4. In the spirit of such complaints, notice how little information was available in 1675 on whether Galileo's and Huygens's results would hold exactly in the absence of air resistance, and if not, what sort of approximations they were
    a. I.e. do they hold skewed or in the mean, and -- air resistance aside -- are they idealizations or mere approximations
    b. Air resistance effects make this question hard to get at, although some progress was made -- e.g. on the physical pendulum
5. Huygens himself developed a mathematically correct theory for motion under resistance proportional to velocity in the 1660s
    a. Horizontal, vertical, and projectile motion
    b. Experiments he conducted then showed that resistance appears to vary with v^2, and he was unable to handle this case mathematically
    c. Published his work only after Newton's *Principia*, preferring his mathematical approach
6. Similarly, little information was available on the ranges over which the various results hold and the *ceteris paribus* conditions -- beyond no air resistance -- under which they hold
    a. E.g. does *g* vary systematically at extreme high altitudes or at great depths below the surface of the earth
    b. Given any observed departures from the results -- e.g. Richer's -- the confounding effects of air resistance and other factors make it difficult to determine what to attribute them to
7. By comparison, a fair amount of information was available to support the claim that the results should be taken to be nomological, both from their derivation from a unified theory and the diverse evidence accruing to this theory, including high quality evidence
    a. Even so, a Cartesian could challenge their nomologicality on the grounds that the split between resistance mechanisms and the mechanisms treated in the results is spurious
    b. More information on underlying mechanisms -- e.g. from a theory grounded on universal rather than parochial axioms -- would strengthen the claim to nomologicality
    c. Still, arguably more claim to nomologicality than Kepler’s rules as of late 1670s

C. Newton: A Biographical Sketch (to 1679)

1. Newton's father died two months before he was born, which was on Christmas day, 1642 (old calendar); and after his mother left Woolsthorpe to remarry three years later, he was raised by his maternal grandmother until 1653, when his step-father died
    a. He rejoined a family with three younger children, but two years later left for grammar school in Grantham, where he was most remembered for "his strange inventions and extraordinary inclination for mechanical works" (Westfall, p. 60)
    b. After a year away from Grantham managing his farm, with marked lack of success, his mother was persuaded in 1659 that he should return to school in preparation for university

2. Newton entered Cambridge -- specifically, Trinity College -- in 1661, one of roughly 300 students entering what had become somewhat of a degree-mill for the well-to-do
    a. Newton entered as a "subsizar", a student earning his keep by performing tasks for the fellows
    b. His education was classical -- including Aristotle -- until roughly 1664, when he started branching out on his own, reading extensively and beginning an intense study of mathematics
    c. Newton was elected to a scholarship in 1664, to a fellowship at Trinity in 1667, and he was appointed Lucasian Professor of Mathematics, succeeding Barrow, in 1669
3. Even though he published virtually nothing at the time, Newton was extraordinarily productive in the decade from 1665 to 1675
    a. By 1666 he had invented the calculus, and was de facto probably the leading mathematician in the world
    b. He followed this up with further work in mathematics, especially further development of the calculus, in the late 1660's and early 1670's: *A Treatise of the Method of Fluxions and Infinite Series, with its Application to the Geometry of Curved Lines* (1671, published in 1730s)
    c. He also devoted time to optics in particular, but to mechanics too and, to a lesser extent, theology, and he began his interest in alchemy during these years, when in his own words he was "in the prime of my age for invention"
4. Cambridge closed twice for periods during the plague years of 1665-66, and Newton returned home to Lincolnshire, where he had his "Annus Mirabilis"
    a. In addition to developing the calculus during that time, he developed his theory of colors and did various work in mechanics, including the first "Moon test"
    b. The attached accounts of this year in the Appendix, including Newton's own, attest to the extraordinary productivity that the year away from Cambridge generated, even after allowances are made for embellishments
5. The unpublished material on mechanics assigned this week presumably derives from work he did in the period 1665 to 1675, with the possible exception of "De Gravitatione" (controversial, but on my view at most a few parts of it date from around 1684)
    a. Newton was a pack rat, so that we now have an enormous body of notebooks, manuscripts, annotated books that he read, etc. on every topic: see the "Newton Project"
    b. But he did not generally date this material, so that we have to surmise when various pieces were written on the basis of his handwriting, the content, and ancillary information
    c. Newton's own later remembrances of this period add to our confusion in dating, for his recollections are not entirely accurate, often in ways that seem disturbingly suited to help him defend various claims to priority
6. The work in mechanics assigned tonight is fully representative of Newton's efforts in this field before 1679 -- indeed, before 1684, when for the first time he began to do more than just dabble

a. An earlier notebook -- "The Waste Book" -- and a brief manuscript -- the "Vellum" manuscript -- contain precursors of some of the papers assigned for tonight, as noted below

b. The only other work was a brief, unsuccessful foray into projectile motion under air resistance -- this following publication of James Gregory's work on this topic and pendulums (1673)

D. Newton's Work in Mathematics: 1664-1680

1. Newton seems to have begun educating himself in mathematics in 1663, from an elementary text on arithmetic and algebra by Oughtred (1631) and a more advanced text by van Schooten (1646)

   a. The work that appears to have brought him to the then-current forefront of the field was van Schooten's second Latin edition (1659) of Descartes' *Géométrie*

   b. From there he turned to numerous sources, including Wallis's work on indivisibles and infinite series and Barrow's works and (presumably) lectures at Cambridge

2. He discovered the fundamentals of what we now call the calculus over a two-year period from 1664 to 1666 (see chart in Appendix), culminating in his first tract, "To resolve problems by motion"

   a. General algorithms for solving problems concerning infinite sums, maxima and minima, tangents (see Appendix), quadratures, being worked on by Fermat, Pascal, and Huygens (among others) in France and by Wallis, Barrow, and Gregory (among others) in England

   b. Employing a Barrow device of a curve described by a moving point, and taking what we would now call derivatives with respect to time, which Newton called "fluxions" of "fluents"

3. This was followed by a tract in Latin, "De Analysi per Aequationes Infinitas," in 1669, which Barrow circulated, gaining Newton recognition as the leading figure in mathematics in England, and then a full-fledged treatise, *De Methodis Serium et Fluxionum*, in 1671, for which Newton was unable to find a publisher; in all of these he continued with fluents unfolding over "time"

   a. The range of the problems addressed in the latter is spectacular (see Appendix, where examples on curvature and a table of integrals are included as well): Newton had full control of the algorithmic methods that came to be known as the calculus by 1671

   b. The history of mathematics would have been quite different if that book had been published then (rather than finally in two different English editions during the 1730s)

   c. Leibniz's initial work on the calculus began in the mid-1670's and came to fruition in the mid-1680's, but unlike Newton's it was published in the leading journals and led to a tradition of research involving the Bernoullis, l'Hôpital, Varignon, and later Euler and several others

4. One shortcoming of Newton's early work on the calculus was a lack of perspicuous notation; only after the *Principia* in 1687 did he invent the dot notation that came to be associated with him

   a. For example, in the early work he often used lower-case letters to represent the fluxions (time-derivatives) of fluents represented by the corresponding upper-case letters

   b. By contrast Leibniz had a more perspicuous notation from the outset

   c. So even if Newton's early works had been published, they might not have caught on quickly