Newton's Empiricism

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ENGAGING SCIENCE.

Seventeenth-century mechanists largely conceived of the qualities of the insensible entities to which their explanations appealed in terms of the qualities "given" in ordinary experience of big, perceivable, bodies: especially size, shape, and motion. It is true that the need for concepts of "force" began to pose problems for the geometrical Cartesian view-point in the post-Cartesian period, and that certain visionaries (such as Leibniz) saw that any form of mechanical corpuscularianism might involve too simplistic an approach to understanding nature. Still, there was little awareness that fundamental explanatory concepts in physics might be as remote from those applied in everyday experience ... as has in fact proved to be the case. (Wilson 1999 [1992], 477)

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- What about Newton?

Empiricism

What does sensory experience contribute to knowledge?

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- Two common empiricist commitments:
  - Knowledge of primary qualities directly, simply related to sensory experience
  - Science grounded in sensory experience

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- Newton’s contrasting commitments
  - Universal qualities *not* directly manifested in experience
  - *Measurable* quantities given a theoretical framework; theory-mediated measurements (Harper, Smith)
  - How to characterize these quantities and their epistemological role?

Outline

1. Locke II.viii and Newton's Rule III
2. Mass (and Force) in the *Principia*
3. Theory-Mediated Measurements
4. Quantitative Empiricism

Essay II.viii.9: Primary Qualities

[Primary qualities of body are those] such as are utterly inseparable from the body, in what state soever it be; and such as in all the alterations and changes it suffers, all the force can be used upon it, it constantly keeps; and such as sense constantly finds in every particle of matter which has bulk enough to be perceived; and the mind finds inseparable from every particle of matter, though less than to make itself singly be perceived by our senses. [...] Solidity, Extension, Figure, Motion, or Rest, and Number.

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Empirical criterion: invariance (maintained through all alterations), universality (found in all sensible bodies)

Conceptual criterion: "inseparable" from body, applicable to insensible bodies

Role of the Criteria

Application of the criteria distills ordinary experience into conception of body, the corpuscularian conception:

The special status of corpuscularianism then, for Locke, stems from the following facts: Corpuscularianism is a uniquely natural theory for human beings because it postulates that the real essence of a body corresponds precisely to the nominal essence of body that we distill from pre-theoretic reflection on ordinary sense experience. (Downing 1998, 403)

Rule III

Those qualities of bodies that cannot be intended and remitted and that belong to all bodies on which experiments can be made should be taken as qualities of all bodies universally.

For the qualities of bodies can be known only through experiments; and therefore qualities that square with experiments universally are to be regarded as universal qualities; and qualities that cannot be diminished cannot be taken away from bodies. Certainly idle fancies ought not to be fabricated recklessly against the evidence of experiments, nor should we depart from the analogy of nature, since nature is always simple and ever consonant with itself. The extension of bodies is known to us only through our senses, and yet there are bodies beyond the range of these senses; but because extension is found in all sensible bodies, it is ascribed to all bodies universally. We know by experience that some bodies are hard. Moreover, because the hardness of the whole arises from the hardness of its parts, we justly infer from this not only the hardness of the undivided particles of bodies that are accessible to our senses, but also of all other bodies. [...]

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Universal qualities: extension, hardness, impenetrability, mobility, force of inertia, gravity

Empirical criterion: invariance (intension and remission), universality (found in all bodies within the range of our experiments)

Transductive inference: inference to micro-constituents, appeal to analogy of nature (McGuire 1968, 1970; McMullin 1978)

Locke *contra* Newton (Stein 1990, 1993, 2004)

1. Why rule out the possibility that there are "fundamental" qualities that are *secondary* qualities (in Locke's sense)?

   Example: Colors treated as "original and connate properties" of rays of light:

   > *[T]he Rays to speak properly are not colored. In them there is nothing else than a certain Power and Disposition to stir up a Sensation of this or that Colour. ... (Opticks, 124-5)*

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2. Why expect that *any* "fundamental" qualities appear to us as sensible qualities?

   Force of inertia / inertial mass directly perceived without inference?

Janiak (2008): Mass as “Semi-Technical Concept”

- *Semi-technical* concept := “cannot be characterized, or understood, independently of Newton’s physical theory” (example: mass, force)
- *Thoroughly technical* := “explicable only in terms of a given theory’s concepts, but also completely divorced from ordinary concepts and ordinary perceptual experience” (example: electron) (116-117)

Rendering Experience More Precise

It is not clear that all the properties of material objects are discoverable through the senses, if by that we mean, by ordinary perceptual experience alone. ... Rather, it seems that our own perception of a body's mass is also at least partially dependent on our knowledge of the concepts in the Principia – hence our perception must be aided by what we might call background knowledge, a kind of epistemic component that is missing in the case of the mechanist properties. ... [W]e cannot perceive the mass of an object without background knowledge. (Janiak 2008, 115-117)

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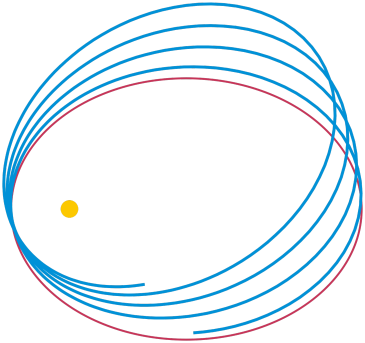
- *Perception*
  - Background knowledge enables us to “see experiences as” reflecting Newtonian universal qualities (mass, gravitational force, ...)
- *Measurement*
  - Phenomena not “ready-made”; qualities not transparent in ordinary experience (even with background knowledge)
  - Revealed by correlations with accessible quantities, in particular experimental or observational situations

Inferring Forces

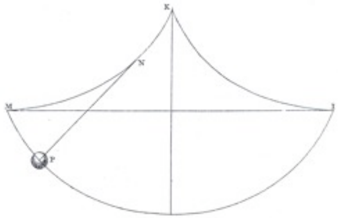
Example: Precession Theorem (Book I. 45)

- Motion of apsides: for $f \propto r^{n-3}$, apsidal angle θ given by $n = (\frac{\theta}{\pi})^2$.
- For stable orbits $\theta = \pi$, then $f \propto r^{-2}$.

General point: features of observed motion → parameters in power law



Huygens’ Pendulum Measurements (g)



Cycloidal Pendulum

Utility of Pendulums

- “Spread out time” to measure distance of free fall / value of surface gravity g

Isochrony?

- Simple pendulum *not* isochronous (approx. for small angles)
- Huygens (1659): Galilean gravity + pathwise-independence of velocity acquired $\rightarrow$ plane cycloid is isochronous

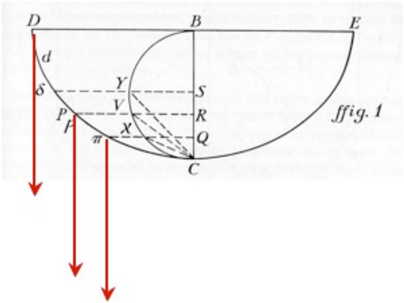
Assessing Reliability

- Stability: agreement in value for g among different pendulums of the same type
- Convergence: agreement in value of g among measurements of different types

  Conical pendulum – different physical principles than cycloidal pendulum

Conical Pendulum, from *Horologium Oscillatorium*

Principia, Section 10: Saving Huygens's Measurement



Galilean Gravity

1. Uniform g
2. Parallel lines of force

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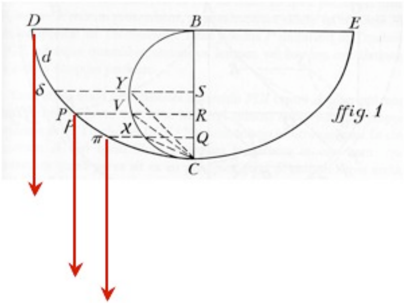

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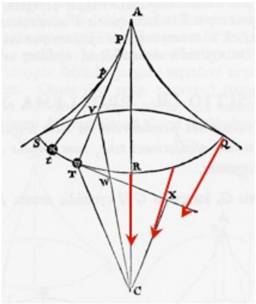
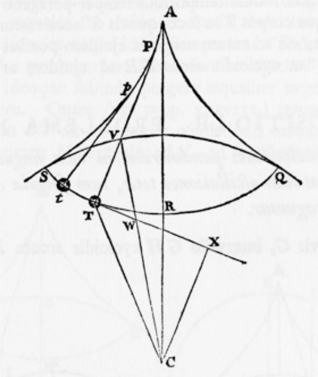


Newtonian Gravity

1. Varying g
2. Centripetal force

Assessing Reliability, Part II



Hypocycloid, isochrone for $f(r) \propto r$

Does Huygens's measurement carry over to Newtonian gravity?

- Isochrone for $f(r) \propto r$
- Pendulum law with "correction factor", $\rightarrow 1$ as $CO \rightarrow \infty$
- *Very small* error

Importance of Being Exact

- Newton's requirement (?) for measurement
  - Identify ideal situation in which *exact* relation between accessible quantity and "target" quantity holds
  - Departures from ideal quantifiable, yield error bounds

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- Newton's requirement (?) for measurement
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  - Departures from ideal quantifiable, yield error bounds
- Example of measurement failure: "global time" (di Salle 2006)
  - *No* actual measurement procedures for global time, given that light does not obey Galilean vector addition

Concluding Remarks

- Distinguishing Locke and Newton
  - Universal qualities *not* primary qualities in Locke's sense, instead: (i) accessible via reliable measurements; (ii) no requirement of simple relationship with sensory qualities
  - Optimism: direct measurement of wavelength of light (cf. Stein 2010)
- Further questions
  - Measurements presuppose theoretical understanding, with modal commitments (assessments of reliability). What is the status of this knowledge?
  - Comparison with Kantian readings of Newton (e.g., Friedman)