Newtonian Mechanics: Particles and Forces

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Outline

1. Application of Forces
2. Contra Forces
   - Unobservable
   - Redundancy Argument
   - Vicious Regress
   - Causal Overdetermination
   - Force-Free Theories
3. Pro Forces
   - Experience of Forces
   - Forces as Dispositions
   - Forces as Causal Relations
   - Forces as Aspects
   - Forces as Intermediaries
4. Ontologies without Forces

Primitive Ontology

fundamental building blocks of matter.

Newtonian mechanics: particles.

particles = property-less point-size objects.

motion on continuous lines in 3-d space.

debate:

- status of laws of motion?
- entire ontology?

Newton's Laws

Law 1

Every body perseveres in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by forces impressed.

Law 2

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modern formulation:

$$\mathbf{F} = m\mathbf{a}.$$

Role of Forces

forces defined as vectors (direction and magnitude).

explanation of motion of particles.

manners of speaking:

- particle A "exerts" a force on particle B.
- because there is a force, particles move in a certain way.
- a particle in a field feels a force.

cause of change of motion?

forces mediated by fields?

George Berkeley 1721

"Force" is similarly attributed to bodies; but this word is taken as if it signified a known quality, and one as distinct from motion, figure and every other sensibile thing as from every affection of a living thing. Yet anyone examining the matter more closely will agree that this is nothing other than an occult quality. Animal effort and corporeal motion are commonly regarded as the symptoms and measures of this occult quality. [1, p. 75]

George Berkeley con't

'Force', 'gravity', 'attraction', and words of this sort are useful for reasonings and computations concerning motion and bodies in motion, but not for understanding the simple nature of motion itself, or for designating so many distinct qualities. [...] These things serve mechanics and computation: but it is one thing to serve computation and mathematical demonstrations, and another to exhibit the nature of things. [1, p. 80]

The Argument

based on Ockham's razor.

the nature of forces is such as to guarantee that they are redundant.

1. force exists iff there is an "exerter" and "exerted upon",
2. laws relating the behavior of "exerter" and "exerted upon".

no explanatory value of forces given the laws.

reply: unification role of forces.

Max Jammer 1957

[T]o show or to predict that a certain body A moves on a certain trajectory B, when surrounded by given constellation of bodies C, D,..., [...] we introduce the middle term "force" and state the two "premises":
(1) The constellation C, D,... gives rise to a force F;
(2) the force F (according to the laws of motion) makes the body A move on the trajectory B.
In our final conclusion, "Body A, surrounded by C, D, ... under the given circumstances, moves along trajectory B," the middle term "force" again drops out. [4, pp. 243–244]

Example: Gravitation

$$\mathbf{F} = m_1 \ddot{\mathbf{x}}_1$$

$$\mathbf{F} = \mathrm{G} \frac{m_1 m_2}{|\mathbf{x}_1 - \mathbf{x}_2|^3} (\mathbf{x}_1 - \mathbf{x}_2)$$

$$\Rightarrow \ddot{\mathbf{x}}_1 = \mathrm{G} \frac{m_2}{|\mathbf{x}_1 - \mathbf{x}_2|^3} (\mathbf{x}_1 - \mathbf{x}_2)$$

forces mediate between causes and effects

$C \Rightarrow F \Rightarrow E$

regress if: C, E same ontological category as F

what mediates between C and F or F and E?

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reply:

- F different category than C and E (dispositions or causal relation),
- unifying role of forces, not generation of motion.

analogy: mental causation

the argument :

1. Changes in motion are causes by forces.
2. Every such change in motion is caused by an entity necessitating the force.
3. Forces and their necessitating entities are distinct.

$\therefore$ Every change in motion is causally overdetermined.

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reply:

- forces as aspects,
- forces as intermediaries.

Sketch of Arguments

other formulations of classical mechanics (LM, HM, HJ) don't require forces.

forces not needed in other fundamental theories like QM or GR.

Poincaré: all forces can be geometrized away into the curvature of spacetime.

Distant and Impact Forces

forces characterized as pushes and pulls

experience of these pushes and pulls
different motion $\Rightarrow$ different forces felt
tensions and pressures $\Rightarrow$ feeling of forces

impact forces (direct contact):

- feeling of force not the object,
- feeling varies with the same object.

Analogy: Fragility

Various fragile objects have something in common, the property of being fragile, and this is essentially linked to various subjunctive [= counterfactual] properties such as breaking if dropped. Yet the microstructures of the different fragile objects could differ. What they have in common is that they have features of their microstructures that will make them break in the right circumstances. And the various varieties of microstructures could lead to noteworthy variations in the kinds of fragility. [2, §4]

Application

disposition = property that has certain effects.

gravitational force = disposition of particles to accelerate,

or

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advantages:

- no regress: different ontological category than C and E,
- unity in explanations,
- account for different kinds of forces.

The Argument (Bigelow et al., 1988)

forces = special kind of causal relation.

on the fundamental level:
special = relation between fields and their effects (acceleration)
presupposing the reality of fields

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advantages:

1. no vicious regress,
2. mediating role,
3. unification of diverse phenomena,
4. but different kinds of fundamental forces possible (gravitational, electromagnetic).

Details

We speculate that, at the fundamental level, a force relates a change in (or a state of) a field, on the one hand, to a change in (or state of) a particle, on the other. Often, we speak of forces as operating between, not events or states, but *objects*. On our view, this is a legitimate but derivative mode of expression. The primary relation holds between events or states; and in virtue of this primary relation there will be various derivative, indirect relations holding between the various salient individuals which are involved in the related events. Some of these indirect relations are naturally describable as forces.

Details con't

The moon, for instance, is a salient object involved in the events that cause the tides. For this reason, we say that the moon exerts a force on the waters of the Earth. In a similar way, we say that the proton in a hydrogen nucleus exerts an electrical force on the orbiting electron.
In both cases, however, the fundamental force is the causal relation between a *field* and a movement, or state, of a particle or particles. The *source* of the field thereby stands in a derivative relation to that movement or state. This derivative relation is supervenient on the fundamental relation between a change in (or state of) a field, and a change in (or state of) a particle. [2, §5]

Mental Causation

goals of nonreductive physicalist approach:

- mental and physical states ontologically distinct,
- without causal overdetermination.

proper subset condition: the causal powers of a mental state are a proper subset of the causal powers of the corresponding brain state.

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advantages:

1. no causal overdetermination,
2. ontological autonomy of the mental state (different causal powers),
3. causal efficacy of the mental state.

Application: The Aspect View (Wilson, 2007)

proper subset condition (psc): the causal powers of any given force are a proper subset of the causal powers of the entity necessitating the force.

aspect view: forces are aspects of the nonforce entities necessitating them, whose causal powers satisfy the psc.

advantages:

- psc plausible: forces multiply realizable,
- forces nothing over and above the necessitating entities,
- no causal overdetermination,
- existence and causal relevance of forces.

Mental Causation: Emergence

denial of proper subset condition

possibilities:

1. denial of the necessitating state (brain state) having causal powers, or
2. brain state having causal powers but different ones from mental states.
   e.g. brain state $\Rightarrow$ mental state $\Rightarrow$ effect

Application: Forces as Intermediaries (Wilson, 2007)

denial of proper subset condition

possibilities:

1. denial of the nonforce entities causing the effects attributed to forces, or
2. necessitating entities cause the effects, but in a different way from forces.
   e.g. necessitating entities $\Rightarrow$ forces $\Rightarrow$ effect

intermediary view: forces are intermediaries between nonforce entities necessitating them and the nonforce entities that they cause, thereby violating psc.

Strategy

contingent development of Humean mosaic.

forces as part of the best system in describing the mosaic.

forces nothing over and above the motion of particles.

entire ontology = primitive ontology.

Proposal

taking the redundancy argument seriously.

laws of motion all there is to account for the behavior of particles.

forces as middle terms.

entire ontology = primitive ontology + laws of motion.

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laws for forces (e.g. Laplace/Poisson equation):

1. interpreted as part of the laws of motion $\rightarrow$ forces as middle terms, or
2. realistic interpretation of forces. ontological status?

Proposals

taking the redundancy argument seriously.

forces as useful middle terms.

entire ontology = primitive ontology + dispositions of particles.

either:

1. mass as an intrinsic disposition, or
2. unnamed disposition reflected by laws of motion.

Laws of Motion

scheme of [3]

$$\frac{\partial x}{\partial t} = D_1(t) + \ldots + D_n(t).$$

only sensible with a realistic interpretation of forces: $D_i(t) = F_i(t)$.

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mass as an intrinsic disposition:

$$\frac{\mathrm{d}^\alpha \mathbf{x}}{\mathrm{d}t^\alpha}(t) = f\left(t, \frac{\mathrm{d}^{\alpha-1}\mathbf{x}(t)}{\mathrm{d}t^{\alpha-1}}, \ldots, \frac{\mathrm{d}\mathbf{x}(t)}{\mathrm{d}t}, \mathbf{x}(t); D_1(\mathbf{x}(t), t), \ldots, D_r(\mathbf{x}(t), t)\right),$$

$D_i(\mathbf{x}(t), t) = m_i$.

forces cancel out.

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[3] J. Blondeau and M. Ghins. Is there an intrinsic criterion for causal lawlike statements? *International Studies in the Philosophy of Science*, 26(4):381–401, 2012.

[4] M. Jammer. *Concepts of Force: A Study in the Foundations of Dynamics*. Harvard: Harvard University Press, 1957.

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