Recall: $F_c = F_{mag}$

$$\frac{mv^2}{r} = qvB$$

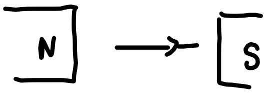
$$r = \frac{mv^2}{qvB}$$

$$r = \frac{\boxed{m}v}{\boxed{q}B}$$

↑ mass to charge ratio

Example

Determine the force per unit length acting on the wire carrying a current of 1.5A in a magnetic field of 4.0×10^{-2} T in each of the situations:



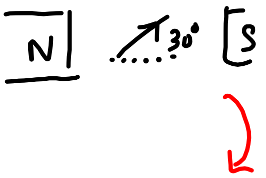
⇝ $F = 0$ $(I \parallel B)$

⇝ $F = BIL\sin\theta$ $(F = B_\perp IL)$

$F = (4.0\times10^{-2}T)(1.5A)(1m)\sin 90^\circ$

$F = 6.0\times10^{-2}N$

$\vec{F} = 6.0\times10^{-2}N$ (into page)



$F = BIL\sin\theta$

$F = (4.0\times10^{-2}T)(1.5A)(1m)\sin 30^\circ$

$F = 3.0\times10^{-2}N$

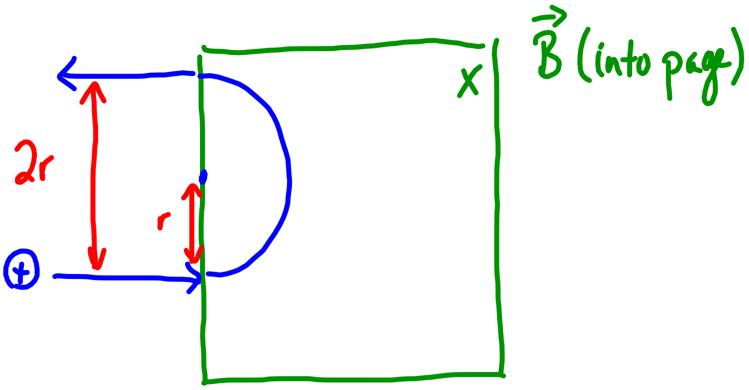
$\vec{F} = 3.0\times10^{-2}N$ (into page)

Example

A proton travelling at $5.0\times10^{6}\,ms^{-1}$ enters at right angles into the region of a magnetic field of strength 2.5T. Draw the path that the proton will follow and determine the radius of the curved path in the field.

$m = 1.7\times10^{-27}\,kg$

$q = 1.6\times10^{-19}\,C$



$$F_{mag} = F_c$$

$$qvB = \frac{mv^2}{r}$$

$$r = \frac{mv}{qB}$$

$$r = \frac{(1.7\times10^{-27}kg)(5.0\times10^{6}ms^{-1})}{(1.6\times10^{-19}C)(2.5T)}$$

$$r = 0.021\ m$$

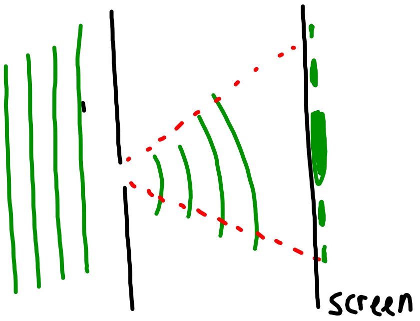
(2.1cm)

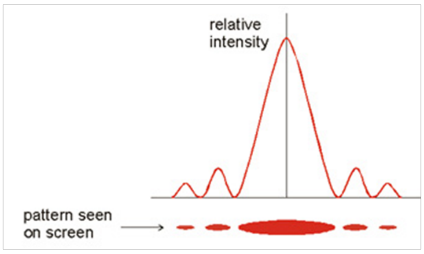
TOPIC 7 - Atomic + Nuclear Physics

Things you need to know already, but don't necessarily know yet!

1. Light (electromagnetic radiation) has wave-like properties.

- principle of superposition
  ↓
  explain diffraction + interference of waves
  ↓
  light displays these phenomena
  ↓
  light has wave-like properties (classical physics)

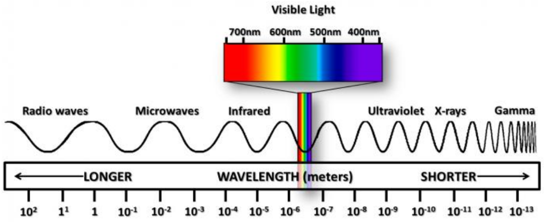




2. Visible light is part of the electromagnetic spectrum.

$$\underbrace{10^{-18}\ (\text{hard } \gamma \text{ rays}) \rightarrow 10^{6}\ (\text{long radio waves})}_{\text{24 orders of magnitude!}}$$

Visible: 4×10^{-7} m (violet) → 7.5×10^{-7} m (red)
(400nm) (750nm)



3. An electromagnetic wave is a self-reproducing combination of an oscillating magnetic field and an oscillating electric field.

moving charge → magnetic field

accelerating charge → changing magnetic field

↓

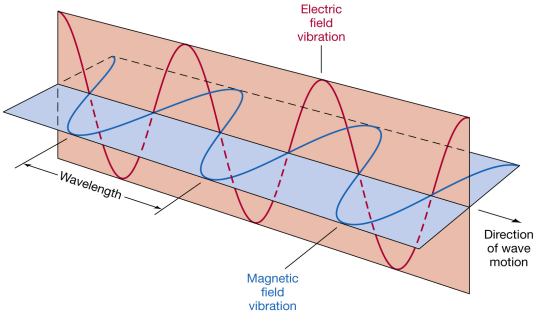
→ changing electric field (induced)

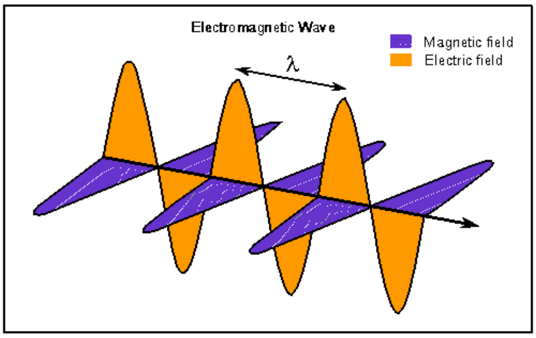
↓

changing magnetic field

electromagnetic waves ←

(the result of oscillating charges





4. Electricity and magnetism can be combined in one theory called electromagnetism, and electric and magnetic forces are together classified as the electromagnetic force.

This theory was proposed by Maxwell in the 1800s -> it mathematically unified the physics of the electric force and the magnetic force into a single theory.

The two forces (electric and magnetic) are considered to be the result of the electromagnetic force.

5. All electromagnetic waves travel at the same speed in a vacuum.

speed of "light" $c = 3.00 \times 10^8 m/s$

6. Accelerated charges radiate their energy as electromagnetic waves.

Energy in the form of an electromagnetic wave is radiated from an electric charge (such as an electron) whenever the charge accelerates.

The frequency of emitted radiation is equal to the frequency of the oscillation of the electric charge.

Examples → radio antenna
light bulb (incandesent)
black body radiations
(f depends on temp)

7. Light has particle-like properties.

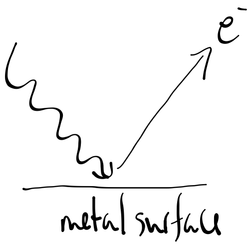
Classical physics → pre 1905 (includes Maxwell's theory of EM radiati and wave theory of light)

Modern physics → 1905 +

- phenomenon (light) not able to be explained using classical theory

Ⓐ photoelectric effect

- a minimum frequency is needed



Ⓑ Black-body radiation

- all bodies radiate energy because they contain electric charges (electrons) that are in random accelerated motion.

Neither effect could be explained properly (quantitatively) using classical physics!

1905

Einstein prosed

- theory of special relativity
- the existence of photons (which led to quantum mechanics)
- quantitatively explained "Brownian Motion"

The next 30 years → significant development of quantum theory.

Photons

- In 1905 Einstein suggested that light consists of particle like entities called photons
  - a "bundle" of radiation energy
  - has particle-like properties, not wave-like properties.
  - travel at speed of light.
  - energy of a photon is proportional to its frequency
  - each photon has an energy:

$$E = hf$$

where f is the frequency (Hz)
h is Planck's constant (6.63×10^{-34} J.s)

$$\text{VIBGYOR} \longrightarrow$$

small λ
hig f
high energy
(violet)

large λ
low f
low energy
(red)

Wave-Particle Duality of Light

wave like behaviour → interference and diffraction (can only be explained using wave theory)

particle-like behaviour → photoelectric effect + black body radiation (can only be explained using particle theory)

Light cannot be both in the same situation or at the same time

↳ Quantum Mechanics

Example

Calculate the energy of a violet light photon whose wavelength is 4.0×10^{-7} m. Answer in J and eV.

$E = hf$
$c = \lambda f$

sort of in data booklet →

$E = hf$

$$\boxed{E = \frac{hc}{\lambda}}$$

$$\boxed{\lambda = \frac{hc}{E}}$$

$$E = \frac{(6.63 \times 10^{-34}\,\text{J.s})(3.00 \times 10^{8}\,\text{ms}^{-1})}{4.0 \times 10^{-7}\,\text{m}}$$

$$\boxed{E = 5.0 \times 10^{-19}\,\text{J}} \leftarrow \text{in J}$$

$$E = \frac{5.0 \times 10^{-19}\,\text{J}}{1.6 \times 10^{-19}\,\text{J eV}^{-1}}$$

$$\boxed{E = 3.1\,\text{eV}} \leftarrow \text{in eV}$$

8. The speed of light is constant for all observers, regardless of the speed of the observer.

1905 Einsteins theory of special relativity

① There is no such thing as absolute rest and so this makes it impossible to distinguish between moving reference frames.

② The speed of light is always the same regardless of the speed of the observer.

→ an observer would measure the speed of light to be $3.0 \times 10^8 ms^{-1}$ no matter whether they were moving relative to the source.

Consequences

① The time interval between two events depends on the speed of the observer

② the length of a moving object depends on the speed of the observer

③ the mass of a moving object depends on the speed of the observer

④ it is impossible for anything other than light itself (or something with zero rest mass) to travel at the speed of light.

* ⑤ mass and energy are equivalend

9. Mass and Energy are equivalent

related by equation:

$$E = mc^2$$

Since mass depends on speed of observer, we need to specify "rest mass" or "relativistic mass"

Example. The rest mass of an electron is 9.1×10^{-31} kg. What is the energy equivalent of this mass?

$$E = mc^2$$

$$E = (9.1 \times 10^{-31} \text{kg})(3.00 \times 10^{8} \text{ms}^{-1})^2$$

$$\boxed{E = 8.2 \times 10^{-14} \text{ J}}$$

$$\boxed{E = 0.51 \text{ MeV}}$$

10. It is impossible for any body with a non-zero rest mass to travel at the speed of light.