Part 1: Physical Background

Quantum Physics

Lecture 1

(slides) 1.1 General Introduction

Jon Marangos j.marangos@imperial.ac.uk
Room 208 Blackett OH Tuesday + Wednesday
13:00-14:00 12:00-13:00

Units: SI with a few exceptions. We will use a lot:

nm – 10^{-9}m
fs – 10^{-15}s
eV – 1 volt potential gain of e 1.6×10^{-19}J $\equiv$ 1eV
Hz – s^{-1} or rads^{-1} or m^{-1}/cm^{-1} $\left(\frac{1}{\lambda}\propto f\right)$

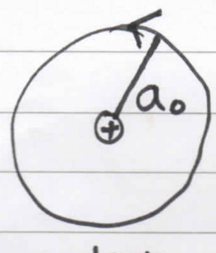
We will take a concept based approach exploring the experimental and theoretical aspects of Quantum Physics

1.2 Sizes of things

EM radiation wavelengths: Radio $\lambda \sim 1$m
Sunlight $\lambda \sim 500$nm
X-rays $\lambda \sim 0.1$nm

proton $\sim 8.7\times10^{-16}$m
atom $\sim 10^{-10}$m
biomolecule $\sim 10^{-8}$m

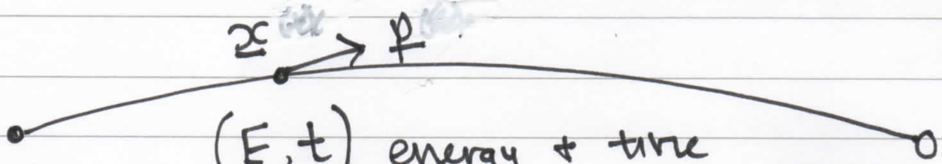
We will see for a hydrogen atom the lowest energy orbit radius: $a_0 = 5.29\times10^{-11}$m



Semi-quantum picture

$$\left\{\begin{aligned} V_0 &= c/137 \text{ ms}^{-1} \\ M_p &= 1.67\times10^{-27}\text{ kg} \\ M_e &= 9.11\times10^{-31}\text{ kg}\end{aligned}\right.$$

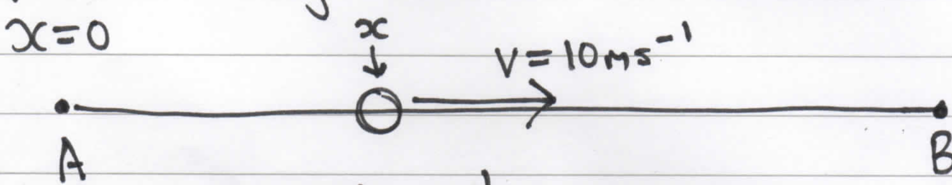
1·3 Classical mechanics + trajectories



(E, t) energy + time also defined throughout trajectory

x + p defined throughout trajectory

example: 1 kg ball in 1-dim. motion



$v = 10\,ms^{-1}$ $\qquad p = 10\ kg\,ms^{-1}$

$x_{AB} = 10\,m$ $\qquad \therefore\ t_{AB} = 1\,s$

$$E = \tfrac{1}{2}mv^2 = 5\ kg\,m^2 s^{-2} = 5\,J$$

1·4 Action

Define the action for a trajectory or path as:

$$S = \int_A^B p \cdot dx$$

dimensions ML^2T^{-2} $\quad kg\,ms^{-1}.\,m$

integral of momentum × position $\qquad kg\,m^2 s^{-1}$ (units of action) (same as for angular momentum)

So for above example $S = 10\ kg\,ms^{-1}.\ 10\,m$
$= 100\ kg\,m^2 s^{-1}$

or

$$S = \int_{t_A}^{t_B} E\,dt$$

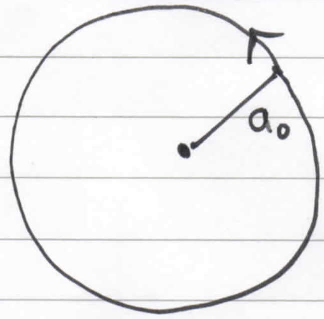
dimensions $J.s$

~~alternative~~ another form $\qquad \equiv kg\,m^2 s^{-1}$ (units of action)

[Total action is the sum]

1·4 Does size matter?

electron in 1st orbit of H



[momentum] × [distance]

$p \qquad 2\pi a_0$

$= 6.65 \times 10^{-34}\ kg\, m^2 s^{-1}$

[Energy][time] $= 3.3 \times 10^{-34}\ kg\, m^2 s^{-1}$

$13.6 \times 1.6 \times 10^{-19}\ J \qquad 1.52 \times 10^{-16}\ s$

Something happens when action $\lesssim 10^{-33}\ J\,s$

Trajectories become fuzzy! p + x can't be simultaneously defined/measured

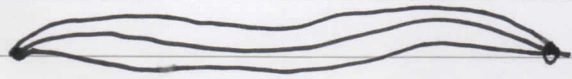
Doesn't matter for macroscopic systems [Action $\gg 10^{-33}$]
<u>but</u> very important in the microscopic scale

Matter – behaves more like a wave Light – behaves more like particles (photons)

this is <u>Quantum Physics</u>

classical paths

fuzzy paths

$\equiv$  Σ quantum paths
[– but each behaves like a wave with phase given by S]

[Need to revise waves]