Galileo's *Two New Sciences*: Local Motion

I. Local Motion Versus Celestial Motion: The Problem

A. Astronomy Versus the "Science" of Motion: 1638

1. 1638, the year in which *Two New Sciences* was published, was the year in which Horrocks was making extraordinarily small changes in the orbital elements of Venus and Earth, to yield an account of Venus's motion within observational accuracy for the first time
    a. I.e. changes Kepler's value of Earth's eccentricity from 0.0180 to 0.0173, of Venus's eccentricity from 0.00692 to 0.00750, and of Venus's semi-major axis from 0.72413 to 0.72333
    b. In the process reducing discrepancies in Venus longitudes from 5 min of arc to less than 2 min, and removing a 0.11% residual difference in Kepler's 3/2 power rule
2. *Two New Sciences*, by contrast, generally shows little concern for such precise agreement between theory and observation, and at many places outrightly dismisses such concerns
    a. Though a mathematically precise theory, no theoretical calculations to high precision save for the Tables at the end of "The Fourth Day", and this precision scarcely pertinent
    b. And almost no numerically precise results of observations
3. Galileo working in the context of a 2000 year tradition of predominately quasi-qualitative claims about motion -- e.g. speed acquired in fall varies directly with weight and inversely with the density of the medium (more or less)
    a. Orbital astronomy concerned with comparatively precise numerical claims of one sort or another from the Babylonians on, and surely from Ptolemy on
    b. With the exception of a few theorems on motion by an imitator of Euclid, no mathematical theory of "local" motion remotely akin to the mathematical theories of planetary motion
    c. Nearest thing to it: impetus theory of Buridan and Oresme, and efforts by Mertonians
4. Galileo himself had held a view of natural motion derived from Archimedean theory in the 1590's (*De Motu*, as per Settle)
    a. Objects have a natural velocity of fall that depends on their density and the density of the medium (our terminal velocity)
    b. This is what one generally observes with bodies falling in water, and also for bodies that are not too heavy in air -- i.e. what happens in nature
    c. Transition to the natural velocity via a gradual decay of non-natural "virtus impressa" after the impressed force ceases to act -- e.g. after what is holding the object is removed
    d. This view gradually gave way to recalcitrant experimental results -- bodies arriving at the ground at virtually the same time and bodies always gaining speed on inclined planes -- which Galileo initially attributed to experimental limitations and imperfections
5. The science of local motion offered in *Two New Sciences* is thus truly immature science -- a new science at its very beginnings

a. The physics in Kepler was immature science, but the efforts on trajectories were far from it; indeed, even Ptolemy was well past the point of immaturity at which Galileo was starting
b. So, here able to see more clearly the process of getting a science off the ground, of the struggle to turn observations into evidence

6. Yet notice that Kepler's orbital astronomy and Galileo's mathematical theory of motion were endeavoring to achieve formally the same sort of thing -- a mathematical specification of motions, trajectories and locations along them versus time
   a. I.e. a mathematical specification of position in space and speed versus time
   b. {Though Galileo imitating in style of presentation not mathematical astronomy, but Archimedes (d. 212 B.C.), whose works (re-published in 1543) he had studied under Ricci at Pisa
   c. Galileo's "paradigm" not just Archimedes legendary *On Floating Bodies*, but also works in "mechanics" as *On the Equilibrium of Planes*, which announces the principle of the lever}
7. And also the same thing evidentially, namely to establish some (presumably lawlike) generalizations concerning certain sorts of motions
   a. Kepler through numerical agreement within observational accuracy-- or, with Horrocks, through progressively closer agreement -- along with plausible underlying physics
   b. Our question now: how was Galileo's approach different from that?

B. The Fundamental Empirical Problems Contrasted

1. Although the formal goals were the same, Galileo faced profoundly different evidential problems in trying to formulate an empirical theory of motion
   a. I.e. problems of bringing observations to bear in order to answer questions
   b. Will spell these problems out and examine Galileo's general approach to them before turning to his substantive theory
2. The fundamental difference: no problem in orbital astronomy observing position versus time -- e.g. geocentric longitude and latitude versus time
   a. Relevant unit of time so long -- e.g. a day, or even 0.001 days (more than 86 sec) -- that no problem making observations
   b. Basic evidential problem was need to infer the missing dimension -- e.g. geocentric distance r -- and also to find preferred reference point for motion (relative to fixed stars) -- e.g. Sun -- in order to distinguish apparent motions from ones observable from fixed stars
3. By contrast, objects fall to Earth in too short a time for us simply to observe the sequence of locations versus time and thus to generate data akin to Tycho's
   a. Questions of distance of object from us and preferred reference for motion no problem at all in local motion
   b. But the relevant unit of time much too short to make useful naked eye observations, or even to recognize qualitatively any general pattern in distance versus time