Light and Matter

$1eV = 1.6 \times 10^{-19} J$

Photon momentum: $P = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$

de Broglie wavelength: $\lambda = \frac{h}{p} = \frac{h}{mv}$

$m_{electron} = 9.11 \times 10^{-31} kg$

h = Planck's constant = $6.63 \times 10^{-34} Js$ = $4.14 \times 10^{-15} eVs$

Particle model

- Sir Isaac Newton, 1671
- Light behaves as particles
- Can't properly explain dispersion, refraction (predicts that speeds up when bends towards normal), interference, polarisation properly
- Have mass and momentum
- Obey f=ma

Wave model

- Christian Huygens, 1678
- Light behaves as waves
- Can't properly explain photoelectric effect, Compton scattering, applying pressure.
- Have no mass or momentum
- Obey $v = f\lambda$

Snell's Law: $\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$

Diffraction

Spreading out or bending of wavefronts as they pass through a gap or around an object.

- Becomes significant when $\lambda \geq d$ (gap width)
- No change in medium, v and λ remain same.
- Causes poor resolution

Destructive Interference

- Two waves arriving out-of-phasel
- Minima, nodal lines.
- Path difference = $(n - 1/2)\lambda$

Constructive Interference

- Two waves arriving in-phase
- Maxima, antinodal lines.
- Path difference = $n\lambda$

Single-slit experiment:

- Light passing adjacent to the edge of the slit will interfere with light passing through the centre of the slit. For every point from the top edge of the slit to the centre, there is a corresponding point between the centre and the bottom edge of the slit that also interferes with the same effect.
- $\sin\theta = \frac{\lambda}{w}$ (angle to 1st minimum)

Young's Double Slit Experiment

- Places where light arrives out-of-phase produces nodes, resulting in dark bands
- Places where light arrives in-phase produces antinodes, resulting in bright bands

[diagram?]

Light as electromagnetic radiation

- James Clark Maxwell
- Light is a wave made up of changing electrical and magnetic fields (ie. visible light is a form of electromagnetic radiation)
- Wavelengths of visible light are 400 – 700 nm

Atoms and spectra

- Ground state, 1st excitation level, etc.
- Amount of energy for electron to escape atom = ionisation level
- Atom can only absorb fixed amounts of energy, ground state can only jump to certain energy levels (excited states)
- “Packages of energy” = quanta
- When it drops to a lower energy level, a photon is emitted
- Energy of photon = Difference in energy between specific excited states

- $E = hf = \frac{hc}{\lambda}$

[Absorption and emission spectra?]

Photoelectric Effect

- If light is being shone onto a metallic surface, then electrons (photoelectrons) can be given off
- Energy to escape is given off by photons
- Doesn't always occur, threshold frequency
- Energy needed for electron to escape is "Work function" (W)
- $hf = W + KE_{electron}$

Max KE / Frequency graph

- Gradient is Planck's constant
- Intercept of freq. axis is threshold freq.
- Intercept of energy axis is negative W

[stuff on Physics Notes p.42]

Electric Power

$$I = \frac{q}{t}$$
$$W = Vq = VIt$$
$$V = IR$$
$$P = VI = I^2 R = \frac{V^2}{R}$$
$$q_e = 1.60 \times 10^{-19} C$$

In series:

$$I = I_1 = I_2 = I_3 = \ldots$$
$$V = V_1 + V_2 = V_3 + \ldots$$
$$R_T = R_1 + R_2 + R_3 + \ldots$$

In parallel:

$$I = I_1 = I_2 = I_3 = \ldots$$
$$V = V_1 = V_2 = V_3 = \ldots$$
$$R_T = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\right)^{-1}$$

$$V_{RMS} = \frac{V_{Peak}}{\sqrt{2}}$$

$$I_{RMS} = \frac{I_{Peak}}{\sqrt{2}}$$

- Calculations should be done using RMS values

Magnetic Induction

- Domains of permanent magnet have an effect on domains of metallic object, causes it to magnetise
- Iron = Magnetised very easily, but only temporary
- Steel = Difficult to magnetise, but becomes permanent.

Magnetic Fields

- North to South
- Direction a little magnet would point
- B = Magnetic fiend strength (magnetic flux density), strength & direction of field
- North pole of Earth is really a magnetic South pole
- Earth's magnetic field is $5 \times 10^{-5} T$
- Current carrying wire - Right hand grip rule
- Cross = coming out, dot = going in to page
- Iron core in solenoid increases its strength
- Increasing current or loops increases strength
- $F = nBIl \sin\theta$
- Force - Right-hand slap rule – Fingers = field, thumb = **conventional** current, direction palm would move = direction of force

D.C. Electric Motor

Parts:

1) Magnets (permanent or electromagnetic)
2) Loop of wire that carries current
3) Commutator

[diagram?]

- Force stays constant (as B, I, l are all constant), torque changes
- Size of current determines speed of motor
- Commutator is needed to reverse current every ½ turn.

Magnetic Flux

- Weber (Wb)
- Vector in same direction of magnetic field
- $\phi = BA$

Electromagnetic Induction

An emf can be induced in a wire if it is placed in a magnetic field and there is relative motion between the wire and magnetic field

- $\epsilon = Blv$
- If wire is moved parallel to magnetic field, there is no induced current/emf
- Maximum current = at right angles
- Faster movement = increases current
- Increasing B = inceases current
- Adding more loops = inceases current
- Direction of induced current, use right hand slap rule – Direction of magnetic force is **opposite** to direction of applied force

- Faraday's Law – $\epsilon = \frac{-N \Delta \phi}{\Delta t}$

Electrical Generators

- Same parts as electrical motor
- Uses kinetic energy to produce electric energy
- Produced by change in flux
- emf/time graph is negative gradient of flux/time graph

Transformers

- Two coils wrapped aroundiron core
- Current is induced only if there is a changing magnetic field!
- Step up increases **voltage**

$$\frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P}$$

$$P_{out} = P_{in}$$

Transmission of Electricity

- Electricity passing along long lengths of wire, some energy is lost as heat.
- $P = I^2 R$

Problems involving transmission

[Diagram?]

- Current is constant from start of wire to end
- Voltage loss is found via V=IR (R is total resistance of **both** wires), and voltage at end is this amount less than voltage at start
- Power loss is found via $P = I^2 R$, and power at end is this amount less than power at start

Synchrotron and its applications

- Synchrotron is giant particle accelerator
- Produced very narrow and intense beam of radiation
- Direction of electric field is given as direction of force that would act on a small **positive** charge
- Electric field for point charge: $E = \frac{F}{q}$
- Electric field between parallel lines: $E = \frac{V}{d}$
- Work done = $Vq = \frac{1}{2} mv^2$

$$F = qvB$$

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

$$r = \frac{mv}{Bq} = \frac{p}{Bq}$$

Features

- **Linear accelerator** – Uses series of electric fields that accelerate electrons to higher and higher speeds in a straight line
- **Booster ring** – Contains magnets that make the electrons travel in circular motion
- **RF Cavities** – Use intense electromagnetic radiation of several megahertz to speed up electrons even further

- **Storage Ring –** Remain for up to 20 hours, radiate photons in form of intense, narrow beam ("synchrotron light")
- **Wigglers** and **undulators** – Enhance beam, make it dramatically brighter
- **Beamlines** – Radiation is directed here

Characteristics of Synchrotron radiation

- **Broad spectrum** – Radiation from infrared, visible, ultraviolet and X-rays can be produced
- **Brighness** – Thousands of times brighter than the Sun
- **Divergence** – Very little divergence, concentrated onto a single spot
- **Pulsed** – Radiation comes in pulses lasting less than one nanosecond
- **Polarised** – In one plane only

Bragg Diffraction

Bragg's Law: $n\lambda = 2d\sin\theta$