2013 Physics (Revised)

Advanced Higher

Finalised Marking Instructions

Part One: General Marking Principles for Physics (Revised) – 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 (Revised) 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 answer 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	$9{\cdot}8$ ms^{-2}	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$kg
Radius of Earth	R_E	$6{\cdot}4 \times 10^{6}$m	Charge on electron	e	$-1{\cdot}60 \times 10^{-19}$C
Mass of Earth	M_E	$6{\cdot}0 \times 10^{24}$kg	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$kg
Mass of Moon	M_M	$7{\cdot}3 \times 10^{22}$kg	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$kg
Radius of Moon	R_M	$1{\cdot}7 \times 10^{6}$m	Mass of alpha particle	m_α	$6{\cdot}645 \times 10^{-27}$kg
Mean Radius of Moon Orbit		$3{\cdot}84 \times 10^{8}$m	Charge on alpha particle		$3{\cdot}20 \times 10^{-19}$C
Solar radius		$6{\cdot}955 \times 10^{8}$ m	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$Js
Mass of Sun		$2{\cdot}0 \times 10^{30}$ kg	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}$ F m^{-1}
1 AU		$1{\cdot}5 \times 10^{11}$ m	Permeability of free space	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
Stefan-Boltzmann constant	σ	$5{\cdot}67\times$ 10–8 W m^{-2} K^{-4}	Speed of light in Vacuum	c	$3{\cdot}0 \times 10^{8}$ m s^{-1}
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}$m^{3}kg^{-1}s^{-2}	Speed of sound in air	v	$3{\cdot}4 \times 10^{2}$ m s^{-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

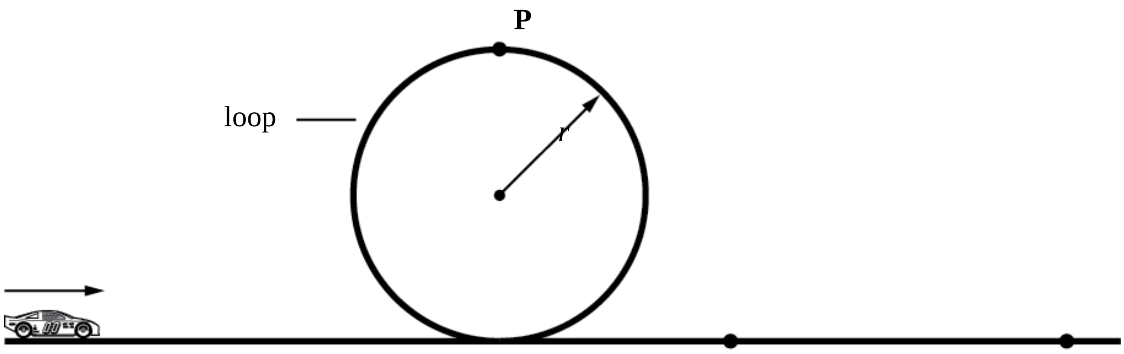
Element	*Wavelength*/nm	*Colour*	*Element*	*Wavelength*/nm	*Colour*
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet	*Lasers*		
	397	Ultraviolet	*Element*	*Wavelength*/nm	*Colour*
	389	Ultraviolet	Carbon dioxide	9550 10590	Infrared
Sodium	589	Yellow	Helium-neon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

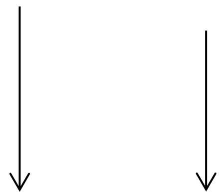
Properties of selected Materials

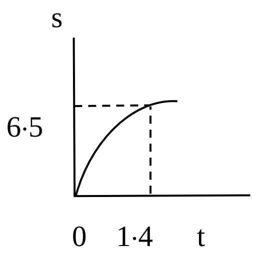
Substance	*Density*/ kg m^{-3}	*Melting Point*/K	*Boiling Point*/K	*Specific Heat Capacity*/ $Jkg^{-1} K^{-1}$	*Specific Latent Heat of Fusion*/ Jkg^{-1}	*Specific latent Heat of Vaporisation* /Jkg^{-1}
Aluminium	$2{\cdot}70 \times 10^3$	933	2623	$9{\cdot}02 \times 10^2$	$3{\cdot}95 \times 10^5$	….
Copper	$8{\cdot}96 \times 10^3$	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	….	$2{\cdot}10 \times 10^3$	$3{\cdot}34 \times 10^5$	….
Glycerol	$1{\cdot}26 \times 10^3$	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	$1{\cdot}29$	….	….	….	….	….
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^4$	….	$4{\cdot}50 \times 10^5$
Nitrogen	$1{\cdot}25$	63	77	$1{\cdot}04 \times 10^3$	….	$2{\cdot}00 \times 10^5$
Oxygen	$1{\cdot}43$	55	90	$9{\cdot}18 \times 10^2$	….	$2{\cdot}40 \times 10^5$

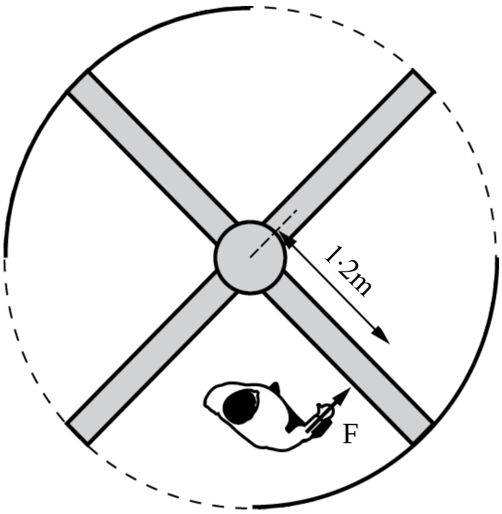
The gas densities refer to a temperature of 273 K and pressure of $1{\cdot}01 \times 10^5$ Pa.

Part Two: Marking Instructions for each Question

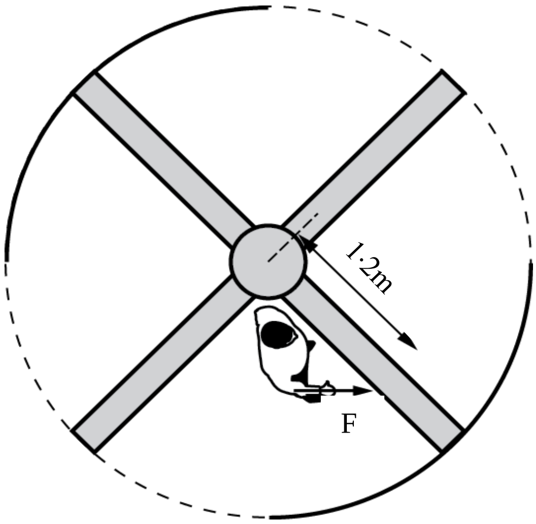
Question			Expected Answer/s	Max Mark	Additional Guidance
1			**A stunt driver is attempting to "loop the loop" in a car as shown in Figure 1. Before entering the loop the car accelerates along a horizontal track.**		
			 Figure 1.		
			The radius *r* of the circular loop is 6·2 m. **The total mass of 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 **Must have equality explicitly stated to progress** $\frac{v^2}{r} = g$ $9.8 = \frac{v^2}{6.2}$ (½ for substitution ½ for data) = 7·8 (m s^{-1}) SHOW QUESTION	2	Type equation here.

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	Accept **force of track** on car.
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) = 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** $$\boldsymbol{s = 9{\cdot}1t - 3{\cdot}2\, t2}$$ **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**	

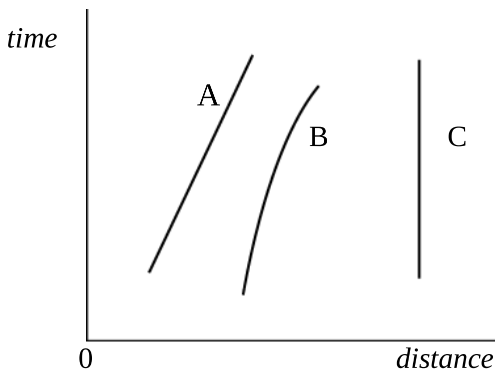
Question			Expected Answer/s	Max Mark	Additional Guidance
2			**The entrance to a building is through a revolving system consisting of 4 doors that rotate around a central axis as shown in Figure 2A.**  Figure 2A **The moment of inertia of the system about the axis of rotation is 54 kg m^2. When it rotates 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}.**		

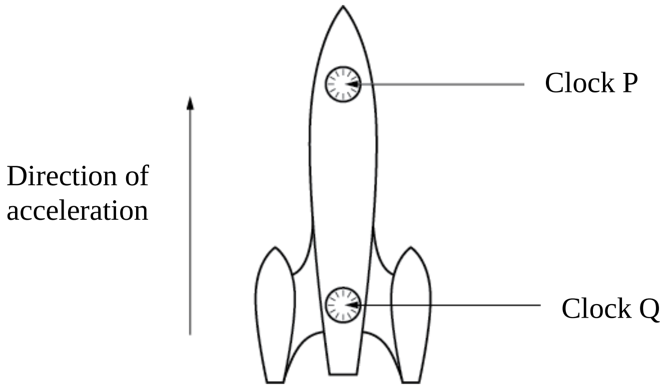
Question			Expected Answer/s	Max Mark	Additional Guidance
2	a		**(Cont.)**		
		i	**Calculate the magnitude of the applied force F.** Unbalanced torque = I α (½) = 54 × 2·4 (½) = 130 (Nm) Applied torque = 129·6 + 25 = 154.6 (Nm) (½) - Applied torque = $F \times r$ (½) 154.6 = $F \times 1{\cdot}2$ F = 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.** $\alpha = \frac{T}{I} = \frac{(\text{-})25}{54} = (-)0 \cdot 46(\text{rads}^{-2})$ (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) $\theta = \omega_o t + \frac{1}{2}\alpha t^2$ $= (1{\cdot}67 \times 3{\cdot}6) + (0{\cdot}5 \times -0{\cdot}46 \times 3{\cdot}6^2)$ = 3·0 rad	3	

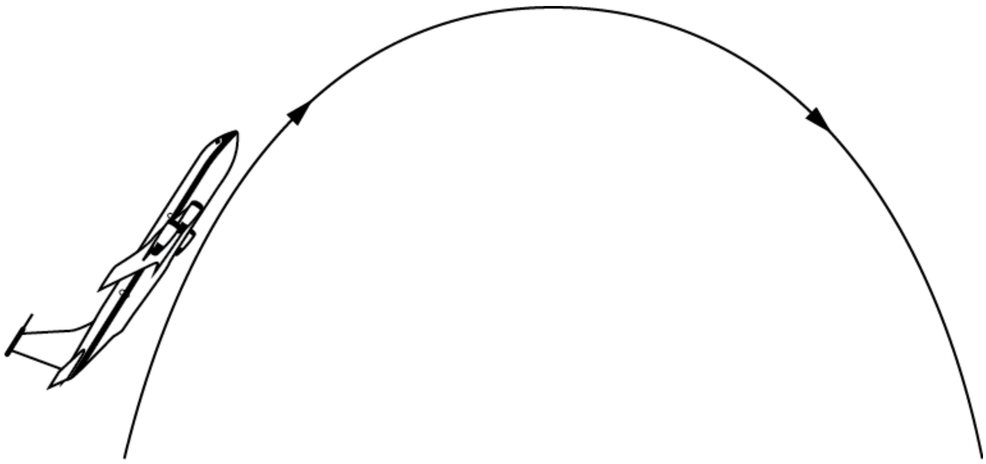
Question			Expected Answer/s	Max Mark	Additional Guidance
2	b		**On exiting the building the person exerts the same magnitude of force F on a door at the same distance from the axis of rotation.** **The force is now applied as shown in Figure 2C.**  Figure 2C **How does the angular acceleration of the 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			**On a trip to a theme park, a student described what happened in the fairground spinner shown in Figure 3.** **“You get thrown outwards by centrifugal force – you can feel it – it pushes you into the wall.”**  Figure 3 **Use your knowledge of physics to discuss this statement.** 0 marks The student has demonstrated no understanding of the physics involved. There is no evidence that the student recognised the area of physics involved or has given any statement of a relevant principle. This mark would also be given when a student merely restates the physic given in the question. 1 mark The student has demonstrated a limited understanding of the physics involved and has made some statement(s) which is/are relevant to the situation, showing at least a little of the physics within the problem is understood.	**3**	

Question				Expected Answer/s	Max Mark	Additional Guidance
3				**(Cont.)** 2 marks The student has demonstrated a reasonable understanding of the physics involved and has made some statement(s) which is/are relevant to the situation, showing that the physics within the problem is understood. 3 marks The maximum available mark would be awarded to a student who has demonstrated a good understanding of the physics involved. The student has demonstrated a good comprehension of the physics of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the appropriate application of these to the problem. This does not mean the answer has to be what might be termed ‘excellent’ or ‘complete’.		

Question			Expected Answer/s	Max Mark	Additional Guidance
4	**a**		**The world lines for three objects A, B and C are shown in Figure 4A.**  Figure 4A **To which of these objects does the General Theory of Relativity apply?** **Explain your choice.** B (1) Object B is accelerating or in non-inertial frame of reference. (1)	**2**	Curved lines on spacetime graphs correspond to non-inertial frames of reference (accelerating) which is governed by the General Theory of Relativity (1)

Question			Expected Answer/s	Max Mark	Additional Guidance
4	**b**		**A rocket ship is accelerating through space. Clocks P and Q are at opposite ends of the ship as shown in Figure 4B.** **An astronaut inside the rocket ship is beside clock P and can also observe clock Q.**  Figure 4B **What does the astronaut observe about the passage of time for these clocks?** **Justify you answer.** Time on clock P will appear to move faster or Time on clock Q will appear to move slower (1) Time passes more slowly at the rear of an accelerating object (1) or Time between pulses from clock Q would take longer to arrive at astronaut (1)	**2**	

Question			Expected Answer/s	Max Mark	Additional Guidance
4	c		**Part of an astronaut's training is to experience the effect of "weightlessness".** **This can be achieved inside an aircraft that follows a path as shown in Figure 4C.**  Figure 4C **Use the equivalence principle to explain how this "weightlessness" is achieved.**		
			The effects of gravity are exactly equivalent to the effect of acceleration. (1) The plane accelerating downwards exactly "cancels out" the effects of being in a gravitational field (1) **Or** Plane and passengers are falling at the same rate due to the gravitational field (are in "free fall").	**(2)**	

Question			Expected Answer/s	Max Mark	Additional Guidance
5			**Hertzsprung-Russell (H-R) diagrams are widely used by physicists and astronomers to categorise stars. Figure 5A shows a simplified H-R diagram.**		

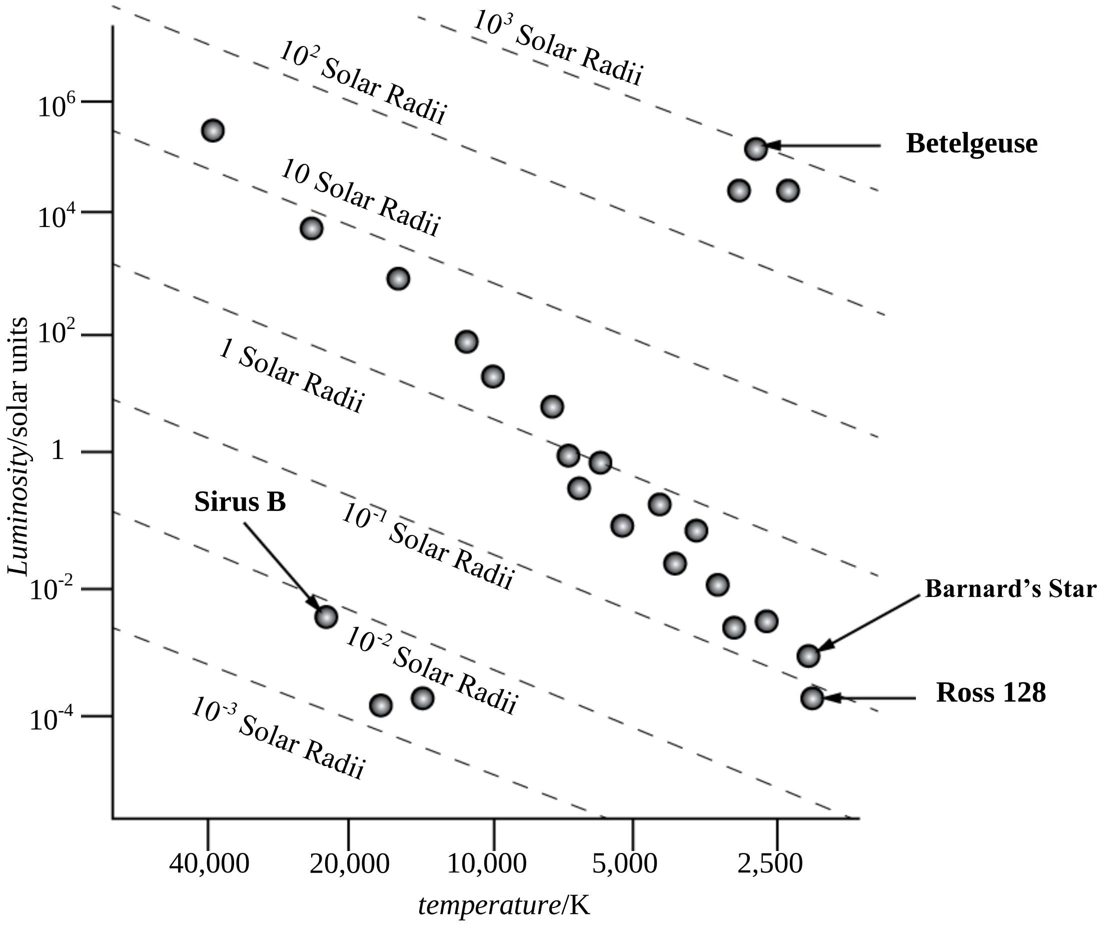
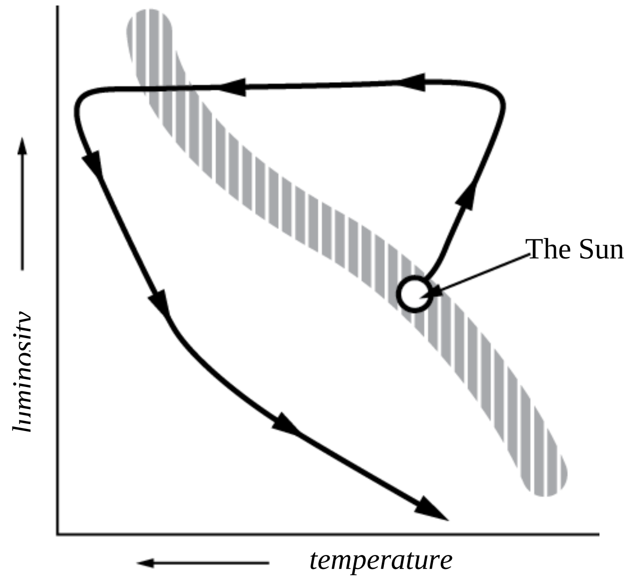


Figure 5A

	a		**What class of star is Sirius B?** White Dwarf (1)	1	

Question			Expected Answer/s	Max Mark	Additional Guidance
5	b		**Estimate the radius in metres of Betelgeuse.** Radius = No. of SR× 1SR (½) Radius = $1000 \times 6{\cdot}955 \times 10^{8}$ (½) Radius = $6{\cdot}955 \times 10^{11}$ m (1)	2	Accept 900SR-1000SR 900 gives 6.260×10^{11}m 950 gives 6.607×10^{11}m
5	c		**Ross 128 and Barnard's Star have a similar temperature but Barnard's Star has a slightly greater luminosity. What other information does this tell you about the two stars?** Bernard's star larger in size (or converse) (1)	1	Ross 128 has a greater lifetime than Bernard's Star (or converse) Accept greater mass

Question			Expected Answer/s	Max Mark	Additional Guidance
5	d		**During the life cycle of the Sun its position in the H-R diagram is expected to change as shown by the arrowed line in Figure 5B.**  Figure 5B **Describe the changes that occur to the Sun during its expected life cycle.** Sun is main sequence, hydrogen burning/ fusing star **Or** Thermal pressure balances gravitational (1) Fuel/hydrogen used up, thermal pressure greater than gravity, star expands (to Red Giant) (1) Loses mass then (inert) core cools, becomes White Dwarf **Or** Sun will become White Dwarf / black dwarf because of its mass. (1)	3	

Question			Expected Answer/s	Max Mark	Additional Guidance
5	e		**Hydrogen fusion in a star is a result of a proton-proton chain. The process eventually results in the production of a helium-4 nucleus.**		
		i	**Show that the percentage loss of mass from four protons to one helium-4 nucleus is 0·7%.** 4 protons' mass = $4 \times 1{\cdot}673 \times 10^{-27}$ (½) = $6{\cdot}692 \times 10^{-27}$ Mass of He nucleus = $6{\cdot}645 \times 10^{-27}$ kg (½) mass to energy $6{\cdot}692 \times 10^{-27} - 6{\cdot}645 \times 10^{-27}$ (½) = $0{\cdot}047 \times 10^{-27}$kg Percentage loss = $0{\cdot}047/6{\cdot}692 \times 100$ (½) = 0·7% SHOW ME QUESTION	2	
5	e	ii	**The luminosity of the Sun is $3{\cdot}8 \times 10^{26}$ W. Using Einstein's energy equation, show that the mass of hydrogen lost per second in the Sun is $4{\cdot}2 \times 10^{9}$ kg.** In one second, $E = mc^2$ (½) $3{\cdot}8 \times 10^{26} = m (3 \times 10^{8})^{2}$ (½) ($m = 4{\cdot}2 \times 10^{9}$ kg)	1	
5	e	iii	**Estimate the lifetime of the Sun in seconds. Assume the mass of hydrogen in the Sun to be the same as the mass of the Sun.** Lifetime = $2{\cdot}0 \times 10^{30} / 4{\cdot}2 \times 10^{9}$ (½) = $4{\cdot}8 \times 10^{20}$ (s) (½)	1	Accept $4{\cdot}762 \times 10^{20}$s $4{\cdot}76 \times 10^{20}$s 5×10^{20}s

Question			Expected Answer/s	Max Mark	Additional Guidance
5	f		**The "no greenhouse" temperature of a planet is the average surface temperature of a planet in the absence of any greenhouse effect. The "no greenhouse" temperature of a planet in kelvin in given by** $T = 280\left(\frac{(1-\text{reflectivity})}{d^2}\right)^{\frac{1}{4}}$ **where *d* is the distance from the Sun in astronomical units (AU).** **The reflectivity is a measure of the percentage of energy reflected from the surface, 1 represents 100% reflectivity and 0 represents no reflectivity.** **Mercury has a reflectivity of 0·12 and is 5·8 × 10^{10} m from the Sun.** **Calculate its "no greenhouse" temperature.** Reflectivity = 0·12 d = 0.387AU (½) (1 AU = 1·5 × 10^{11}m) $T = 280\left(\frac{1-reflectivity}{d^2}\right)^{\frac{1}{4}}$ $T = 280\left(\frac{1-0.12}{(0.387)^2}\right)^{\frac{1}{4}}$ (½) = 440 K (1)	2	

Question				Expected Answer/s	Max Mark	Additional Guidance
6				**Detailed observations of sunspots have been obtained by the Royal Greenwich Observatory since 1874. These observations include information on the sizes and positions of sunspots as well as their numbers. The number of sunspots is an indication of solar activity. A graph of the average number of sunspots since 1950 is shown in Figure 6.**		

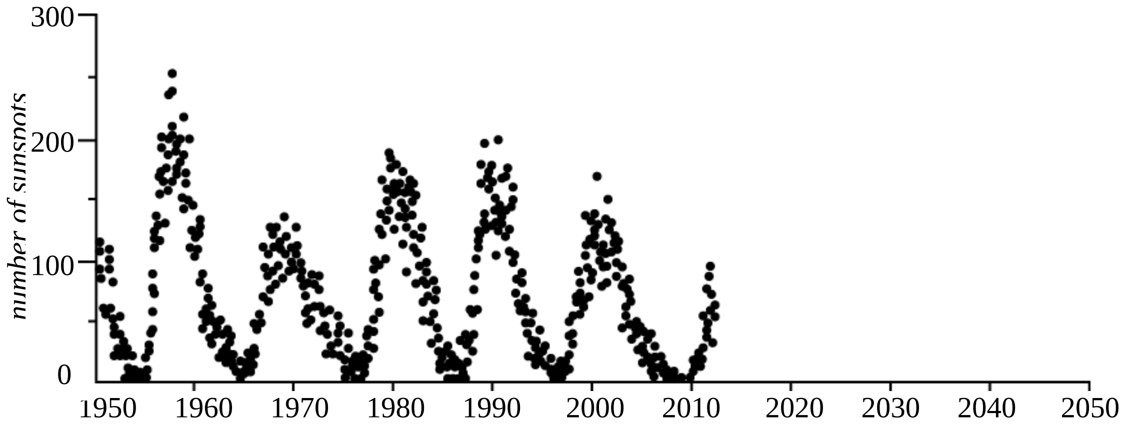


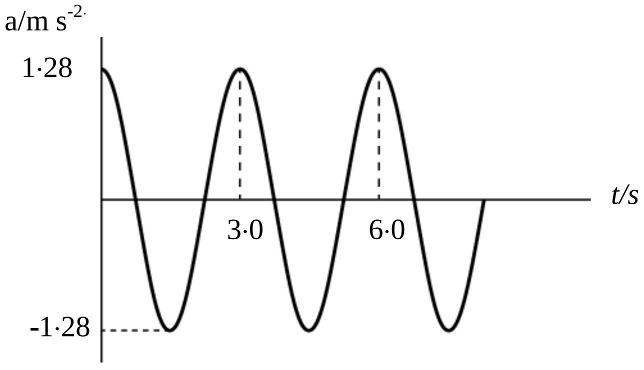
Figure 6

Coronal mass ejections (CME) are one type of solar activity. CMEs are huge magnetic bubbles of plasma that expand away from the Sun at speeds as high as 2000 km s^{-1}. A single CME can carry up to ten million tonnes (10^{10} kg) of plasma away from the Sun.

Use your knowledge of physics to discuss the potential effects that solar activity could have on Earth over the next few years.

Question				Expected Answer/s	Max Mark	Additional Guidance
6				**(Cont.)** 0 marks The student has demonstrated no understanding of the physics involved. There is no evidence that the student recognised the area of physics involved or has given any statement of a relevant principle. This mark would also be given when a student merely restates the physics given in a question. 1 mark The student has demonstrated a limited understanding of the physics involved and has made some statement(s) which is/are relevant to the situation, showing at least a little of the physics within the problem is understood. 2 marks The student has demonstrated a reasonable understanding of the physics involved and has made some statement(s) which is/are relevant to the situation, showing that the physics within the problem is understood. 3 marks The maximum available mark would be awarded to a student who has demonstrated a good understanding of the physics involved. The student has demonstrated a good comprehension of the physics of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the appropriate application of these to the problem. This does not mean the answer has to be what might be termed ‘excellent’ or ‘complete’.	**3**	

Question			Expected Answer/s	Max Mark	Additional Guidance
7			**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 7A.**  Figure 7A **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
7	b		**The acceleration-time graph for the seat with no energy loss is shown in Figure 7B.**  Figure 7B		
		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) $= 2{\cdot}1\ (\text{rad s}^{-1})$ (½) $1.28 = (-) 2{\cdot}1^2\ y$ (½) (= 0·29 m) SHOW QUESTION	3	

Question			Expected Answer/s	Max Mark	Additional Guidance
7	b	ii	**Calculate the velocity of the seat when its displacement is 0·10 m.** $v = (\pm)\omega\sqrt{A^2 - y^2}$ (½) $= (\pm)2\cdot1\sqrt{0\cdot29^2 - 0\cdot10^2}$ (½) $= (\pm)\ 0{\cdot}57\ \text{m s}^{-1}$ (1)	2	
7	c		**Calculate the displacement of the seat when the kinetic energy and potential energy are equal.** $(E_k = E_p)$ $½\ m\omega^2 A^2 - ½\ m\omega^2 y^2 = ½\ m\omega^2 y^2$ **(½) for E_k** **(½) for E_p** OR $½\ m\omega^2 A^2 = m\omega^2 y^2$ $½\ A^2 = y^2$ (½) $y^2 = 0{\cdot}5 \times 0{\cdot}29^2$ (½) $y = 0{\cdot}21$ m (1)	3	

Question			Expected Answer/s	Max Mark	Additional Guidance
8			**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 8A.**		

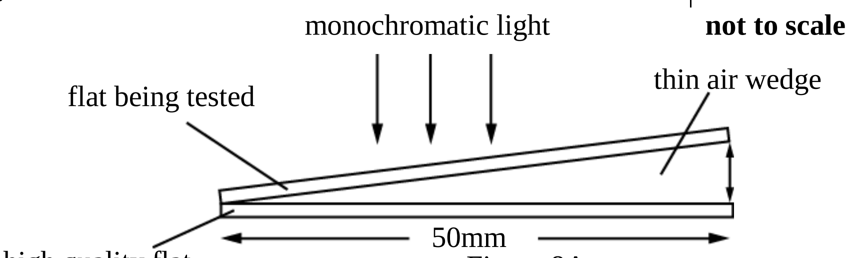


Figure 8A

			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 8B.		

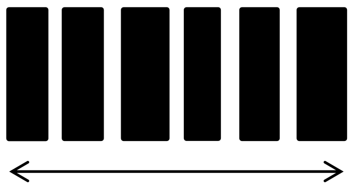
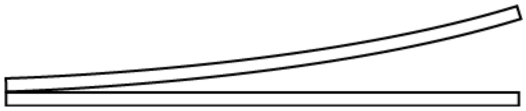
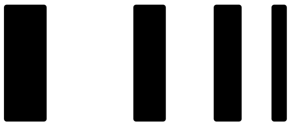
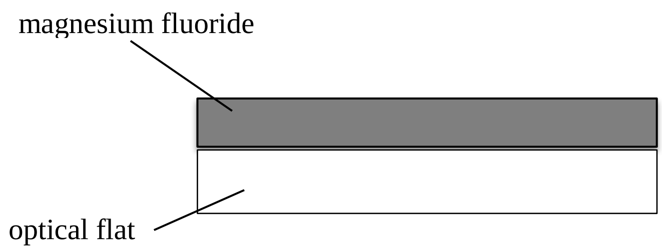
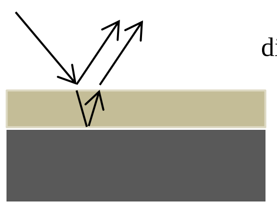


Figure 8B

			Calculate the wavelength of the monochromatic light.		
			$\Delta x = \dfrac{1{\cdot}2\times10^{-3}}{5} = 2{\cdot}4\times10^{-4}$ (1)		
			$\Delta x = \dfrac{\lambda L}{2d}$ (½) $2{\cdot}4 \times 10^{-4} = \dfrac{\lambda\times0{\cdot}05}{2\times6{\cdot}2\times10^{-5}}$ (½) $\lambda = 6{\cdot}0 \times 10^{-7}$ m (1)	**3**	

Question			Expected Answer/s	Max Mark	Additional Guidance
8	b		**A second flat is tested using the same method as in part (*a*). This flat is slightly curved as shown in Figure 8C.**  Figure 8C **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
8	c		**Good quality optical flats often have a non-reflecting coating of magnesium fluoride applied to the surface as shown in Figure 8D.**  Figure 8D		
		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 surfaces must be considered and correct or 1 mark max for correct diagram.
8	c	ii	**Calculate the minimum thickness of magnesium fluoride required to make the flat non-reflecting for yellow light from a sodium lamp.** $d = \dfrac{\lambda}{4n}$ (½) $= \dfrac{589\times10^{-9}}{4\times1{\cdot}38}$ (½) $= 1{\cdot}07 \times 10^{-7}$ m (1)	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
9			**A water wave of frequency 2·5 Hz travels from left to right.** **Figure 9 represents the displacement *y* of the water at one instant in time.**		

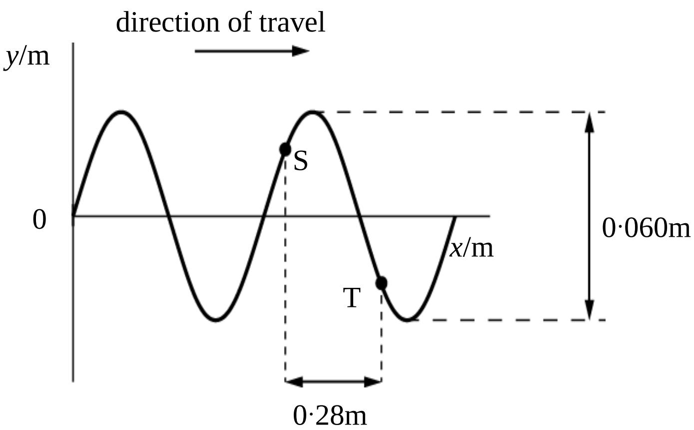


Figure 9

Question			Expected Answer/s	Max Mark	Additional Guidance
	a		**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.** **Calculate the wavelength of this wave.** $\varphi = \frac{2\pi x}{\lambda}$ (½) $3\cdot 5 = \frac{2\pi \times 0\cdot 28}{\lambda}$ (½) λ = 0·50 m (1)	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
9	b		**A second wave with double the frequency travels in the same direction through the water. This wave transfers five times the energy of the wave in part (*a*).** **Calculate:**		
		i	**the speed of this wave;** $\lambda = 0{\cdot}25\text{m}$ $v = f\lambda$ $= 5{\cdot}0 \times 0{\cdot}25$ $= 1{\cdot}3\text{m s}^{-1}$ (1)	1	Or since speed is the same as in (a) $v = f\lambda$ $= 2{\cdot}5 \times 0{\cdot}5$ $= 1{\cdot}3 \text{ m s}^{-1}$ Accept $1{\cdot}25 \text{ m s}^{-1}$
9	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 $\frac{I_1}{0 \cdot 03} = \frac{5I_1}{A_2^2}$ (½) $A_2 = 0{\cdot}07$ m (1)	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
10			**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 10A shows some of the possible orbits for the electron in a hydrogen atom.**		

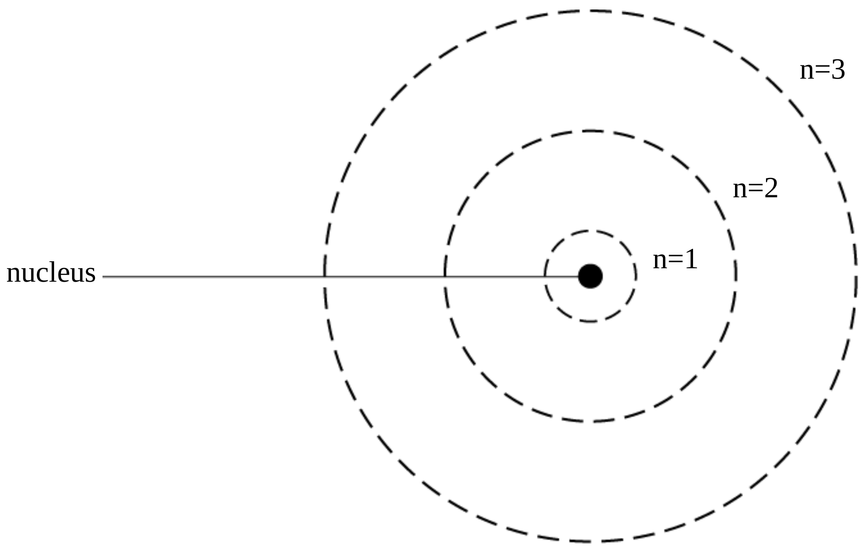


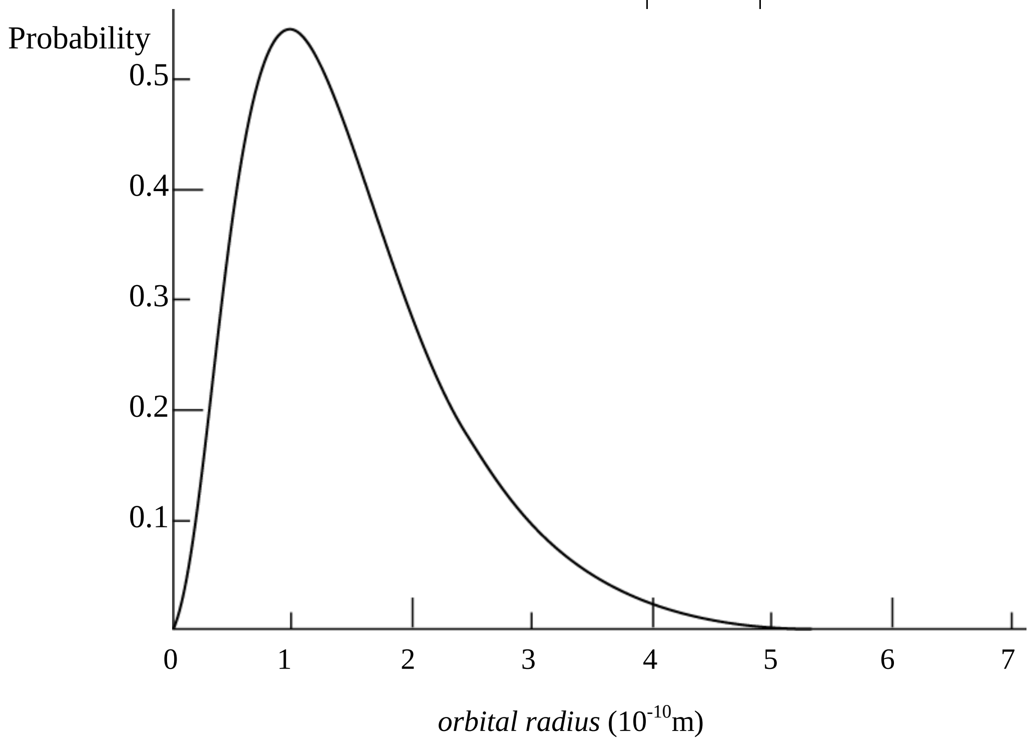
Figure 10A

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
	a				

Question			Expected Answer/s	Max Mark	Additional Guidance
10	a		**Calculate the speed of the electron in orbit number 3.** $mvr = \frac{nh}{2\pi}$ (½) (½) $9.11\times10^{-31}\times v\times4.8\times10^{-10}=\frac{3\times6\cdot63\times10^{-34}}{2\times\pi}$ $v = 7{\cdot}2 \times 10^{5}$ m s^{-1} (1) Rounding might give 7.3×10^{5} m s^{-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}
10	b		**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	

Question			Expected Answer/s	Max Mark	Additional Guidance
10	c	i	**Some of the limitations of the Bohr model of the atom are addressed by Quantum Mechanics.** **The position of an electron in a hydrogen atom was measured with an uncertainty of 0·15 nm.** **Calculate the minimum uncertainty in its momentum.** $\Delta x \times \Delta p \geq \frac{h}{4\pi}$ (½) $0{\cdot}15 \times 10^{-9} \times \Delta p \geq \frac{6.63\times10^{-34}}{4\pi}$ (½) $\Delta p_{min} = 3{\cdot}5 \times 10^{-25}$ kg m s^{-1} (1)	2	
10	c	ii	**A diagram of electron probability distribution for the hydrogen atom is shown in Figure 10B.**  Figure 10B **Comment on the position of the electron in this orbital.**		

Question			Expected Answer/s	Max Mark	Additional Guidance
10	**c**	**ii**	**(Cont.)** Greatest probability of being found at approx. 1×10^{-10} m/at the peak. (1) We cannot predict exactly the position of the electron (1) No probability of electron being at a radius greater than 5×10^{-10}m (1) Greater probability of electron being at a lower orbital radius than a higher orbital radius (1) No probability that an electron orbits at a radius of 0 m (1) **Any 2**	**2**	Quantum mechanics allows the probability that an electron will be found at a particular place at a particular time to be calculated (1)

Question			Expected Answer/s	Max Mark	Additional Guidance
11			**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 11.**		

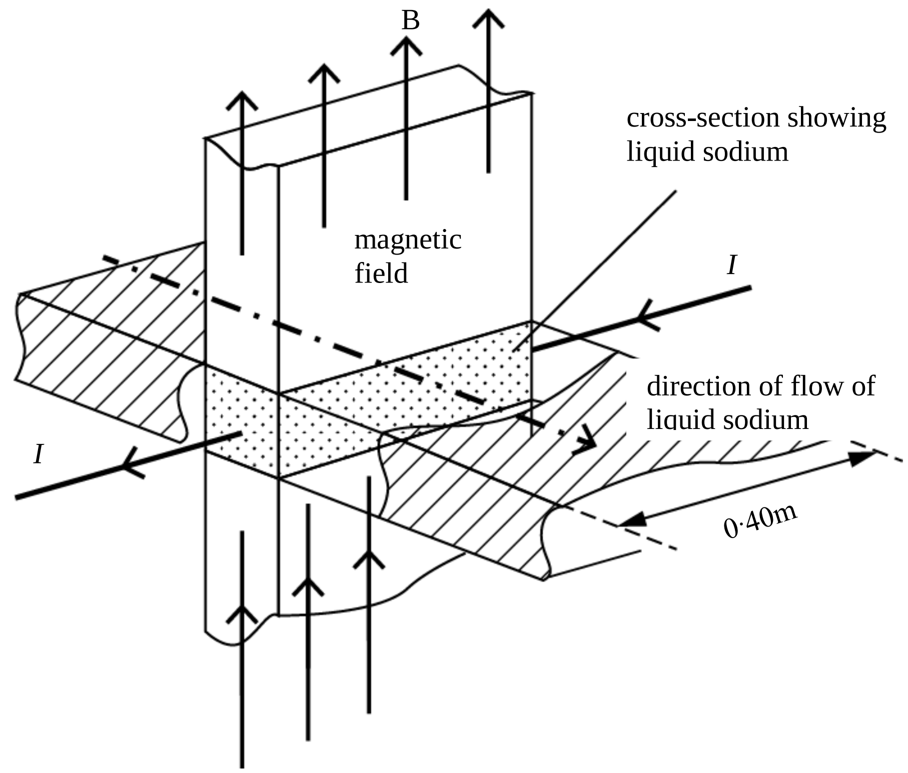


Figure 11

Question			Expected Answer/s	Max Mark	Additional Guidance
	a		**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.** **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	

Question			Expected Answer/s	Max Mark	Additional Guidance
11	b		**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	
11	c		**An engineer must install a long, straight, current carrying wire 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
12			**A student is investigating the electrical potential around a point charge Q. Point P is at a distance of (0·65 ± 0·02) m from Q as shown in Figure 12. The potential at point P is (2·1 ± 0·1) V.**		

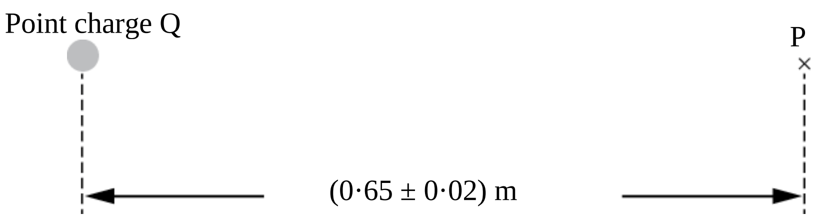


Figure 12

Question			Expected Answer/s	Max Mark	Additional Guidance
	a		**Calculate the value of the point charge Q.** $V = \frac{Q}{4\pi\varepsilon_o r}$ (½) $2{\cdot}1 = \frac{Q}{4\times3{\cdot}14\times 8{\cdot}85\times10^{-12}\times 0{\cdot}65}$ (½) $Q = 1{\cdot}5 \times 10^{-10}$ C (1)	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
12	b		**Calculate the absolute uncertainty in the charge.** $\% \Delta r = \frac{0 \cdot 02}{0 \cdot 65} \times 100 = (\pm) 3\%$ (½) $\% \Delta V = \frac{0 \cdot 1}{2 \cdot 1} \times 100 = (\pm) 4 \cdot 8\%$ (½) $\% \Delta Q = (\pm) \sqrt{\% \Delta r^2 + \% \Delta V^2}$ $\% \Delta Q = (\pm) \sqrt{9 + 23}$ **= (±)** 5·7% (½) $\Delta Q = (\pm) 8 \cdot 6 \times 10^{-12} C$ (½)	2	Fractional calculation is valid alternative.

Question			Expected Answer/s	Max Mark	Additional Guidance
13			**A student is investigating the charging and discharging of a capacitor. The circuit used is shown in Figure 13A.**		

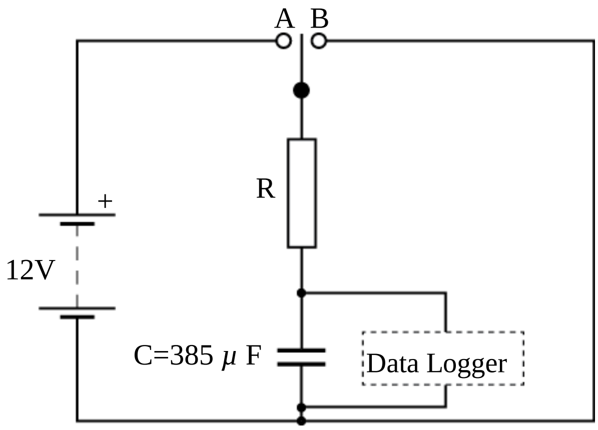
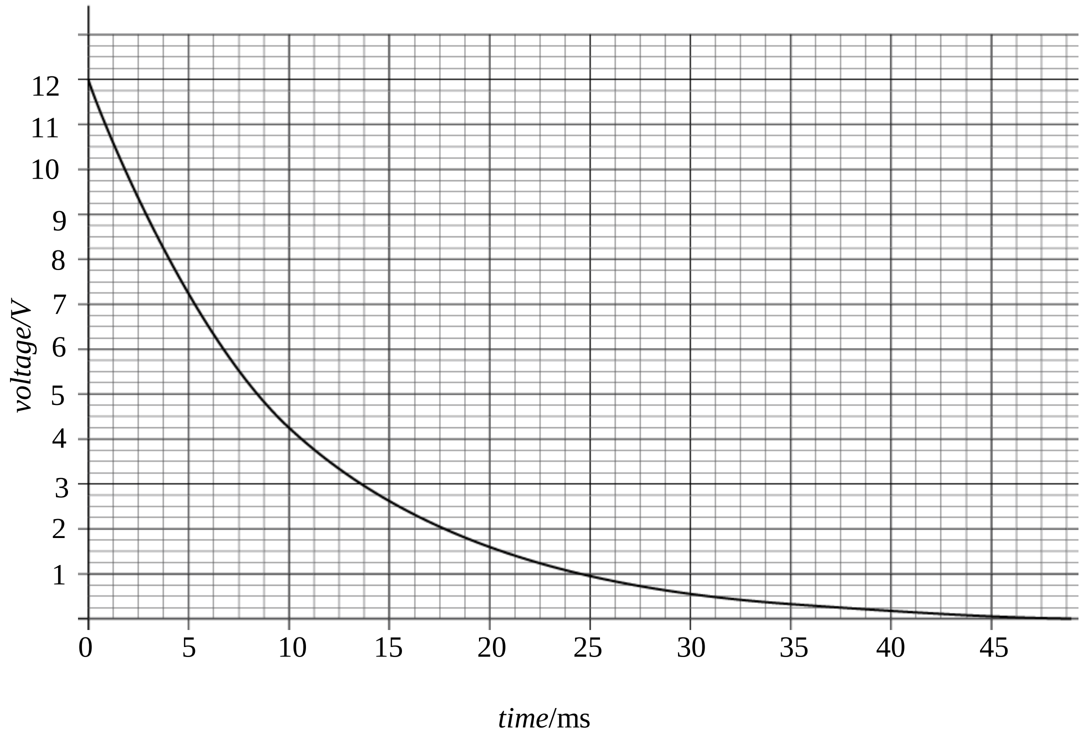
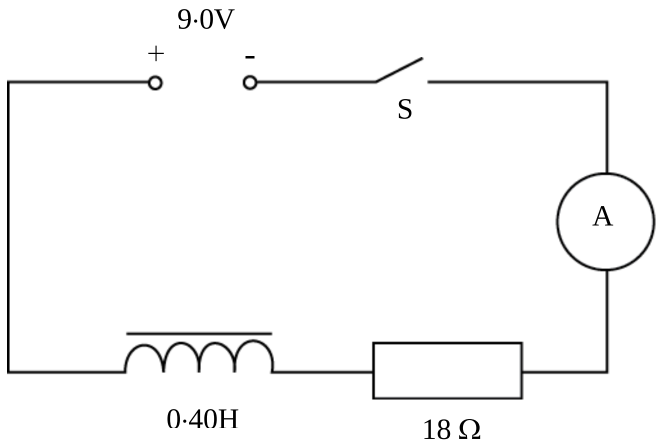
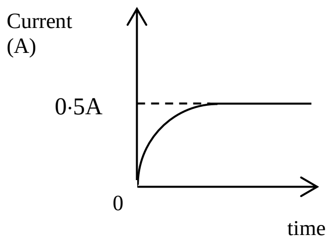


Figure 13A.

			With the switch in position A, the capacitor charges. To discharge the capacitor, the switch is moved to position B. The data logger monitors the voltage across the capacitor. **The graph in Figure 13B shows how the voltage across the capacitor changes during discharge.**		

Question			Expected Answer/s	Max Mark	Additional Guidance
13			**(Cont.)**  Figure 13B		
13	**a**		**Determine the time constant from the graph.** 0·37 (1) 0·37 × 12 = 4·44V. Reading 4·44V from graph (accept 4·4 - 4·5V) This gives 9·5 ms from graph (1)	**2**	Accept (9·0 – 10) ms
13	**b**		**Calculate the resistance of resistor R.** t = RC RC = $9{\cdot}5 \times 10^{-3}$ (½) R ×385 × 10^{-6} = $9{\cdot}5 \times 10^{-3}$ (½) R = 25 Ω (1)	**2**	Follow through consistent with (a)

Question			Expected Answer/s	Max Mark	Additional Guidance
14			**A 0·40 H inductor of negligible resistance is connected in a circuit as shown in Figure 14. Switch S is initially open.**  Figure 14		
	a	i	**Sketch a graph of current against time after the switch S is closed. Numerical values are required on the current axis.**  Shape (1) 0·5 A (1)	2	
		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
14	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) $\frac{dI}{dt} = 23\,\text{A s}^{-1}$ (1)	**2**	Value comes as 22.5 A s^{-1}

Question			Expected Answer/s	Max Mark	Additional Guidance
15			**A student sets up an LC circuit, as shown in Figure 15A.**		

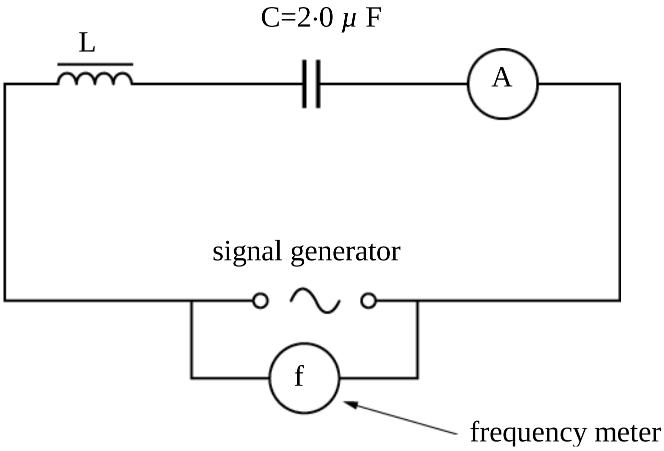
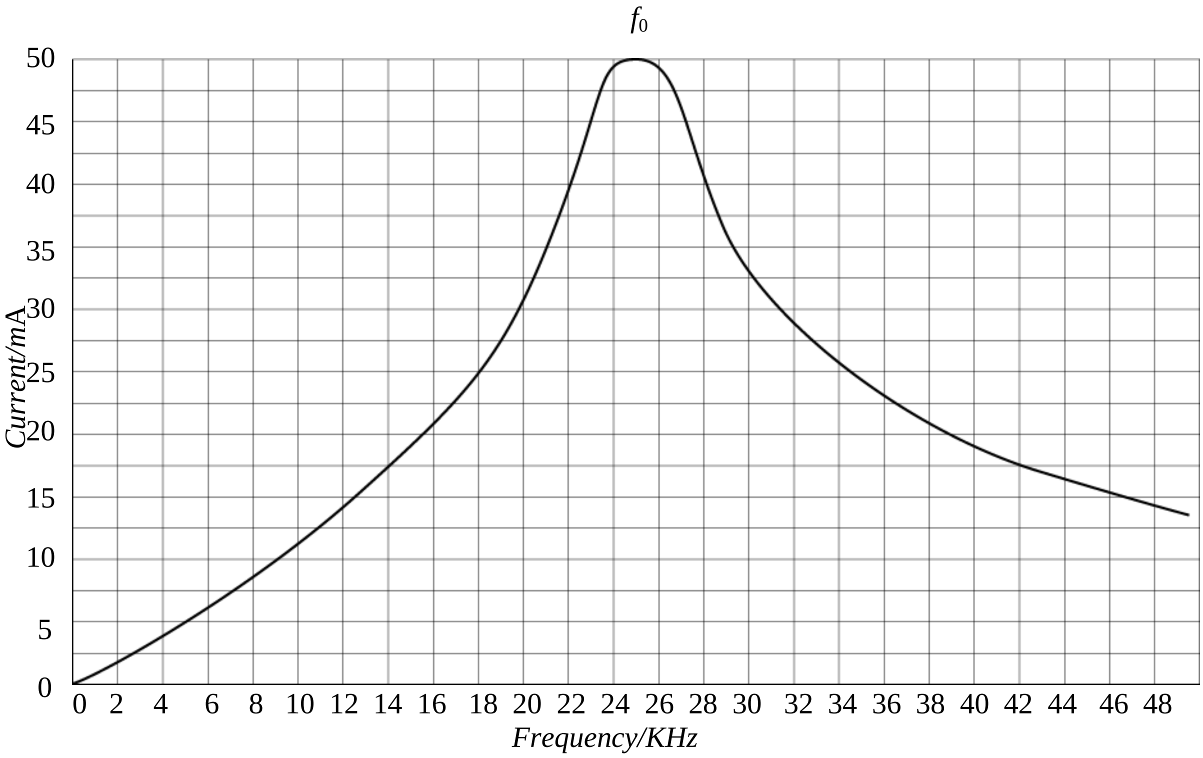
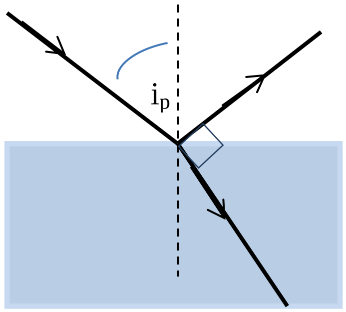


Figure 15A

Question			Expected Answer/s	Max Mark	Additional Guidance
			Maximum current occurs at the resonant frequency f_0. Resonance occurs when the capacitive reactance equals the inductive reactance. The student varies the supply frequency and records the corresponding current. A graph of current against frequency is shown in Figure 15B.		

Question			Expected Answer/s	Max Mark	Additional Guidance
15			**(Cont.)**  Figure 15B		

Question			Expected Answer/s	Max Mark	Additional Guidance
15	a		**Show that the resonant frequency f_0 is given by** $$f_o = \frac{1}{2\pi\sqrt{LC}}$$ $2\pi f_o L = \frac{1}{2\pi f_o C}$ (½) for both eqns + (½)equality	**1**	
15	b		**The capacitance of C is 2·0 μF. Calculate the inductance of L.** $f_o = 25000$ (½) $f_o = \frac{1}{2\pi\sqrt{LC}}$ $25000 = \frac{1}{2\pi\sqrt{L \times 2 \times 10^{-6}}}$ (½) $L = 2{\cdot}0 \times 10^{-5}$ H (1)	**2**	
15	c		**The student wants to change the design of this circuit in order to double the resonant frequency. Describe, in detail, a change the student could make to achieve this.** Reduce L or reduce C (1) by a factor of 4 (× ¼) (1)	**2**	

Question			Expected Answer/s	Max Mark	Additional Guidance
16	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	
16	b		**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.** 		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) .

[END OF MARKING INSTRUCTIONS]