Unit 5D Turning Points in Physics

This option is intended to enable key developments in Physics to be studied in depth so that students can appreciate, from a historical viewpoint, the significance of major conceptual shifts in the subject both in terms of the understanding of the subject and in terms of its experimental basis. Many present day technological industries are the consequence of such key developments and the topics illustrate how unforeseen technologies develop from new discoveries.

D.4.1 The discovery of the Electron

- **Cathode rays**

  Production of cathode rays in a discharge tube.

- **Thermionic emission of electrons**

  The principle of thermionic emission.

  Work done on an electron accelerated through a pd

  $\frac{1}{2}mv^2 = eV$

- **Determination of the specific charge of an electron, *e/m*, by any one method**

  Significance of Thomson's determination of e/m.

  Comparison with the specific charge of the hydrogen ion.

  The use of equations

  $F = \frac{eV}{d}$ $\quad F = Bev \quad$ $r = \frac{mv}{Be}$

- **Principle of Millikan's determination of Q**

  Condition for holding a charged oil droplet, of charge Q, stationary between oppositely charged parallel plates

  $\frac{QV}{d} = mg$

  Motion of a falling oil droplet with and without an electric field; terminal speed, Stokes' Law for the viscous force on an oil droplet used to calculate the droplet radius

  $F = 6\pi\eta rv$

- **Significance of Millikan's results**

  Quantisation of electric charge.

D.4.2 Wave Particle Duality

- **Newton's corpuscular theory of light**

  Comparison with Huygens' wave theory in general terms.

  The reasons why Newton's theory was preferred.

- **Significance of Young's double slits experiment**

  Explanation for fringes in general terms, no calculations are expected.

  Delayed acceptance of Huygens' wave theory of light.

- ## Electromagnetic waves

Nature of electromagnetic waves.

Maxwell's formula for the speed of electromagnetic waves in a vacuum

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}},$$

where μ_0 is the permeability of free space and ε_0 is the permittivity of free space.

Candidates should appreciate that ε_0 relates to the electric field strength due to a charged object in free space and μ_0 relates to the magnetic flux density due to a current-carrying wire in free space.

Hertz's discovery of radio waves.

- ## The discovery of photoelectricity

The failure of classical wave theory to explain observations on photoelectricity; the existence of the threshold frequency for the incident light and the variation of the stopping potential with frequency for different metals.

Candidates should appreciate how the stopping potential is measured using a potential divider and a vacuum photocell.

Candidates should also appreciate that photoelectric emission takes place almost instantaneously and that the maximum kinetic energy of the emitted photoelectrons is independent of the intensity of the incident light.

Einstein's explanation of photoelectricity and its significance in terms of the nature of electromagnetic radiation.

- ## Wave particle duality

de Broglie's hypothesis supported by electron diffraction experiments

$$p = \frac{h}{\lambda} \qquad \lambda = \frac{h}{\sqrt{2meV}}$$

- ## Electron microscopes

Estimate of anode voltage needed to produce wavelengths of the order of the size of the atom.

Principle of operation of the transmission electron microscope (T.E.M.).

Principle of operation of the scanning tunnelling microscope (S.T.M.).

D.4.3 Special Relativity

- ## The Michelson-Morley experiment

Principle of the Michelson-Morley interferometer.

Outline of the experiment as a means of detecting absolute motion.

Significance of the failure to detect absolute motion.

The invariance of the speed of light.

- ## Einstein's theory of special relativity

The concept of an inertial frame of reference.

The two postulates of Einstein's theory of special relativity:

(i) physical laws have the same form in all inertial frames,

(ii) the speed of light in free space is invariant.

- ## Time dilation

Proper time and time dilation as a consequence of special relativity.

Time dilation

$$t = t_0\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$

Evidence for time dilation from muon decay.

- ## Length contraction

Length of an object having a speed v

$$l = l_0\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}$$

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- ## Mass and energy

Equivalence of mass and energy

$$E = mc^2 \qquad E = \frac{m_0c^2}{\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$