given that the whole phenomenon, which is controlled exclusively by tide-generating force, is quasi-static, i.e. in essence, extremely slow). On the contrary, water passes beyond the 'equilibrium point' and only by 'repeated oscillations of travel' does it reduce itself to 'a state of rest'. What Galileo has in mind here is the image of a swinging pendulum. In fact the passage quoted above goes on to explain that

> In exactly this way we see that a weight suspended by a cord, once removed from the state of rest (that is, the perpendicular), returns to this and comes to rest by itself, but only after having gone to and fro many times, passing beyond this perpendicular position in its coming and going.[15]

And this image becomes the *trait d' union* with the statement of the laws of motion of water within basins that immediately follows

> [...] the reciprocations of movement just mentioned are made and repeated with greater or less frequency (that is, in shorter or longer times) according to the various lengths of the vessels containing the water. *In the shorter space, the reciprocations are more frequent, and they are rarer in the longer*, just as in the above example of the plumb bobs the reciprocations of those which are hung on long cords are seen to be less frequent than those hanging from shorter threads. [...] it is not only a greater or lesser length of vessel which causes the water to perform its reciprocations in different times, but a greater or lesser depth does the same thing. It happens that *for water contained in vessels of equal length but of unequal depth, the deeper water will make its vibrations in briefer times, and the oscillations will be less frequent in the shallower.*[16]

Thus, Galileo knew exactly that: a) thanks to gravity – be it an internal tendency or an external accidental cause – water contained in vessels continues to oscillate freely after having been excited; b) the frequency of free oscillation depends on the width and depth of the vessel, i.e. on its geometry; c) the frequency increases in relation to the depth of the vessel and decreases in relation to its width. What he almost certainly did not know, or, at least, what he was not able to work out satisfactorily enough to support his claims, was the quantitative relations by means of which the two laws of basins might be expressed in an appropriate mathematical language. This lack of 'quantitative' refinement

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where the author discusses the question in relation to Galileo's concept of inertia and projectile motion; P. Galluzzi, *Momento. Studi Galileiani*, Roma, Edizioni dell' Ateneo & Bizzarri, 1979, particularly pp. 309–329, where Galileo's different theories of 'acceleration' and its cause are discussed). However that may be, Galileo's analysis of the oscillatory behaviour within basins appears to be totally independent of the question as to the physical cause that determines its behaviour. And whether 'gravity', or 'heaviness', acts as an internal principle 'naturally' common to all heavy bodies, or as an external 'accidental' cause, so that weight is simply proportional to this cause, Galileo's description of oscillating phenomena emerges unscathed.

15 G. Galilei, *Dialogue on the Two Chief World Systems, op. cit.*, p. 428.

16 *Ibid.*, pp. 428–429. Italics are mine.

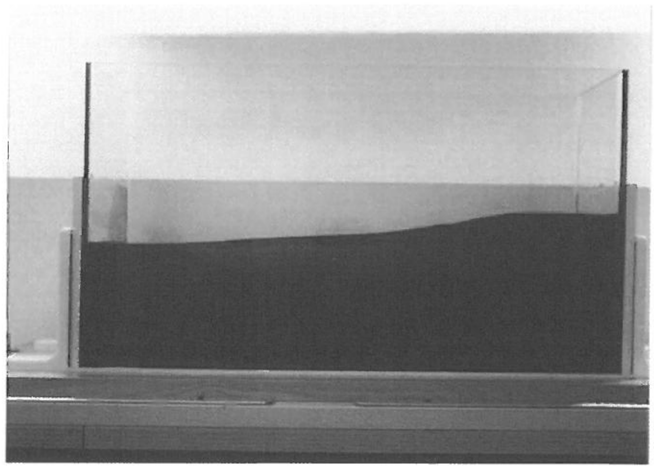

Figure A4.6

Whether Galileo even suspected such 'regularity' and performed these simple calculations, or simply accepted the more qualitative evidence stemming from such experiments without any further investigation, we do not know. But one thing is clear: the law of depth and the law of width (which may be verified by a practically identical procedure so that we can spare the reader the boredom of analogous data and computations) were well within the 'compass' of experiments the same or similar to these. Yet, it must have been the astonishing complexity of the many combinations of motions that waves display that in the end prevented Galileo from making public his results and furnishing the necessary evidence that such important discoveries would have deserved.

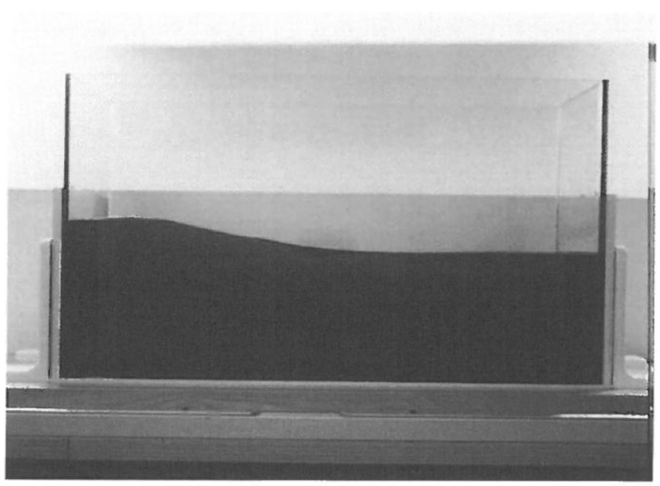

Figure A4.7