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PHIL236
25 April 2024

Paper 2

In the classic substantivalist versus relationist debate, Newton attempted to prove the existence of absolute space and time through his argument about two yolked globes. The following argument is summarized as follows:

1. In the first universe, there are two globes connected by a string in empty space. The globes are at rest.
2. In the second universe, there are two globes connected by a string in empty space. The globes are rotating about a fixed axis in the center of the string in uniform circular motion.
3. The difference between the first and second universe is that the second pair of globes experiences a constant force, which is observable by the tension in the string.
4. A relationist cannot tell the difference between the first and second universe because there is no other object from which to measure the motion of the rotating globes. Therefore, the second pair of globes are also at rest in the relationist point of view.
5. The substantivalist sees that the second pair of globes has tension in the string and is rotating in absolute uniform circular motion in relation to space itself; therefore, absolute space must exist.

In objection to this argument, Ernst Mach said that an empty universe with two globes rotating in uniform circular motion cannot exist. Instead, he claimed that the physical behavior of material objects can be observed using fixed stars as a frame of reference. A relationist may also accept the difference in the two universes and devise new primitives that can distinguish the two pairs of globes. Several additional primitives may be added to the relationist version of physics, including infinitely many direction primitives and an angle primitive. Mach's theory of motion suffers from problems of practicality, some additional relationist primitives may allow for the differentiation between the two pairs of globes, and I explain my own views regarding the globe argument and absolute motion.

In the late 19th century, Mach rejected the possibility of two systems of yolked globes, instead positing his own theory of motion. Mach viewed Newton's yolked globe argument as directed against relationism and as a thought experiment that attempted to prove the existence of absolute space (Huggett et al.). By contrast, Mach argued that Newton's conclusions are only true in a hypothetically empty universe and under the assumption that a physical system retains its essential properties in empty space (Lichtenegger and Mashhoon 5). In other words, nobody can draw conclusions about the two systems of yolked globes because they exist in arbitrary settings where the laws of physics may be different. Nobody is knowledgeable enough to predict what could happen in an empty universe. Therefore, the string connecting the two globes may

not be under tension in either system (Huggett et al.). Mach rejects the concept of absolute motion, insisting that absolute space and motion solely exist as ideas in the mind. They cannot be revealed by experience or experimentation, so are therefore “meaningless metaphysical concepts” (Lichtenegger and Mashhoon 5). Overall, Mach asserts that the argument is too far from reality to seriously consider from the perspective of actual experience.

As a response to Newton’s globe and bucket arguments, Mach formed his own theory of motion. For the purposes of this paper, Newton’s bucket experiment also attempted to prove absolute motion and absolute space. In the bucket argument, the bucket contains water and hangs by a string. The bucket rotates in midair and the water also experiences a force, causing it to assume a paraboloid shape. The water rises up the sides of the bucket. Newton claims that the relationist cannot identify whether the bucket is rotating or not without the use of absolute space as the reference frame to establish absolute rotation (Rynasiewicz). Since Mach rejects absolute space, he must formulate a theory of motion without absolute motion. His theory states that relative motion can be accounted for by reference to the sphere of fixed stars (Maudlin 45). This perspective is not a full theory, however, because it cannot predict all observable phenomena which Newton’s theory does (Maudlin 45). Mach intended for the laws of physics to be reformulated in terms of relative quantities, with fixed stars as the reference frame. In the case of the bucket experiment, Mach’s theory states that the water is accelerating with respect to the fixed stars (Huggett et al.). The theory would also reject the globe argument because such an empty universe cannot exist in the first place according to the theory, as the stars do not exist in that universe. Under some circumstances, the fixed stars may be limited as a reference frame due to the problem of distance. In addition, framing observable behavior is not intuitive under this perspective due to the constant need to refer to fixed stars. Mach’s theory of motion is not sufficient to explain physical phenomena because physics cannot be formulated entirely in terms of observable entities.

Unlike Mach, mainstream relationists may accept that such a difference between the two globes exists. Relationists may add primitives to their version of physics that allow for differentiation between the two pairs of globes. Before discussing potential additional primitives, it is crucial to understand substantivalist primitives which differ from those of relationism. First, Newton presupposes absolute space to have the structure of three-dimensional Euclidean geometry and absolute time to have one-dimensional Euclidean structure (Maudlin 25). The substantivalist primitives are the existence of points of space, points of time, congruence of points of space, congruence of points of time, betweenness of points of space, betweenness of points of time, the property of being a material object, and location (Ltpx where particle p is located at point x at time t). Using these primitives, the substantivalist can distinguish between the two pairs of yolked globes. Put simply, the particles of the globes are located at different points of space at different points of time. For example, Lt_1px, Lt_2py. Since the globes are rotating in a circle, they will return to the same points of space at later points of time (i.e. $Lt_{10}px$, $Lt_{11}py$). Newton concludes that the motion must be in relation to absolute space itself because the globes occupy different locations in space (Maudlin 23). The core primitives of relationism are

the existence of points of matter, the existence of point-like events, Dxyr (where r is the distance between points of matter x and y), and Txyr (where r is the time elapsed between point-like events x and y). Both measures of distance and time map to real numbers. These primitives cannot differentiate between the two pairs of yolked globes because there are no other objects. No other points of matter or point-like events exist to provide a frame of reference from which to compare the yolked globes. The points of matter in the closed system of the yolked globes remain at the same distance from other points of matter because the globes are rotating in uniform circular motion. Likewise, the point-like events of the rotating globes are all the same and do not change during the globes' rotation, so it is impossible to compare differences in the time elapsed between point-like events. This is why it is necessary for the relationist to introduce new primitives.

Many of the following possible primitives are derived from ideas in class lectures led by Professor Bacon. The first option for the relationist is to add infinitely many direction primitives. The relationist would say that as the globes are rotating in circular motion, they move in a particular direction for a certain period of time. For example, point of matter z is traveling in the left direction during Txyr. The problem with this primitive is devising a method of notating infinitely different directions without the use of numbers. Another directional primitive is mapping infinite directions onto a mathematical system of angles. For example, point of matter z is traveling at angle 20° during Txyr. The introduction of numerical angles contributes more structure at the cost of risking relationism to become reliant on numbers. Two other primitives are the property of being taut and the property of rotating in uniform circular motion. In the case of the rotating globes, the string would have the property of being taut because tension is present in the string. This property signifies to the relationist that some force is acting on the system, so the globes must be rotating in circular motion. The property of rotating in uniform circular motion would apply to the second pair of globes because they are rotating due to a force acting on the globes. The problem with these primitives is that they are difficult to define in a universe with no other material objects. In conclusion, the relationist faces obstacles in devising new primitives to differentiate the two globes because each potential primitive has some sort of tradeoff.

Before extrapolating my own views regarding the globes, I must reiterate that I am taking Newton's globes as a thought experiment. I follow the "classical interpretation" of Newton's writings, which is that "The example of the globes is lumped together with the example of a rotating water bucket. Their joint role is to show the existence of absolute motion (and by inference to the best explanation, the existence of absolute space)," (Solomon 3). Recent examinations of the Scholium, the essay where Newton wrote about the globes, argue that this interpretation of the globes as a thought experiment is flawed. While this may be important in further discussions of the Scholium, most people consider the globes as a thought experiment. As such, I will ignore this consideration and continue discussing the globes as a thought experiment.

The notions of absolute space and by extension absolute motion and rest are logical constructs for classical mechanics under Newton's views of space and time. Mach found these notions to be problematic, and the idea underlying his theory of motion is that since physics is about observable properties of observable bodies, physics should be formulated in those terms (Maudlin 46). However, physics best explains observable behavior by postulating unobservable entities. These entities, such as absolute space, allow for easier explanation of observable facts. At the time of his writings, Newton's three laws of motion were central to physics. The theory of relativity did not yet challenge the postulation of absolute space. Newton's views on space, time, and motion dominated physics until the advent of the theory of relativity in the 20th century, despite receiving frequent criticism (Rynasiewicz). In the context of Newtonian mechanics, the postulation of absolute motion and rest make sense. The concept of absolute rest is implicit in the first law of motion. An object remains at rest if no forces act upon it. This signifies that an object remains at the same points of space over subsequent points of time. The first pair of globes are at absolute rest in relation to space itself. Since Newton's first law is widely accepted, the globe experiment must also be accepted because absolute rest does not violate Newtonian postulations of space and time. Likewise, the second pair of globes in absolute motion are akin to an object moving in uniform motion in a straight line in absolute space, as seen implicitly in the first law. Maudlin summarizes my view, "Newton knew that absolute space and time are not, in themselves, observable, but he also explained how postulating them could help explain the observable facts. Why is this any worse than postulating atoms?" (Maudlin 46). The thought experiment of the yolked globes demonstrates absolute motion and rest, which are necessary logical constructs to help explain observable behavior.

To summarize, Mach rejected Newton's argument and formulated an impractical relationist theory of motion, the relationist may add potential primitives to be able to differentiate the two pairs of globes, and I argue that the notions of absolute motion and rest are logical constructs within Newtonian mechanics. Ernst Mach denied the existence of an empty universe containing rotating globes and postulated his own theory of motion which relates everything to fixed stars, but it is insufficient in explaining all physical phenomena. The relationist can accept that a difference exists between the two pairs of rotating globes and devise new primitives to explain the difference, but potential primitives present various shortcomings. Lastly, Newton's globes serve as a thought experiment that postulates absolute motion and rest as unobservable yet logical constructs that help explain observable phenomena.

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