Émilie Du Châtelet and the foundations of physical science

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What is the subject-matter of a physical theory?
1. The problem of bodies
2. Du Châtelet’s solution
3. A difficulty for Du Châtelet’s solution arising from gravitational theory

Du Châtelet’s philosophy of physical science
4. Du Châtelet on method
5. Du Châtelet’s *Foundations of Physics*
6. Recovering her text
1. The problem of bodies

Descartes, *Principles of Philosophy, Part II* (1644)
Goal: to explain all the rich variety of the world as we experience it in terms of
- matter (extension)
- in motion (local motion)
- moving according to laws (three laws of nature, which refer to bodies)

The problem of bodies: What are the “bodies” that are the subject-matter of the laws of nature?

Available resources: extension (shape and size), local motion, laws.

By 1740 (Du Châtelet’s *Foundations of Physics*) it had become clear that this is a really big problem.
What are the “bodies” that are the subject-matter of the laws?
Resources: matter (extension), motion (local motion), laws

Three options:
(1) Motion and rest
(2) Laws
(3) Modify the account of matter

(1) Motion and rest

Descartes (*Principles*, II.25): “By one body, or one part of matter, I here understand everything which is simultaneously transported”

Problem: once you allow extension to be divided into parts by motion, it’s not at all clear that you can prevent “division-to-dust” (Garber).
(Leibniz and Newton)
(2) Laws

Use the laws in a constitutive role with respect to their subject-matter (Newton’s solution)

**Problem with this approach:**

- By the 1730s it was becoming clear to the French mathematicians that the resources of the *Principia* (especially Newton’s second law of motion) were insufficient to handle extended bodies.

- Tendency towards point masses.
(3) Modify the account of matter

(3a) Atomism

(i) That which is extended is divisible
(ii) Atoms are extended
(iii) Atoms are indivisible

These are inconsistent, and (i) is to be rejected, but how? If we can’t explain how, then we risk admitting something unintelligible (perhaps self-contradictory) into our physics at the outset (epistemic risk)
(3) Modify the account of matter

(3b) Add further essential properties to matter
Unless there is a finite sized least part of extension necessary for the instantiation of that property, the division-to-dust problem isn’t solved.
(3) Modify the account of matter

(3c) Add “forces”

- If to glue bodies together: hopeless.

- If added to point particles to give “effective” extension, this option appears later in the 18th century.

- Leibniz’s solution: add something non-material
  “There seem to be elements, i.e. indestructible bodies, because there is a mind in them.”
The problem of bodies

What are the “bodies” that are the subject-matter of the laws?
Resources: matter (extension), motion (local motion), laws

Three options:
(1) Motion and rest
(2) Use the laws
(3) Modify the account of matter (atomism; additional essential properties of matter; add forces)

By the 1730s, when Du Châtelet was writing, it was clear that all of the proposed solutions faced serious problems.

So what?
2. Du Châtelet’s solution to the problem of bodies

From non-extended simples to extended bodies:

(P1): Bodies are composite beings, composed of a multiplicity of non-extended simple beings.

(P2): All simple beings are interconnected (see Chapter 7.130: “All is linked in the world; each being has a relationship to all the beings that coexist with it”)

From (P1) and (P2), (C1): Bodies are composed of a multiplicity of interconnected simple beings

(P3): We necessarily represent a multiplicity as spatially extended (see Chapter 4)

Conclusion (from (C1) and (P3)): We necessarily represent (i.e. represent to ourselves) composite beings (i.e. bodies) as spatially extended.
Du Châtelet’s solution to the problem of bodies

Why the resulting extended bodies do not face the divisibility problem:

- Geometrical bodies have only potential parts and are divisible to infinity.
- Physical bodies have determinate, finite, actual parts and are not divisible to infinity.

Why? Because each extended body arises from a determinate number of simple beings standing in determinate relations to one another: the smallest physical body arises from a determinate number of simples standing in determinate relations to one another, and it cannot be further divided, qua physical body.
Du Châtelet’s solution to the problem of bodies

Upshot: Bodies that are

- Extended
- Non-overlapping
- Capable of action and reaction by contact

Claim: This is what it takes to make Descartes’s project of a physics based on extended bodies in collision viable.
Some other things to notice in Du Châtelet’s solution to the problem of bodies...

1) Idealism about the *extension* of bodies

2) “All simple beings are interconnected”

3) Geometrical and physical extension distinguished

*But I’m not going to talk about any of these...*

Instead: one of the things that’s very interesting about Du Châtelet’s *Foundations of Physics* is the interplay between metaphysics and physics, and her awareness of how the details of the physics bear on the metaphysics.

Examples:
- *vis viva* controversy
- gravitation
Newtonian universal gravitation versus vortex theories of gravitation

Newtonian universal gravitation

Newton’s argument for universal gravitation, in Book 3 of the *Principia*, concludes as follows (Proposition 7, Corollary 1):

“Therefore the gravity toward the whole planet arises from and is compounded of the gravity toward the individual parts.”

i.e. particle-to-particle gravitation

Vortex theory

Huygens (and others) rejected this last step in the argument, maintaining that the phenomena of gravitation arise by local action of particles in contact with other particles.

Du Châtelet’s account of bodies favors vortex theory. However, for Du Châtelet this is not sufficient to decide the issue. Having introduced the two approaches, Du Châtelet turns to the empirical evidence.
Argument from empirical evidence 1: planetary motions

Newton, *Principia*, Book 2, Section 9, Scholium to Proposition 53: if the matter making up the vortex is of the same kind as the matter making up the planets, and is therefore subject to Newton’s laws of motion, then “the hypothesis of vortices can in no way be reconciled with astronomical phenomena.”

Huygens responds:

- Reject the assumptions and idealizations about fluids that are needed to make this argument go through
- Offer a vortex theory that recovers the trajectories of the planets

Upshot: the empirical evidence does not distinguish between Newtonian universal gravitation and vortex theory.
Argument from empirical evidence 2: the shape of the Earth
Du Châtelet notes that the two approaches give rise to different predictions (15.379):

“M. Huygens believed the gravity to be the same everywhere [because it pertains to the body considered as a whole], and Newton assumed it to be different in different places on earth and dependent on the mutual attraction of the parts of matter: the only difference between them is the shape they attribute to the earth – since from M. Newton’s theory arises a greater flattening than from that of M. Huygens.”

So she is very clear about the difference between the two approaches being due to the disagreement over gravitation (i.e. whether it is particle to particle or not), and on where the observational consequences differ...
Newtonian universal gravitation versus vortex theories of gravitation

Argument 2: the shape of the Earth
Du Châtelet is up-to-date with the efforts to measure the shape of the Earth, and reports that she is awaiting further results that will help determine the question between Huygens and Newton.
She reports the initial results from the measurements taken on the expedition to the pole led by Maupertuis:

“The one that comes from the measurements at the Pole is approximately as the one that M. Newton had determined with his theory. Thus, it is true to say that M. Newton made great discoveries owing to the measurements and observations of the French and that he will most likely receive confirmation.” (Institutions, 15.384)

Upshot: By the late 1730s, the empirical evidence favors Newtonian universal gravitation.
But: this puts huge pressure on the concept of body as extended and impenetrable.
Now, if there is matter that continually pushes the bodies, it must be that this matter is fluid and subtle enough to penetrate the substance of all the bodies: but how can a body that is subtle enough to penetrate the substance of the hardest bodies and rarified enough to not be perceptibly opposed to the movement of bodies, push considerable bodies toward each other with so much force? How does this force increase following the proportion of the mass of the body that the other body is pushed towards? Where does it come from that all bodies, in supposing the same distance and the same body towards which they tend, move with the same speed? Finally, as regards a fluid that only acts on the surface, whether that be of the bodies themselves or their interior particles, how can it communicate to the bodies a quantity of movement that follows exactly the proportion of the quantity of matter enclosed in the bodies?
Du Châtelet and Newtonian gravitation

It remains “to be examined if some subtle matter is not the cause of this phenomenon… perhaps a time will come when we will explain in detail the directions, movements, and combinations of fluids that operate the phenomena that the Newtonians explain by attraction, and that is an investigation with which the physicians must occupy themselves.” (16.399)

Why does she say this? Why doesn’t she just accept the empirical evidence against vortex theory?

1) conflict with her solution to the problem of bodies
2)
The problem of bodies is a really big problem, it’s central to Du Châtelet’s text, and it’s an important lens through which to understand how and why the split between philosophy and physics came about.
Du Châtelet and Newtonian gravitation

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2) broader methodological issues

Du Châtelet’s methodological prescription is to seek a theory of gravitation satisfying both the principles of knowledge (e.g. PSR) and the empirical details
4. Du Châtelet on Method

Clear divisions in the debate over method:

- Cartesian hypotheses
- Leibniz’s Principle of Sufficient Reason
- Newton: “I feign no hypotheses”; Rules of Reasoning; *Opticks*.

Disputes:

- What principles should be used to constrain theorizing?
- What interplay should there be between these principles and empirical evidence?
- What should the role(s) of hypotheses be?
- What criteria should be used for assessing hypotheses?
Du Châtelet’s assessment of the state of Cartesian physics in France:

Despite Descartes’s many important contributions to physics, as a result of features of his method “the books of philosophy, which should have been collections of truths, were filled with fables and reveries” (4.55)

An improved methodology is needed.
Du Châtelet on principles of knowledge

Reject: Descartes’s criterion of “clear and distinct ideas” as a principle of knowledge.

“This method, moreover, would only serve to perpetuate disputes, for among those with opposing views, each has this lively and internal sense of what they put forward. Thus, no one has to yield, since the evidence is equal on the two sides.” (Institutions, 1.2)

Adopt instead: The principle of contradiction and Leibniz’s principle of sufficient reason (Institutions, 1.4 & 1.8)

“the source of the majority of false reasoning is forgetting sufficient reason, and you will soon see that this principle is the only thread that could guide us in these labyrinths of error the human mind has built for itself in order to have the pleasure of going astray.

“So we should accept nothing that violates this fundamental axiom; it keeps a tight rein on the imagination, which often falls into error as soon as it is not restrained by the rules of strict reasoning.”
Du Châtelet on hypotheses

Cartesians admit too many hypotheses

“Descartes, who had established much of his philosophy on hypotheses ... gave the whole learned world a taste for hypotheses; and it was not long before these fell into fictions. Thus, the books of philosophy, which should have been collections of truths were filled with fables and reveries.” (4.55)

Newtonians admit too few hypotheses (none)

“M. Newton, and above all his disciples, have fallen into the opposite excess...” (4.55)

“If we take the trouble to study the way the most sublime discoveries were made, we will see that success came only after many unnecessary hypotheses... for hypotheses are often the only available means to discover new truths. (4.57) Hypotheses must then find a place in the sciences, since they promote the discovery of truth and offer new perspectives...” (4.58)

Instead: Admit hypotheses but adopt much stronger criteria for assessing them
Du Châtelet on criteria for assessing hypotheses

“Without doubt there are rules to follow and pitfalls to be avoided in hypotheses. The first is, that it not be in contradiction with the principle of sufficient reason, nor with any principles that are the foundations of our knowledge. The second rule is to have certain knowledge of the facts that are within our reach, and to know all the circumstances attendant upon the phenomena we want to explain. This care must precede any hypothesis invented to explain it; for he who would hazard a hypothesis without this precaution would run the risk of seeing his explanation overthrown by new facts that he had neglected to find out about.” (4.61)
Du Châtelet emphasizes exploring the empirical consequences of a theory, and not merely seeking consistency with prior observations:

“If it is found that these experiments confirm it, and that it not only explains the phenomenon that one had proposed to explain with it, but also all the consequences drawn from it agree with observations, its probability grows to such a point that we cannot refuse our assent to it.” (4.58)

Acceptance of a hypothesis depends on all its consequences agreeing with observations, not just those observations for which it was originally constructed.
Asymmetry between acceptance and rejection (falsification):

“One experiment is not enough for a hypothesis to be accepted, but a single one suffices to reject it when it is contrary to it.” (4.64)

Selective falsification:

“Thus, in making a hypothesis one must deduce all the consequences that can legitimately be deduced, and next compare them, with experiment; for should all these consequences by confirmed by experiments, the probability would be greatest. But if there is a single one contrary to them, either the entire hypothesis must be rejected, if this consequence follows from the entire hypothesis, or that part of the hypothesis from which it necessarily follows.” (4.66)
No ad-hoc modifications (condition on a good hypothesis):

“it is necessary… that the phenomenon result necessarily, and without the obligation to make new suppositions”

“When the necessary consequences do not follow from it, and to explain the phenomenon, a new hypothesis must be created in order to use the first, this hypothesis is only a fiction unworthy of a philosopher.” (4.69)
Upshot:

Inter-play between:

- principles of our knowledge (contradiction, PSR, law of continuity)
- empirical evidence (working out the detailed consequences; disciplined about acceptance and rejection)

Examples:

- *vis viva* controversy
- gravitation

N.B. The *Encyclopedia* of Diderot and d’Alembert
Take-home messages:

1) Du Châtelet’s *Foundations of Physics* is an important text in the history of philosophy of science.

2) The problem of bodies is a really big problem, it’s central to Du Châtelet’s text, and it’s an important lens through which to understand how and why the split between philosophy and physics came about.
5. Du Châtelet’s *Foundations of Physics*

Her major works:

*Institutions de physique*
1st edition, 1740
2nd edition, 1742
German translation, 1743
Italian translation, 1743

Translation of Newton’s *Principia*, with commentary
1st edition, 1756
2nd edition, 1759

Gabrielle Émilie Le Tonnelier de Breteuil, marquise du Châtelet (17 December 1706 – 10 September 1749)
Du Châtelet’s *Foundations of Physics*

- Brings together Descartes, Leibniz, Wolff, Newton

“This is surely very unfortunate that the opinions of Newton and of Descartes have become a sort of national affair. About a book of physics one must ask if it is good, not if the author is English, German, or French.”

- Brings them together into a whole

- Addresses the major unsolved foundational issues in physical science of the period:
  - Bodies
  - Force
  - Method
Du Châtelet’s *Foundations of Physics*

She begins with Descartes as the presupposed background, and then sets out to introduce a French audience to Leibnizian (and Wolffian) and Newtonian ideas.

Her interest is in the physical, metaphysical, and epistemological viability of the whole:

“Physics is an immense building that surpasses the powers of a single person. Some lay a stone there, while others build whole wings, but all must work on the solid foundations that have been laid for this edifice in the last century, by means of geometry and observations; still others survey the plan of the building, and I, among them.”
Du Châtelet’s *Foundations of Physics*

Topics covered include:

- the principles of our knowledge
- the existence of God
- essence, attributes and modes
- hypotheses
- space and time
- the elements of matter and the nature of bodies
- the divisibility and subtlety of matter
- the shape and the porosity of bodies
- motion and rest
- gravity, falling bodies, the pendulum, projectiles
- Newtonian gravity and attraction
- dead and living forces of bodies

The text is:

- Pedagogical
- Epistemological and methodological
  (surveying the plan of the whole; integrating disparate elements into a whole)
Remarkable in its historical context as her achievement is, we should perhaps accept her own verdict that it was by means of translation and exposition rather than original work that she was best equipped to help the cause of enlightenment. It seems unlikely, then that in this sphere she can have exerted any real influence on Voltaire’s thought…” (1967)
Existing scholarship on Du Châtelet

(2) Du Châtelet as a philosopher

 кудь Carolyn Iltis, 1977, “Madame Du Châtelet’s metaphysics and mechanics”
 кудь Linda Gardner Janik, 1982, “Searching for the metaphysics of science: the structure and composition of Mme Du Châtelet’s Institutions de physique”
 кудь Julie Hayes, 1999, “Physics and figuration in Du Châtelet’s ‘Institutions de physique’”
 кудь Judith Zinsser and Julie Hayes (eds), 2006, Emilie Du Châtelet: rewriting Enlightenment philosophy and science
 кудь Ruth Hagengruber (ed), 2012, Emilie Du Châtelet between Leibniz and Newton
 кудь Karen Detlefsen, 2013, Stanford Encyclopedia of Philosophy entry

- Andrew Janiak and Karen Detlefsen’s project
- Notre Dame research group
6. Recovering the text

Why is the *Foundations of Physics* so invisible today?

- sociological and political reasons
- philosophical reasons
Treating Newtonian physics as a Kuhnian paradigm makes Du Châtelet’s *Foundations of Physics* invisible.

“Effective research scarcely begins before a scientific community thinks it has acquired firm answers to questions like the following: What are the fundamental entities of which the universe is composed? How do these interact with each other and with the senses? What questions may legitimately be asked about such entities and what techniques employed in seeking solutions?” (Kuhn, *Structure*, pp. 4-5)
Take-home messages:

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2) The problem of bodies is a really big problem, it’s central to Du Châtelet’s text, and it’s an important lens through which to understand how and why the split between philosophy and physics came about.

1) Treating Newtonian physics as a Kuhnian paradigm established soon after the publication of Newton’s *Principia* makes (1) and (2) invisible.
“I will not write for you here the history of the revolutions experienced by physics; a thick book would be needed to report them all. I propose to make you acquainted less with what has been thought than with what must be known.

Up to the last century, the sciences were an impenetrable secret... Descartes appeared in that profound night like a star come to illuminate the universe. The revolution that this great man caused in the sciences is surely more useful, and perhaps even more memorable, than that of the greatest empires...”

(Foundations of Physics, Avant-Propos, V)