Metaphysical Problems of Physics
Lecture 2
Maxwell's *Matter and Motion* II: Dynamics

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Contents

1 Dynamics

BEGIN RECORDING

1.1 Causal Structure: Interaction (or "Mutual Action")

The metaphysics of causation, as it were, in this system is *NOT* of the Humean kind; the fundamental conception of force is that of *inter*action, not of action—how much conceptual muddle and just plain bad philosophy must be laid at Hume's feet we shall never be able to reckon, not if we were reckoners counting the grains of sand on a beach for a king.

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1. "cause" and "effect" are simultaneous with each other

2. each system entering into the interaction plays both roles simultaneously

3. the interaction, in so far as it eventuates in a change in relative configurations, *is* the conceptual and metaphysical heart of the "event" that forms the basic unit of the metaphysics: it is the form of the interaction, as a force law, that defines the regular succession to which the given kind of event is subject

4. we thus begin to get an idea of why Maxwell chose "event" as the basic genus for his system of natural kinds

1.2   Mass

The property of mass, which serves to differentiate bodies from each other in so far as they themselves differentiate events in the way relevant to determination of the force law governing its regular succession:

1. this property is defined by the role it plays in the construction and application of the laws of motion

2. it is not defined independently and then required to fit into the dynamical framework defined by the laws (which, recall, was part of Descartes' error, §16)

3. the metaphysics must be built up in a dialectical fashion, each part supporting and being supported in turn by the other parts; we return again and again to elaborate, develop and clarify concepts based on new knowledge, which in turn allows us to acquire new knowledge and to clarify other related concepts

2   The Laws of Motion

First Law empirically verifiable! but also strongly suggested by the relational character of our knowledge of space and time in conjunction with the General Maxim of Physical Science

Second Law It is NOT a definition of 'force', as often claimed—it implies an empirically verifiable proposition, which has been greatly substantiated over the years (§100):

> It is when we come to define equal forces as those which produce equal rates of acceleration in the same mass, and equal masses as those which are equally accelerated by equal forces, that we find that these definitions of equality amount to the assertion of the physical truth, that the comparison of quantities of matter by the forces required to produce in them a given acceleration is a method which always leads to consistent results, whatever be the absolute values of the forces and the accelerations.

1. We are now in a position to fully understand Maxwell's decision to use "event" as the basic unit for defining natural kinds: that is what the action and reaction of a force is. In so far as natural kinds ought to respect the metaphysics of causality of a system of dynamics by fitting compatibly into the scheme of a possible causal nexus in accord with the dynamics, "event" is what is needed.

2. Note how this fits with Maxwell's picture of concept formation, elaboration, development and clarification, in dialectical progression with other related concepts, that I sketched in Lecture 1.

3. Whence the form of the Second Law? Why is it a *second-order* differential equation? [Write $\vec{F} = m\vec{a} = m\ddot{\vec{x}} = m\,\mathrm{d}^2x/\mathrm{d}x^2$ on the board.] Ask: why do we focus on force and acceleration in Newtonian mechanics? (Perhaps better: why is force proportional to acceleration?) Why not on, for example, the third derivative of position with respect to time? Because Newton discovered by empirical investigation that position and velocity jointly suffice to characterize a system with respect to its dynamical evolution, for prediction and modeling. To specify the second-derivative as part of the fixed initial conditions (as part of its "instantaneous state"), rather than treating it as a quantity to be solved for, yields a problem that is inconsistent with the observde behavior of physics. That's physics.

4. In a deliciously wicked (and entirely just) review of the second volume of Thomson (Lord Kelvin who was to be) and Tait's *Natural Philosophy*, Maxwell (1879, pp. 779–780) takes them to task for forwarding a "Manichean doctrine of the innate depravity of matter, whereby it is disabled from yielding to the influence of a moving force unless that force actually spends itself on it":[1]

   [T]he capacity of the student is called upon to accept the following statement [quoted from Thomson and Tait]:—

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   1. Maxwell (1878), in a whimsical review of a whimsical book entitled *Paradoxical Philosophy* (written pseudonymously by P. Tait and B. Stewart), offers as well the following gem:

   "I feel myself compelled to believe," says the learned Doctor [whose work Maxwell is reviewing], "that all kinds of matter have their motions accompanied with certain simple sensations. In a word, all matter is, in some occult sense alive." This is what we may call the "levelling up" policy, and it has been expounded with great clearness by Prof. von Nägeli in a lecture, of which a translation was given in *Nature*, Vol. XVI, p. 531.
   He can draw no line across the great chain of being, and say that sensation and consciousness do not extend below that line. He cannot doubt that every molecule possesses something related, though distantly, to sensation, "since each one feels the presence, the particular condition, the peculiar forces of the other, and, accordingly, has the inclination to move, and under circumstances really begins to move—becomes alive, as it were;" . . . "If, therefore, the molecules feel something which is related to sensation, then this must be pleasure if they can respond to attraction and repulsion, *i.e.*, follow their inclination or disinclination; it must be displeasure if they are forced to execute some opposite movement, and it must be neither pleasure nor displeasure if they remain at rest."
   Prof. von Nägeli must have forgotten his dynamics, or he would have remembered that the molecules, like the planets, move along like the blessed gods. They cannot be disturbed from the path of their choice by the action of any forces, for they have a constant and perpetual will to render to every force precisely that amount of deflexion which is due to it. Their condition must, therefore, be one of unmixed and unbroken pleasure.

"Matter has an innate power of resisting external influences, so that every body, as far as it can, remains at rest or moves uniformly in a straight line."

Is it a fact that "matter" has any power, either innate or acquired, of resisting external influences? Does not every force which acts on a body always produce exactly the change in the motion of the body by which its value, as a force, is reckoned? Is a cup of tea to be accused of having an innate power of resisting the sweetening influence of sugar, because it persistently refuses to turn sweet unless the sugar is actually put into it?

In this light, one perhaps ought rather say, with all due respect for anachronism, that the equations of motion of physical theories express formal Aristotelian formal causes rather than efficient ones, or, perhaps even better, that they are Platonic forms of which physical systems partake or which they mimic.[2]

Third Law encodes the most important feature of the causal structure of classical mechanics: that all processes are *inter*actions; not an empirically testable truth, but rather a consequence of the First Law in conjunction with the General Maxim of Science (§19); note, again, how this calls for the idea of "event" as the basic unit of analysis in the metaphysics

What further mathematical structures are needed to formulate and apply the Laws of Motion?

1. from the continuity of motion in the further development of the kinematics in ch. II, §25, we finally move from an affine module with congruence to an affine space with a distance function

2. acceleration as change of direction of velocity requires a conformal structure for the concept of orthogonality, which gives us a Euclidean inner product up to a constant factor (which leaves us the freedom to choose the unit of measurement)

3. we have now acquired all the structure we need to formulate and apply the Laws of Motion: space is a 3-dimensional affine space with Euclidean inner product (and, although, it did not come up explicitly, it is standard to endow it with a global orientation); time is a 1-dimensional affine space appropriately compatible with the affine structure and inner-product of space

Why You Should Care In conjunction with the structures required by various steps in the exposition in the earlier chapters, as spelled out in the section "Space, Time and Motion" of Curiel (2021), Maxwell has now given us a *clear and compelling physical interpretation of every aspect of the spatial and temporal geometries required by the physics, both in isolation and in relation to the other aspects*—he has told us the physical significance of the mathematical structures we are to use to model physical systems, by reference to their intrinsic qualities, to the theoretical uses we require of them, and to the way they ground the possibility of observing and measuring the properties of events and the physical quantities of the systems involved in the events.

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2. Stein (1995) gives an extended discussion of many matters relating to this idea.

3   The Metaphysical System

In the end, the cogency of the metaphysical system, the way it supports propriety in representation by the dynamical framework, and supports the framework's adequacy for prediction, description and all the other tasks we set for dynamics, all the kinds of knowledge it can provide, its *fruitfulness in application*: these are the criteria used to judge whether the system of metaphysics is good or not.

4   Invitation to a Short Essay

I invite you to write me a short discussion (no more than 2 pages, *i.e.*, no more than 1000 words) on any issue discussed in this lecture or any of this week's readings, required or suggested. You can raise further questions, propose answers or interpretations, or whatever seems of most interest to you. If you get it to me by the start of next lecture (27. Apr), then I will return it to you with my comments the following week.

References

Curiel, Erik. 2021. "Lecture Notes on Maxwell's *Matter and Motion*: Epistemology and Metaphysics; Concepts; Representation; Kinematics". The basis for lectures given in the course "Metaphysical Problems of Physics" taught by Curiel at the Munich Center for Mathematical Philosophy, summer semester 2021, http://strangebeautiful.com/lmu/lectures/metaphys-probs-phys-lect-01-matt-mot-i-kins.pdf.

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