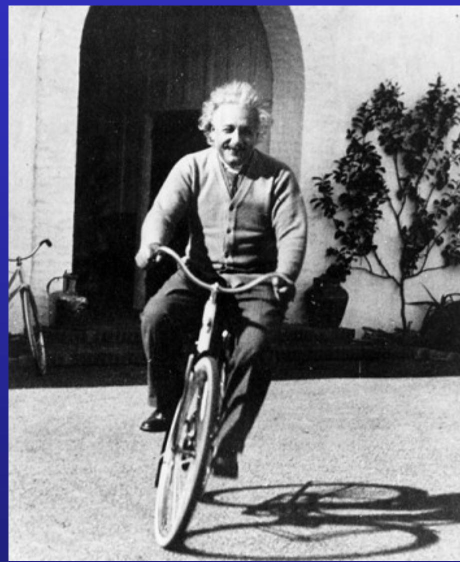
UNIVERSITY OF Southampton
School of Physics and Astronomy

Classical Mechanics

PHYS 2006

Tim Freegarde



Classical Mechanics

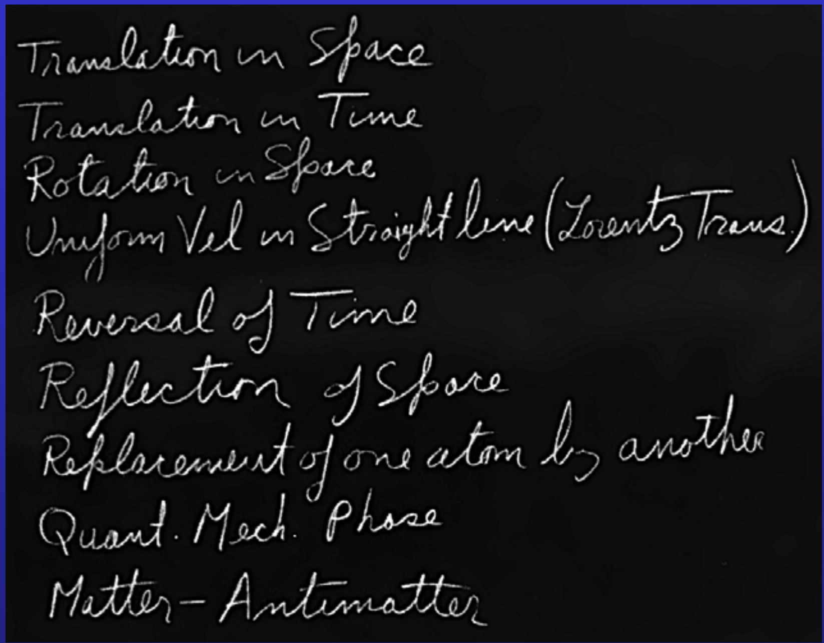
LINEAR MOTION OF SYSTEMS OF PARTICLES	centre of mass
	Newton's 2nd law for bodies (internal forces cancel)
	rocket motion
ANGULAR MOTION	rotations and infinitessimal rotations
	angular velocity vector, angular momentum, torque
	parallel and perpendicular axis theorems
	rigid body rotation, moment of inertia, precession
GRAVITATION & KEPLER'S LAWS	conservative forces, law of universal gravitation
	2-body problem, reduced mass
	planetary orbits, Kepler's laws
	energy, effective potential
NON-INERTIAL REFERENCE FRAMES	centrifugal and Coriolis terms
	Foucault's pendulum, weather patterns
NORMAL MODES	coupled oscillators, normal modes
	boundary conditions, Eigenfrequencies

Symmetries and conserved quantities

symmetry		quantity / label
translation in space	$\mathbf{r} \to \mathbf{r}+\delta\mathbf{r}$	momentum
translation in time	$t \to t+\delta t$	energy
rotation	$\vartheta \to \vartheta+\delta\vartheta$	angular momentum
change of inertial frame	$\mathbf{v} \to \mathbf{v}+\delta\mathbf{v}$	centre of mass
reversal of time	$t \to -t$	entropy; 'T'
reflection in space	$x \to -x,\ y \to -y,\ z \to -z$	parity; 'P'
matter-antimatter interchange	$p \to \overline{p}$	'charge conj.'; 'C'
change of quantum mechanical phase	$\psi \to \mathrm{e}^{\mathrm{i}\varphi}\psi$	electrical charge
exchange of identical particles	$\{1,2\} \to \{2,1\}$	'exchange'
spatial periodicity	$x \to x+na$	quasi-momentum

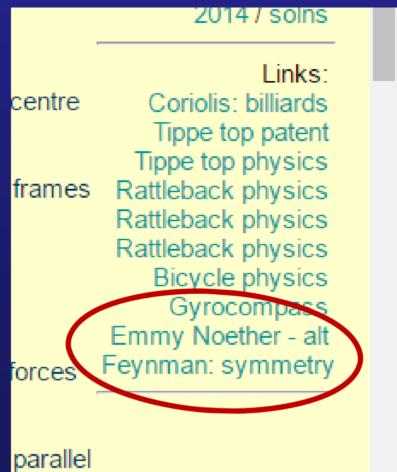
Emmy Noether (1882-1935)

Coupled oscillators

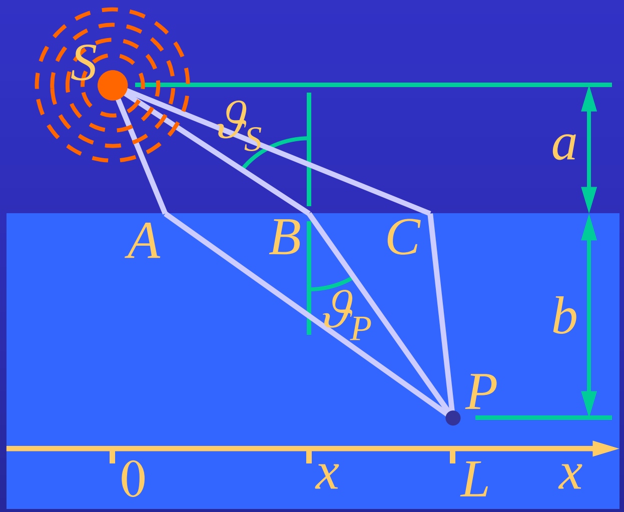


- Feynman Lectures in Physics I, chapter 52

Richard P Feynman (1918-1988)



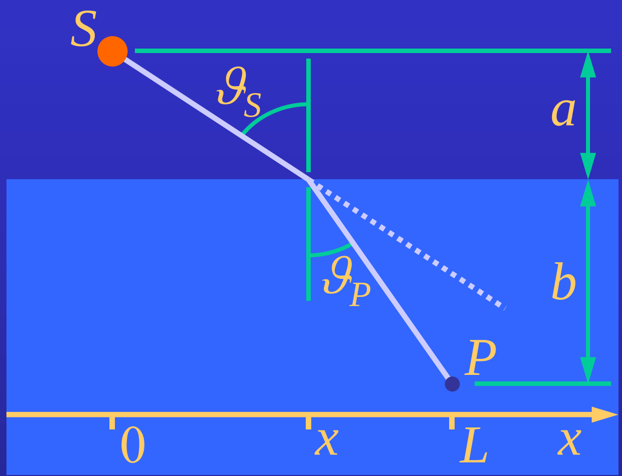
Fermat's principle of least time



- refraction at a plane surface

Pierre de Fermat (1601-1665)

Fermat’s principle of least time

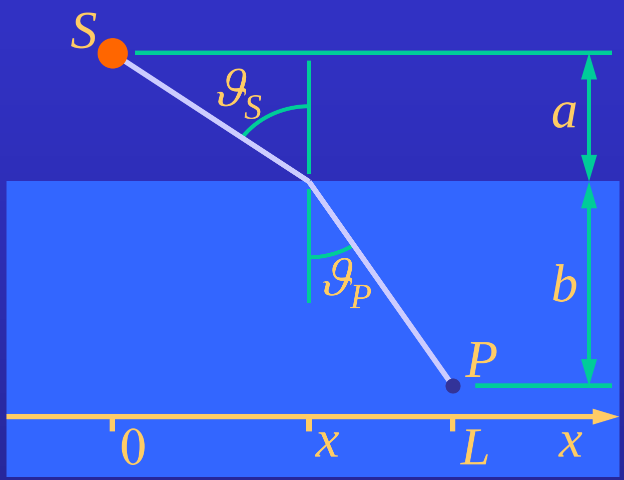


- refraction at a plane surface

- light rays follow the path of least time between two points

Pierre de Fermat (1601-1665)

Snell's law of refraction



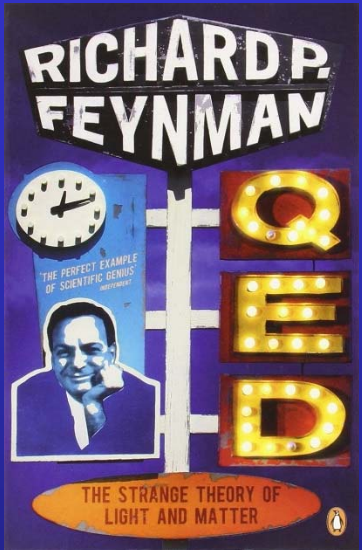
- refraction at a plane surface

- light rays follow the path of least time between two points

$$\eta_S \sin\vartheta_S = \eta_P \sin\vartheta_P$$

Willebrord Snel van Royen
(Leiden, 1580-1626)

Feynman path integral



PRINCIPLE OF LEAST ACTION

- trajectory is that which minimizes

$$\mathcal{S} = \int_{t_1}^{t_2} \mathcal{L}\,\mathrm{d}t$$ ACTION

where $\mathcal{L} = \mathcal{T} - \mathcal{V}$ LAGRANGIAN

Richard P Feynman (1918-1988)

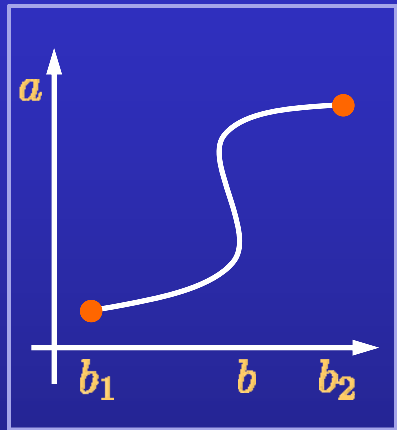
Lagrangian Mechanics

CALCULUS OF VARIATIONS

if $\mathcal{F}(a, a')$ has been chosen to minimize

$$\mathcal{S} = \int_{b_1}^{b_2} \mathcal{F}(a, a')\, \mathrm{d}b$$ *least (or stationary) action*

then $$\frac{\partial \mathcal{F}}{\partial a} - \frac{\mathrm{d}}{\mathrm{d}b}\left(\frac{\partial \mathcal{F}}{\partial a'}\right) = 0$$ EULER-LAGRANGE EQUATION

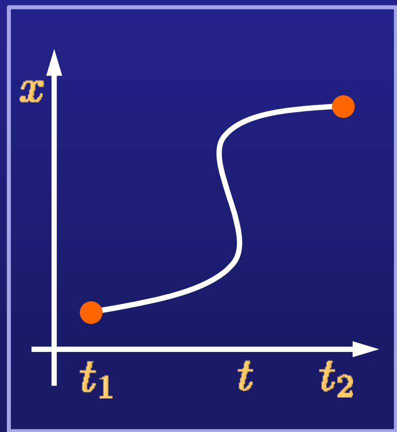


LAGRANGIAN MECHANICS

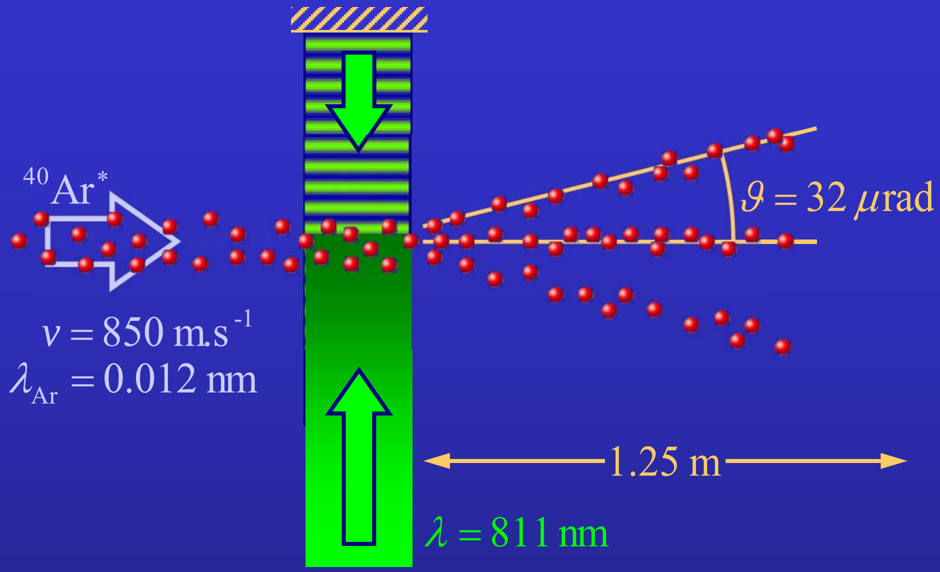
set $\mathcal{F} \rightarrow \mathcal{L} = \mathcal{T} - \mathcal{V}$

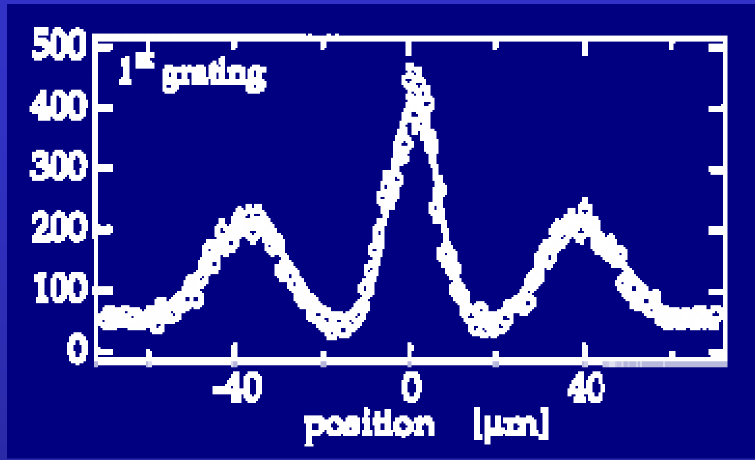
$a \rightarrow x,\ y,\ \vartheta$ etc. (coordinate variables)

$b \rightarrow t$



Diffracting atoms



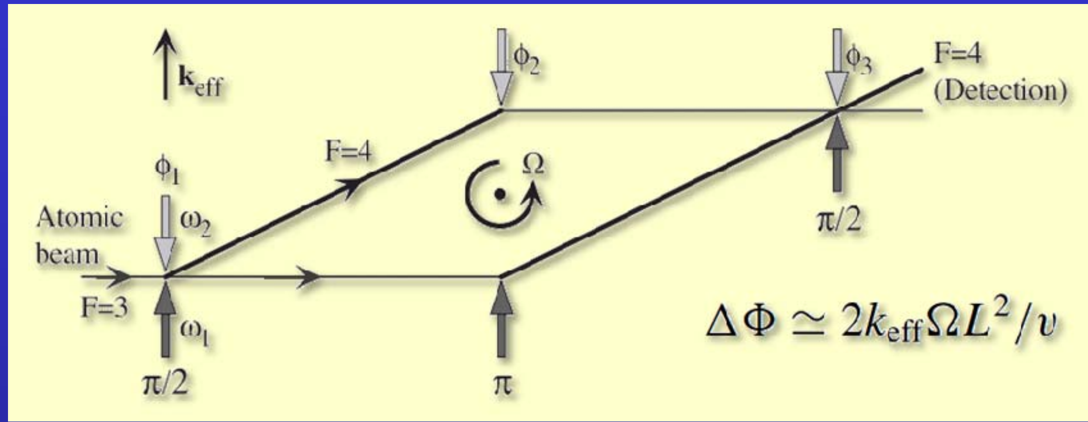


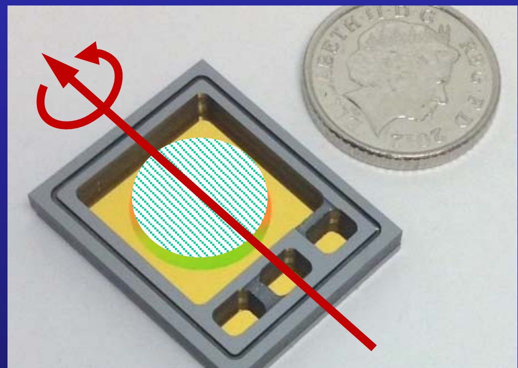
E M Rasel et al, Phys Rev Lett **75** 2633 (1995)

- stimulated Raman transitions equivalent to Bragg scattering from moving standing wave

Inertial sensing using light

- Mach-Zehnder interferometer
- quantum wavefunction split and recombined
- laser-cooled atoms sense inertial Coriolis acceleration
- phase depends upon rotation





UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

EPSRC

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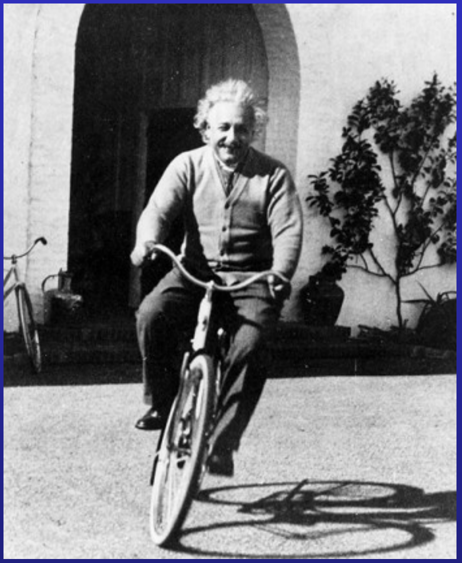

Question terminology

- State, What, Identify, Express, Find
  - no derivation required
- Explain, Describe, How
  - in words…
- Derive, Prove, Show that, Determine
  - state assumptions, proceed logically
- Evaluate, Indicate, Calculate, Estimate
  - numbers, with clear assumptions
- Sketch
  - as it says…

DEGREE CLASSIFICATIONS

- First class (70%)
  - Ability to extend or adapt standard derivations & manipulations to unseen problems
  - Demonstrate good insight & knowledge beyond course material
- 2:1 (60%)
  - Recall of standard derivations, manipulations & examples
  - Ability to discuss critically & demonstrate some insight
- 2:2 (50%)
  - Recall of simple derivations, manipulations & examples
  - Some ability to discuss critically
- Third (40%)
  - Knowledge of basic definitions, formulae, phenomena & examples
  - Ability to apply formulae directly

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