UNIT 3 Force Fields

Recommended Prior Knowledge Students should understand what is meant by gravitation and the acceleration of free fall (AS Unit 2). Circular motion (A2 Unit 1) is required for orbital motion. The electrostatics studied in AS Unit 3 is an essential pre-requisite for the work on electric fields.

Context In this Unit, the work on gravitational fields and electric fields (introduced in AS) is continued. Magnetic fields are also studied in preparation for A2 Unit 4 on electromagnetic induction. The three types of field are compared under the heading of 'force fields'.

Outline The Unit commences with a study of gravitational effects including fields, field strength and potential. Electric fields are then studied together with capacitance. The similarities and differences between the two types of force field are highlighted. The unit closes with a study of magnetic fields.

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 Applets do not cover the particular topic.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
	Gravitational Field			
8(a)	Show an understanding of the concept of a gravitational field as an example of field of force and define gravitational field strength as force per unit mass.	Students should study the gravitational field pattern due to a point mass and a uniform spherical mass.		
8(b)	Recall and use Newton's law of gravitation in the form $F = G(m_1m_2)/r^2$.	It should be emphasised that the law applies to point masses. For extended masses, the separation must be much greater than the dimensions of the masses.		
8(c)	Derive, from Newton's law of gravitation and the definition of gravitational field strength, the equation $g = \frac{GM}{r^2}$ for the gravitational; field strength of a point mass.	Students should appreciate that, for distances greater than the radius, a uniform homogeneous sphere behaves as if its whole mass were concentrated at its centre.		

8(d)	Recall and solve problems using the equation $g = \frac{GM}{r^2}$ for the gravitational field of a point mass.			
8(e)	Show an appreciation that on the surface of the Earth *g* is approximately constant and is called the acceleration of free fall.	The approximation $(r + h)^2 \approx r^2$ when $r >> h$ should be emphasised.		9702/4 Nov 02, 4(a)(b)
8(f)	Define potential at a point as the work done in bringing unit mass from infinity to the point.	Defining the potential at infinity as zero and the fact that gravitational forces are always attractive leads to all potentials as being negative.	See introduction Applet: Central Forces. Some of this will be used later for work on alpha particle scattering.	
8(g)	Solve problems using the equation $\Phi = \frac{GM}{r}$ for the potential in the field of a point mass.	Change in gravitational potential energy as being equal to $GMm(-\frac{1}{r_1} + \frac{1}{r_2})$ must be understood. The practice of students to state that energy = $G(m_1m_2)/r^2 \times r$ must be actively discouraged.		9702/4 Nov 02, 4(a)(b)
8(i)	Analyse circular orbits in inverse square law fields by relating the gravitational force to the centripetal acceleration it causes.	The relation $T^2 \propto d^3$ should be derived.	See introduction Applet: Kepler's laws The third law applet shows Mercury, Venus and Earth revolving round the Sun with distances and periods scaled correctly. Measurements can be taken from the screen to show the third law.	
8(j)	Show an understanding of geostationary orbits and their application.	Students should appreciate the west→east nature of the equatorial orbit as well as the period of rotation.		9702/4 May 02, 1(b)

	Electric Fields			
17(f)	Recall and use Coulomb's law in the form $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ for the force between two point charges in free space or air.	Polystyrene spheres covered with aluminium foil and suspended form nylon threads may be used as an alternative to charged rods to demonstrate electrostatic forces.		9702/4 May 02, 5(a)
17(g)	Recall and use $E = Q/4\pi\varepsilon_0 r^2$ for the field strength of a point charge in free space or air.	It may be necessary to revise the electrostatics work in AS Unit 3.		
17(h)	Define potential at a point in terms of the work done in bringing unit positive charge from infinity to the point.	Potential at infinity is defined as being zero. Potentials may be positive or negative because the forces may be repulsive or attractive. The example of parallel charged plates should be considered.	See introduction Applet: Electricity-Electric Field Lines. A particularly good starting point to enable students to visualise electric fields.	
17(i)	State that the field strength of the field at a point is numerically equal to the potential gradient at that point.			
17(j)	Use the equation $V = Q/4\pi\varepsilon_0 r$ for the potential in the field of a point charge.	Students should appreciate that, for distances greater than the radius, a charged conducting sphere behaves as if its whole charge were concentrated at its centre.		9702/4 Nov 02, 6(d) The Earth's magnetic field is familiar to students but the Earth's electric field, with a value about 300 V m^{-1} at the surface and down towards the surface is less well known.
8(h) 17(k)	Recognise the analogy between certain qualitative and quantitative aspects of gravitational field and electric field.	Students could be asked to draw up a list of similarities and differences. In order to compare the magnitudes of the forces, the ratio of the forces on two protons in a nucleus may be calculated.	Useful revision. See introduction. Applet: Central Forces. There is a good section here which relates electric field to alpha particle deflection by a gold nucleus.	
	Capacitance			
18(a)	Show an understanding of the function of capacitors in simple circuits.	Storage of charge, blocking of d.c. and for time delays may be considered.		
18(b)	Define capacitance and the farad.	Plotting a graph of *Q* against *V* leads to the concept of capacitance, the farad and $C = Q/V$. Practical units of capacitance should be considered. A worthwhile exercise is to calculate the capacitance of the Earth.		
18(c)	Recall and solve problems using $C = Q/V$.			9702/4 May 02, 5(b)(c)

18(d)	Derive, using the formula $C = Q/V$, conservation of charge and the addition of p.ds, formulae for capacitors in series and in parallel.		http://www.phy.ntnu.edu.tw/java/index.html then go to electromagnetics and on to RC circuits (DC)	
18(e)	Solve problems using formulae for capacitors in series and in parallel.			
18(f)	Deduce from the area under a potential-charge graph, the equation $W = ½QV$ and hence $W = ½CV^2$.	It may be necessary to revise $\Delta W = V\Delta Q$ from AS Unit 3.		`9702/4 Nov 02, 5(a)(b) 9702/4 May 02, 5(c)
	Magnetic fields			
21(a)	Show an understanding that a magnetic field is an example of a field of force produced either by current-carrying conductors or by permanent magnets.			All the following textbooks deal with this and the previous topic s in detail.
21(b)	Represent a magnetic field by field lines.	The field pattern due to a bar magnet and that between large parallel poles of a horseshoe magnet should be studied.		Understanding Physics for Advanced Level: Breithaupt ISBN: 0748743146
	Electromagnetism			
22(a)	Show an appreciation that a force might act on a current-carrying conductor placed in a magnetic field.	Small forces are made obvious if aluminium foil is used as the current-carrying conductor.		Physics: Hutchings ISBN 0174387318
22(b)	Recall and solve problems using the equation $F = BIl \sin\theta$, with directions as interpreted by Fleming's left-hand rule.	Aspects of the equation may be investigated by placing a horseshoe magnet on a top-pan balance and having a fixed current-carrying wire between its poles.		Physics 2: Sang (Editor) ISBN 0521797152 Advanced Physics: Duncan ISBN 0719576695
22(c)	Define magnetic flux density and the tesla.	The flux density between the poles of a horseshoe magnet may be determined.		
22(d)	Show an understanding of how the force on a current-carrying conductor can be used to measure the flux density of a magnetic field using a current balance.			AS/A-level Physics Question and Answer Guide: Crundell ISBN 0860037754
22(e)	Predict the direction of the force on a charge moving in a magnetic field.	A revision of conventional current as opposed to electron flow is important.	See introduction Applet: Electricity - Charged Particle in a	Practice in Physics: Akrill

22(f)	Recall and solve problems using $F = BQv \sin\theta$.	The 'derivation' from $F = BIl \sin\theta$ is not required but the analogy should be discussed.	Magnetic Field.	ISBN 0340758139 9702/4 Nov 02, 6(b)
22(g)	Sketch flux patterns due to a long straight wire, a flat circular coil and a long solenoid.	If iron filings are used to illustrate flux patterns, then a compass is necessary to give the direction of the field. A flux pattern includes direction. The formulae for flux density are not required.		
22(h)	Show an understanding that the field due to a solenoid may be influenced by the presence of a ferrous core.			
2(a)(9)	Use a calibrated Hall probe	Relevant features of the flux patterns in 22(g) may be shown using the probe. For example, ratio of flux density at centre and at end of a solenoid, $B \propto 1/r$ for a long straight wire etc.		
22(i)	Explain the forces between current-carrying conductors and predict the direction of the forces.	The mutual nature of the forces must be emphasised. The force may be demonstrated using two parallel lengths of aluminium foil.		
22(j)	Describe and compare the forces on mass, charge and current in gravitational, electric and magnetic fields, as appropriate.	Students could be asked to draw up a list of similarities and differences.	See introduction Applet: Electricity - 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.	9702/4 Nov 02, 6(a)