

# **A scamper through quantum mechanics**

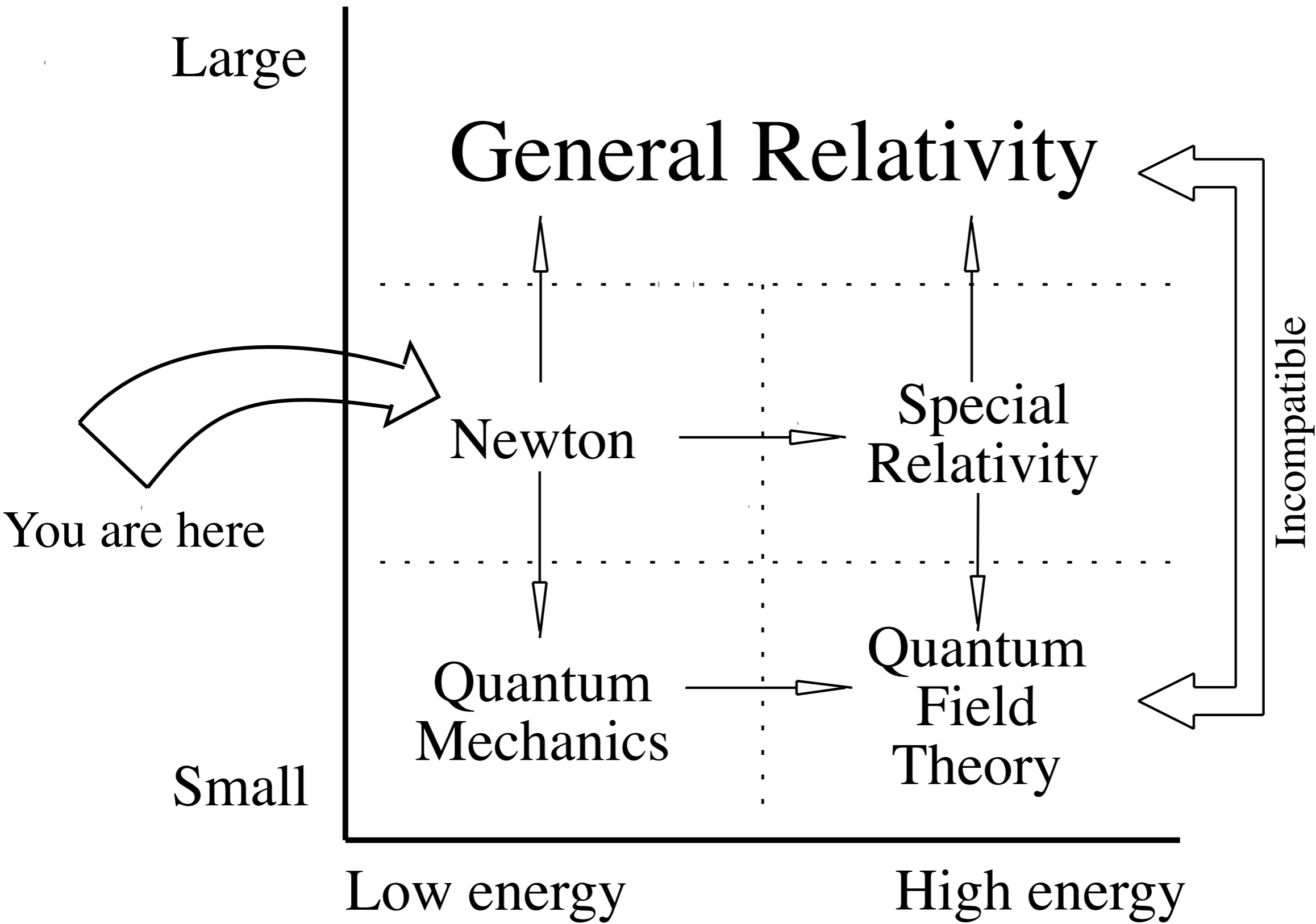
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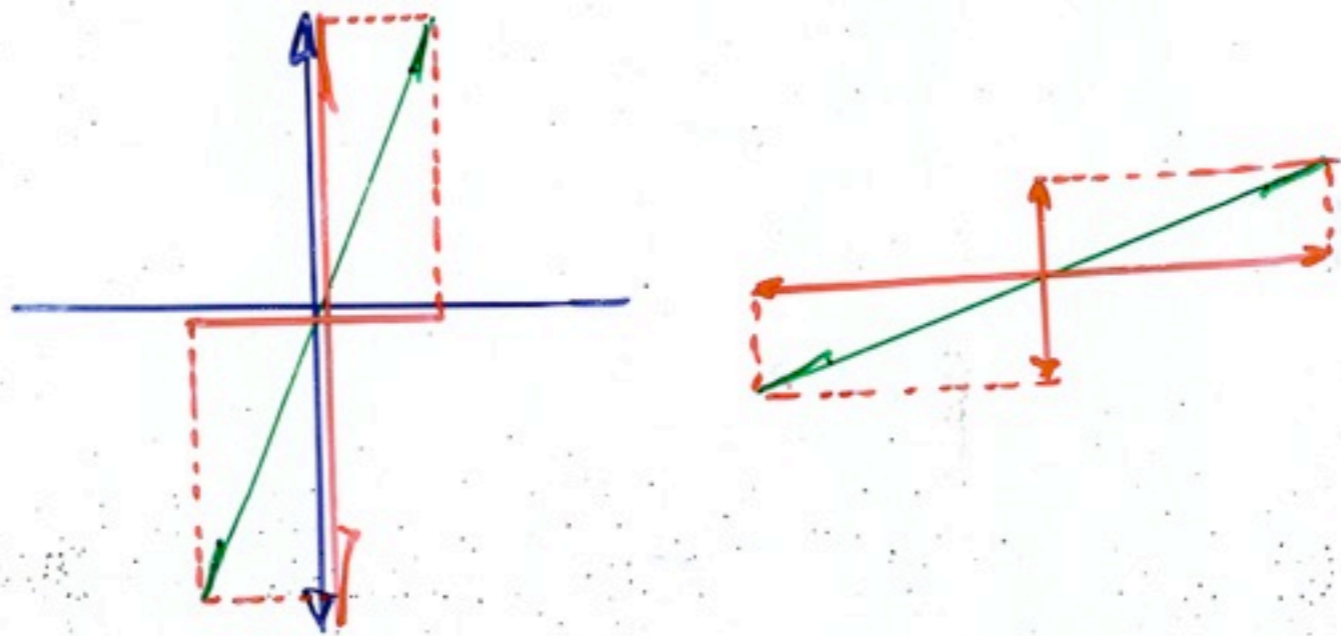
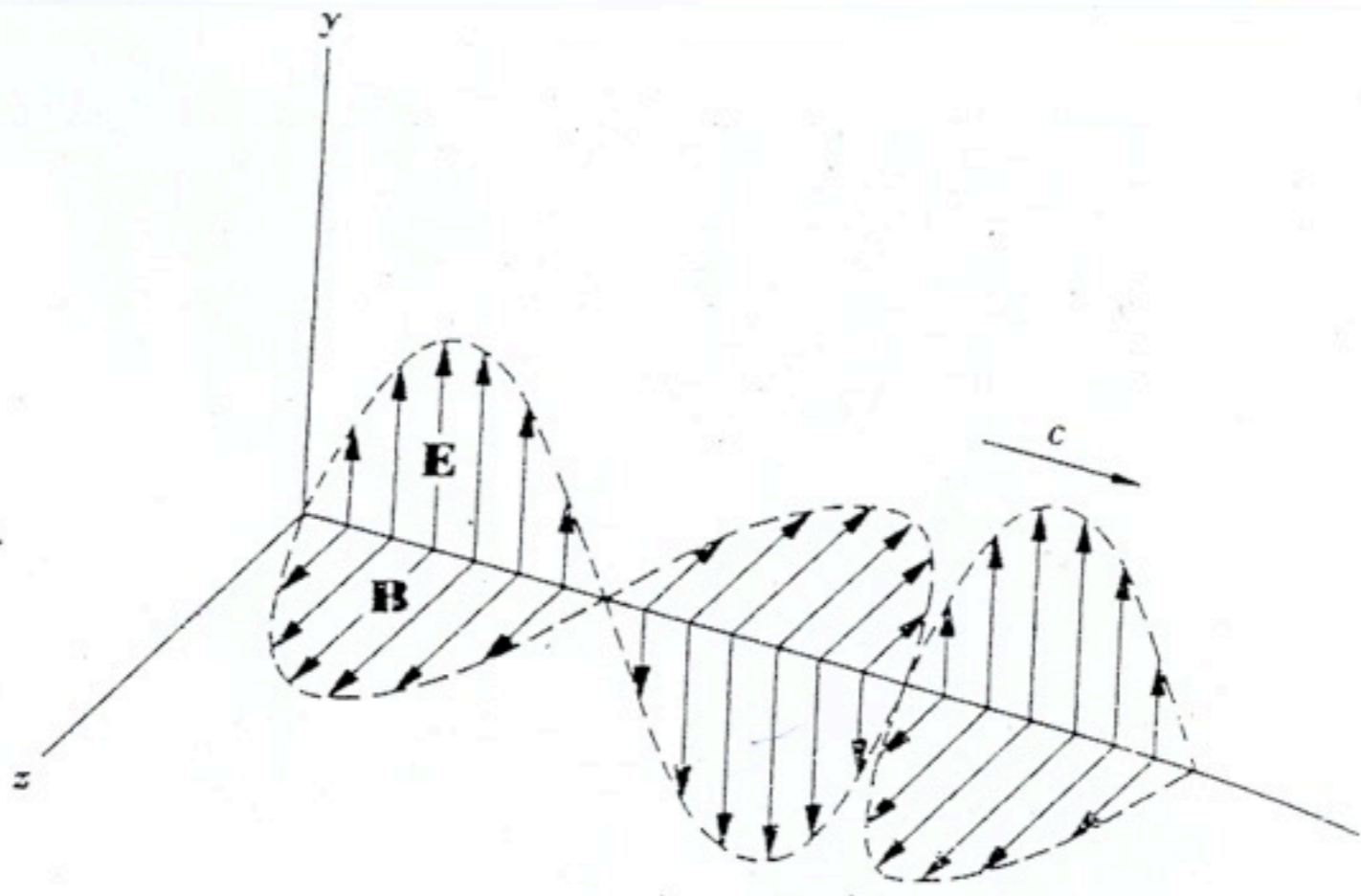
2013 February 4

The beauty and clearness of the dynamical theory, which asserts heat and light to be modes of motion, is at present obscured by two clouds. I. The first involves the question, How could the earth move through an elastic solid, such as essentially is the luminiferous ether? II. The second is the Maxwell-Boltzmann doctrine regarding the partition of energy.

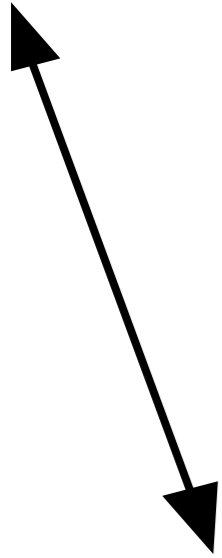
— William Thomson (Lord Kelvin),  
*Philosophical Magazine Series 6*, **2(7)**, 1 (1901)  
doi:10.1080/14786440109462664



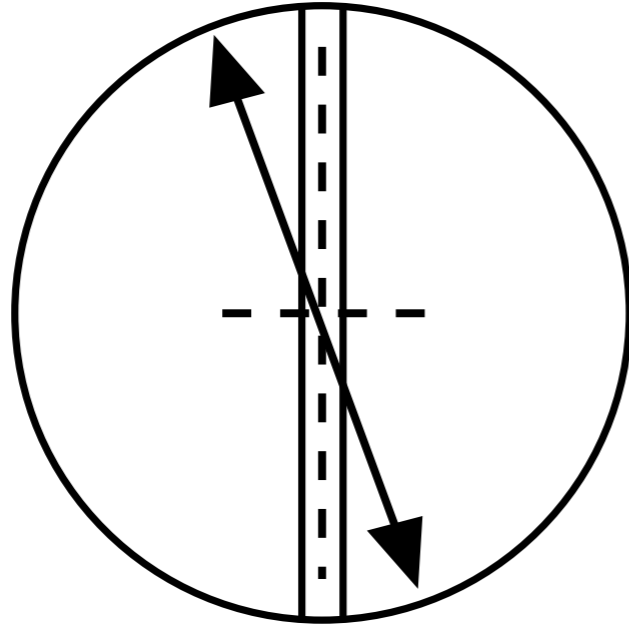
—  $\rightarrow$  = "is a special case of"



Polarisation components



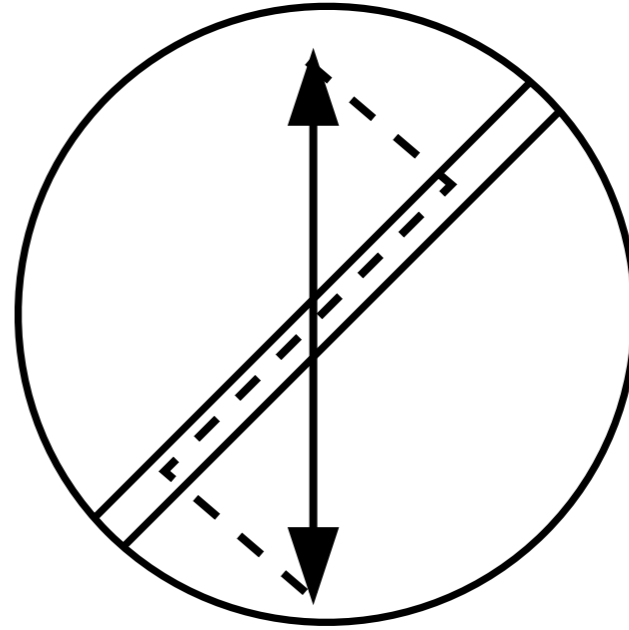
(a)



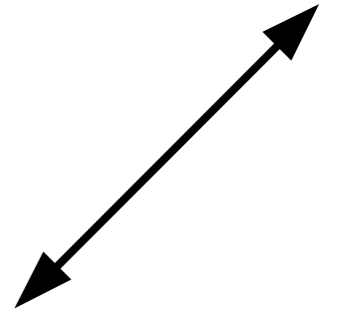
(b)



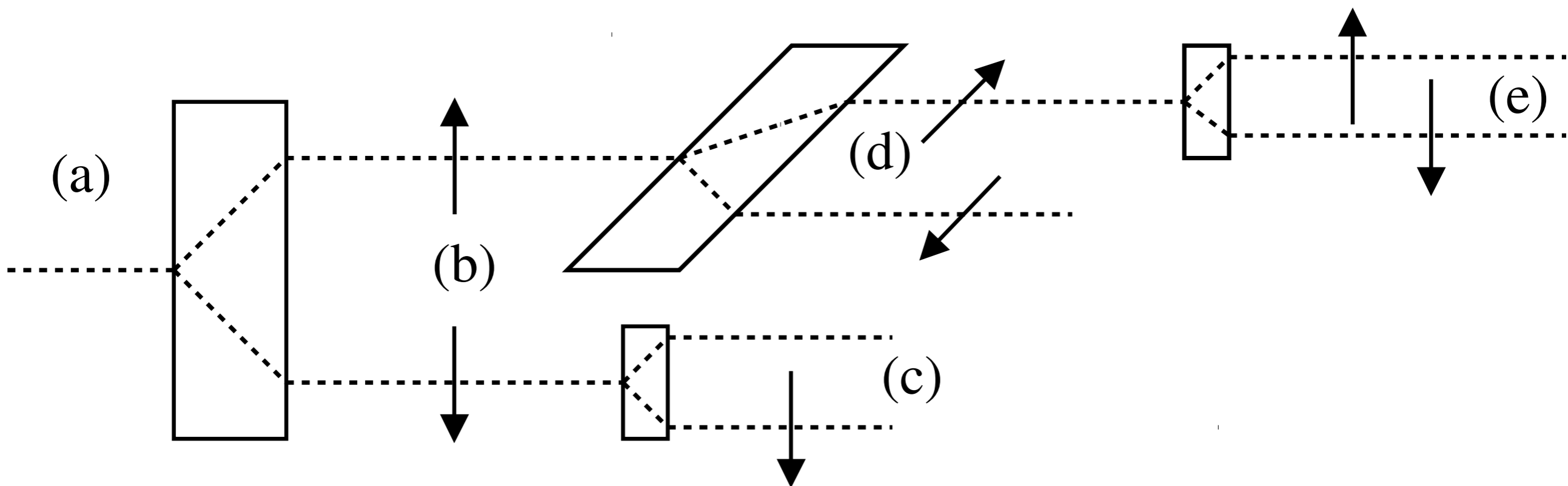
(c)



(d)



(e)



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# quantum mechanics

- The wavefunction contains all there is to know about the system
- The wavefunction evolves deterministically under the control of the Schrödinger Equation
- A 'measurement' of the wavefunction collapses it into one of several 'eigenstates'
- Some pairs of measurements are incompatible

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# interpretations

- Positivism: 'Science' is about verifiable statements; we can only talk about measurements
- Realism: there is a real world out there, with properties independent of us
- Copenhagen Interpretation (Bohr): "there is no quantum world"; complementarity; straightforwardly positivist



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# einstein-bohr debates

- Einstein tried and failed to show (Bohr) that QM was inconsistent.
- Instead, it must be **incomplete**.

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# the epr paradox

“If, without in any way disturbing a system, we can predict with certainty... the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity”

— A Einstein, B Podolsky and N Rosen,  
*Phys Rev*, **47**(10), 777–780 (1935)  
doi:10.1103/PhysRev.47.777

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## the epr paradox

- EPR aren't saying that the thought experiment wouldn't work,
- ...or that QM would predict the wrong answer,
- ...but that it couldn't work in the way QM said it did, so QM must be **incomplete**.

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## bell's theorem

- An inequality satisfied by all *local hidden-variable theories*.
- The predictions of QM violate this inequality.
- If physics (and thus QM's predictions) does in fact behave as the EPR experiment says it does, then QM *cannot* be a local hidden-variable theory.

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## the aspect experiments

- 1981 and 1982
- Two analysers 6m apart (ie 20ns light travel time)
- ...and the measurements synchronised to better than 20ns (and, later, chosen while the photons were in flight).
- So Bell's Inequality is violated; QM has no hidden variables.

odd, that...