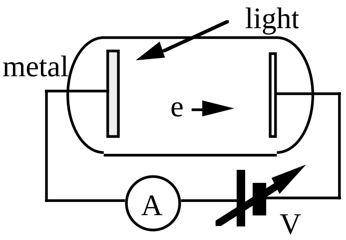
Introduction to quantum physics

Notes for Higher Physics 1b. Joe Wolfe

The photoelectric effect



Experiment:
$eV_o = hf - hf_o$

$eV_{stop} = K$ $\quad$ $hf = hf_o + K$ $\quad$ hf_o = work function

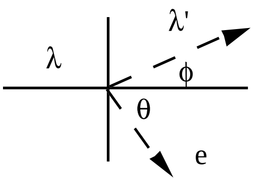
Photon energy $\quad E = hf$

$$p = \frac{E}{c}$$ *classical EM result*

for photon $\quad \therefore \quad p = \frac{hf}{c} = \frac{h}{\lambda}$

Compton scattering

X-ray photon from e



$$hf = hf' + mc^2\left(\gamma - 1\right)$$

$$\frac{h}{\lambda} = \frac{h}{\lambda'} + mc\left(\gamma - 1\right)$$

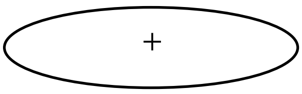
$$\frac{h}{\lambda} = \frac{h}{\lambda'}\cos\phi + mv\gamma\cos\theta$$

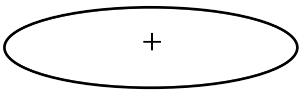
$$0 = \frac{h}{\lambda'}\sin\phi - mv\gamma\sin\theta$$

eliminate v,θ $\rightarrow \quad \Delta\lambda = \frac{h}{mc}(1 - \cos\phi)$

de Broglie $p = h/\lambda$ for massive particles

Bohr - de Broglie atom





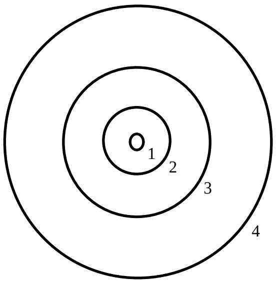
$2\pi r = n\lambda$ constructive interference

$2\pi r \neq n\lambda$ destructive interference

Constructive interference, $F_{elec} = ma = mv^2/r \rightarrow$

$$E = -\left(\frac{me^4}{8\varepsilon_o^2 h^2}\right)\frac{1}{n^2}$$

Hydrogen spectrum



Quantum numbers n.

e from n_2 to $n_i \rightarrow$

$$\frac{1}{\lambda} = \frac{\Delta E}{hc} =$$

$$-R.\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

R Rydberg's const

Photon: $\begin{pmatrix}\text{probability of}\\ \text{absorption}\end{pmatrix} \propto \begin{pmatrix}\text{amplitude}\\ \text{of EM field}\end{pmatrix}^2$

Massive particles $\begin{pmatrix}\text{probability of}\\ \text{'finding' it}\end{pmatrix} \propto \Psi\Psi^*$

Heisenberg's Uncertainty Principle

(Finite) Fourier transform: finite length sample $\rightarrow$ limited precision in f. $\delta f \geq 1/2\pi T$

$E = hf. \quad \therefore \quad \delta E = h\delta f \gtrsim h/2\pi\delta t$

$$\delta E.\delta t \geq h/2\pi$$

Similarly: $\delta(1/\lambda) \gtrsim 1/2\pi\delta x \rightarrow \delta p.\delta x \geq h/2\pi$

Examples: Heisenberg's microscope,
'Orbit' of the H atom (in ground state),
Virtual particles, especially Yukawa's pion,
Diffraction through a slit,
Young's experiment with localisation

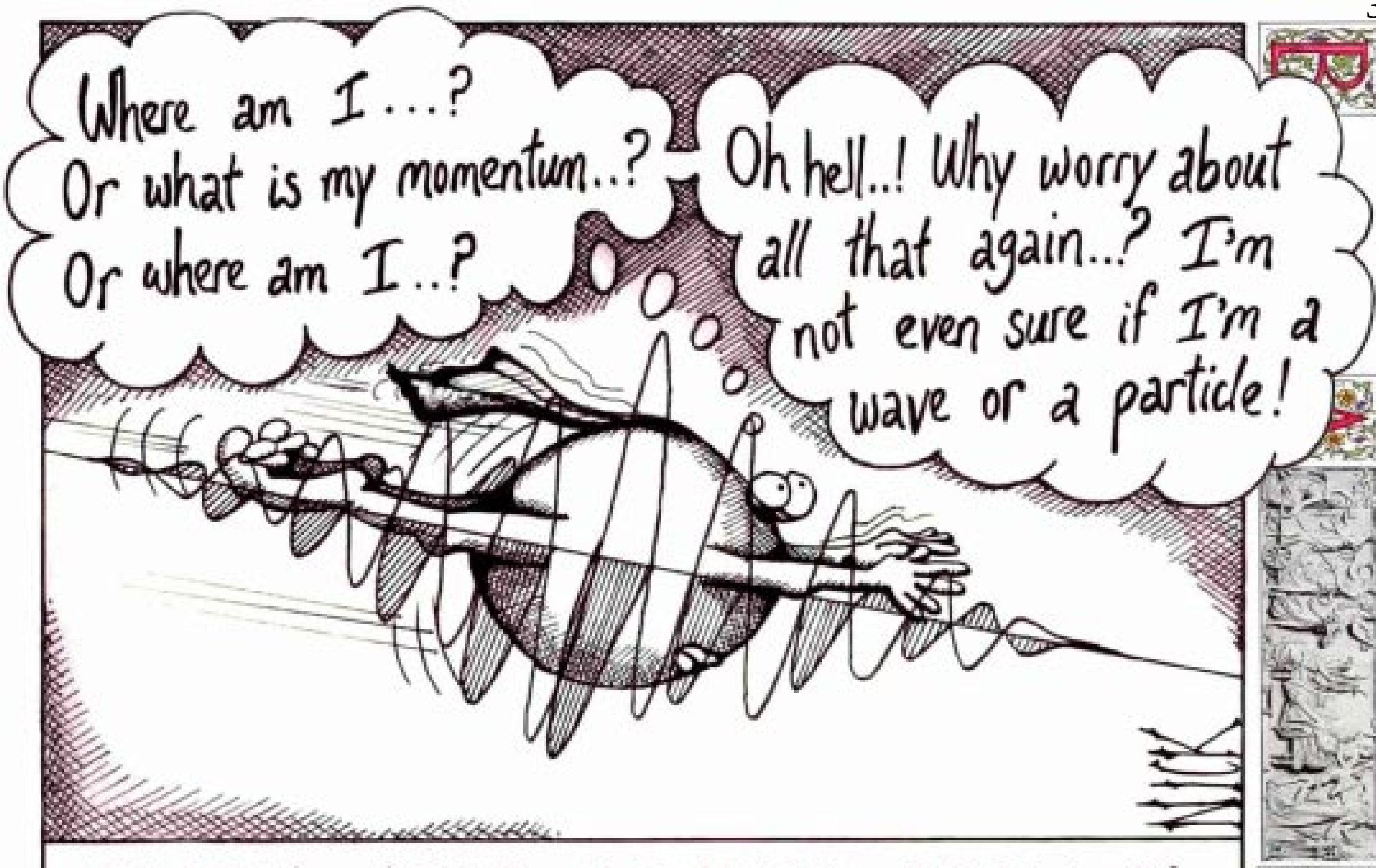
Quantum tunnelling

$$\frac{h^2}{8\pi^2 m}\frac{\partial^2\Psi}{\partial x^2} + (E - V)\Psi = 0$$

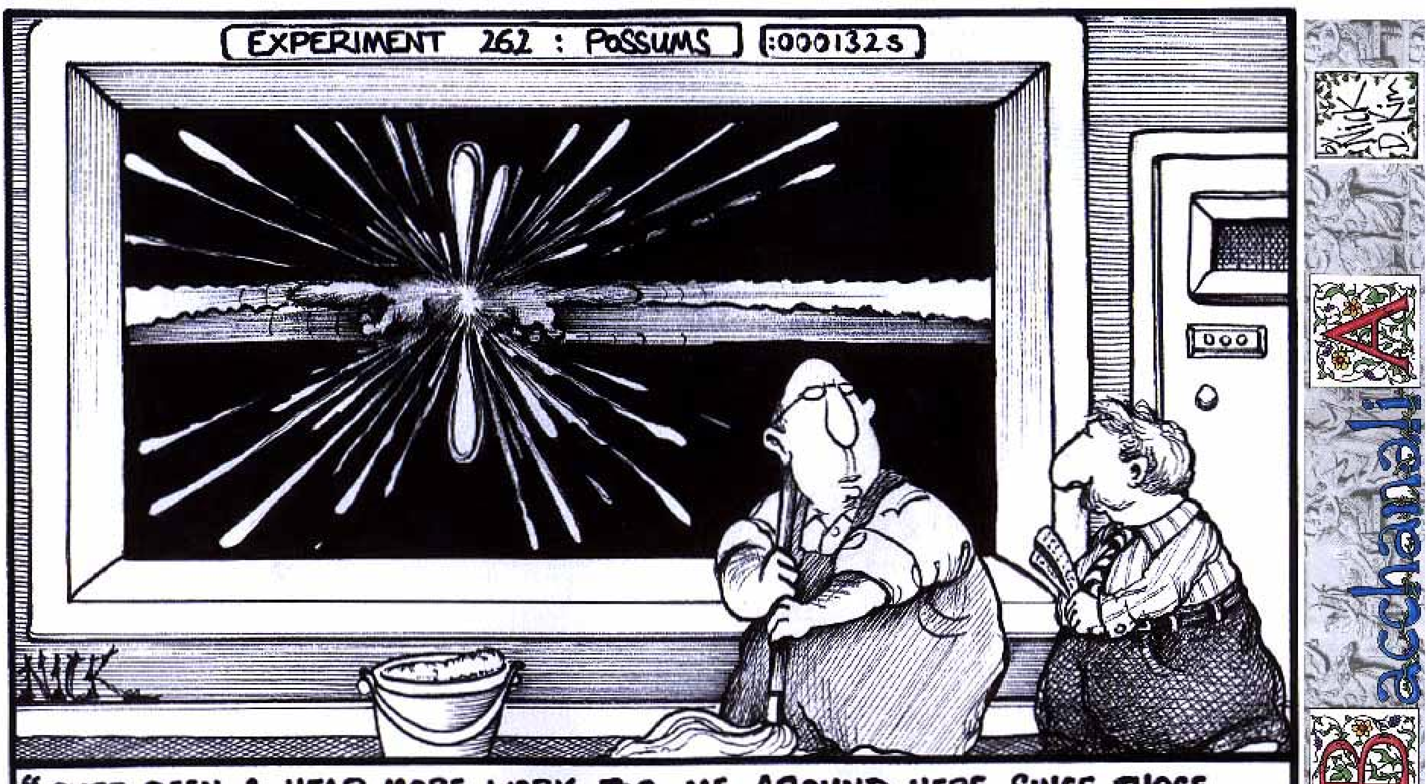
if $K > 0$, Ψ has wave solutions (cos or sin x)

if $K < 0$ Ψ has exponential decay

Examples α decay, tunnel diode, Scanning Tunnelling Electron Microscope



PHOTON SELF-IDENTITY PROBLEMS



"SURE BEEN A HEAP MORE WORK FOR ME AROUND HERE SINCE THOSE BIOLOGISTS GOT GRANTED RESEARCH TIME ON THE OL' SUPERCOLLIDER..."