UNIT 2: motion, force and energy

Recommended Prior Knowledge Students should be able to describe the action of a force on a body. They should be able to describe the motion of a body and recognise acceleration and constant speed. They should be able to use the relationship *average speed = distance / time*. A study of aspects of Unit 1 is necessary for the understanding of the quantities and units involved.

Context Motion, force, energy and power are important aspect of physics e.g. waves and oscillations. As such, work studied in this Unit will be applied to all other units.

Outline The motion of objects is studied using graphical and mathematical techniques. The concept of momentum is introduced and conservation laws related to collisions are studied. Energy conservation is extended to cover work done in different situations and also efficiency. Power is introduced as rate of dissipation of energy.

Learning Outcomes		**Suggested Teaching Activities**	**Resources**
	Candidates should be able to		
			Reference should be made to the list of textbooks printed in the syllabus Document. Note that some of these texts are more suitable as reference texts for the teacher whilst others are more suitable as student texts. Some Internet sites are shown within certain topics. The list of sites is by no means comprehensive but provides examples of what is available. Material may provide a link with O-level and IGCSE studies, thus providing background experience, as well as reinforcing AS studies. All examples of examination questions are taken from Physics 8702 and 9702 Papers.
3.(a)	define displacement, speed, velocity and acceleration.	Discussion: distinction between distance moved and displacement distinction between speed and velocity	http://www.glenbrook.k12.il.us/gbssci/phys/class/newtlaws/newtltoc.html

		meaning of acceleration / deceleration / retardation Formal definitions.	
3.(b) 3.(d)	use graphical methods to represent displacement, speed, velocity and acceleration. use the slope of a displacement-time graph to find the velocity.	Revision of graph plotting. Displacement/time graphs: recognition of stationary object constant speed / velocity acceleration / deceleration Distinction between displacement / time and distance / time graphs.	If available: motion sensor, data logger and display to plot displacement of a pendulum bob etc. Examples sheet including Specimen Paper 1, question 7 Oct/Nov 2001, Paper 1, question 6 May/June 2001, Paper 1, question 9 May/June 2002, Paper 1, question 7
3.(e)	use the slope of a velocity-time graph to find the acceleration.	Velocity / time and speed / time graphs: recognition of constant velocity / speed constant acceleration / deceleration	If available: motion sensor, data logger and display to plot velocity of a pendulum bob, trolley moving down a slope etc.
3.(c)	find displacement from the area under a velocity-time graph.	Idea of an area *representing* a distance Techniques for finding the area – counting squares – by calculation	See the Mathematical Requirements as given in the Syllabus Document Examples sheet including Specimen Paper 1, question 8 May/June 2001, Paper 2, question 2 May/June 2002, Paper 1, question 8
3.(f)	derive, from the definitions of velocity and acceleration, equations which represent uniformly accelerated motion in a straight line.	Discussion: need for equations of motion. Derivation of $v = u + at$ from definition of constant acceleration. Derivation of $s = ut + ½at^2$ from definition of mean speed. Expt: acceleration of a ball down a slope Derivation of $v^2 = u^2 + 2as$ by combining the above two equations.	Flat board or two metre rules taped to form a channel, wood blocks, steel/glass sphere, stopclock

		Limitations on equations Use of the equations	
3.(g)	solve problems using equations which represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a uniform gravitational field without air resistance.	Worked examples on use of equations The acceleration of free fall	Examples sheet including Oct/Nov 2001, Paper 1, question 9 Guinea and feather experiment
3.(i)	describe an experiment to determine the acceleration of free fall using a falling body.	Expt: acceleration of free fall Warning: If computer packages are available, then students must still be able to give the theory of the experiment	Apparatus for experiment to determine *g* by free fall method See also Specimen Paper 1, question 9 May/June 2001, Paper 1, question 7 Oct/Nov 2001, Paper 1, question 8 Oct/Nov 2001, Paper 2 question 2 May/June 2002, Paper 1, question 4
3.(j)	describe qualitatively the motion of bodies falling in a uniform gravitational field with air resistance.	Effect of air resistance – air resistance increases with speed. Discussion of motion of body falling through air - increasing speed gives rise to increasing drag and reducing acceleration thus leading to terminal speed.	Guinea and feather.
5.(c)	show a qualitative understanding of frictional forces and viscous forces including air resistance. (No treatment of the coefficients of friction and viscosity is required.)	Expt: Factors affecting terminal speed in fluids Other friction forces – all friction is not 'evil'.	Measuring cylinders with different liquids, steel balls of various diameters, stopwatch, metre rule See also May/June 2002, Paper 1, question 6

3.(k)	describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction.	Revision of resolution of vectors Plotting out trajectories on graph paper Worked examples based on trajectories N.B. formulae for (maximum) range and height are not required.	'Monkey and gun' experiment Handout of examples including Specimen Paper 2, question 2 May/June 2001, Paper 1, question 8 Oct/Nov 2001, Paper 1, question 7
4.(f)	recall and solve problems using the relationship $F = ma$, appreciating that acceleration and force are always in the same direction.	Discussion: what causes an acceleration? Expt: relation between force and acceleration	Ticker timer, tape, trolleys, elastic bands, metre ruler and/or Linear air track, timers, metre rule and/or trolleys and runway, motion sensor, data logger and means of display
4.(b)	show an understanding that mass is the property of a body that resists change in motion.	Discussion: what is mass? Equations $F \propto a$, $F = ma$, m and a are base/derived units, leading to definition of the unit of force (newton	Objects with different masses – estimating masses newton balances, estimating forces See also Oct/Nov 2001, Paper 1, question 12 May/June 2001, Paper 1, question 11, 13 May/June 2002, Paper 1, question 10
4.(c) 3.(h)	describe and use the concept of weight as the effect of a gravitational field on a mass. recall that the weight of a body is equal to the product of its mass and the acceleration of free fall.	Discussion: what is weight? weight = mass $\times$ g g as m s^{-2} or N kg^{-1} Compare/contrast mass and weight	Exercise on base units of N kg^{-1} and m s^{-2} See also Oct/Nov 2001, Paper 2, question 1
5.(a)	Describe the forces on mass (and charge) in a uniform gravitational (and electric) fields, as appropriate	Discussion: force on mass is - in direction of the field (acceleration) - independent of speed of mass - equal to mg	

5.(e)	show an understanding that the weight of a body may be taken as acting at a single point known as its centre of gravity.	Discussion: what is centre of gravity? refer briefly to centre of mass Expt: determination of C.G. of a lamina	lamina, pin and cork, plumbline, stand, boss, clamp See also Oct/Nov 2001, Paper 3, question 1 May/June 2002, Paper 2, question 3(a) http://www.tri.co.uk/ncap_tests.html
4.(d)	define linear momentum as the product of mass and velocity.	Discussion: idea of 'violence' of a collision depends on mass and velocity Develop definition of momentum	
4.(e)	define force as rate of change of momentum.	Definition of force - direction of force / change in momentum - concept of impulse Worked example of rocket motor	See also Specimen Paper 1, question 11, 13 May/June, Paper 1, question 10
4.(a)	state each of Newton's laws of motion.	Laws developed as 'common sense' from previous knowledge	http://www.treasure-troves.com/bios/Newton.html http://www.phys.virginia.edu/classes/109N/more_stuff/Applets/newt/newtmtn.html
4.(g)	state the principle of conservation of momentum.	Idea of a 'collision' and a closed system Statement of law of conservation of momentum Expt. 'Verification' of the law Law of conservation of momentum as a consequence of Newton's laws	See also Specimen Paper 1, question 10 2 trolleys and masses, runway, 2 timers, ticker tape OR linear air track, 2 timers and light gates OR use of trolleys/ linear air track with motion sensors, data loggers and means of display.

4.(h)	apply the principle of conservation of momentum to solve simple problems including elastic and inelastic interactions between two bodies in one dimension. (Knowledge of the concept of coefficient of restitution is not required).	Worked examples (illustrated if possible) including - colliding spheres (newton's cradle) - impact of a ball with a solid surface - magnetic/electrostatic interaction	Newton's cradle air table (if available) linear air track (if available)
4.(i) 4.(j)	recognise that, for a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation. show an understanding that, whilst momentum of a system is always conserved in interactions between bodies, some change in kinetic energy usually takes place.	Discussion: elastic and inelastic collisions Conservation (or otherwise) of total energy, linear momentum and kinetic energy. Examples of elastic and inelastic collisions	Examples sheet including Specimen Paper 2, question 3(a), 3(c) May/June 2001, Paper 1, question 12 May/June 2001, Paper 2, question 3 Oct/Nov 2001, Paper 1, question 13 May/June 2002, Paper 1, question 9, 11 May/June 2002, Paper 2 , question 4(c),(d)
9.(a)	define the term density	Discussion; definition of density Estimations/typical values of density of substances	Handout giving some values of density of various substances See also Specimen Paper 2, question 5
9.(g)	derive, from the definitions of pressure and density, the equation $p = \rho gh$	Revision: definition of pressure unit of pressure	
9.(h)	use the equation $p = \rho gh$	Pressure in a liquid – dependence (if at all) on - direction - shape of vessel - depth Derivation of equation $p = \rho gh$ - incompressible fluid - pressure due to fluid only Use of a manometer Expt: measuring gas supply or lung pressure The mercury barometer and atmospheric pressure	water-filled balloons Pascal's vases (or equivalent) plastic bottle with holes drilled down one side water manometer, metre rule Mercury barometer (if available) Examples sheet including Specimen Paper 1, question 21 May/June 2001, Paper 1, question 23 Oct/Nov 2001, Paper 1, question 22

5.(b)	show an understanding of the origin of the upthrust acting on a body in a fluid.	meaning of an upthrust in a fluid Expt: measuring an upthrust Discussion on the origin of the upthrust. Mention of flotation/submarines as illustrations	Containers of water and other liquids such as cooking oil, ethanol See also Oct/Nov 2001, Paper 2, question 4(a), 4(b) Oct/Nov 2001, Paper 1, question 14 May/June 2002, Paper 1, question 12, 14
5.(f)	show an understanding that a couple is a pair of forces which tends to produce rotation only.	Discussion: force(s) producing rotation Single force – turning effect and moment of a force	Suspended metre rule, newton meters, thread, protractor http://www.explorescience.com
5.(g)	define and apply the moment of a force and the torque of a couple.	Two forces – a couple and torque (turning effect) of a couple	See also Specimen Paper 1, question 14 Specimen Paper 2, question 4(c) Oct/Nov 2001, Paper 1, question 10, 11, 16 May/June 2002, Paper 1, question 13
5.(h)	show an understanding that, when there is no resultant force and no resultant torque, a system is in equilibrium.	Discussion: what is meant by equilibrium? - no resultant force *in any direction* - no resultant moment *about any point*	See also May/June 2001, Paper 1, question 15, 17 May/June 2002, Paper 2 , question 3(b)
5.(i)	apply the principle of moments.	Principle of moments defined (as one condition for equilibrium) Expt: verification of principle Revision of centre of gravity Worked examples	metre rule, pin and cork, stand, boss, clamp, thread, various weights, pulley, protractor Examples sheet including Specimen Paper 1, question 16 Specimen Paper 2, question 3(a), 3(b) Oct/Nov 2001, Paper 2, question 3(a), 3(b) May/June 2001, Paper 1, question 14, 16 Oct/Nov 2001, Paper 1, question 17

5.(d)	use a vector triangle to represent forces in equilibrium.	Discussion: equilibrium of a body under the action of three forces - lines of action must pass through one point - revision of vector triangles and use for forces in equilibrium	Examples sheet including Specimen Paper 1, question 3, 12, 15 Oct/Nov 2001, Paper 1, question 15 May/June 2002, Paper 1, question 15
6.(b)	show an understanding of the concept of work in terms of the product of a force and the displacement in the direction of the force.	Discussion: what is work? - definition of work done - units - N m as work done and moment of a force!	
6.(c)	calculate the work done in a number of situations including the work done by a gas which is expanding against a constant external pressure: $W = p\Delta V$.	$W = p\Delta V$ derived as an example of the use of $W = Fx$ Work done on/by gas discussed	See also May/June 2001, Paper 1, question 19, 20 Oct/Nov 2001, Paper 1, question 20
6.(h)	derive, from the defining equation $W = Fs$, the formula $E_p = mgh$ for potential energy changes near the Earth's surface.	$E_p = mgh$ derived as an example of use of $W = Fx$	
6.(i)	recall and use the formula $E_p = mgh$ for potential energy changes near the Earth's surface.	Potential energy changes discussed	
6.(d)	derive, from the equations of motion, the formula $E_k = ½mv^2$.	Revision of equations of motion Derivation of $Fx = ½mv^2 - ½mu^2$ Homogeneity of equation gives each term as energy, hence $E_k = ½mv^2$	
6.(e)	recall and apply the formula $E_k = ½mv^2$.	Discussion: $E_k – E_p$ exchanges e.g. simple pendulum, falling object leading to principle of conservation of energy Worked examples	Examples sheet including Specimen Paper 1, question 18, 20 Specimen Paper 2, question 3(b) Oct/Nov 2001, Paper 2, question 3(c) May/June 2002, Paper 1, question 18

6.(a)	give examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation to simple examples.	Discussion: different forms of energy Discussion: examples of energy transfers	
6.(f)	distinguish between gravitational potential energy, (electric potential energy) and elastic potential energy	Discussion: elastic energy as energy due to non-permanent change of shape	See also May/June 2002, Paper 2 , question 5(a), (c)
6.(j)	show an understanding of the concept of internal energy.	Internal energy as sum of random kinetic energy and potential energy of atoms. Difference between random and ordered kinetic energy	
6.(g)	show an understanding and use the relationship between force and potential energy in a uniform field to solve problems.	Discussion: plotting ΔE_p against Δh, what does the gradient represent? Worked example for object on the Moon.	
6.(k)	show an appreciation for the implications of energy losses in practical devices and use the concept of efficiency to solve problems.	Energy 'losses' related to energy conservation. Role of friction forces. Efficiency defined. Expt: efficiency of an electric motor Worked examples	Either voltmeter, ammeter or joulemeter. Low voltage motor, thread, weights, stopclock, metre rule. Examples sheet including Specimen Paper 1, question 19 Oct/Nov 2001, Paper 1, question 19 May/June 2002, Paper 1, question 16

6.(l)	define power as work done per unit time and derive power as the product of force and velocity.	Discussion: what is power? - it is not force - power defined - units of power Expt: measuring output power of person Expt: measuring output power of a motor Derivation of power = *Fv* Worked Examples	 Stairs. Bathroom scales, metre rule, stopclock Low voltage motor, thread weights, metre rule, stopclock Examples sheet including Specimen Paper 1, question 17 May/June 2001, Paper 1, question 18 Oct/Nov 2001, Paper 1, question 18 May/June 2002, Paper 1, question 19