2013 Physics

Advanced Higher

Finalised Marking Instructions

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Part One: General Marking Principles for Physics – Advanced Higher

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this Paper. These principles must be read in conjunction with the specific Marking Instructions for each question.

(a) Marks for each candidate response must always be assigned in line with these general marking principles and the specific Marking Instructions for the relevant question.

GENERAL MARKING ADVICE: Physics – Advanced Higher

The marking schemes are written to assist in determining the "minimal acceptable answer" rather than listing every possible correct and incorrect answer. The following notes are offered to support Markers in making judgements on candidates' evidence, and apply to marking both end of unit assessments and course assessments.

1. **Numerical Marking**

   (a) The fine divisions of marks shown in the marking scheme may be recorded within the body of the script beside the candidate's answer. If such marks are shown they must total to the mark in the inner margin.

   (b) The number recorded should always be the marks being awarded.
   The number out of which a mark is scored SHOULD NEVER BE SHOWN AS A DENOMINATOR. (½ mark will always mean one half mark and never 1 out of 2.)

   (c) Where square ruled paper is enclosed inside answer books it should be clearly indicated that this item has been considered. Marks awarded should be transferred to the script booklet inner margin and marked G.

   (d) The total for the paper should be rounded up to the nearest whole number.

2. **Other Marking Symbols which may be used**

TICK	–	Correct point as detailed in scheme, includes data entry.
SCORE THROUGH	–	Any part of answer which is wrong. (For a block of wrong answer indicate zero marks.) Excess significant figures.
INVERTED VEE	–	A point omitted which has led to a loss of marks.
WAVY LINE	–	Under an answer worth marks which is wrong only because a wrong calculated value has been carried forward from a previous part.
"G"	–	Reference to a graph on separate paper. You MUST show a mark on the graph paper and the SAME mark on the script.
"X"	–	Wrong Physics
✳	–	Wrong order of marks

No other annotations are allowed on the scripts.

3. **General Instructions (Refer to National Qualifications Marking Instructions Booklet)**

(a) No marks are allowed for a description of the wrong experiment or one which would not work.
Full marks should be given for information conveyed correctly by a sketch.

(b) Surplus answers: where a number of reasons, examples etc are asked for and a candidate gives more than the required number then wrong answers may be treated as negative and cancel out part of the previous answer.

(c) Full marks should be given for a correct answer to a numerical problem even if the steps are not shown explicitly. The part marks shown in the scheme are for use in marking partially correct answers.

However, when the numerical answer is given or a derivation of a formula is required every step must be shown explicitly.

(d) Where 1 mark is shown for the final answer to a numerical problem ½ mark may be deducted for an incorrect unit.

(e) Where a final answer to a numerical problem is given in the form 3^{-6} instead of 3×10^{-6} then deduct ½ mark.

(f) Deduct ½ mark if an answer is wrong because of an arithmetic slip.

(g) No marks should be awarded in a part question after the application of a wrong physics principle (wrong formula, wrong substitution) **unless specifically allowed for in the marking scheme – eg marks can be awarded for data retrieval.**

(h) In certain situations, a wrong answer to a part of a question can be carried forward within that part of the question. This would incur no further penalty provided that it is used correctly. Such situations are indicated by a horizontal dotted line in the marking instructions.

Wrong answers can always be carried forward to the next part of a question, over a solid line without penalty.

The exceptions to this are:

- where the numerical answer is given
- where the required equation is given.

(i) ½ mark should be awarded for selecting a formula.

(j) Where a triangle type "relationship" is written down and then not used or used incorrectly then any partial ½ mark for a formula should not be awarded.

(k) In numerical calculations, if the correct answer is given then converted wrongly in the last line to another multiple/submultiple of the correct unit then deduct ½ mark.

(l) Significant figures.

Data in question is given to 3 significant figures.

Correct final answer is 8·16J.

Final answer 8·2J or 8·158J or 8·1576J – No penalty.

Final answer 8J or 8·15761J – Deduct ½ mark.

Candidates should be penalised for a final answer that includes:

- three or more figures too many

  or

- two or more figures too few. **ie accept two higher and one lower.**

Max ½ mark deduction per question. Max 2½ deduction from question paper.

(m) Squaring Error

$E_K = ½ mv^2 = ½ \times 4 \times 2^2 = 4J$ **Award 1½** Arith error

$E_K = ½ mv^2 = ½ \times 4 \times 2 = 4J$ **Award ½ for formula.** Incorrect substitution.

The General Marking Instructions booklet should be brought to the markers' meeting.

Physics – Marking Issues

The current in a resistor is 1·5 amperes when the potential difference across it is 7·5 volts. Calculate the resistance of the resistor.

	Answers	Mark + comment	Issue
1.	$V=IR$ $7{\cdot}5=1{\cdot}5R$ $R=5{\cdot}0\Omega$	(½) (½) (1)	Ideal Answer
2.	$5{\cdot}0\Omega$	(2) Correct Answer	GMI 1
3.	5·0	(1½) Unit missing	GMI 2(a)
4.	$4{\cdot}0\Omega$	(0) No evidence/Wrong Answer	GMI 1
5.	______Ω	(0) No final answer	GMI 1
6.	$R=\frac{V}{I}=\frac{7{\cdot}5}{1{\cdot}5}=4{\cdot}0\,\Omega$	(1½) Arithmetic error	GMI 7
7.	$R=\frac{V}{I}=4{\cdot}0\,\Omega$	(½) Formula only	GMI 4 and 1
8.	$R=\frac{V}{I}=$______Ω	(½) Formula only	GMI 4 and 1
9.	$R=\frac{V}{I}=\frac{7{\cdot}5}{1{\cdot}5}=$______Ω	(1) Formula + subs/No final answer	GMI 4 and 1
10.	$R=\frac{V}{I}=\frac{7{\cdot}5}{1{\cdot}5}=4{\cdot}0$	(1) Formula + substitution	GMI 2(a) and 7
11.	$R=\frac{V}{I}=\frac{1{\cdot}5}{7{\cdot}5}=5{\cdot}0\,\Omega$	(½) Formula but wrong substitution	GMI 5
12.	$R=\frac{V}{I}=\frac{75}{1{\cdot}5}=5{\cdot}0\,\Omega$	(½) Formula but wrong substitution	GMI 5
13.	$R=\frac{I}{V}=\frac{7{\cdot}5}{1{\cdot}5}=5{\cdot}0\,\Omega$	(0) Wrong formula	GMI 5
14.	$V=IR\quad 7{\cdot}5=1{\cdot}5\times R$ $R=0{\cdot}2\,\Omega$	(1½) Arithmetic error	GMI 7
15.	$V=IR$ $R=\frac{I}{V}=\frac{1{\cdot}5}{7{\cdot}5}=0{\cdot}2\,\Omega$	(½) Formula only	GMI 20

Data Sheet

Common Physical Quantities

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Gravitational acceleration on Earth	g	$9{\cdot}8\ \text{ms}^{-2}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\text{kg}$
Radius of Earth	R_E	$6{\cdot}4 \times 10^{6}\text{m}$	Charge on electron	e	$-1{\cdot}60 \times 10^{-19}\text{C}$
Mass of Earth	M_E	$6{\cdot}0 \times 10^{24}\text{kg}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\text{kg}$
Mass of Moon	M_M	$7{\cdot}3 \times 10^{22}\text{kg}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\text{kg}$
Radius of Moon	R_M	$1{\cdot}7 \times 10^{6}\text{m}$	Mass of alpha particle	m_α	$6{\cdot}645 \times 10^{-27}\text{kg}$
Mean Radius of Moon Orbit		$3{\cdot}84 \times 10^{8}\text{m}$	Charge on alpha particle		$3{\cdot}20 \times 10^{-19}\text{C}$
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}\text{m}^3\text{kg}^{-1}\text{s}^{-2}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\text{Js}$
Speed of light in vacuum	c	$3{\cdot}0 \times 10^{8}\text{ms}^{-1}$	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}\text{Fm}^{-1}$
Speed of sound in air	v	$3{\cdot}4 \times 10^{2}\text{ms}^{-1}$	Permeability of free space	μ_0	$4\pi \times 10^{-7}\text{Hm}^{-1}$

Refractive Indices

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Glycerol	1·47
Glass	1·51	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49	Magnesium Fluoride	1·38

Spectral Lines

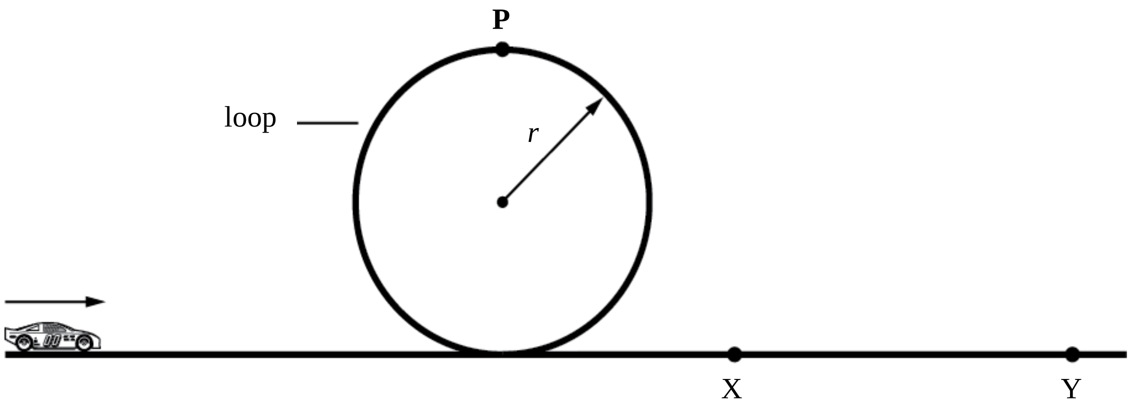
Element	*Wavelength*/nm	*Colour*	*Element*	*Wavelength*/nm	*Colour*
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet		*Lasers*	
	397	Ultraviolet	*Element*	*Wavelength*/nm	*Colour*
	389	Ultraviolet	Carbon dioxide	9550 10590	Infrared
Sodium	589	Yellow	Helium-neon	633	Red

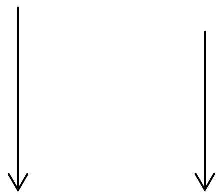
Properties of selected Materials

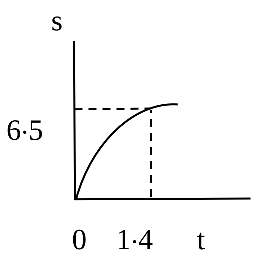
Substance	*Density/* kg m^{-3}	*Melting Point*/K	*Boiling Point*/K	*Specific Heat Capacity/* Jkg^{-1} K^{-1}	*Specific Latent Heat of Fusion/* Jkg^{-1}	*Specific latent Heat of Vaporisation*/Jkg^{-1}
Aluminium	$2{\cdot}70 \times 10^3$	933	2623	$9{\cdot}02 \times 10^2$	$3{\cdot}95 \times 10^5$	….
Copper	$8{\cdot}96 \times 10^3$	1357	2853	$3{\cdot}86 \times 10^2$	$2{\cdot}05 \times 10^5$	….
Glass	$2{\cdot}60 \times 10^3$	1400	….	$6{\cdot}70 \times 10^2$	….	….
Ice	$9{\cdot}20 \times 10^2$	273	….	$2{\cdot}10 \times 10^3$	$3{\cdot}34 \times 10^5$	….
Gylcerol	$1{\cdot}26 \times 10^3$	291	563	$2{\cdot}43 \times 10^3$	$1{\cdot}81 \times 10^5$	$8{\cdot}30 \times 10^5$
Methanol	$7{\cdot}91 \times 10^2$	175	338	$2{\cdot}52 \times 10^3$	$9{\cdot}9 \times 10^4$	$1{\cdot}12 \times 10^6$
Sea Water	$1{\cdot}02 \times 10^3$	264	377	$3{\cdot}93 \times 10^3$	….	….
Water	$1{\cdot}00 \times 10^3$	273	373	$4{\cdot}19 \times 10^3$	$3{\cdot}34 \times 10^5$	$2{\cdot}26 \times 10^6$
Air	1·29	….	….	….	….	….
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^4$	….	$4{\cdot}50 \times 10^5$
Nitrogen	1·25	63	77	$1{\cdot}04 \times 10^3$	….	$2{\cdot}00 \times 10^5$
Oxygen	1·43	55	90	$9{\cdot}18 \times 10^2$	….	$2{\cdot}40 \times 10^5$

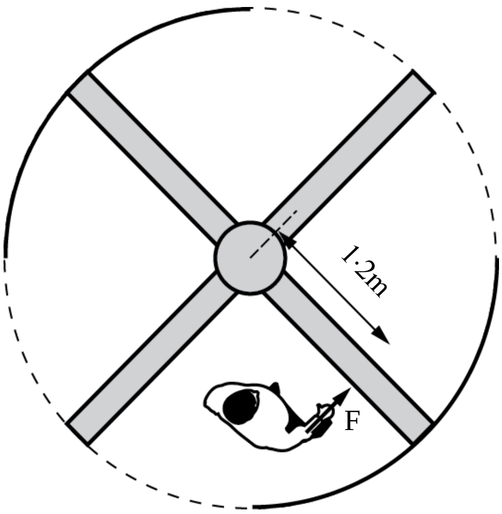
The gas densities refer to a temperature of 273 K and pressure of $1{\cdot}01 \times 10^5$ Pa.

Part Two: Marking Instructions for each Question

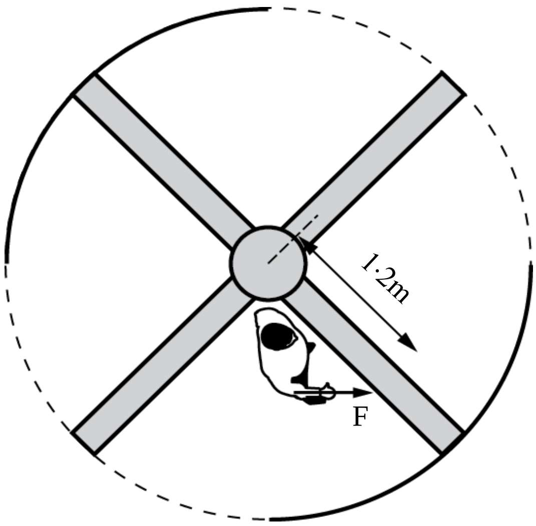
Question			Expected Answer/s	Max Mark	Additional Guidance
1			**A stunt driver is attempting to "loop the loop" in a car as shown in Figure 1.** **Before entering the loop the car accelerates along a horizontal track.**		
			 Figure 1		
			The radius r of the circular loop is 6·2 m. **The total mass of the car and driver is 870 kg.**		
	a		**Show that the car must have a minimum speed of 7·8 m s^{-1} at point P to avoid losing contact with the track.** $\frac{mv^2}{r} = mg$ (½) for both eqns (½) for equality $\frac{v^2}{r} = g$ $9.8 = \frac{v^2}{6.2}$ (½ for substitution ½ for data) = 7·8 (m s^{-1}) SHOW QUESTION	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
1	b		**During one attempt the car is moving at a speed of 9·0 m s^{-1} at point P.**		
		i	**Draw a labelled diagram showing the vertical forces acting on the car at point P.**  weight (½) reaction (½)	1	
1	b	ii	**Calculate the size of each force.** $\frac{mv^2}{r} = 11000N$ (½) eqn + (½) value Weight = mg = 870 × 9·8 = 8500N (½) eqn + (½) value R = 11000 – 8500 (½) subtraction = 2500N (½) Subtract ½ if N does not appear on final answer	3	.

Question			Expected Answer/s	Max Mark	Additional Guidance
1	c		**When the car exits the loop the driver starts braking at point X. For one particular run the displacement of the car from point X until the car comes to rest at point Y is given by the equation** $\boldsymbol{s = 9{\cdot}1t - 3{\cdot}2\, t^2}$ **Sketch a graph to show how the displacement of the car varies with time between points X and Y.** **Numerical values are required on both axes.** By differentiation $v = 9{\cdot}1 - 6{\cdot}4t$ for $v = 0$, $t = 1{\cdot}4$ (s) (1) Max displacement, $s = 9{\cdot}1t - 3{\cdot}2t^2$ $s = (9{\cdot}1 \times 1{\cdot}4) - (3{\cdot}2 \times 1{\cdot}4^2)$ $s = 6{\cdot}5$ (m) (1)  shape (1) NB No units required.	**3**	

Question			Expected Answer/s	Max Mark	Additional Guidance
2			**The entrance to a building is through a revolving system consisting of 4 doors that rotate around a central axis as shown in Figure 2A.**  Figure 2A **The moment of inertia of the system about the axis of rotation is 54 kg m^2. When it rotates, a constant frictional torque of 25 N m acts on the system.**		
	a		**The system is initially stationary. On entering the building a person exerts a constant force F perpendicular to a door at a distance of 1·2 m from the axis of rotation as shown in Figure 2B.**  Figure 2B **The angular acceleration of the system is 2·4 rad s^{-2}.**		

Question			Expected Answer/s	Max Mark	Additional Guidance
2	a	i	**(Cont.)** **Calculate the magnitude of the applied force F.** Unbalanced torque = I α (½) = 54 × 2·4 = 129·6 (Nm) (½) Applied torque = 129·6 + 25 = 154·6 (Nm) (½) - - - - - - - - - - Applied torque = $F \times r$ (½) 154·6 = $F \times 1{\cdot}2$ F = 130 N (1)	3	
2	a	ii	**The applied force is removed and the system comes to rest in 3·6 s.** **Calculate the angular displacement of the door during this time.** $\alpha = \frac{T}{I} = \frac{(-)25}{54} = (-)0 \cdot 46(\text{rads}^{-2})$ (½ eqn + ½ answer) $\omega = \omega_o + \alpha t$ $0 = \omega_o + (-0{\cdot}46 \times 3{\cdot}6)$ $\omega_o = 1{\cdot}67$ (rad s^{-1}) (½) both equations of motion (½) $\theta = \omega_o t + \frac{1}{2}\alpha t^2$ = (1·67 × 3·6) + (0·5 × -0·46 × 3·6^2) = 3·0 rad (1)	3	

Question			Expected Answer/s	Max Mark	Additional Guidance
2	b		**On exiting the building the person exerts the same magnitude of force F on a door at the same distance from the axis of rotation.** **The force is now applied as shown in Figure 2C.**  Figure 2C **How does the angular acceleration of the door system compare to that given in part (*a*)?** **Justify your answer.** Acceleration is less (1) Applied torque is less (1) Or (Component of) applied force perpendicular to door is less (1)	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
3			**Planets outside our solar system are called exoplanets.** **One exoplanet moves in a circular orbit around a star as shown in Figure 3.**		

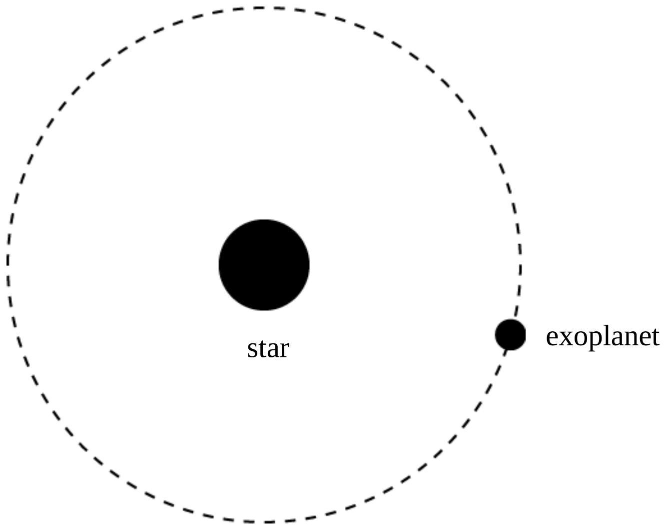


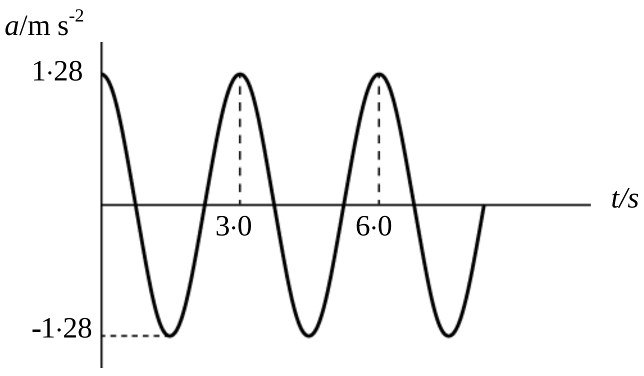
Figure 3

Question			Expected Answer/s	Max Mark	Additional Guidance
			The period of orbit is 14 days. The mass M_s of the star is $1 \cdot 7 \times 10^{30}$ kg.		
	a	i	**Show that the radius of the orbit can be given by the relationship** $$r^3 = GM_s \frac{T^2}{4\pi^2}$$ **where the symbols have their usual meaning.**		

Question			Expected Answer/s	Max Mark	Additional Guidance
3	a	i	**(Cont.)** $\frac{mv^2}{r} = \frac{GMm}{r^2}$ Both equations (½) equality (½) $\frac{v^2}{r} = \frac{GM}{r^2}$ MUST STATE $v = \frac{2\pi r}{T}$ (½) $r = \frac{Gm}{v^2} = \frac{GMT^2}{4\pi^2 r^2}$ for correct substitution (½) $r^3 = \frac{GMT^2}{4\pi^2}$ **SHOW THAT**	2	OR $m\omega^2 r = \frac{GMm}{r^2}$ (½) + (½) $\omega^2 = \frac{GM}{r^3}$ MUST STATE $\omega = \frac{2\pi}{T}$ (½) $\frac{4\pi^2}{T^2} = \frac{GM}{r^3}$ for correct substitution (½) $r^3 = \frac{GMT^2}{4\pi^2}$
3	a	ii	Calculate the radius of this orbit. $r^3 = GM\frac{T^2}{4\pi^2}$ $= \frac{6 \cdot 67 \times 10^{-11} \times 1 \cdot 7 \times 10^{30} \times (14 \times 24 \times 3600)^2}{4 \times \pi^2}$ **(½)** $r = 1{\cdot}6 \times 10^{10}$ m (½)	1	If time not converted to seconds then 0 marks

Question			Expected Answer/s	Max Mark	Additional Guidance
3	b		**The radius of the exoplanet is $1{\cdot}2 \times 10^8$ m and its mass is $5{\cdot}4 \times 10^{26}$ kg.** **Calculate the value of the gravitational field strength *g* on the surface of the exoplanet.** $mg = \frac{GMm}{r^2}$ both equations (½) equality (½) $g = \frac{GM}{r^2} = \frac{6\cdot67\times10^{-11}\times5\cdot4\times10^{26}}{(1\cdot2\times10^8)^2}$ $= 2{\cdot}5$ N kg^{-1} (1)	2	
3	c		**Astrophysicists have identified many black holes in the universe.**		
		i	**State what is meant by the term *black hole*.** An object with an escape velocity greater than the speed of light.	1	
3	c	ii	**A newly discovered object has a mass of $4{\cdot}2 \times 10^{30}$ kg and a radius of $2{\cdot}6 \times 10^4$ m.** **Show by calculation whether or not this object is a black hole.** escape velocity $v = \sqrt{\frac{2GM}{r}}$ (½) $= \sqrt{\frac{2\times4\cdot2\times10^{30}\times6\cdot67\times10^{-11}}{2\cdot6\times10^4}}$ (½) $= 1{\cdot}5 \times 10^8$ m s^{-1} (½) not a black hole (½)	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
4			**A “saucer” swing consists of a bowl shaped seat of mass 1·2 kg suspended by four ropes of negligible mass as shown in Figure 4A.**  Figure 4A **When the empty seat is pulled back slightly from its rest position and released, its motion approximates to simple harmonic motion.**		
	a		**Define the term *simple harmonic motion.*** Acceleration/unbalanced force is directly proportional to displacement (½) And in the opposite direction/directed towards the equilibrium position. (½)	1	

Question			Expected Answer/s	Max Mark	Additional Guidance
4	b		**The acceleration-time graph for the seat with no energy loss is shown in Figure 4B.**  Figure 4B		
		i	**Show that the amplitude of the motion is 0·29 m.** $a = 1{\cdot}28\ \text{m s}^{-2}$ (from graph) (½) T = 3.0s (½) $a = (-)\ \omega^2 y$ (½) $\omega = \frac{2\pi}{T}$ (½) Can be implied by substitution. No need to explicitly state in this question only $= 2{\cdot}1\ (\text{rad s}^{-1})$ (½) $1.28 = (-)2{\cdot}1^2\ y$ (½) (= 0·29 m) SHOW QUESTION	3	

Question			Expected Answer/s	Max Mark	Additional Guidance
4	b	ii	**Calculate the velocity of the seat when its displacement is 0·10 m.** $v = (\pm)\omega\sqrt{A^2 - y^2}$ (½) $= (\pm)2 \cdot 1\sqrt{0 \cdot 29^2 - 0 \cdot 10^2}$ (½) = (±) 0·57 m s^{-1} (1)	2	
4	c		**Calculate the displacement of the seat when the kinetic energy and potential energy are equal.** ($E_k = E_p$) $\frac{1}{2} m\omega^2 A^2 - \frac{1}{2} m\omega^2 y^2 = \frac{1}{2} m\omega^2 y^2$ **(½) for E_k** **(½) for E_p** OR $\frac{1}{2} m\omega^2 A^2 = m\omega^2 y^2$ $\frac{1}{2} A^2 = y^2$ (½) $y^2 = 0 \cdot 5 \times 0 \cdot 29^2$ (½) y = 0·21 m (1)	3	

Question			Expected Answer/s	Max Mark	Additional Guidance
5			**The Bohr model of the atom suggests that the angular momentum of an electron orbiting a nucleus is quantised.** **A hydrogen atom consists of a single electron orbiting a single proton. Figure 5 shows some of the possible orbits for the electron in a hydrogen atom.**		

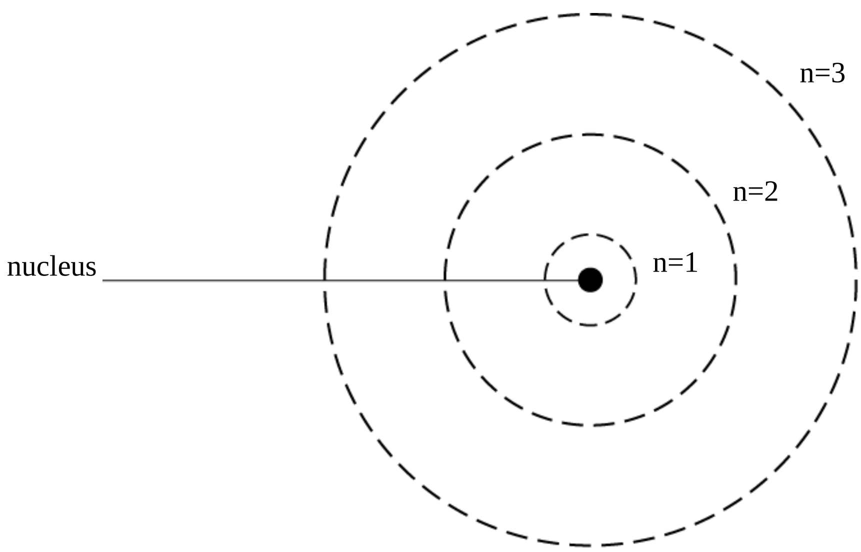


Figure 5

The table shows the values of the radii for the first three orbits.

Orbit number, n	*Orbital radius*/10^{-10} m
1	0·53
2	2·1
3	4·8

Question			Expected Answer/s	Max Mark	Additional Guidance
5	a	i	**Calculate the speed of the electron in orbit number 3.** $mvr = \frac{nh}{2\pi}$ (½) (½) $9.11\times10^{-31} \times v \times 4.8\times10^{-10} = \frac{3\times6\cdot63\times10^{-34}}{2\times\pi}$ $v = 7{\cdot}2 \times 10^5$ m s^{-1} (1) Rounding might give 7.3×10^5 ms^{-1}	2	Alternatively $\frac{mv^2}{r} = \frac{Q_1Q_2}{4\pi\varepsilon_o r^2}$ $v^2 = \frac{Q_1Q_2}{4\pi\varepsilon_o mr}$ $= \frac{(1\cdot6\times10^{-19})^2}{4\times\pi\times8\cdot85\times10^{-12}\times9\cdot11\times10^{-31}\times4\cdot8\times10^{-10}}$ $v = 7{\cdot}3 \times 10^5$ m s^{-1} Rounding might give 7.2×10^5 ms^{-1}
5	a	ii	**Calculate the de Broglie wavelength associated with this electron.** $\lambda = \frac{h}{p}$ $= \frac{h}{mv}$ (½) $= \frac{6\cdot63\times10^{-34}}{9\cdot11\times10^{-31}\times7\cdot2\times10^5}$ (½) $= 1{\cdot}0 \times 10^{-9}$ m (1)	2	
5	a	iii	**What is the name given to the branch of physics that treats electrons as waves and predicts their position in terms of probability?** Quantum mechanics	1	

Question			Expected Answer/s	Max Mark	Additional Guidance
5	b		**Compare the magnitudes of the electrostatic and gravitational forces between an electron in orbit number 1 and the proton in the nucleus.** **Justify your answer by calculation.** $F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$ $= \frac{(1.6 \times 10^{-19})^2}{4 \times \pi \times 8.85 \times 10^{-12} \times (5.3 \times 10^{-11})^2}$ (½) $= 8{\cdot}2 \times 10^{-8}$ (N) (½) **Both equations** (½) $F = \frac{G m_1 m}{r^2}$ $= \frac{6.67 \times 10^{-11} \times 9.11 \times 10^{-31} \times 1.673 \times 10^{-27}}{(5.3 \times 10^{-11})^2}$ (½) $= 3{\cdot}6 \times 10^{-47}$ (N) (½) ie electrostatic force is (much) greater than the gravitational force (½)	3	

Question			Expected Answer/s	Max Mark	Additional Guidance
6			**A research physicist is investigating collisions between protons and the nuclei of metallic elements. Protons are accelerated from rest across a potential difference of 4·0 MV. The protons move through a vacuum and collide with a metal target as shown in Figure 6A.**		

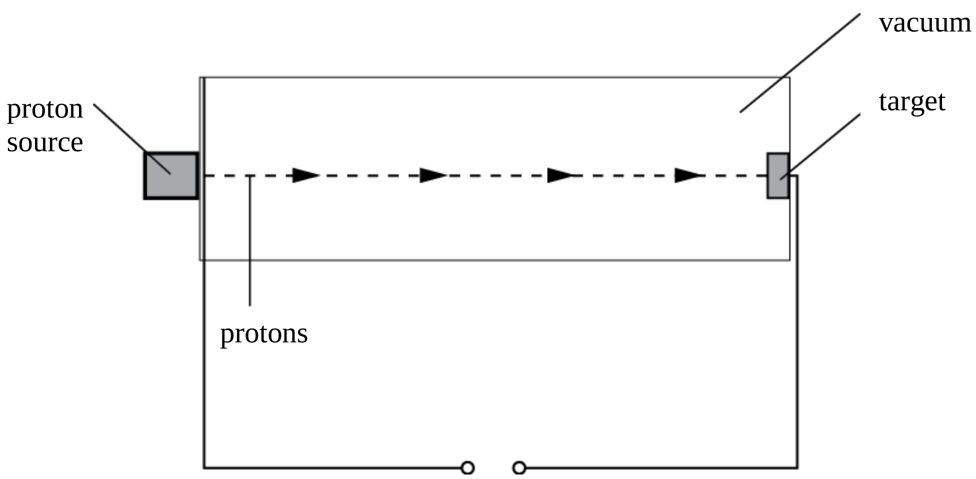


Figure 6A

Question			Expected Answer/s	Max Mark	Additional Guidance
	a	i	**Calculate the maximum speed of the protons as they hit the target.** $q \times V = ½ \times m \times \upsilon^2$ (½) $1{\cdot}60 \times 10^{-19} \times 4{\cdot}0 \times 10^{6} = ½ \times 1{\cdot}673 \times 10^{-27} \times v^2$ (½) $\upsilon^2 = 7{\cdot}65 \times 10^{14}$ $\upsilon = 2{\cdot}8 \times 10^{7}$ ms^{-1} (1)	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
6	a	ii	**In one test the researcher uses zirconium as the target. A proton of charge *q* and velocity *v* travels directly towards a zirconium nucleus as shown in Figure 6B. The zirconium nucleus has charge *Q*.**  Figure 6B **Show that the distance of closest approach *r* to the metal target is given by** $$r = \frac{qQ}{2\pi\varepsilon_o mv^2}$$ **where the symbols have their usual meaning.**		
			$\frac{1}{2} \times m \times v^2 = \frac{qQ}{4\pi\varepsilon_o r}$ (1) $r = \frac{qQ}{2\times\pi\times\varepsilon_o\times m\times v^2}$	1	
6	a	iii	**Calculate the distance of closest approach for a proton travelling towards a zirconium nucleus in the target.** $Q = 40 \times 1{\cdot}6 \times 10^{-19}$ (1) $= 6{\cdot}4 \times 10^{-18}$ $r = \frac{qQ}{2\times\pi\times\varepsilon_o\times m\times v^2}$ $= \frac{1{\cdot}60\times10^{-19}\times 6{\cdot}4\times10^{-18}}{2\times\pi\times8{\cdot}85\times10^{-12}\times1{\cdot}673\times10^{-27}\times(2{\cdot}8\times10^{7})^2}$ (1) $= 1{\cdot}4\times10^{-14}$ m (1)	3	

Question			Expected Answer/s	Max Mark	Additional Guidance
6	b		**At CERN protons are accelerated to speeds approaching the speed of light. Calculate the relativistic energy of a proton moving at 0·8*c*.** $m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$ (½) $= \frac{1\cdot 673\times 10^{-27}}{\sqrt{1-\left(\frac{0.8c}{c}\right)^2}}$ (½) $= 2{\cdot}79 \times 10^{-27}$ (kg) (1) - $E = mc^2$ (½) $= 2{\cdot}8 \times 10^{-27} \times (3\times 10^8)^2$ (½) $= 2{\cdot}5 \times 10^{-10}$ J (1)	4	
6	c		**A student visiting CERN asks why the protons in the nucleus of an atom do not just fly apart. Explain fully why protons in a nucleus do not behave in this way** Spanning less than 10^{-14} (m) (1) Strong force attractive (1) Strong force much greater than electrostatic (1)	3	

Question			Expected Answer/s	Max Mark	Additional Guidance
7			**In a nuclear power station liquid sodium is used to cool parts of the reactor.** **An electromagnetic pump keeps the coolant circulating. The sodium enters a perpendicular magnetic field and an electric current, *I*, passes through it. A force is experienced by the sodium causing it to flow in the direction shown in Figure 7A.**		

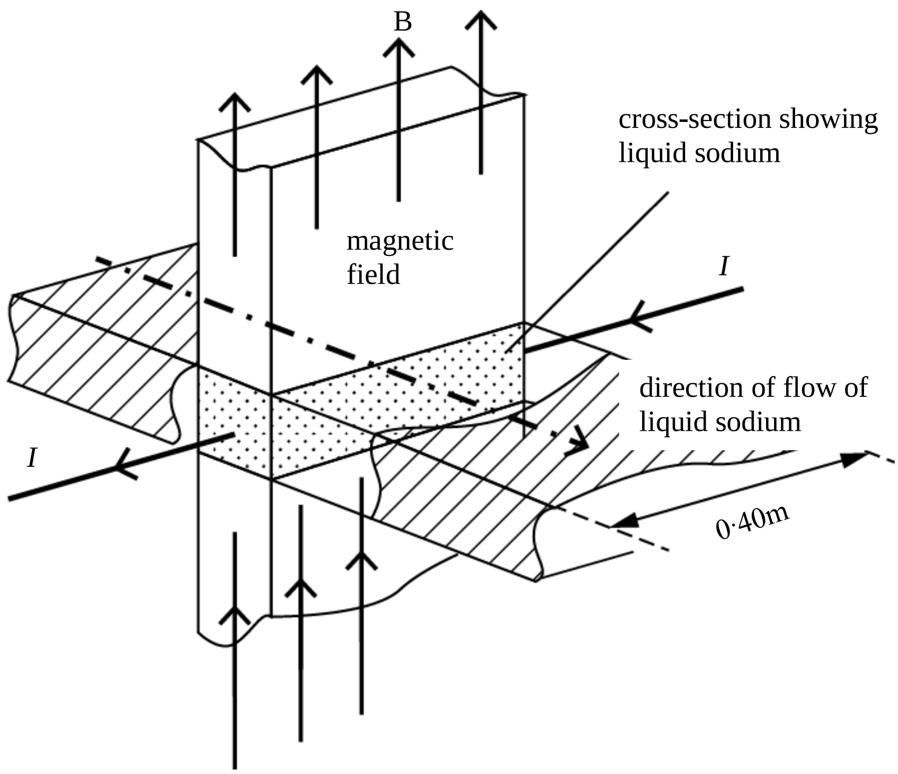
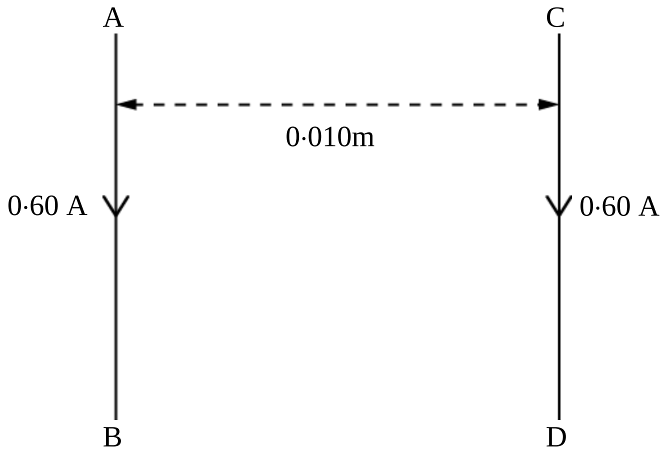
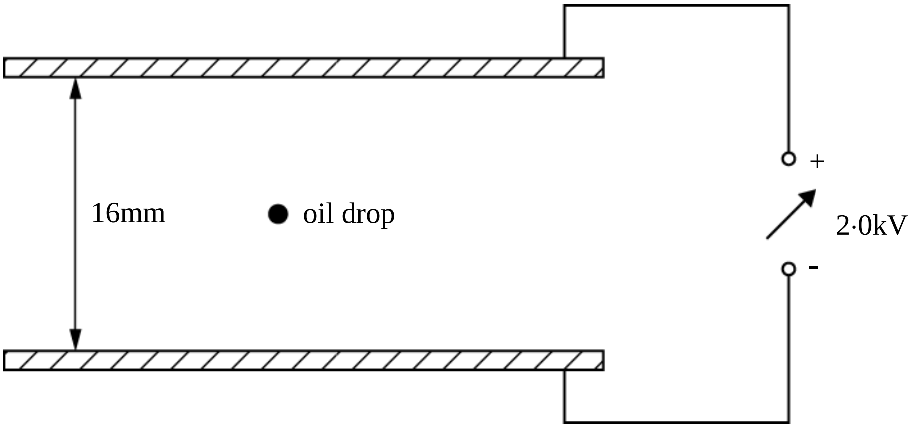
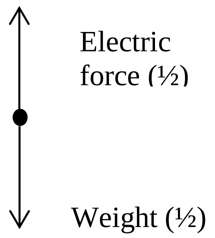


Figure 7A

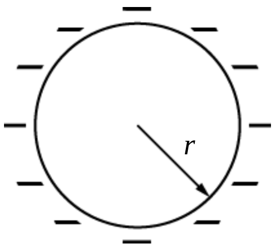
Question			Expected Answer/s	Max Mark	Additional Guidance
			The magnetic induction *B* is 0·20 T. **The current *I* in the sodium is 2·5 A and is perpendicular to the magnetic field.**		
	a		**Define one tesla.**		
			One tesla is the magnetic induction of a magnetic field in which a conductor of length one metre carrying a current of one Ampere is acted on by a force of one Newton.	1	

Question			Expected Answer/s	Max Mark	Additional Guidance
7	b		**Calculate the force acting on the 0·40 m length of sodium within the magnetic field.** $F = BIl$ (½) $F = 0{\cdot}20 \times 2{\cdot}5 \times 0{\cdot}4$ (½) $F = 0{\cdot}20$ N (1)	**2**	
7	c		**The pump is moved during maintenance and as a result the direction of the magnetic field is changed so that it is no longer perpendicular to the current. What effect does this have on the rate of flow of sodium passing through the pump?** **You must justify your answer.** Flow rate will fall (½) $F = BIl \sin\theta$ explanation (1) Force will be reduced (½)	**2**	
7	d		**An engineer must install a long, straight, current carrying wire AB close to the pump and is concerned that the magnetic induction produced may interfere with the safe working of the pump.** **The wire is 750 mm from the pump and carries a current of 0·60 A.** **Show by calculation that the magnetic induction at this distance is negligible.** $B = \frac{\mu_\circ I}{2\pi r}$ (½) $B = \frac{4\pi \times 10^{-7} \times 0 \cdot 6}{2 \times \pi \times 0{\cdot}75}$ (½) $B = 1{\cdot}6 \times 10^{-7}$ T (1)	**2**	

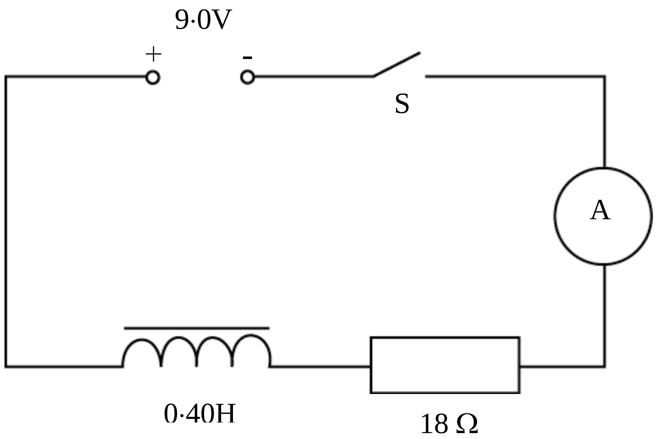
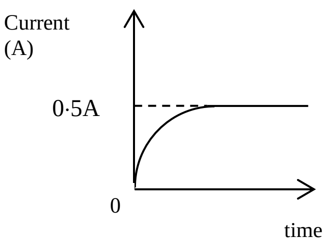
Question			Expected Answer/s	Max Mark	Additional Guidance
7	e		**A second long straight wire CD is installed parallel to the first wire AB as shown in Figure 7B.**  Figure 7B		
		i	**It also carries a current of 0·60 A in the same direction as in the first wire AB. Calculate the size of the force per unit length exerted on wire CD by wire AB.** $\frac{F}{l} = \frac{\mu_o \times I_1 \times I_2}{2\pi r}$ (½) $\frac{F}{l} = \frac{4\pi \times 10^{-7} \times 0 \cdot 6 \times 0 \cdot 6}{2\pi \times 0 \cdot 010}$ (½) $= 7 \cdot 2 \times 10^{-6}$ Nm^{-1} (1)	**2**	
7	e	ii	**State the direction of the force on the wire CD.** **Justify your answer.** To the left /towards AB or a diagram (1) Interaction between the magnetic fields. (1)	**2**	

Question			Expected Answer/s	Max Mark	Additional Guidance
8			**In 1909 Robert Millikan devised an experiment to investigate the charge on a small oil drop. Using a variable power supply he adjusted the potential difference between two horizontal parallel metal plates until an oil drop was held stationary between them as shown in Figure 8.**  Figure 8		
	a		**What was Millikan's main conclusion from this experiment?** Charge is quantised	1	
8	b		**Draw a labelled diagram showing the forces acting on the stationary oil drop.**  **Must have direction**	1	

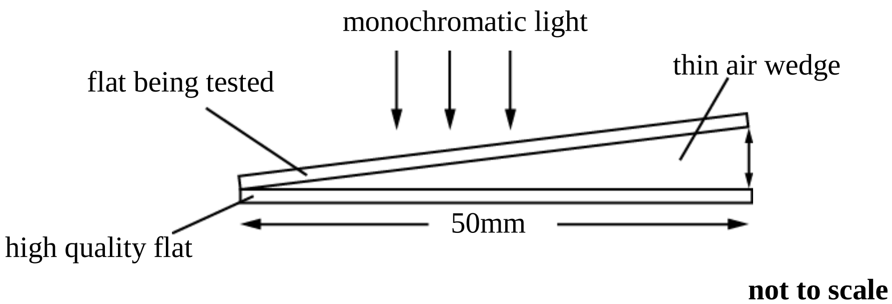
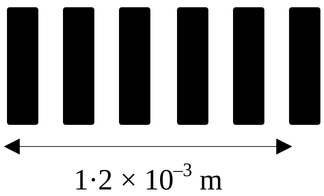
Question			Expected Answer/s		Max Mark	Additional Guidance
8	c		**The parallel plates are fixed 16 mm apart. In one experiment the charge on the oil drop was found to be $2{\cdot}4 \times 10^{-18}$ C.** **Calculate the mass of the oil drop.** $E = \frac{V}{d}$ $EQ = m\,g$ (½ for each equation) $m = \frac{QV}{gd}$ $= \frac{2\cdot4\times10^{-18}\times2000}{9\cdot8\times0\cdot016}$ $= 3{\cdot}1 \times 10^{-14}$ kg	(½) (1) (½) (1)	3	$E=V/d=125000$ (Vm^{-1}) (½ eqn + ½ answer) $F=QE= 3.0\text{x } 10^{-13}$ (N) (½ eqn + ½ answer) $m=F/g=3.1 \text{ x } 10^{-14}$ kg (½ eqn + ½ answer) Equation ½ marks are independent

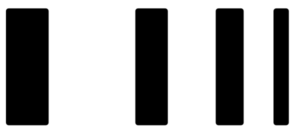
Question			Expected Answer/s	Max Mark	Additional Guidance
9			**The charge *Q* on a hollow metal sphere is (–15·0 ± 0·4) μC. The sphere has a radius *r* of (0·65 ± 0·02) m.**  Figure 9		
	A		**Calculate the electrostatic potential at the surface of the metal sphere.** $V = \frac{Q}{4\pi\varepsilon_o r}$ (½) $V = \frac{-15\times10^{-6}}{4\times3\cdot14\times8\cdot85\times10^{-12}\times0\cdot65}$ (½) $V = -2\cdot1\times10^{5}$ V (1)	**2**	
9	**B**		**Calculate the absolute uncertainty in the electrostatic potential.** $\%\Delta r = \frac{0\cdot02}{0\cdot65}\times100 = 3\%$ (½) $\%\Delta Q = \frac{0\cdot4}{15}\times100 = 2\cdot7\%$ (½) $\%\Delta V = (\pm)\sqrt{\%\Delta r^2 + \%\Delta Q^2}$ $= (\pm)\sqrt{9+7\cdot1}$ $= (\pm)4\cdot0\%$ (½) $\Delta V = \pm\frac{4\cdot0}{100}\times2\cdot1\times10^{5} = (\pm)\,8\times10^{3}$ V (½)	**2**	Can be fractional

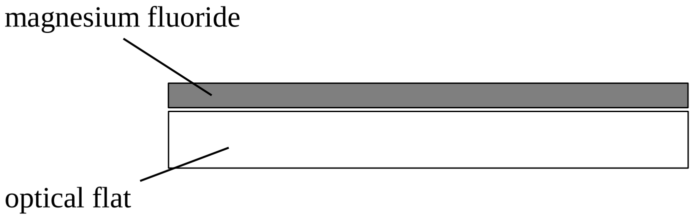
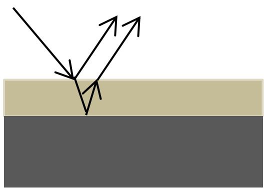
Question			Expected Answer/s	Max Mark	Additional Guidance
9	**c**		**State the electrostatic potential at the centre of the sphere.** $V = -2{\cdot}1 \times 10^5$ V (1) Consistent with (a)	**1**	

Question			Expected Answer/s	Max Mark	Additional Guidance
10			**A 0·40 H inductor of negligible resistance is connected in a circuit as shown in Figure 10. Switch S is initially open.**  Figure 10		
	a	i	**The switch S is closed. Sketch a graph of current against time giving numerical values on the current axis.**  Shape (1) 0·5 A (1)	**2**	
10	a	ii	**Explain fully the shape of the graph.** Changing magnetic field (1) Produces a back e.m.f in the inductor (1)	**2**	

Question			Expected Answer/s	Max Mark	Additional Guidance
10	b		**Calculate the initial rate of change of current when switch S is closed.** $E = -L\frac{dI}{dt}$ (½) E = -9·0 (V) $\frac{dI}{dt} = \frac{E}{-L} = \frac{-9\cdot 0}{-0\cdot 40}$ (½) $\frac{dI}{dt} = 23\,As^{-1}$ (1)	2	Value comes out as 22.5 As^{-1}

Question			Expected Answer/s	Max Mark	Additional Guidance
11			**High quality *optical flats* made from glass are often used to test components of optical instruments. A high quality optical flat has a very smooth and flat surface.**		
	a		**During the manufacture of an optical flat, the quality of the surface is tested by placing it on top of a high quality flat. This results in a thin air wedge between the flats as shown in Figure 11A.**  Figure 11A **The thickness *d* of the air wedge is $6{\cdot}2 \times 10^{-5}$ m.** **Monochromatic light is used to illuminate the flats from above. When viewed from above using a travelling microscope, a series of interference fringes is observed as shown in Figure 11B.**  Figure 11B **Calculate the wavelength of the monochromatic light.** $\Delta x = \frac{1\cdot 2\times 10^{-3}}{5} = 2\cdot 4\times 10^{-4}$ (1) - - - - - - - - - - - - - - - - - - $\Delta x = \frac{\lambda L}{2d}$ (½) $2{\cdot}4 \times 10^{-4} = \frac{\lambda \times 0\cdot 05}{2\times 6\cdot 2\times 10^{-5}}$ (½) $\lambda = 6{\cdot}0 \times 10^{-7}$ m (1)	**3**	If

Question			Expected Answer/s	Max Mark	Additional Guidance
11	b		**A second flat is tested using the same method as in part (*a*). This flat is slightly curved as shown in Figure 11C.**  Figure 11C **Draw the fringe pattern observed.**  Accept Spacing of fringes decreases from left to right or Width of fringes decreases from left to right.	1	

Question			Expected Answer/s	Max Mark	Additional Guidance
11	**c**		**Good quality optical flats often have a non-reflecting coating of magnesium fluoride applied to the surface as shown in Figure 11D.**  Figure 11D		
		i	**With the aid of a diagram explain fully how the coating reduces reflections from the flat for monochromatic light.**  diagram (1) The two reflected rays interfere destructively (1)	**2**	Phase change not required in answer but if phase change on reflection mentioned both rays must be considered and be correct or 1 mark max for correct diagram.
11	**c**	**ii**	**Calculate the minimum thickness of magnesium fluoride required to make the flat non-reflecting for yellow light from a sodium lamp.** $d = \frac{\lambda}{4n}$ (½) $= \frac{589 \times 10^{-9}}{4 \times 1{\cdot}38}$ (½) $= 1{\cdot}07 \times 10^{-7}$ m (1)	**2**	

Question			Expected Answer/s	Max Mark	Additional Guidance
12			**A water wave of frequency 2·5 Hz travels from left to right.** **Figure 12 represents the displacement *y* of the water at one instant in time.**		

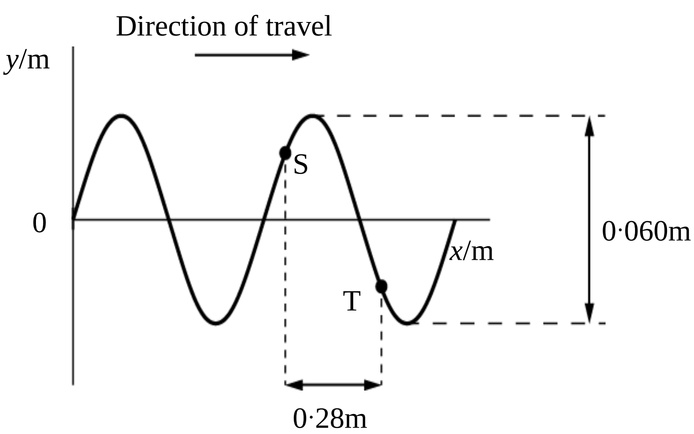
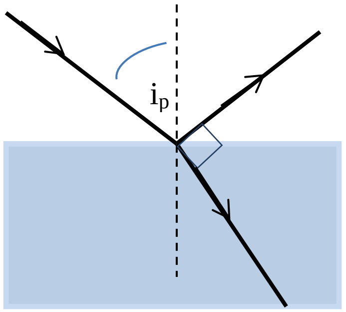


Figure 12

Question			Expected Answer/s	Max Mark	Additional Guidance
			Points S and T are separated by a horizontal distance of 0·28 m. **The phase difference between these two points is 3·5 radians.**		
	a		**Calculate the wavelength of this wave.** $\varphi = \frac{2\pi x}{\lambda}$ (½) $3\cdot5 = \frac{2\pi \times 0\cdot28}{\lambda}$ (½) $\lambda = 0\cdot50$ m (1)	**2**	

Question			Expected Answer/s	Max Mark	Additional Guidance
12	b		**A second wave with double the frequency travels in the same direction through the water. This wave has five times the intensity of the wave in part (*a*).** **Calculate:**		
		i	**the speed of this wave;** $\lambda = 0{\cdot}25$m $v = f\lambda$ $= 5{\cdot}0 \times 0{\cdot}25$ $= 1{\cdot}3$m s^{-1} (1)	**1**	Or since speed is the same as in (a) $v = f\lambda$ $= 2{\cdot}5 \times 0{\cdot}5$ $= 1{\cdot}3$ m s^{-1} Accept $1{\cdot}25$ m s^{-1} If units wrong then deduct ½
12	b	ii	**the amplitude of this wave.** $\frac{I_1}{A_1^2} = \frac{I_2}{A_2^2}$ (½) Or I proportional to A^2 $\frac{I_1}{0 \cdot 03^2} = \frac{5I_1}{A_2^2}$ (½) $A_2 = 0{\cdot}07$ m (1)	**2**	Accept $0{\cdot}067$m

Question			Expected Answer/s	Max Mark	Additional Guidance
13	a		**A student is investigating polarisation of waves.** **State what is meant by *plane polarised light.*** In plane polarised light (the electric field vector of the light) **vibrates/oscillates** in **one plane**. (1)	1	
13	b		**The student wishes to investigate polarisation of sound waves and asks a teacher for suitable apparatus. The teacher says that sound waves cannot be polarised.** **Why can sound waves not be polarised?** Sound waves are not transverse waves. (1)	1	Accept sound waves are longitudinal.
13	c	i	**While doing some background reading the student discovers that the Brewster angle i_p for the liquid solvent triethylamine is given as 54·5°.** **Explain using a diagram what is meant by the Brewster angle.** 	2	1 mark for identifying the angle between the reflected and refracted ray as 90° angle. Second mark is dependent on getting the first mark correct. 90° must be marked. 1 mark for Brewster Angle (either incident or reflected angle)
13	c	ii	**Calculate the refractive index of triethylamine.** $n = \tan i_p$ (½) $= \tan 54{\cdot}5$ $= 1{\cdot}40$ (½)	1	

[END OF MARKING INSTRUCTIONS]