UNIT 5 Modern Physics

Recommended Prior Knowledge The study of charged particles requires a knowledge of the force on charged particles in electric and in magnetic fields (A2, Unit 3). This will also involve recall of the formulae for centripetal force (A2, Unit 1). Students should also be familiar with wave properties (AS, Unit 5) and energy conservation. For the section on nuclear physics, the work covered previously (AS, Unit 4) would be advantageous.

Context The Unit draws together concepts from different areas of the syllabus and is likely to be taught near the end of the course. Not only is the content of the Unit important in its own right, but also, it helps to prevent fragmentation of the course and gives purpose to the study of some of the more theoretical concepts.

Outline The first part of the Unit is concerned with electrons. Means by which the charge, specific charge and mass of electron may be determined are studied Quantum physics is introduced through a study of the photoelectric effect and this is further developed to include wave-particle duality. Stability of nuclei is introduced via Einstein's mass-energy relationship and the exponential nature of radioactive decay is investigated.

Online Resources. In this unit repeated use is made of Java Applets. These are usually well animated programmes. It has been found preferable to use one main source of computer programmes as both teachers and students can become familiar with the procedure for using the resource and are therefore more likely to connect to the web. This particular set of animations can be found using the web address http://surendranath.tripod.com . Once this has been found then the Applet menu enables the particular topic to be found. There is no need to subscribe to Tripod, just ignore their adverts and click on to either the Applets Menu or the 'Click here' instruction about any problem with the menu. Do read the instructions for each Applet by scrolling down past the 'Start Applet' command. In the Online Resources column reference will be made to this introduction and then the Applet menu title will be given. Where other addresses are used it is because the surendranath Applets do not cover the particular topic.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
	Charged Particles			
25(a)	Show an understanding of the main principles of determination of *e* by Millikan's experiment.	The work on force on a charged particle in an electric field should be revised. Students should be aware of the expression $4\pi r^3(\rho - \rho_a)g/3 = qE$ and that *r* is found by measuring the terminal speed of the oil drop.		
25(b)	Summarise and interpret the experimental evidence for quantisation of charge.	This is best approached through an example where a number of different values for the charge are given to students and the highest common multiple is determined.		All the following books cover this topic in full. Further details may be found on the CIE website. www.CIE.org.uk AS/A2 Physics; Mee ISBN 0340757795
25(c)	Describe and analyse qualitatively the deflection of beams of charged particles by uniform electric and magnetic fields.	Demonstrations of the paths using cold-cathode tubes (e.g. 'Teltron' tubes) are most valuable. Students should realise that the path in an electric field can be analysed in a similar way to trajectory motion in a gravitational field. In magnetic field, the path is the arc of a circle given by $mv^2/r = Bqv$ when the path of the particle is initially normal to the field. More able students may like to consider the helix formed when the path is at an angle to the field.	See introduction Applet: Electric Field Lines-Charge in E and B field. This is, of course, a three dimensional problem and it is somewhat tricky to get the orientation correct. Start with velocity in one direction zero and then proceed to spiral paths later.	

25(d) 25(e)	Explain how electric and magnetic fields can be used in velocity selection. Explain the main principles of one method for the determination of v and e/m_e for electrons.	It is important to consider the directions of the 'crossed' fields. Students should be able to derive the expression $v = E/B$. Students should realise that electrons released as a result of thermionic emission and accelerated through a potential difference v have a speed given by $\frac{1}{2}mv^2 = eV$. Speed may also be determined from the circular orbit in a magnetic field of known flux density or using a velocity selector. A 'fine-beam' tube or 'Teltron tube' should be used to demonstrate the principles of the determination of specific charge. Students should appreciate that, knowing e/m_e and the charge e, the mass of the electron may be found.		Understanding Physics for Advanced Level: Breithaupt ISBN: 0748743146 Physics: Hutchings ISBN 0174387318 Physics 2: Sang (Editor) ISBN 0521797152 AS/A-level Physics Question and Answer Guide: Crundell ISBN 0860037754 Practice in Physics: Akrill ISBN 0340758139
26(c)	**Quantum Physics** Show an understanding that the photoelectric effect provides evidence for a particulate nature if electromagnetic radiation while phenomena such as interference and diffraction provide evidence for a wave nature.	The photoelectric effect may be demonstrated using a clean zinc plate on a charged electroscope. The electroscope (both positively and negatively charged) may be illuminated with sodium light and ultraviolet light. The failure of wave theory can be discussed. The fact that the electron must be given energy (work function energy) to escape the metal surface should be introduced together with the idea that light is not a continuous wave but a series of 'pulses'.		9702/4 May 02, 7(a)
26(a)	Show an appreciation of the particulate nature of electromagnetic radiation.			
26(b)	Recall and use $E = hf$.	Each 'pulse', or photon has a certain amount of energy (hf). This should be introduced as a consequence of conservation of energy. The reason for photoelectrons having less than the maximum energy should be discussed.	http://www.walter-fendt.de/ph14e then 'Physics of Atoms' followed by 'Photoelectric Effect'	9702/4 Nov 02, 2(a)
26(e)	Explain photoelectric phenomena in terms of photon energy and work function energy.			9702/4 May 02, 7(d)
26(g)	Recall, use and explain the significance of $hf = \Phi + \frac{1}{2}mv_{max}^2$.			9702/4 May 02, 7(b)(c)

26(d)	Recall the significance of threshold frequency.	Candidates should be able to sketch graphs of maximum kinetic energy against frequency (or wavelength). They should realise that, at constant intensity, the rate of arrival of photons is dependent on frequency.		
26(f)	Explain why the maximum photoelectric energy is independent of intensity whereas the photoelectric current is proportional to intensity.		http://www.colorado.edu/physics/2000/index then 'The Atomic Lab' followed by 'Interference experiments' and 'Electron interference'	
26(h)	Describe and interpret qualitatively the evidence provided by electron diffraction for the wave nature of particles.	This can be demonstrated using a 'Teltron' tube. The effect of change of electron speed (accelerating voltage) should be discussed. A similar diffraction pattern using light can be demonstrated if a parallel beam of light is shone through lycopodium powder (or cork dust) on a microscope slide.		
26(i)	Recall and use the relation for the de Broglie wavelength $\lambda = h/p$.			
26(k)	Distinguish between emission and absorption line spectra.	A sodium lamp and a diffraction grating may be used to demonstrate a line spectrum. Examples of other line spectra should be shown so that students appreciate that each spectrum is a characteristic of the element.		
26(j)	Show an understanding of the existence of discrete electron energy levels in isolated atoms (e.g. atomic hydrogen) and deduce how this leads to spectral lines.	The simple Bohr model may be introduced. The absorption of photons of the appropriate energy can be introduced, leading to the absorption spectrum. The absorption of light energy and its re-emission in all directions may be shown by shining sodium light through a Bunsen flame and observing the 'shadow'. The shadow intensifies when a drop of salt solution is put in the flame.		9702/4 Nov 02, 2(b)
26(l)	Recall and solve problems using the relation $hf = E_1 - E_2$.		http://www.walter-fendt.de/ph14e then 'Physics of Atoms' followed by 'Bohr's Theory of the hydrogen atom'	
	Nuclear Physics			
27(k)	Show an appreciation of the association between energy and mass as represented by $E = mc^2$ and by recalling this relationship.	One possible introduction is to consider the mass of a helium nucleus and the total mass of the constituent nucleons. The mass defect can then be associated with binding energy.		
27(l)	Sketch the variation of binding energy per nucleon with nucleon number.	Nucleon number should not be confused with proton number.		

27(m)	Explain the relevance of binding energy per nucleon to nuclear fusion and to nuclear fission.	Binding energy per nucleon must be multiplied by nucleon number to determine binding energy. A larger binding energy is associated with a more stable nucleus. The distinction between fission and fusion must be made clear.		
27(n)	Define the terms activity and decay constant and recall and solve problems using $A = \lambda N$.	The distinction between activity and count rate should be made. Decay constant as probability of decay of a nucleus per unit time, leading to $A = \lambda N$, should be made clear. An understanding of the mole is important.	http://www.walter-fendt.de/ph14e then 'Nuclear Physics' followed by 'Law of Radioactive Decay'	9702/4 Nov 02, 8(a)(b)
27(o)	Infer and sketch the exponential nature of radioactive decay and solve problems using the relationship $x = x_0\exp(-\lambda t)$ where x could represent activity, number of undecayed particles or received count rate.	Candidates should realise that rate of decay proportional to number present is the general form of an exponential decay.	http://www.colorado.edu/physics/2000/index then 'Isotopes and Radioactivity' followed by 'Half life'	9702/4 Nov 02, 8(c)
27(p)	Define half-life.	The exponential decay curve leads naturally to the idea of half-life.		
27(q)	Solve problems using the relation $\lambda = 0.693/t_{½}$.	Although not essential, the derivation of this relation is a valuable exercise in the use of the exponential equation.		9702/4 Nov 02, 8(c)