e. But then that distinction is going to be drawn in terms of the action of real forces in contrast to the actions of such apparent forces as the Coriolis force Newton has idnetified

5. The definition of quantity of motion is outwardly Cartesian, though presumably the reference to velocity makes it a vector quantity
   a. Quantity of matter -- not solid matter -- here being distinguished from weight, though this is also done by Descartes
   b. It "is to be estimated from the amount [*copia*] of the corporeal matter which is usually proportional to its gravity" -- "usually" leaves open the possibility that not always
   c. (Remarks about pendulum experiments will be commented on below, in conjunction with the further Definitions)
6. Definition of centripetal forces lists gravity ("tending to the centre of the earth"!), magnetic force tending to the center of the magnet (?), and "the celestial force preventing the planets from flying off in the tangents of their orbit"
   a. Note that gravity and magnetism here distinguished from the celestial force
   b. Centripetal force contrasted to innate or internal force – it is an impressed force
   c. No distinction in any of the discussion of forces between impulse-like and continuous forces

C. Drafts of New "Laws": The Third Law

1. The first two laws are in effect "Newton's first two laws", perhaps stated with more concern for clarity than in Version 3 of De Motu
   a. Claim that Galileo employed these two laws to discover the parabolic trajectory of projectiles is, of course, open to question, as is the claim about experiments supporting it
   b. The thing to notice here is that Newton is now feeling the need to offer some sort of explicit defense of the two laws
   c. Question: what is defense supposed to show -- that the laws are true, that they are warranted, or that they are just reasonable?
2. The third is "Newton's third law", to be found earlier in his work on impact in the Waste Book and in the Lucasian lectures on algebra (as in earlier handouts on impact)
   a. The empirical arguments offered in its defense appear to be saying nothing more than that it is compatible with known empirical phenomena
   b. The "derivation" of this law from Definitions 12 and 14, as Newton's explanation of the derivation shows, presupposes the main content of the law -- equal and opposite -- and hence does not add much
3. In fact the third law goes together with the fourth and the fifth -- Laws 3 and 4 of De Motu Version 3; Newton remarks that they "mutually confirm each other", but offers no demonstration
   a. The fifth law does most of the work in De Motu Version 3, but the claim it makes seems least open to any sort of comparatively direct empirical test

b. Newton may have turned to the third law while searching for a preferred law that would give him the fifth law

c. The fifth law holds for the interaction of two bodies if and only $\Delta(B_a v_a)+\Delta(B_b v_b)=0$

d. The obvious virtue of the third law is that it does lend itself to a more direct empirical defense

e. The fact that all three laws are stated on a par here suggests that Newton is leaving open the choice over which among them is primary

4. The sixth law is simply a more refined version of the claims about resistance offered in the two versions of De Motu

a. What is striking is the refusal to assert that this law is exact

b. Questions: (1) in what sense will it suffice for this law to be approximately true?; (2) why the exception here and not above?

c. Finally, notice the relegation of sphericity to a mere assumption of convenience here

5. Newton's orientation seems to be one of searching for laws that will give him the results of De Motu Version 3 -- in particular, Copernicanism -- in contrast to searching for still further laws to extend these results, or for a minimal set of laws from which to derive these results

a. The greater preoccupation with offering a defense of the laws here than in De Motu suggests that he is looking for laws that will not raise objections

b. The question then is why he feels more of a need for a defense here than in the version of De Motu that he sent to London

c. We should be cautious not to jump to conclusions on the basis of looking at these redrafted laws from the perspective of the *Principia* rather than that of De Motu

D. Further Drafts of Definitions: The Concept of Mass

1. Herivel's second set of draft definitions mistakenly combines an intended insert into the first set with a preliminary draft of definitions for the subsequent Lucasian lectures for 1685

a. As facsimile in Appendix shows, definitions 6, 7, and 12 intended as revision of first set

b. Insert later because the mass-weight experiment is here discussed as having been completed

2. Thus, the systematic distinction among three "quantities of centripetal force -- the absolute, the accelerative, and the motive -- comes after the fragment entitled "... in uniformly yeilding media"

a. This distinction and the clear assertion about weight first appear in the second half of 1685, accompanied by the first uses of *massa* and *inertia* in 1685

b. “Accelerative force” stems from wanting a term for forces that produce the same acceleration at any point in all bodies

3. The important new feature is the attempt to draw a clearer distinction between weight and quantity of matter, with the latter strictly proportional to the former

a. "*Pondus*" a word used widely to somewhat the same end in Lucretius’s *De Rerum Natura*, though Newton, clearly not happy with the ambiguity of the word, later changes to "*massa*"

b. Appeal to pendulum experiment without much explanation of why it shows what he claims for it
c. Motive force producing motion of the pendulum is gravity, with resistance forces the same when velocity the same, and motion produced is a product of quantity of matter and change in velocity
d. If quantity of matter were not strictly proportional to weight, pendulums of the same weight, but with different materials inside identical bobs should (or might) display different motions
e. (Reasoning should be considered in the light of Descartes' analysis of the relationship between weight and quantity of matter)

4. Question: what considerations are leading him to draw the distinction here, but not in De Motu Versions 1 and 3?; here is one possibility
   a. The pivotal conclusion in the "proof" of Copernicanism was that $C_h/C_j = r_j/r_h$, for this was the basis for reaching a conclusion about r_h
   b. But the point to which these radii are referred is a "center of gravity", so that $W_j*r_j = W_h*r_h$, where the W's refer to what the Sun and Jupiter would weigh at the surface of the earth
   c. In other words, $C_h/C_j = W_h/W_j$
   d. But their weight at the surface of the earth is a parochial quantity; we want a quantity that they have everywhere, independently of being at the surface of the earth, and that would yield their weight at this surface
5. By the reasoning that distinguishes the three quantities of centripetal force and justifies the claim that the quantity of matter is proportional to the weight, can now relate the absolute force to a non-parochial quantity: $C_h/C_j = M_h/M_j$, where M represents the quantity of matter
   a. But Newton is doing more than just this, for, by virtue of the pendulum experiment, he is also tying this non-parochial quantity to the resistance a body displays to changes of motion
   b. And hence to bulk (*moles*) in impact, "apart from considerations of gravity"

E. The Law of Gravity Emerges
   1. With the distinction of what he later came to call *mass* and the relation $C_h/C_j = M_h/M_j$, now have the law of gravity staring us in the face
      a. Centripetal acceleration at any point is proportional to $C/r^2 = M/r^2$
      b. Force is proportional to change in motion and hence to Mm/r^2
      c. Therefore, forces must be equal, via symmetry, yielding the third law as well, this time holding for mutually interactive centripetal forces, and not just forces in impact
   2. Alternatively, Newton might have reached law of gravity by first using the second law to conclude that the force on each body is proportional to its mass, the C of the other, and inversely proportional to the square of the distance between them
      a. He could then have invoked the third law to equate these two forces, allowing him to conclude that their respective C's are proportional to their masses (as he does in the *Principia*)