that is, his four different kinds of answers to “why” questions

6. The bedrock character of the laws raises a special problem that we have been noting in passing: how can one effectively test claims of this much generality
    a. Conceptualization: where explanation stops with brute descriptive fact -- i.e. with a way of describing what is happening
    b. How does one discover empirically where this is, for must describe e.g. motion before adducing any empirical considerations

V. Descartes' Rules of Perfectly Elastic Impact

A. Change of Motion and the Concept of Force

1. Descartes' rules of impact are standardly dismissed as crazy (as evidenced by the Millers' footnotes); still, however infamous they may be, they are historically important
    a. Even Descartes' defenders acknowledge how difficult the arguments for the rules are to follow, and they typically point out that the rules were added to the Latin edition at the last moment, then amplified in sometimes clumsy ways in the French
    b. I occasionally think of the criticism of Descartes here by historians and philosophers who should know better as a case of lesser minds taking comfort from others' mistakes
    c. It is not just that Descartes did not have the luxury of looking the correct answers up in a textbook, as the Millers can
    d. More, it is a matter of Descartes doing something different, which others have not elected to follow him on
2. The problem Descartes addresses is how to determine the force of resistance to motion which, once known, would allow change of motion to be determined via the rules

    In order to determine, from the preceding laws, how individual bodies increase or decrease their movements or turn aside in different directions because of encounters with other bodies; it is only necessary to calculate how much force (*virium*) to move or to resist movement there is in each body; and to accept as a certainty that the one which is stronger will always produce its effect.... This could easily be calculated if only two bodies were to come in contact, and if they were perfectly solid..." (45)

    a. The laws of motion themselves do not determine the outcome, for there are an infinity of before-to-after solutions to the equation, $(B_1*v_1 + B_2*v_2)_{before} = (B_1*v_1 + B_2*v_2)_{after}$ -- one equation in two unknowns not sufficient
    b. Worse, nothing said in laws about which force is greater, the force impressed on a body by another, or the force to resist
3. Descartes' picture is that of a contest between two forces, one impressed and the other resisting, with the greater dominating
    a. The force of rest -- to resist change from rest to motion -- is taken quite differently from the force to resist a change of motion

b. The third law says that if the impressed force is greater than the force to resist, a change in motion occurs, with a loss in the impressing body's capacity to cause subsequent changes in motion

c. Problem then is which force is greater -- indeed, how are we even to measure force

4. Quantity of motion [$\Delta(B*v)$] transferred from one body to another becomes a measure of the force effecting the motion, hence a measure of the amount the impressed force exceeded the force to resist

a. $\Delta(B*v)$ is like Galileo's proposed measure of percussive force since what happens upon percussive impact is a complete loss of motion

b. At least it is so long as B is taken to be quantity of matter here, so that neutral between Galileo's weight and Descartes' volume

5. A critical point, all too often ignored: forces themselves cannot be seen, but can only be inferred from change of motion, lack thereof, etc. -- indeed, even in the tradition of statics where the term was used in conjunction with balances and levers

a. Descartes' problem is that he gives rules for inferring the unseen forces, but only under unobservable conditions

b. He then gets criticized for not predicting what happens in the observable case -- something he is not even trying to do

6. In short, we need to keep two things separate here: the problem as Descartes poses and solves it and the problem posed and solved by others

a. The historical significance of Descartes' rules of impact does not lie in his failure to solve a problem posed and solved by others after him

b. Rather, it lies in the fact that his rules forced others to think through the principles of impact

B. The Rules for Change of Motion After Impact

1. The reasoning behind the first three rules is comparatively transparent

a. Rule 1: equal bodies at equal speed recoil, with reason given only in French edition -- absence of cause to change motion

b. Rule 2: if one slightly larger, then both move off at same speed in direction of the larger, for it wins the contest

c. Rule 3: if same size, but one slightly faster, then it wins the contest, transferring the minimum amount of speed to the other needed to end the contest

2. The next three rules concern what happens when one of the two bodies is at rest

a. Rule 4: if larger at rest, then never moved regardless of speed of smaller, for the force of resisting motion in a body at rest "increases in proportion to the difference in speeds"

(1) Which it would if this force is equal to the amount of change of speed involved in raising the at-rest object to the speed of the approaching one

(2) Descartes here speaks of "the resistance to receiving twenty degrees of speed"

b. Rule 5: if smaller at rest, then it loses the contest, with the minimum amount of speed transferred to it as needed to end the contest

c. Rule 6: if same size, then a compromise between the preceding two rules: "the two effects must be equally shared"

3. Finally, Rule 7 generalizes Rules 4, 5, and 6 to the case of objects moving in the same direction, but at different speeds

a. Contest again, but this time between B_1*v_1 and B_2*v_2; the object with the greater motion wins, where v designates (scalar) speed, not (vectorial) velocity

b. When impacting body smaller, it recoils, with no change in speed of impacted

4. In a subsequent letter to Clerselier, Descartes enunciates a principle underlying these rules (see Appendix)

a. A principle of least modal mutation, which together with that of conservation of total motion yields a unique solution

b. Spinoza states this principle outrightly (Proposition xxiii)

c. Trouble is that Rule 6 does not conform to this, but instead to a principle of the mean

5. Thus, whether Descartes himself had clear principles underlying the rules is a matter of some controversy, and we can say with some confidence that if he did, they do not appear in print

a. (Gabbey develops this point at length: pp. 247- 272)

b. However important it is to understanding Descartes, its main importance historically is that it invites others to reconceptualize the problem here, since they have trouble understanding Descartes' conceptualization

c. Spinoza's account instructive, for intended to be sympathetic to Descartes (Props. xxiv- xxxvii, as in Appendix)

C. Empirical Problems: Descartes' Defense

1. As Descartes openly acknowledges, "experience often seems to contradict the rules" (53)

"However, because there cannot be any bodies in the world which are thus separated from all others, and because we seldom encounter bodies which are perfectly solid; it is very difficult to perform the calculation to determine to what extent the movement of each body may be changed by collision with others. Since, {before we can judge whether these rules are observed here or not,} we must simultaneously calculate the effects of all those bodies which surround the bodies in question and which affect their motion"

2. In effect, then, Descartes' reply to the obvious line of empirical objection is that the rules are idealizations

a. No effects from surrounding medium and perfect elasticity

b. Rules address encounters between two bodies at a time; in real world many bodies involved in all encounters