Galilean Principles of "Local" Motion

In the absence of air resistance, bodies descending from rest

1. **In vertical descent acquire equal increments of speed in equal increments of time.**

2. **Acquire the same speed in descending from the same height regardless of their weight or shape.**

3. **Acquire the same speed in falling from a given height whether falling vertically or along an inclined plane.**

4. **Acquire a speed in descending from any given height which is just sufficient to raise them to that height.**

What experimental evidence did Galileo and those in the decade following him provide in support of each of these principles; and how telling was that evidence in showing whether each holds merely to high approximation or exactly?

Galilean Principles and Evidence for Them

Descent in the absence of air resistance the same for all bodies, regardless of weight, shape, and density

1. **Qualitative experiments falsifying Aristotle**
2. **Qualitative experiments in different media**
3. **Qualitative experiments on paired pendulums**

Descent in the absence of air resistance is a uniformly accelerated motion, so that $\Delta v \propto \Delta t$ and $\Delta s \propto (\Delta t)^2$

1. **Galileo's experiments on shallow inclined planes**
2. **Riccioli's experiments on direct vertical fall**
3. **(Challenged somewhat by Mersenne's experiments)**

The same speed is acquired in descent from rest from the same height in the absence of air resistance, whether the descent be directly vertical or along an inclined plane of any angle

1. **Comparison of Galileo's results for different angles of inclined planes: $\Delta v \propto \sin \alpha$**

The speed acquired in descent from any given height in the absence of air resistance is just sufficient to raise the body back to that height

1. **Qualitative experiments with pendulums**

Problems with Experiments in Mechanics

1. **Elapsed times were short (e.g. < 5 sec) making any result highly sensitive to small errors in time measurements**

2. **There was no direct way to measure velocities, yet many central claims concerned them**

3. **Experiments needed at least to control for, if not minimize, resistance effects, yet the only ways acknowledged for doing this were to employ very heavy bodies and keep speeds low**

Upshot: ***Discrepancies between theory and experimental results were ambiguous: (1) insufficient control of "external" effects, (2) measurement error; (3) inadequate theory; but then so too ambiguous was the absence of discrepancies.***

Galileo's Approach

- **Develop a mathematical theory from hypotheses that appear reasonable and mathematically tractable**

- **Derive some "striking" predictions within that theory, like the 1, 3, 5, ... pattern, among others**

  Predictions that are *prima facie* counterintuitive

  Predictions that involve qualitative contrasts

- **Design experiments to test the striking predictions, hoping at the very least that the results do not clearly falsify them (limited effects of air resistance notwithstanding)**

"One finds in this subject a kind of demonstration which does not carry with it so high a degree of certainty as that employed in geometry; and which differs distinctly from the method employed by geometers in that they prove their propositions by well-established and incontrovertible principles, while here principles are tested by the inferences which are derivable from them. The nature of the subject permits of no other treatment. It is possible, however, in this way to establish a probability which is little short of certainty. This is the case when the consequences of the assumed principles are in perfect accord with the observed phenomena, and especially when these verifications are numerous; but above all when one employs the hypothesis to predict new phenomena and finds his expectations realized."

Christiaan Huygens, 1690