

10. Berkeley and Mach

1. Berkeley On Absolute Space and Absolute Motion

1. George Berkeley
2. Ernst Mach
3. Mach's (Attempted)
Relational Theory of Inertia

"[T]hat [absolute] space is infinite, immoveable, indivisible, insensible, without relation and without distinction. That is, all its attributes are privative or negative. It seems therefore to be mere nothing. The only slight difficulty arising is that it is extended, and extension is a positive quality. But what sort of extension, I ask is that...no part of which can be perceived by sense or pictured in the imagination. For nothing enters the imagination which from the nature of the thing cannot be perceived from sense. Pure intellect, too, knows nothing of absolute space. That faculty is concerned only with spiritual and inextended things... From absolute space then let us take away now the words of the name, and nothing will remain in sense, imagination, or intellect. Nothing else then is denoted by these words than pure privation or negation, i.e., mere nothing."



George Berkeley
(1685-1753)

- Absolute space is described in negative terms: it cannot be perceived by the senses, nor known by the intellect. Thus it denotes "mere nothing".

"The laws of motion... hold without bringing absolute motion into account. As is plain from this that since according to the principles of those who introduce absolute motion we cannot know by any indication whether the whole frame of things is at rest, or moved uniformly in a direction, clearly we cannot know the absolute motion of any body."



- Absolute velocity is in-principle undetectable according to the very theory (Newton's theory of motion) for which it is posited.
- But: We've already heard this from Leibniz (who, in addition, offers *reasons* for why this is a bad thing).



"Then let two globes be conceived to exist and nothing corporeal besides them. Let forces be conceived to be applied in some way; whatever we may understand by the application of forces, a circular motion of the two globes cannot be conceived by the imagination. Then let us suppose that the sky of the fixed stars is created; suddenly from the conception of the approach of the globes to different parts of that sky the motion will be conceived. That is to say that since motion is relative in its own nature, it could not be conceived before the correlated bodies were given."

- Motion cannot be conceived in the absence of reference bodies.
- So: Purely absolute motion (motion with respect to absolute space) is inconceivable.
- In particular: The motion of two globes in an otherwise empty universe is inconceivable.

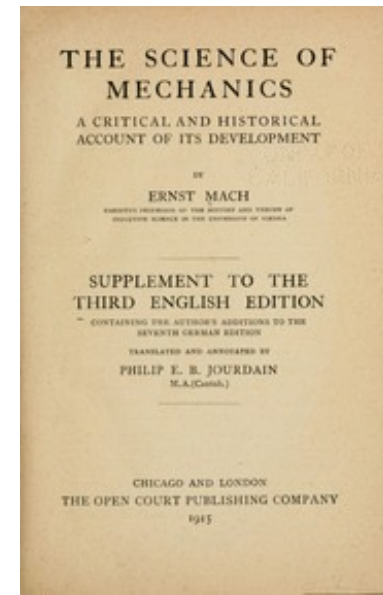
2. Mach On Absolute Space and Absolute Motion



Ernst Mach
(1836-1916)

"No one is competent to predicate things about absolute space and absolute motion; they are pure things of thought, pure mental constructs, that cannot be produced in experience."

"All our principles of mechanics are, as we have shown in detail, experimental knowledge concerning the relative positions and motions of bodies... No one is warranted in extending these principles beyond the boundaries of experience. In fact, such an extension is meaningless, as no one possesses the requisite knowledge to make use of it."



First edition 1883



- (a) Only motion with respect to reference bodies is observable.
 - (b) Absolute motion (motion with respect to absolute space) is unobservable.
 - (c) What is meaningful to mechanics is observable motion.
- ∴ Therefore, absolute space and absolute motion are not meaningful to mechanics.

Claim: The motion of a body K in the absence of other reference bodies cannot be determined.

"In the first place, we cannot know how K would act in the absence of $A, B, C...$ "



"...and in the second place, every means would be wanting of forming a judgment of the behaviour of K and of putting to the test what we had predicated, -- which latter therefore would be bereft of all scientific significance."

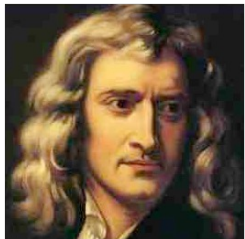
- In other words: The only data we have to test claims about motion is data on *relative* motions.
- So: The only motions we can predict or measure are relative motions.

Berkeley and Mach:

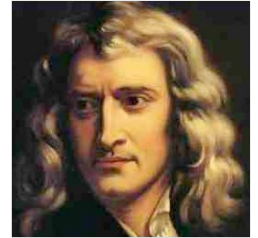
- There is no direct observational evidence for absolute motion.
- There is only direct observational evidence for relative motion.

- But: Newton agrees!

"But because the parts of Space cannot be seen, or distinguished from one another by our Senses, therefore in their stead we use sensible measures of them... And so instead of absolute places and motions, we use relative ones; and that without any inconvenience in common affairs; but in Philosophical disquisitions, we ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them..."



"But we may distinguish Rest and Motion, absolute and relative, one from the other by their Properties, Causes and Effects... The Effects which distinguish absolute from relative motion are, the forces of receding from the axe of circular motion. For there are no such forces in a circular motion purely relative, but in a true and absolute circular motion, they are greater or less, according to the quantity of the motion."



- Newton: While there is no direct observational evidence for absolute motion, there is *indirect* observational evidence (inertial effects).
- And: The onus is on the relationist to provide an account of these effects.

What the Relationist Must Do:

Provide an account of inertial effects *solely* in terms of relative motions.

3. Mach's Attempt at a Relational Theory of Inertia

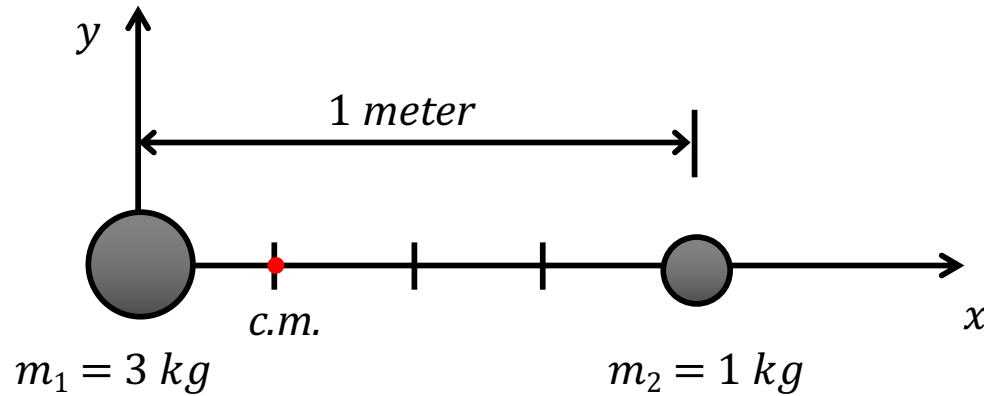
- Recall Bucket Experiment: What is *actually observed* (as opposed to fancifully observed) = inertial effects occur when water is rotating with respect to the fixed stars (fixed *observable* inertial frame of reference).



"Newton's experiment with the rotating vessel of water simply informs us, that the relative rotation of the water with respect to the sides of the vessel produces *no* noticeable centrifugal forces, but that such forces *are* produced by its relative rotation with respect to the mass of the earth and the other celestial bodies."

- How to make this more precise: Identify *center of mass of universe* as fixed observable inertial frame of reference.
 - *The center of mass (c.m.) of the universe can be calculated from the observed known masses.*
 - And: *Any object has a definite distance, call it R_u , from c.m.*

Example 1: Universe with two masses m_1, m_2

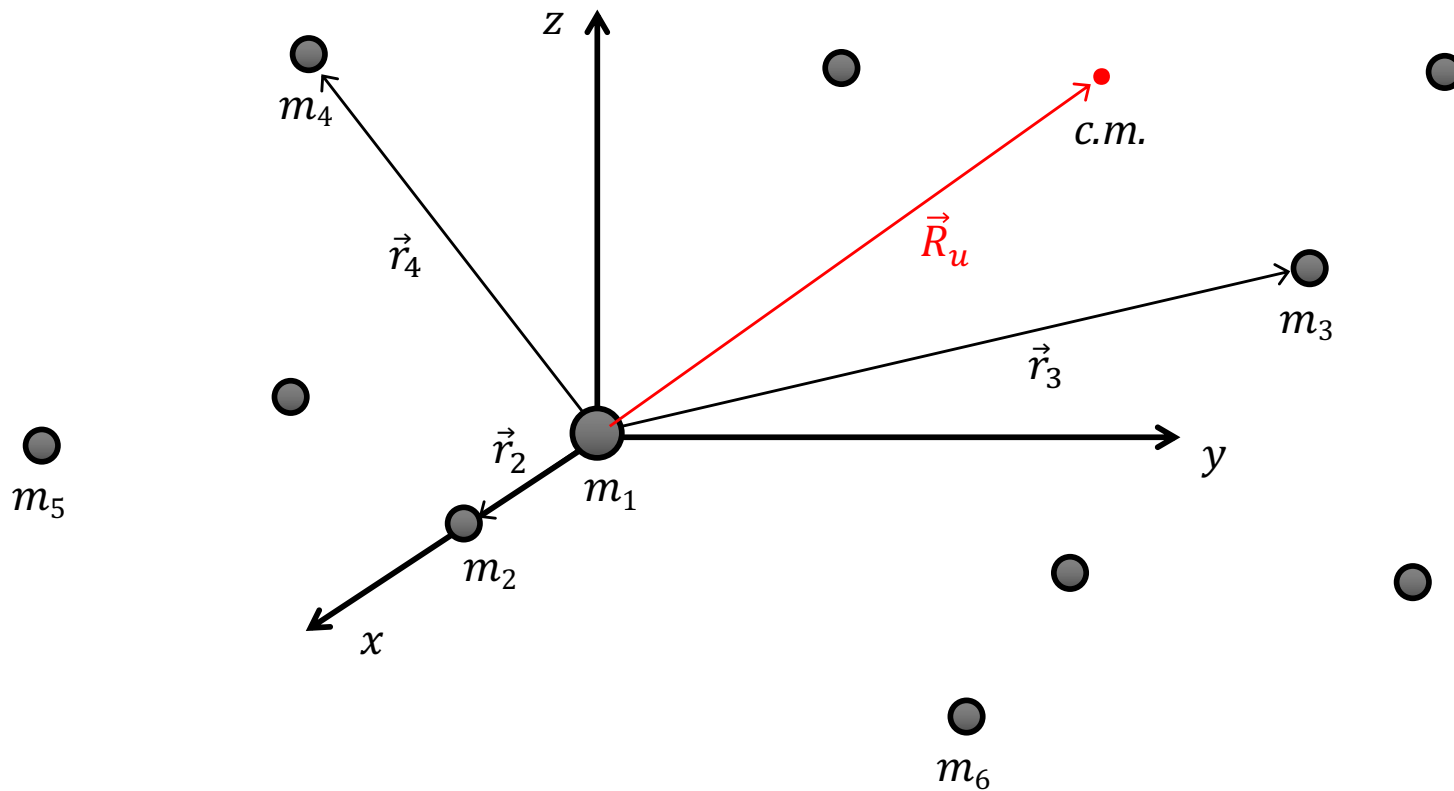


- For the mass m_1 at the origin, the distance R_u from the *c.m.* is:

$$R_u = \frac{\sum_{i=1}^2 m_i r_i}{\sum_{i=1}^2 m_i} = \frac{(3\text{kg})(0\text{m}) + (1\text{kg})(1\text{m})}{3\text{kg} + 1\text{kg}} = 0.25\text{m}$$

- R_u is a weight-averaged sum of the positions r_1, r_2 of the masses (weighted by their masses).

Example 2: Universe with n masses m_1, m_2, \dots, m_n



- For the mass at the origin m_1 , the distance \vec{R}_u from the *c.m.* is:

$$\vec{R}_u = \frac{\sum_{i=1}^n m_i \vec{r}_i}{\sum_{i=1}^n m_i}$$

Mach's Relational Principle of Inertia

For any object, $\frac{d^2 \vec{R}_u}{dt^2} = 0$, unless that object is acted upon by external forces, where \vec{R}_u is the distance between it and the center of mass of the universe.



"When, accordingly, we say, that a body preserves unchanged its direction and velocity *in space*, our assertion is nothing more or less than an abbreviated reference to *the entire universe*."

- But: This only defines *what* the privileged inertial reference frame is (*i.e.*, the *c.m.* of the universe).
- It does not explain *how* this privileged frame accounts for inertial effects.

What a Machian Theory of Inertia Must Do

Give an account of how the arrangement of matter in the universe:

- (a) acts *only* on objects *accelerating* with respect to the *c.m.* of the universe; but
- (b) does *not* act on objects *moving uniformly* with respect to the *c.m.* of the universe.

- Note: The gravitational force certainly does not act in this way.
- And: In such a Machian theory, there would be no distinction between natural and forced motion:
 - *All motion would be forced (due to interactions between objects).*
 - *There would be no natural motions determined either by the geometry of space (Einstein), or by internal "natures" (Aristotle, Leibniz).*

(A) Question posed by Newton: What explains inertial effects?

- Absolutist: Motion with respect to absolute space.
- Relationist: Motion with respect to a privileged material reference frame.

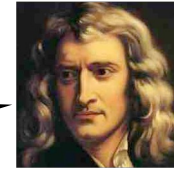
(B) Slightly different question: What *causally* explains inertial effects?

- Einstein's Newton: Absolute space resisting non-uniform motion through it.
 - Relationist: ?
- Mach provides a relationist definition of inertial frame, and hence (charitably) delivers on (A).
 - But: Mach *doesn't* deliver on a relationist *causal* explanation of inertia.
 - Does Berkeley?



"As regards circular motion many think that, as motion truly circular increases, the body necessarily tends ever more and more away from the axis. This belief arises from the fact that circular motion can be seen taking its origin, as it were, at every moment from two directions, one along the radius and the other along the tangent, and if in this latter direction only the impetus be increased, then the body in motion will retire from the center.. But if the forces be increased equally in both directions the motion will remain circular though accelerated."

*But there will still be a centrifugal force
(in need of explanation)!*



Therefore we must say that the water forced round in the bucket rises to the sides of the vessel, because when new forces are applied in the direction of the tangent of any particle of water, in the same instant new equal centripetal forces are not applied. From which experiment it in no way follows that absolute circular motion is necessarily recognized by the forces of retirement from the axis of motion."



- Berkeley mistakenly thinks there is nothing that needs an explanation!