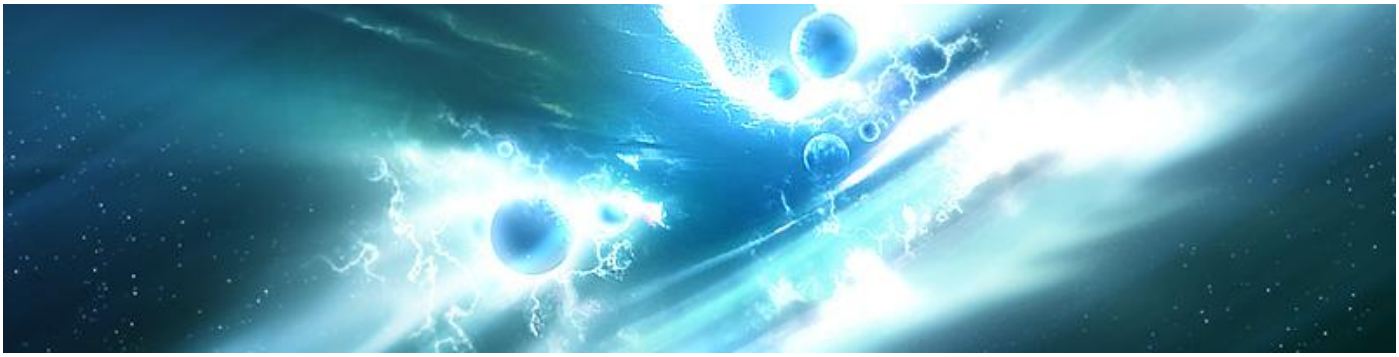
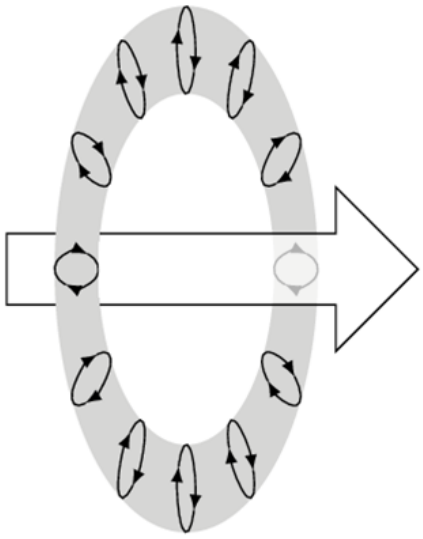
Limits of Classical Mechanics



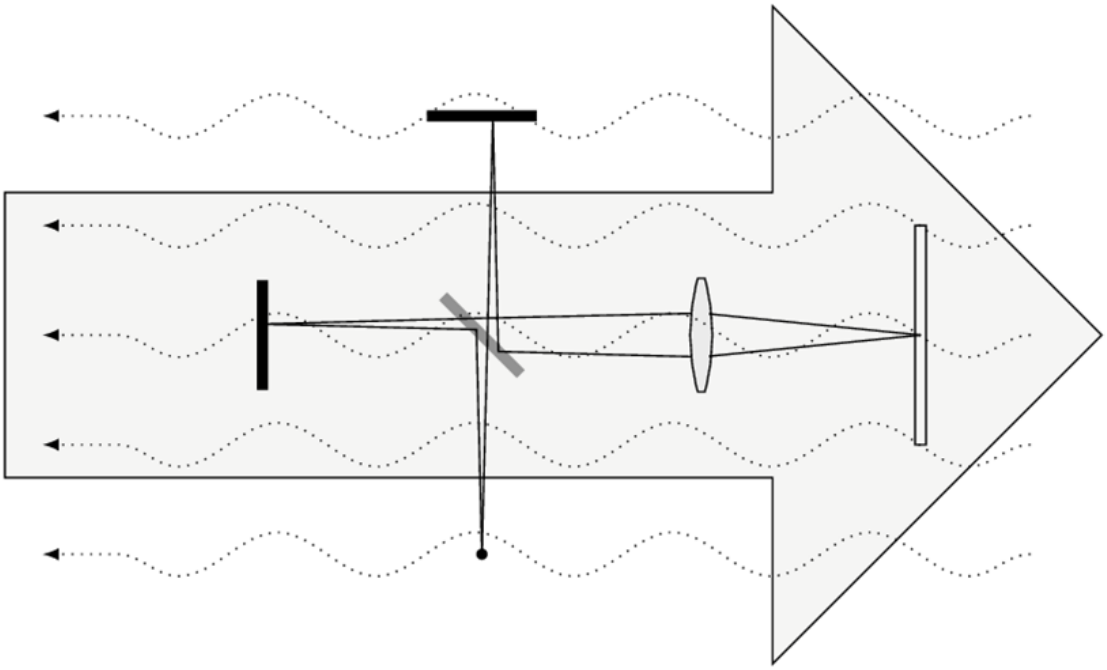
EM theory predicts that light will carry momentum — perhaps the ether is a fluid?

- Ether is solid?
  - Supports waves
  - Supports polarization
  - Does not support momentum transfer
- Ether is fluid?
  - Supports waves
  - Supports momentum transfer
  - Does not support polarization

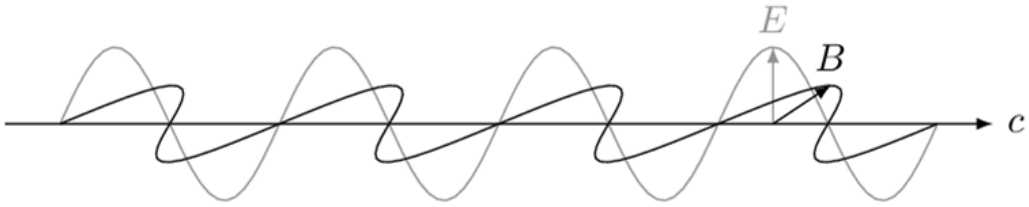


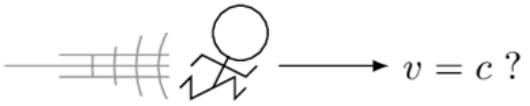
Atomic model?

Michelson and Morley experiment should but does not detect any "ether wind"



Special relativity: the ether is dead — but must rethink space-time mechanics

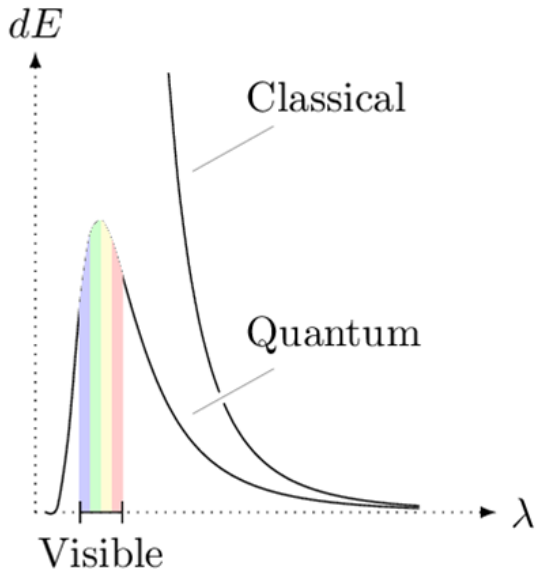


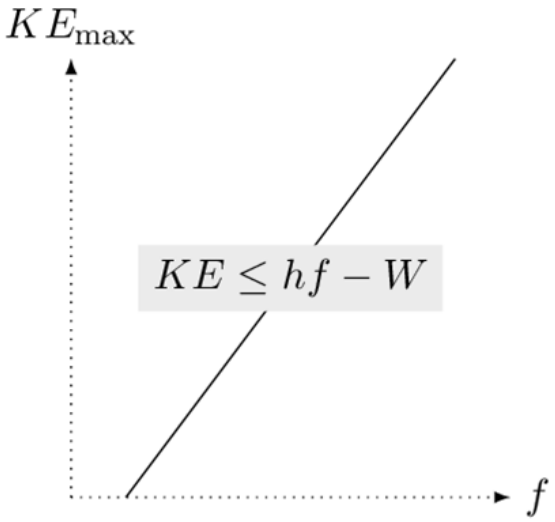


$$v_{ac} = \frac{v_{ab} + v_{bc}}{1 + v_{ab}v_{bc}/c^2}$$

$$E^2 = p^2c^2 + m^2c^4$$

Quantum mechanics discovered at the same time as relativity but for different reasons





Problems in low temperature kinetic theory: specific heats of solids, also "superstuff"

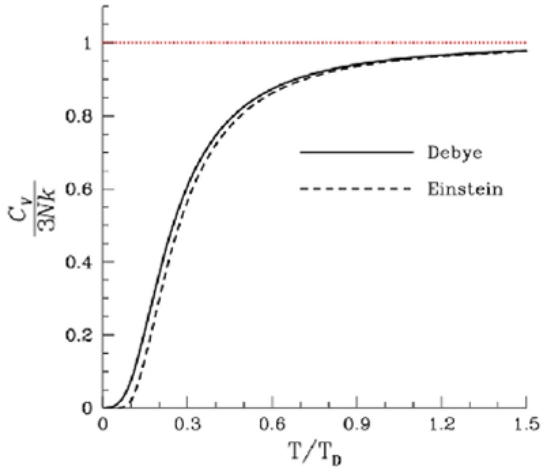


Image credit: http://en.wikipedia.org/wiki/File:DebyeVSEinstein.jpg

- Superstuff happens when fermions act like bosons
  - Superconductivity: Resistance drops to zero
  - Superfluid: Viscosity drops to zero
- Typically only occurs at very low temperatures
  - LN_2 temperature (77 K) superconductor was a goal
  - Achieved in 1987 (YBCO)
  - Highest known superconducting temperature is 135 K

Problems in atomic theory: atom should be unstable, spectroscopy inexplicable

Hydrogen

Image credit: http://upload.wikimedia.org/wikipedia/commons/4/4c/Emission_spectrum-H.png

Iron

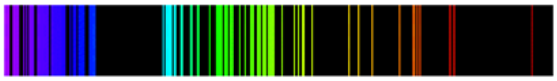
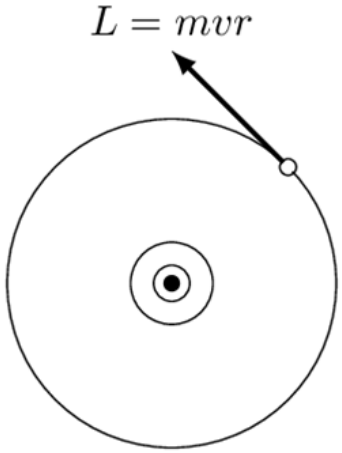
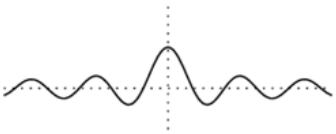


Image credit: http://upload.wikimedia.org/wikipedia/commons/4/43/Emission_spectrum-Fe.png



Quantum mechanics has wave-particle duality in a way similar to optics

Physical Optics



Quantum Mechanics

$$-\frac{h^2}{8\pi m}\nabla^2\psi = E\psi$$

Geometric Optics

Classical Mechanics

$$E = \frac{p^2}{2m}$$

Quantum field theory is the "natural" combination of special relativity with QM

Spin 1 particles

Spin 1/2 particles

	Photon γ 0	Gluon g 0	Weak W $\sim$ 80000
Electron e 0.511	-1	0	
Neutrino ν_e > 0	0	0	
Quark d 4.8	-1/3	g	
Quark u 2.4	2/3	g	

Couplings