3.12 Turning points in physics (A-level only)

This option is intended to enable key concepts and developments in physics to be studied in greater depth than in the core content. Students will be able to appreciate, from historical and conceptual viewpoints, the significance of major paradigm shifts for the subject in the perspectives of experimentation and understanding. Many present-day technological industries are the consequence of these key developments and the topics in the option illustrate how unforeseen technologies can develop from new discoveries.

3.12.1 The discovery of the electron (A-level only)

3.12.1.1 Cathode rays (A-level only)

Content

Production of cathode rays in a discharge tube.

3.12.1.2 Thermionic emission of electrons (A-level only)

Content

The principle of thermionic emission.

Work done on an electron accelerated through a pd V ; $\frac{1}{2}mv^2 = eV$

3.12.1.3 Specific charge of the electron (A-level only)

Content

Determination of the specific charge of an electron, $\frac{e}{m_e}$, by any one method.

Significance of Thomson's determination of $\frac{e}{m_e}$

Comparison with the specific charge of the hydrogen ion.

3.12.1.4 Principle of Millikan's determination of the electronic charge, *e* (A-level only)

Content

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 to determine the mass and the charge of the droplet.

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.

3.12.2 Wave-particle duality (A-level only)

3.12.2.1 Newton's corpuscular theory of light (A-level only)

Content

Comparison with Huygens' wave theory in general terms.

The reasons why Newton's theory was preferred.

3.12.2.2 Significance of Young's double slits experiment (A-level only)

Content

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

Delayed acceptance of Huygens' wave theory of light.

3.12.2.3 Electromagnetic waves (A-level only)

Content

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.

Students 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 including measurements of the speed of radio waves.

Fizeau's determination of the speed of light and its implications.

3.12.2.4 The discovery of photoelectricity (A-level only)

Content

The ultraviolet catastrophe and black-body radiation.

Planck's interpretation in terms of quanta.

The failure of classical wave theory to explain observations on photoelectricity.

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

3.12.2.5 Wave–particle duality (A-level only)

Content

de Broglie's hypothesis: $p = \frac{h}{\lambda}$;
$\lambda = \frac{h}{\sqrt{2meV}}$

Low-energy electron diffraction experiments; qualitative explanation of the effect of a change of electron speed on the diffraction pattern.

3.12.2.6 Electron microscopes (A-level only)

Content

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 (TEM).

Principle of operation of the scanning tunnelling microscope (STM).

3.12.3 Special relativity (A-level only)

3.12.3.1 The Michelson-Morley experiment (A-level only)

Content

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.

3.12.3.2 Einstein's theory of special relativity (A-level only)

Content

The concept of an inertial frame of reference.

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

1 physical laws have the same form in all inertial frames

2 the speed of light in free space is invariant.

3.12.3.3 Time dilation (A-level only)

Content

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

Time dilation:

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Evidence for time dilation from muon decay.

3.12.3.4 Length contraction (A-level only)

Content

Length of an object having a speed v

$$l = l_0\sqrt{1 - \frac{v^2}{c^2}}$$

3.12.3.5 Mass and energy (A-level only)

Content

Equivalence of mass and energy, $E = mc^2$; $E = \frac{m_0c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$

Graphs of variation of mass and kinetic energy with speed.

Bertozzi's experiment as direct evidence for the variation of kinetic energy with speed.