Evan B. Kozierachi

# Newton's (Epistemological) Defect

Einstein's General (and special) Theory of Relativity is revolutionary from many perspectives, but I will focus on the epistemological shift from Newton's heuristic to Einstein's. Einstein claims: "In classical mechanics (and no less in the special theory of relativity) there is an inherent epistemological defect" (Dover 112). By classical mechanics, Einstein means "the mechanics of Galileo and Newton" (111). What is this epistemological defect, and how does Einstein's heuristic eliminate it?

Einstein elucidates the epistemological defect by providing the following example: "Two fluid bodies of the same size and nature hover freely in space at so great a distance from each other and from all other masses that only those gravitational forces need be taken into account which arise from the interaction of different parts of the same body" (112). The thought-experiment Einstein establishes, here, is inspired by Newton's bucket and balls in his Scholium (where he introduces Absolute time, space, place, and motion) after the Principia's definitions of masses. Einstein continues:

> Let the distance between the two bodies be invariable, and in neither of the bodies let there be any relative movements of the parts with respect to one another. But let either mass, as judged by an observer at rest relatively to the other mass, rotate with constant angular velocity about the line joining the masses. This is a verifiable relative motion of the two bodies. Now let us imagine that each of the bodies has been surveyed by means of measuring instruments at rest relatively to itself, and let the surface of $S_1$ prove to be a sphere, and that of $S_2$ an ellipsoid of revolution. (112)

Then, what is asked is the cause for this difference in the two bodies. Einstein stipulates for an epistemologically satisfactory answer *observable* facts as causes and effects.

Newton ascribes the cause as absolute motion (i.e. motion relative to absolute space). Furthermore, "the effects distinguishing absolute motion from relative motion are the forces of receding from the axis of circular motion, for in purely *relative* circular motion these forces are null," he adds (California 412). For Einstein, Newton's cause is not epistemologically satisfactory because the reason given is not an "observable fact" (Dover 113). In other words, since absolute motion is not an observable cause for the distinguishing effects on the bodies, there is no epistemological reason to accept this cause (and effect). Newton acknowledges his own epistemological dissatisfaction, when he grants: "It is certainly very difficult to find out the true motions of individual bodies and actually to differentiate them from apparent motions, because the parts of that immovable space in which the bodies truly move make *no* impression on the senses" (California 414). Therefore, Newton, himself, claims that the distinction between absolute space and apparent space is not an 'observable fact of experience.'

Einstein articulates this merely "factitious cause" of a privileged space (i.e. Absolute Space) as "not a thing that can be observed" (Dover 113). To further illustrate his point, Einstein makes this analogous to a situation with identically constructed pans half-filled with water, in which one emits steam and the other does not. The observer will be epistemologically dissatisfied until he discovers a bluish flame under the one steaming, which can be attributed as the cause (or effect) of the steam. In this way, Einstein "seeks in vain for a *real* something in classical mechanics (or in the special theory of relativity) to which [he] can attribute the different behavior of bodies" (Penguin 68). What is needed is an expansion of the special theory to a general theory of relativity to explain acceleration on bodies (i.e. forces), "regardless of the reference-systems K and K'" (68). This would include a re-interpretation of Newton's bucket and balls.

As stated before, Newton privileged one system of reference (as Absolute Space) to explain the centrifugal effects on the fluid body (i.e. the forces of receding from the axis of circular motion). Einstein counters by stating, “Of all imaginable spaces $R_1$, $R_2$, etc., in any kind of motion relatively to one another, there is none which we may look upon as privileged *a priori* without reviving the above-mentioned epistemological objection” (Dover 113). The objection refers to the epistemological need for observable facts to explain causes and effects, not an arbitrary, privileged frame of reference; in other words, “the laws of physics must be of such a nature that they apply to systems of reference in any kind of motion” (113). Therefore, we must extend the postulate of relativity to incorporate accelerated motion.

The democratic principle that Einstein seeks requires laws of nature (e.g. the laws of mechanics or the law of the propagation of light *in vacuo*) to remain the same regardless of how the observer’s motion; in other words, the laws must be covariant. The special theory compares different perspectives of the observable world only for uniform motion, but the general theory would remove that restriction and allow for the movement of acceleration, including rotation. The general theory of relativity reaches a road block at first by the “absolute physical reality [attributed] to non-uniform motion” since, for example, the fundamental law of Galileo, or Newton’s first law, (and special relativity) “does not hold with respect to [a] non-uniformly moving carriage” (Penguin 59). Einstein addresses this factitious cause (i.e. ‘Absolute physical reality’) by considering an accelerative force, gravity.

In a gravitational field, everything falls with the same acceleration. This is strange since the force of gravity acting on a body is proportional to its mass, the same quality that emerges when determining its *resistance* to acceleration (i.e. its inertia). Einstein addresses this ‘purely accidental coincidence of gravitational and inertial mass’ in classical mechanics by extending the postulate of relativity to a thought-experiment, in which gravity is seen much like any other accelerating system.

The following thought-experiment takes place in empty space like in the aforementioned one: a man living in a chest is constantly accelerated through space by a rope, which a ‘being’ pulls. The man in the chest, “relying on his *knowledge* of the gravitational field…will thus come to the conclusion that he and the chest are in a gravitational field which is constant with regard to time” (64). By this man’s reasonable conclusion, we have good grounds for the generalization of the postulate of relativity. In this was, “we are able to ‘produce’ a gravitational field merely by changing the system of co-ordinates” (Dover 114). Furthermore, this thought-experiment accounts for the equal effect of gravity on all objects, and the equality of inertial and gravitational masses, to the required degree of epistemological satisfaction (i.e. observable facts of experience as cause and effect).

Now, we can use the reasoning (from the generalized postulate of relativity) that an observer, who is at rest relative to “Galilean space” (or Absolute Space), would agree with the chest-man’s measured acceleration due to the ‘produced’ gravitational field in order to invalidate Newton’s privileged reference-system, Absolute Space, which will be referred to as K (Penguin 64). In other words, the accelerating system relative to ‘Galilean Space’ has a gravitational field like earth, a massive body *at rest*. Furthermore, we are, now, justified to incorporate Newton’s balls within general relativity.

Newton’s spinning (i.e. accelerating) balls--removed sufficiently far from any other gravitating bodies (i.e. masses)--*were* a justification for his idea of an Absolute Space (i.e. Galilean Space). Alas, his balls are (epistemologically) defective for this justification according to general relativity! Since “Galilean Space” is no longer a privileged frame of reference, his balls can be *at rest* (relative to a rotating K’ system) and still possess an accelerating force (relative to K, the Galilean reference body). Einstein imagines Newton’s balls as a rotating disc, and an “observer on the disc may regard his disc as a reference-body which is ‘at rest’” (Penguin 73). Therefore, the force acting on this observer and any other body which is at rest relative to this disc may be regarded as an effect of gravity.

Unfortunately, not only do Newton's balls (or Einstein's rotating disc) dismount Absolute space from an epistemological ground, but also Euclidean geometry (from the perspective of general relativity)! Keeping in mind that the aforementioned observer is moving relative to the center of Einstein's disc; if he puts a measuring rod along the edge of the disc in the direction of motion, in order to measure the circumference, the rod will be shorter there than it would be at the center. Thus, the rod suffers a Lorentz contraction. However, the rod will not be shortened when measuring the diameter since there is no relative motion in this direction. Therefore, the measured circumference ($C = \pi d$) will be greater than expected if pi (π, 3.14…) is multiplied by the measured diameter. Alas! Since the effective length of the rod can change, Euclidean geometry, also, becomes untenable for general relativity.