6. Another consequence of Newton's style was that he often thought of problems in rather different ways, not always being informed of the most current way of thinking about them in, say, London
   a. We will see this tonight in work paralleling that of Huygens, in which Newton had his own distinctive approach
   b. Being out of the mainstream put Newton in a position to alter the course of the history of physics

II. Newton's Early Laws of Motion (vs. Descartes, Huygens)

A. Newton's Conceptualization of the Problem

1. Material in the "Lawes of Motion" paper appears to be in response to his reading Descartes' *Principia* in 1664; but the amaneunsis handwriting (John Wickens) in the first half points to its dating between 1672 and 1675, perhaps in response to the *Phil. Trans*. 1669 papers
   a. Descartes' rules of impact not only difficult to comprehend, but glaringly in conflict with observation, putting the problem at the forefront in both Paris and London in the 1660's
   c. But, given Newton's distinctive approach, we have no clear evidence of how the "Lawes" relates to work by others
2. His first efforts on impact in the Waste Book are restricted to spherical objects colliding head-on
   a. He adopts Descartes' Bulk∗velocity measure of force, but restricts the conservation of motion to one direction at a time
   b. And he conceptualizes impact itself as involving elastic deformation of the spheres, with the force tied to the distortion, yielding the principle, separation v = approach v
3. The most striking feature of the way in which he conceptualizes the problem in the "Lawes of Motion" paper is its generality: arbitarily shaped objects at arbitrary angles of attack with respect to one another, not just spheres head-on
   a. Given Descartes' three kinds of matter, this is the appropriate form in which to pose the problem (though no one else did so)
   b. The obvious disadvantage is that it makes the problem mathematically much more complicated
4. Newton also conceptualizes the problem within the context of Descartes' three laws of motion, though with some modifications
   a. Presupposes straight line, constant velocity motion in the absence of forces -- in the form of motion in absolute space
   b. The force to persevere in a given motion is equivalent to the motion that it can create or destroy in another body -- expressed in terms of $\Delta(B*v)$, just as in Descartes' third law
5. Newton, however, distinguishes components of motion, and adds a parallelogram rule for compounding these components
   a. No hint of Galileo's parallelogram rule in this addition to Descartes
   b. Presumably prompted by demands on the problem when he allowed impact other than head-on

B. The Principles Governing Angular Motion

1. Newton proceeds to distinguish progressive (translational) and angular (rotational) motion, in the process indicating how to conceptualize the full motion of a rigid body
    a. Each body has a center of motion -- a point about which it can revolve with centrifugal tendencies counterpoised
        (1) Notice here the influence of Descartes again: use centrifugal tendencies as basis, counterpoised to explain why no net effect
        (2) Center of motion of course identical with center of gravity, as suggested in Paragraph 4
    b. Progressive motion is that of the center of motion
    c. What we now call inertia holds for both the translational, and also for the motion of the common centers of gravity of any system of interacting bodies (as per Huygens)!
2. Newton offers two measures of angular motion, one applicable to a single body in isolation, and the other allowing for comparisons among bodies
    a. For a single body: angular velocity
    b. More generally: quantity of motion, to be determined experimentally in terms of the amount of translational motion needed to produce it
    c. (An experimental measure only here because Newton not in a position to propose the $I*\omega$ counterpart to $B*v$ (just as Huygens wasn't in his work on the physical pendulum))
3. This measure, without a mathematical specification, introduces an obvious limitation on the theory by restricting the possibilities of mathematical proof
    a. A sharp contrast between this paper and Huygens's on the same topic is lack of mathematical proofs in this one
    b. In part because Newton was pursuing different objectives, but also because his approach interfered with such proofs
4. Newton then extends first the parallelogram rule to angular motions, employing an axis of compound angular motion, and then the principle of inertia
    a. I.e. constant angular motion about axis if counterpoised
    b. If not counterpoised, then axis changes in body, resulting in a spiral motion of the axis when viewed from outside the body
5. All these claims about angular motion presumably from "physical intuition" since he offers no proofs or experiments to support them
    a. No worse than Descartes in this regard, and hence not retreating to a lower standard as far as he could see
    b. (This is evidence of his being unaware of Galileo's *Two New Sciences* and the higher standard it exhibits, as illustrated in Huygens's efforts on impact)

C. The General Laws of Reflection on Impact

1. As already remarked, Newton poses the problem of perfectly elastic impact in a general form, in contrast to Descartes and Huygens
    a. What are the resulting rotational and translational motions after two arbitrarily shaped bodies, both moving rotationally as well as translationally, impact one another at a single point
    b. This is the problem Descartes really needs a solution for in his rules of impact, given the irregular shapes of particles of the first and third kinds of matter
2. Newton bases his solution on two principles, one of which is derivative from Descartes, and the other of which came from his Waste Book
    a. The velocity of separation of the points of contact = the velocity of approach -- a principle which Huygens derives from more fundamental hypotheses
    b. The total change of motion is distributed among the four components proportionately to the easiness with which each component of velocity changes -- akin to Descartes' least modal mutation principle announced in the letter to Clerselier
3. The algebraic solution (see page 212) is readily obtained from these two
    a. Herivel indicates that the solution is fully correct, though I am not sure that he isn't filling in lacunae in a generous fashion in reaching this conclusion
    b. Whether it is correct or not is unimportant for our purposes
    c. (We should notice, however, that Newton is in a position to see the difference between rolling and falling, for in transferring motion to a body, part can go into translation and part into rotation
        (1) Had anyone ever asked him and he had remembered this paper, he would surely have distinguished between rolling and falling
        (2) But he never says so anywhere that I know of)
4. The procedure for determining a solution, unlike Huygens's, requires an experimental step in lieu of specifications of moments of inertia for the impacting bodies
    a. E.g. the radii G and γ for angular motion have to be determined experimentally
    b. The solution is therefore not of great theoretical interest
5. But Newton has provided a correction of Descartes' rules while generalizing them to the problem he needed to be addressing
    a. I.e. provides rules for impact that are compatible with observation and with (Galilean) principle of relativity
    b. Like Descartes, Newton is reasoning from physical intuitions, but from "correct" physical intuitions -- i.e. intuitions that do not become warped by the effort to come up with tractable rules
    c. This reliance on physical intuition is an impressive feature of the "Lawes of Motion" paper, showing how the young Newton was able to devise a non-metaphysical solution to Descartes' problem, in the process remaining within the context of Descartes' fundamental principles