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National
Qualifications
SPECIMEN ONLY

Mark

S857/77/01 **Physics**

Date — Not applicable

Duration — 3 hours

S85777701

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 155

Attempt ALL questions.

Reference may be made to the Physics Relationships Sheet S857/77/11 and the Data Sheet on *page 02*.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Gravitational acceleration on Earth	g	$9{\cdot}8\ \text{m s}^{-2}$	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 Jupiter	M_J	$1{\cdot}90 \times 10^{27}$ kg	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Radius of Jupiter	R_J	$7{\cdot}15 \times 10^{7}$ m	Mass of alpha particle	m_α	$6{\cdot}645 \times 10^{-27}$ kg
Mean Radius of Jupiter Orbit		$7{\cdot}79 \times 10^{11}$ 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	$6{\cdot}63 \times 10^{-34}$ J s
Mass of Sun		$2{\cdot}0 \times 10^{30}$ kg	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}\ \text{F m}^{-1}$
1 AU		$1{\cdot}5 \times 10^{11}$ m	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \text{H m}^{-1}$
Stefan-Boltzmann constant	σ	$5{\cdot}67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$	Speed of sound in air	v	$3{\cdot}4 \times 10^{2}\ \text{m s}^{-1}$

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
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	Wavelength (nm)	Colour
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	Wavelength (nm)	Colour
Carbon dioxide	9550 } 10 590 }	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density (kg m^{-3})	Melting Point (K)	Boiling Point (K)	Specific Heat Capacity ($\text{J kg}^{-1}\ \text{K}^{-1}$)	Specific Latent Heat of Fusion (J kg^{-1})	Specific Latent Heat of Vaporisation (J kg^{-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	$4{\cdot}18 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	$2{\cdot}26 \times 10^{6}$
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	$9{\cdot}18 \times 10^{2}$	....	$2{\cdot}40 \times 10^{4}$

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

Total marks — 155 marks

Attempt ALL questions

1.


Calvin Chan/shutterstock.com

A car on a long straight track accelerates from rest. The car's run begins at time $t = 0$.

Its velocity v at time t is given by the equation

$$v = 0{\cdot}135t^2 + 1{\cdot}26t$$

where v is measured in m s^{-1}
and t is measured in s.

Using calculus methods

(a) determine the acceleration of the car at $t = 15{\cdot}0$ s **3**

Space for working and answer

(b) determine the displacement of the car from its original position at this time. **3**

Space for working and answer

2. Water is removed from clothes during the spin cycle of a washing machine. The drum holding the clothes has a maximum spin rate of 1250 revolutions per minute.

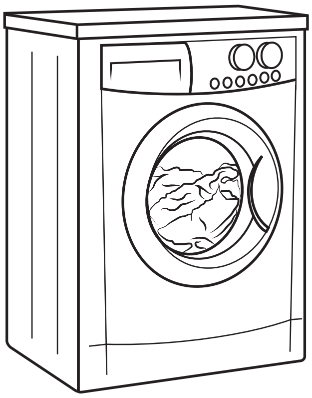

Figure 2A

(a) Show that the maximum angular velocity of the drum is 131 rad s^{-1}. **2**

Space for working and answer

(b) At the start of a spin cycle the drum has an angular velocity of 7·50 rad s^{-1}. It then takes 12·0 seconds to accelerate to the maximum angular velocity.

(i) Calculate the angular acceleration of the drum during the 12·0 seconds, assuming the acceleration is uniform. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

2. (b) (continued)

(ii) Determine how many revolutions the drum will make during the 12·0 seconds. **4**

Space for working and answer

(c) When the drum is rotating at maximum angular velocity, an item of wet clothing of mass $1{\cdot}5 \times 10^{-2}$ kg rotates at a distance of 0·28 m from the axis of rotation, as shown in **Figure 2B**.

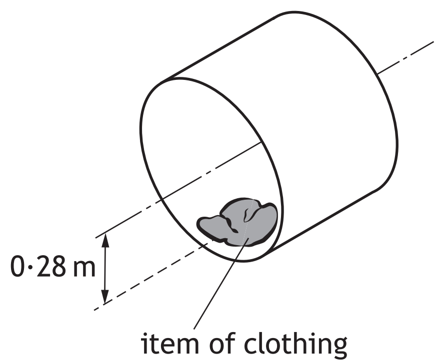

Figure 2B

Calculate the centripetal force acting on the item of clothing. **3**

Space for working and answer

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[Turn over

2. (continued)

(d) The outer surface of the drum has small holes, as shown in **Figure 2C**. These holes allow most of the water to be removed.

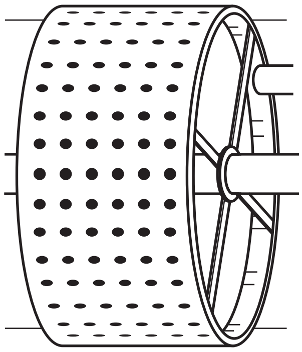

Figure 2C

(i) Explain why the water separates from the item of clothing during the spin cycle. **2**

(ii) The drum rotates in an anticlockwise direction.

Indicate on **Figure 2D** the direction taken by a water droplet as it leaves the drum. **1**

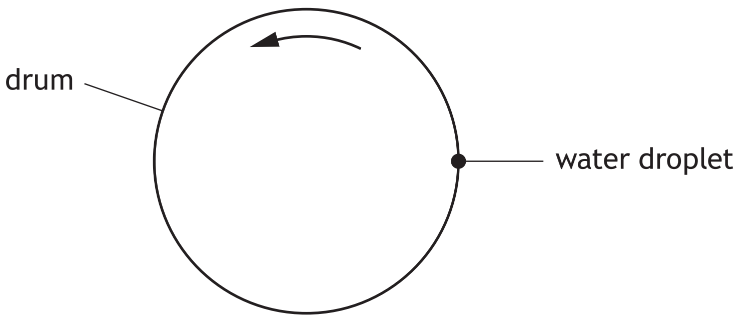

Figure 2D

2. (d) (continued)

(iii) Explain what happens to the magnitude of the force acting on an item of clothing inside the drum as it rotates at its maximum angular velocity. **2**

[Turn over

3. A disc of mass 6·0 kg and radius 0·50 m is allowed to rotate freely about its central axis, as shown in **Figure 3A**.

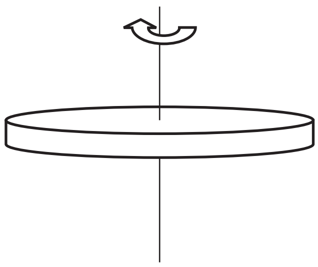

Figure 3A

(a) Show that the moment of inertia of the disc is 0·75 kg m^2. **2**

Space for working and answer

(b) The disc is rotating with an angular velocity of 12 rad s^{-1}. A cube of mass 2·0 kg is then dropped onto the disc. The cube remains at a distance of 0·40 m from the axis of rotation, as shown in **Figure 3B**.

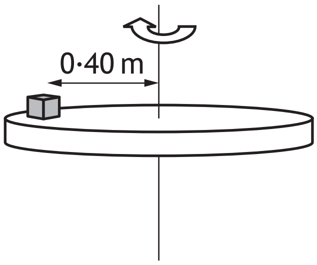

Figure 3B

3. (b) (continued)

(i) Determine the total moment of inertia of the disc and cube. **3**

Space for working and answer

(ii) Calculate the angular velocity of the disc after the cube lands. **3**

Space for working and answer

(iii) State one assumption you have made in your response to b(ii). **1**

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

3. (continued)

(c) The cube is removed and the disc is again made to rotate with a constant angular velocity of 12 rad s^{-1}. A sphere of mass 2·0 kg is then dropped onto the disc at a distance of 0·40 m from the axis, as shown in **Figure 3C**.

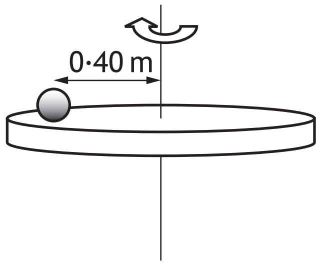

Figure 3C

State whether the resulting angular velocity of the disc is greater than, the same as, or less than the value calculated in b(ii).

Justify your answer. **2**

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4. The International Space Station (ISS) is in orbit around the Earth.

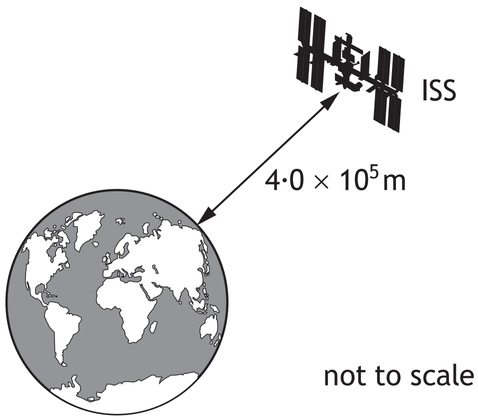

Figure 4A

(a) (i) The gravitational pull of the Earth keeps the ISS in orbit.

Show that for an orbit of radius r the period T is given by the expression

$$T = 2\pi\sqrt{\frac{r^3}{GM_E}}$$

where the symbols have their usual meaning. **2**

(ii) Calculate the period of orbit of the ISS when it is at an altitude of $4{\cdot}0 \times 10^5$ m above the surface of the Earth. **2**

Space for working and answer

* S 8 5 7 7 7 0 1 1 1 *

[Turn over

4. **(continued)**

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(b) The graph in **Figure 4B** shows how the altitude of the ISS has varied over time. Reductions in altitude are due to the drag of the Earth's atmosphere acting on the ISS.

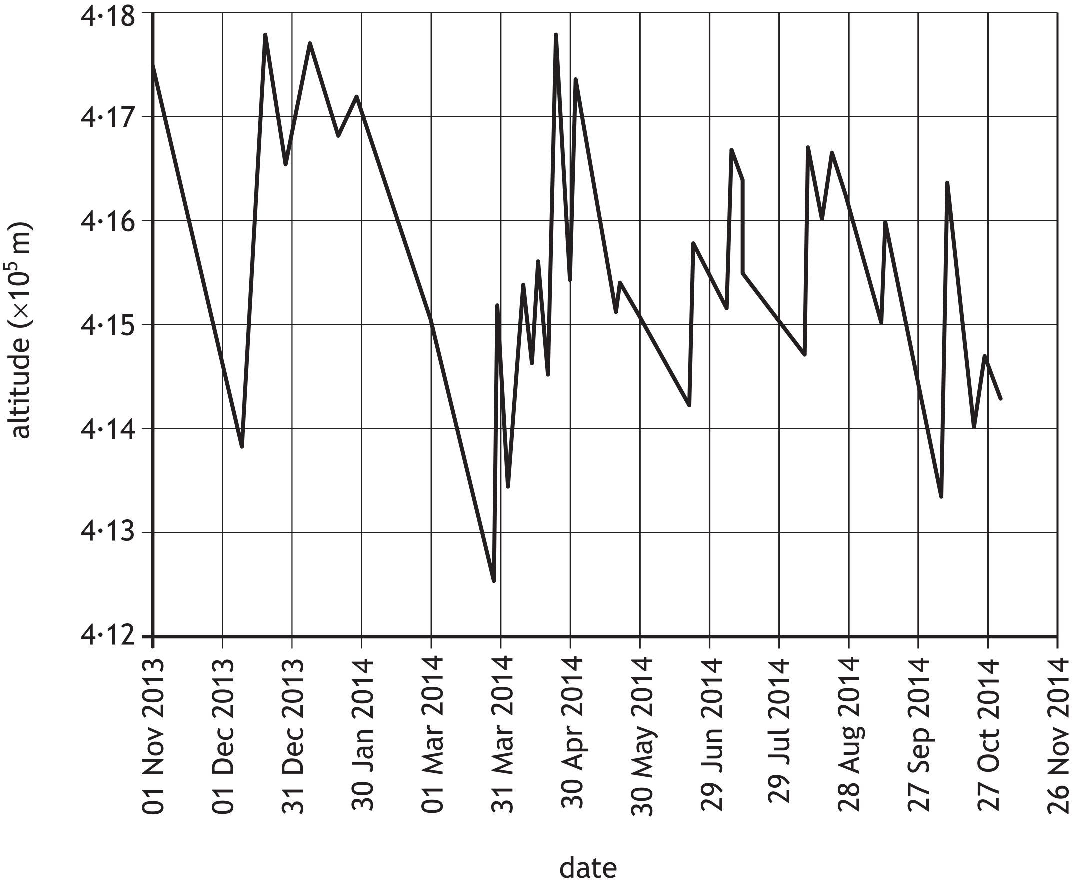

Figure 4B

(i) Determine the value of Earth's gravitational field strength at the ISS on 1 March 2014. **4**

Space for working and answer

4. (b) (continued)

(ii) In 2011 the average altitude of the ISS was increased from 350 km to 400 km.

Suggest an advantage of operating the ISS at this higher altitude. **1**

(c) Clocks designed to operate on the ISS are synchronised with clocks on Earth before they go into space. On the ISS a correction factor is necessary for the clocks to remain synchronised with clocks on Earth.

Explain why this correction factor is necessary. **2**

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5. The constellation Orion, shown in **Figure 5A**, is a common sight in the winter sky above Scotland.

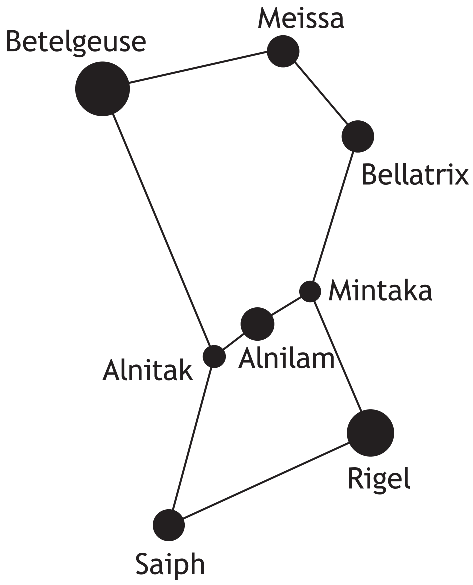

Figure 5A

Two of the stars in this constellation are known as Betelgeuse and Rigel. Their positions are shown on the Hertzsprung–Russell (H-R) diagram in **Figure 5B**.

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5. (continued)

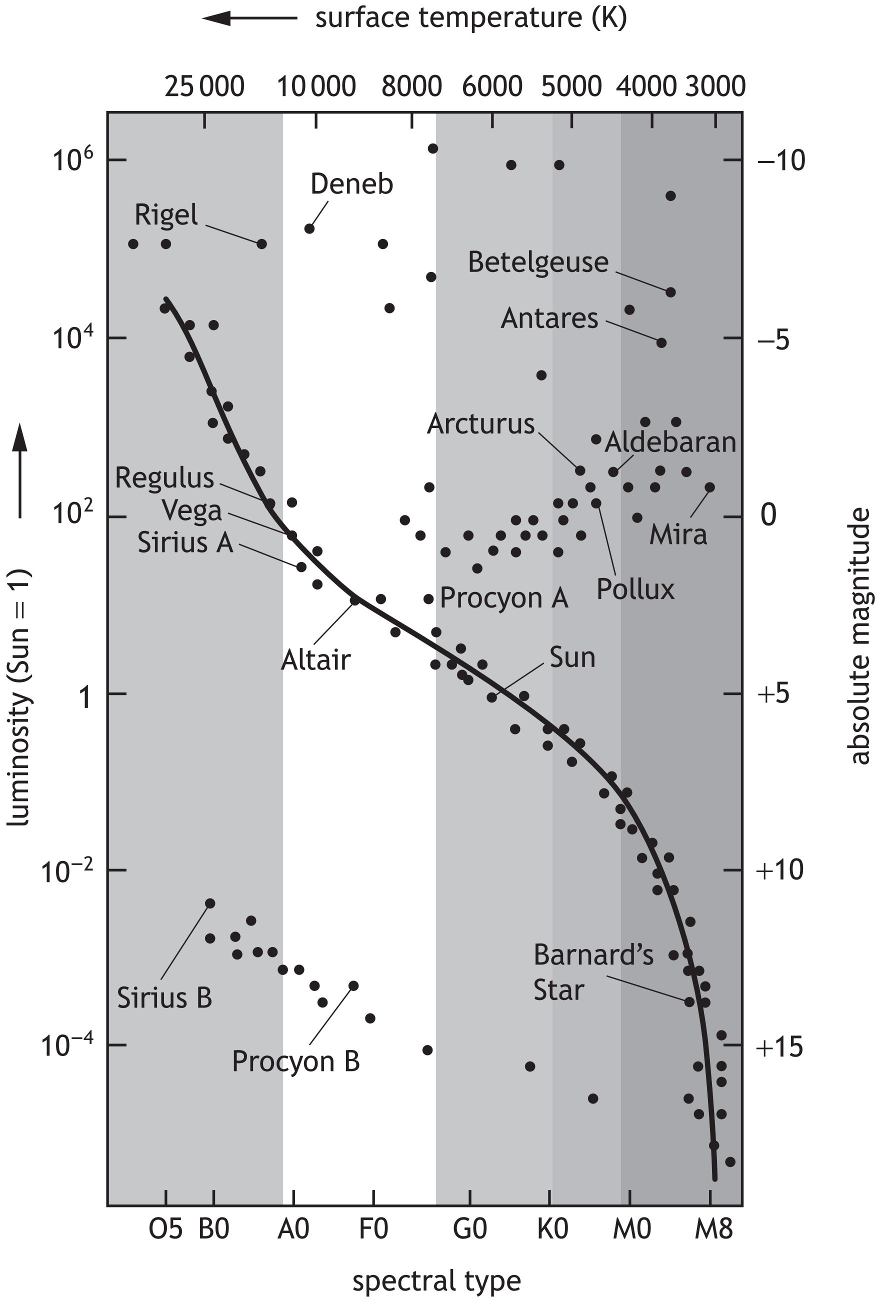

Figure 5B

(a) Using the H-R diagram, predict the colour of Betelgeuse. **1**

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5. (continued)

(b) The table shows some of the physical properties of Rigel.

Property of Rigel	
Surface temperature	$(1 \cdot 20 \pm 0 \cdot 05) \times 10^4$ K
Radius	$(5 \cdot 49 \pm 0 \cdot 50) \times 10^{10}$ m
Mass	18 ± 1 solar masses
Distance to Earth	773 ± 150 light years

(i) (A) Calculate the luminosity of Rigel. **3**

Space for working and answer

(B) State the assumption made in your calculation. **1**

5. (b) (continued)

(ii) Calculate the absolute uncertainty in the value of the luminosity of Rigel. **4**

Space for working and answer

(c) Calculate the apparent brightness of Rigel as observed from the Earth. **4**

Space for working and answer

(d) Betelgeuse is not on the Main Sequence region of the H-R diagram.

State two changes that took place in the core of Betelgeuse at the point it left the Main Sequence. **2**

(e) Explain, in terms of thermal pressure and gravitational force, the change in the radius of Betelgeuse between leaving the Main Sequence and becoming a supergiant. **2**

6. The Bohr model of the hydrogen atom consists of a single electron orbiting a single proton. Due to the quantisation of angular momentum, in this model, the electron can only orbit at particular radii.

Figure 6A shows an electron with principal quantum number $n = 1$.

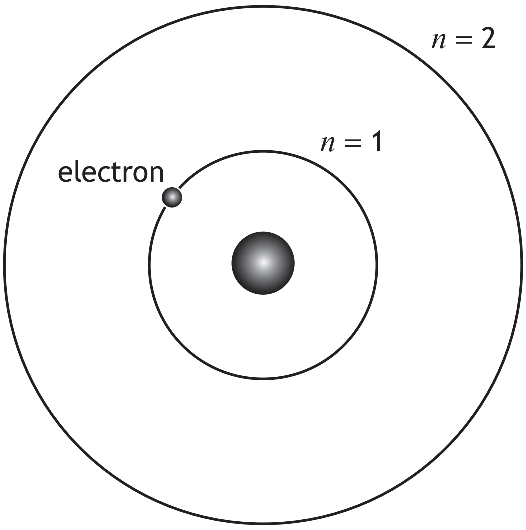

Figure 6A

(a) Explain what gives rise to the centripetal force acting on the electron. **1**

(b) (i) Show that the kinetic energy of the electron is given by

$$E_k = \frac{e^2}{8\pi\varepsilon_0 r}$$

where the symbols have their usual meaning. **2**

MARKS | DO NOT WRITE IN THIS MARGIN

6. (b) (continued)

(ii) Calculate the kinetic energy for an electron with orbital radius 0·21 nm. **2**

Space for working and answer

(c) Calculate the principal quantum number for an electron with angular momentum $4{\cdot}22 \times 10^{-34}\ \mathrm{kg\,m^2\,s^{-1}}$. **3**

Space for working and answer

(d) The Heisenberg uncertainty principle addresses some of the limitations of classical physics in describing quantum phenomena.

(i) The uncertainty in an experimental measurement of the momentum of an electron in a hydrogen atom was determined to be $\pm 1{\cdot}5 \times 10^{-26}\ \mathrm{kg\,m\,s^{-1}}$.

Calculate the minimum uncertainty Δx_{min} in the position of the electron. **3**

Space for working and answer

6. (d) (continued)

(ii) In a scanning tunnelling microscope (STM) a sharp metallic tip is brought very close to the surface of a conductor. As the tip is moved back and forth, an electric current can be detected due to the movement ('tunnelling') of electrons across the gap between the tip and the conductor, as shown in **Figure 6B**.

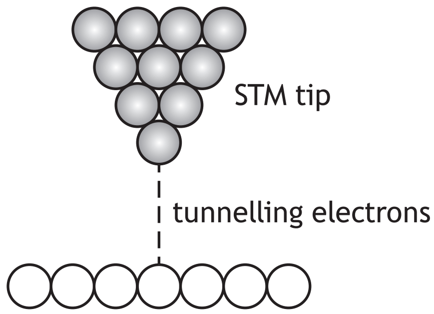

Figure 6B

According to classical physics, electrons should not be able to cross the gap as the kinetic energy of each electron is insufficient to overcome the repulsion between electrons in the STM tip and the surface.

Explain why an electron is able to cross the gap. **3**

7. A proton, travelling with a speed of $2{\cdot}6 \times 10^{7}$ m s^{-1}, enters the magnetic field around the Earth at an angle of 50° as shown in **Figure 7B**. The magnetic field strength is 58 μT.

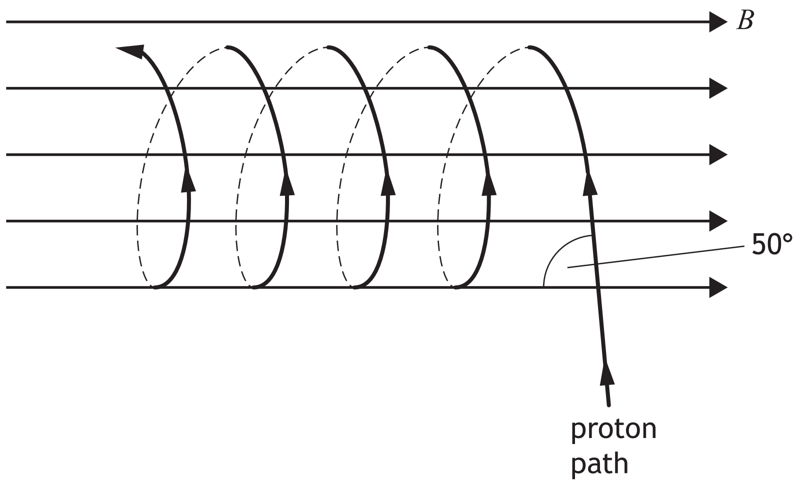

Figure 7B

(a) Explain the shape of the path followed by the proton in the magnetic field. **2**

(b) Calculate the radius of curvature of this path. **5**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

(c) An antiproton, travelling with a speed of $2{\cdot}6 \times 10^{7}$ m s^{-1} enters the same region of the Earth's magnetic field at an angle of 30° to the field.

Describe two differences in the paths taken by the antiproton and the original proton. **2**

* S 8 5 7 7 7 0 1 2 2 *

8. **Figure 8A** shows a snowboarder in a half pipe. The snowboarder is moving between positions P and Q. The total mass of snowboarder and board is 85 kg.

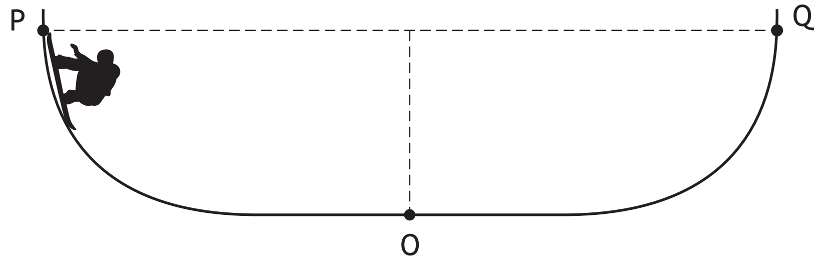

Figure 8A

A student attempts to model the motion of the snowboarder in the horizontal plane as simple harmonic motion (SHM).

The student uses measurements of amplitude and period to produce the displacement-time graph shown in **Figure 8B**.

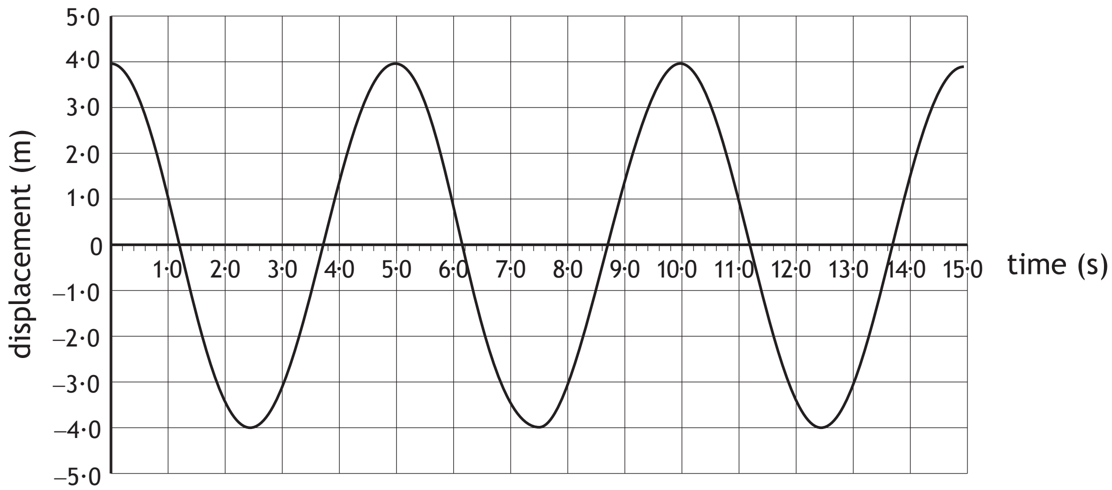

Figure 8B

(a) (i) State what is meant by the term *simple harmonic motion*. **1**

[Turn over

8. (a) (continued)

(ii) Determine the angular frequency of the motion. **4**

Space for working and answer

(iii) Calculate the maximum acceleration in the horizontal plane experienced by the snowboarder. **3**

Space for working and answer

(iv) Sketch a velocity-time graph for one period of the motion in the horizontal plane.

Numerical values are required on both axes. **3**

You may wish to use the square-ruled paper on *page 36*.

8. (a) (continued)

(v) Calculate the maximum potential energy of the snowboarder. **3**

Space for working and answer

(b) Detailed video analysis shows that the snowboarder's motion is not fully described by the SHM model.

Using your knowledge of physics, comment on possible reasons for this discrepancy. **3**

9. When a microwave oven is switched on a stationary wave is formed inside the oven.

(a) Explain how a stationary wave is formed. **1**

(b) A student carries out an experiment to determine the speed of light using a microwave oven. The turntable is removed from the oven and bread covered in butter is placed inside. The oven is switched on for a short time, after which the student observes that the butter has melted only in certain spots, as shown in **Figure 9A**.

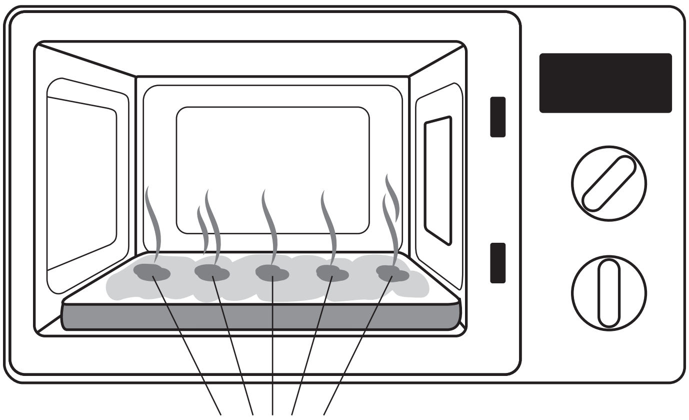

Figure 9A

Explain why the butter has melted in certain spots and not in others. **2**

9. (continued)

(c) The student measures the distance between the first melted spot and fifth melted spot as 264 mm.

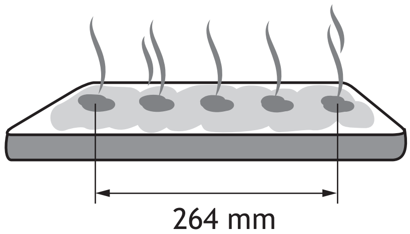

Figure 9B

From the data obtained by the student determine the wavelength of the microwaves. **2**

Space for working and answer

(d) The quoted value for the frequency of the microwaves is 2·45 GHz. The student calculates the speed of light using data from the experiment.

Show that the value obtained by the student for the speed of light is $3{\cdot}23 \times 10^8\ \mathrm{m\,s^{-1}}$. **2**

Space for working and answer

9. (continued)

(e) The student repeats the experiment and obtains the following values for the speed of light.

$3{\cdot}26 \times 10^8$ m s^{-1}, $3{\cdot}19 \times 10^8$ m s^{-1}, $3{\cdot}23 \times 10^8$ m s^{-1}, $3{\cdot}21 \times 10^8$ m s^{-1}

Comment on both the accuracy and precision of the student's results. **2**

10. A beam of electrons is incident on a grating as shown in **Figure 10A**.

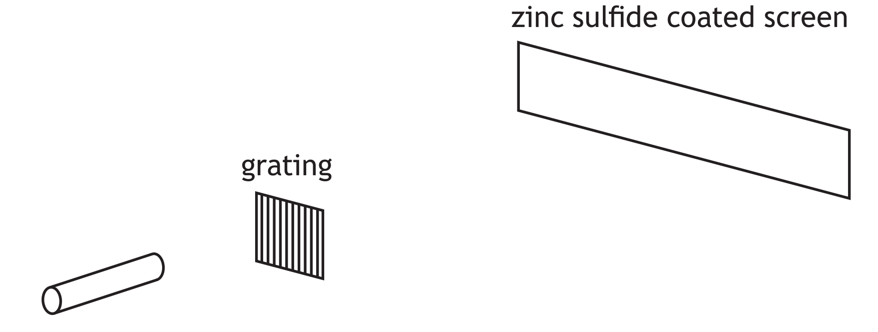

Figure 10A

(a) After passing through the grating the electrons are incident on a zinc sulfide coated screen. The coating emits light when struck by electrons.

Describe the pattern observed on the screen. **1**

(b) Scientists perform similar experiments with large molecules. One such molecule is buckminsterfullerene (C_{60}) with a mass of $1{\cdot}20 \times 10^{-24}$ kg.

For C_{60} molecules with a velocity of 220 m s^{-1} estimate the slit spacing required to produce a pattern comparable to that observed for the electrons.

You must justify your answer by calculation. **4**

Space for working and answer

11. As part of a physics project a student carried out experiments to obtain values for the permeability of free space and the permittivity of free space.

MARKS DO NOT WRITE IN THIS MARGIN

The results obtained by the student were

permeability of free space, $\mu_0 = (1{\cdot}32 \pm 0{\cdot}05) \times 10^{-6}\,\text{Hm}^{-1}$

permittivity of free space, $\varepsilon_0 = (8{\cdot}93 \pm 0{\cdot}07) \times 10^{-12}\,\text{Fm}^{-1}$

(a) State the number of significant figures in the value of each result. **1**

(b) Use these results to determine a value for the speed of light. **3**

Space for working and answer

(c) (i) Determine which of the uncertainties obtained by the student is more significant for the calculation of the speed of light.

You must justify your answer by calculation. **3**

Space for working and answer

(ii) Calculate the absolute uncertainty in the value obtained for the speed of light. **2**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

12. (a) Two point charges Q_1 and Q_2 are separated by a distance of 0·60 m as shown in **Figure 12A**.

The charge on Q_1 is −8·0 nC. The electric field strength at point X is zero.

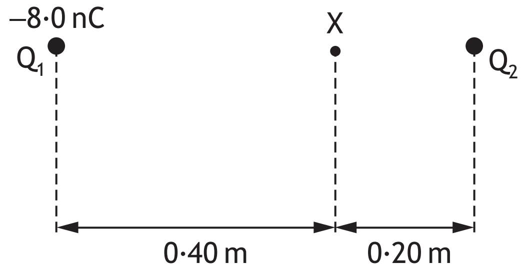

Figure 12A

(i) State what is meant by *electric field strength*. **1**

(ii) Show that the charge on Q_2 is −2·0 nC. **2**

Space for working and answer

(iii) Determine the electrical potential at point X. **5**

Space for working and answer

12. (continued)

(b)

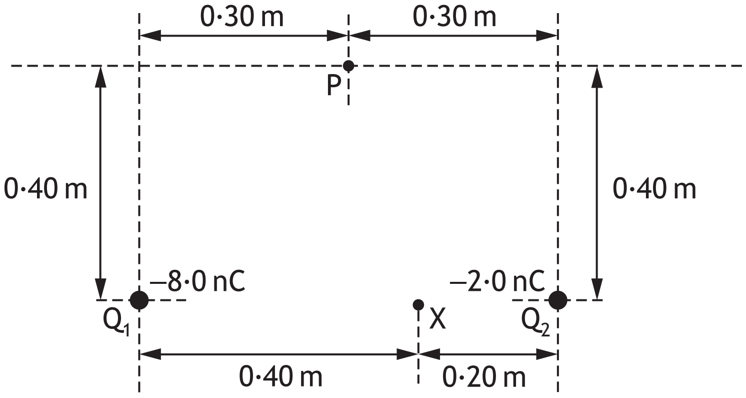

Figure 12B

(i) Determine the electrical potential at point P. **3**

Space for working and answer

(ii) Determine the energy required to move a charge of +1·0 nC from point X to point P. **4**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

13. The Nobel Prize-winning physicist Richard Feynman once stated 'things on a small scale behave nothing like things on a large scale'.

Using your knowledge of physics, comment on his statement. **3**

[Turn over

14. A student carries out a series of experiments to investigate properties of capacitors in AC circuits.

(a) The student connects a 5·0 μF capacitor to an AC supply of EMF 15 V_{rms} and negligible internal resistance as shown in **Figure 14A**.

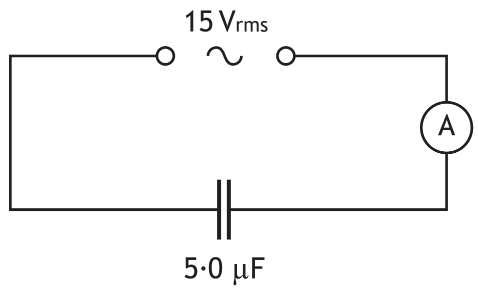

Figure 14A

The frequency of the AC supply is 65 Hz.

(i) Calculate the reactance of the capacitor. **3**

Space for working and answer

(ii) Calculate the current in the circuit. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

(b) The student uses the following circuit to determine the capacitance of a second capacitor.

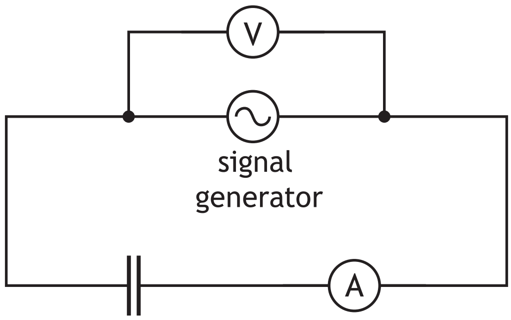

Figure 14B

The student obtains the following data.

X_c (Ω)	f (Hz)
$1{\cdot}60 \times 10^6$	10
$6{\cdot}47 \times 10^5$	40
$2{\cdot}99 \times 10^5$	100
$1{\cdot}52 \times 10^5$	200
$6{\cdot}35 \times 10^4$	500
$3{\cdot}18 \times 10^4$	1000

(i) On the square-ruled paper on *page 37*, plot a graph of X_c against $\frac{1}{f}$. **3**

(ii) Use your graph to determine the capacitance of this capacitor. **3**

Space for working and answer

[END OF SPECIMEN QUESTION PAPER]

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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

MARKS DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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S857/77/11

Physics
Relationships sheet

Date — Not applicable

Duration — 3 hours

Relationships required for Physics Advanced Higher

$$v = \frac{ds}{dt}$$

$$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$\omega = \frac{d\theta}{dt}$$

$$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

$$\omega = \omega_o + \alpha t$$

$$\omega^2 = {\omega_o}^2 + 2\alpha\theta$$

$$\theta = \omega_o t + \frac{1}{2}\alpha t^2$$

$$s = r\theta$$

$$v = r\omega$$

$$a_t = r\alpha$$

$$\omega = \frac{2\pi}{T}$$

$$\omega = 2\pi f$$

$$a_r = \frac{v^2}{r} = r\omega^2$$

$$F = \frac{mv^2}{r} = mr\omega^2$$

$$I = \sum mr^2$$

$$\tau = Fr$$

$$\tau = I\alpha$$

$$L = mvr = mr^2\omega$$

$$L = I\omega$$

$$E_{k(rotational)} = \frac{1}{2}I\omega^2$$

$$E_P = E_{k(translational)} + E_{k(rotational)}$$

$$F = \frac{GMm}{r^2}$$

$$F = \frac{GMm}{r^2} = \frac{mv^2}{r} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$$

$$V = -\frac{GM}{r}$$

$$E_P = Vm = -\frac{GMm}{r}$$

$$v_{esc} = \sqrt{\frac{2GM}{r}}$$

$$r_{Schwarzschild} = \frac{2GM}{c^2}$$

$$b = \frac{L}{4\pi d^2}$$

$$\frac{P}{A} = \sigma T^4$$

$$L = 4\pi r^2 \sigma T^4$$

$$E = hf$$

$$mvr = \frac{nh}{2\pi}$$

$$\lambda = \frac{h}{p}$$

$$\Delta x\, \Delta p_x \geq \frac{h}{4\pi}$$

$$\Delta E\, \Delta t \geq \frac{h}{4\pi}$$

$$F = qvB$$

$$F = \frac{mv^2}{r}$$

$$F = -ky$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

$$a = \frac{d^2y}{dt^2} = -\omega^2 y$$

$$y = A\cos\omega t \quad \text{or} \quad y = A\sin\omega t$$

$$v = \pm\omega\sqrt{\left(A^2 - y^2\right)}$$

$$E_k = \frac{1}{2}m\omega^2\left(A^2 - y^2\right)$$

$$E_P = \frac{1}{2}m\omega^2 y^2$$

$$E = kA^2$$

$$y = A\sin 2\pi\left(ft - \frac{x}{\lambda}\right)$$

$$\phi = \frac{2\pi x}{\lambda}$$

$$opd = n \times gpd$$

$$opd = m\lambda \text{ or } \left(m + \frac{1}{2}\right)\lambda \text{ where } m = 0,1,2\ldots$$

$$\Delta x = \frac{\lambda l}{2d}$$

$$d = \frac{\lambda}{4n}$$

$$\Delta x = \frac{\lambda D}{d}$$

$$n = \tan i_P$$

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$$

$$V = \frac{Q}{4\pi\varepsilon_o r}$$

$$E = \frac{Q}{4\pi\varepsilon_o r^2}$$

$$F = QE$$

$$V = Ed$$

$$W = QV$$

$$E_k = \frac{1}{2}mv^2$$

$$B = \frac{\mu_o I}{2\pi r}$$

$$F = IlB\sin\theta$$

$$F = qvB$$

$$\tau = RC$$

$$X_C = \frac{V}{I}$$

$$X_C = \frac{1}{2\pi fC}$$

$$\varepsilon = -L\frac{dI}{dt}$$

$$E = \frac{1}{2}LI^2$$

$$X_L = \frac{V}{I}$$

$$X_L = 2\pi fL$$

$$c = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$$

$$\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$$

$$\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$$

$$\left(\frac{\Delta W^n}{W^n}\right) = n\left(\frac{\Delta W}{W}\right)$$

$$d = \bar{v}t$$

$$s = \bar{v}t$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$s = \frac{1}{2}(u+v)t$$

$$W = mg$$

$$F = ma$$

$$E_W = Fd$$

$$E_P = mgh$$

$$E_K = \frac{1}{2}mv^2$$

$$P = \frac{E}{t}$$

$$p = mv$$

$$Ft = mv - mu$$

$$F = G\frac{Mm}{r^2}$$

$$t' = \frac{t}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

$$l' = l\sqrt{1-\left(\frac{v}{c}\right)^2}$$

$$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$$

$$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$$

$$z = \frac{v}{c}$$

$$v = H_0 d$$

$$W = QV$$

$$E = mc^2$$

$$E = hf$$

$$E_K = hf - hf_0$$

$$E_2 - E_1 = hf$$

$$T = \frac{1}{f}$$

$$v = f\lambda$$

$$d\sin\theta = m\lambda$$

$$n = \frac{\sin\theta_1}{\sin\theta_2}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

$$\sin\theta_c = \frac{1}{n}$$

$$I = \frac{k}{d^2}$$

$$I = \frac{P}{A}$$

$$V_{peak} = \sqrt{2}V_{rms}$$

$$I_{peak} = \sqrt{2}I_{rms}$$

$$Q = It$$

$$V = IR$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$R_T = R_1 + R_2 + \ldots$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$

$$E = V + Ir$$

$$V_1 = \left(\frac{R_1}{R_1 + R_2}\right)V_S$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

$$C = \frac{Q}{V}$$

$$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$$

path difference $= m\lambda$ or $\left(m + \frac{1}{2}\right)\lambda$ where $m = 0, 1, 2\ldots$

random uncertainty $= \dfrac{\text{max. value} - \text{min. value}}{\text{number of values}}$

Additional relationships

Circle

circumference $= 2\pi r$

area $= \pi r^2$

Sphere

area $= 4\pi r^2$

volume $= \frac{4}{3}\pi r^3$

Trigonometry

$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$

$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$

$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$

$\sin^2\theta + \cos^2\theta = 1$

Moment of inertia

point mass
$I = mr^2$

rod about centre
$I = \frac{1}{12}ml^2$

rod about end
$I = \frac{1}{3}ml^2$

disc about centre
$I = \frac{1}{2}mr^2$

sphere about centre
$I = \frac{2}{5}mr^2$

Table of standard derivatives

$f(x)$	$f'(x)$
$\sin ax$	$a\cos ax$
$\cos ax$	$-a\sin ax$

Table of standard integrals

$f(x)$	$\int f(x)dx$
$\sin ax$	$-\frac{1}{a}\cos ax + C$
$\cos ax$	$\frac{1}{a}\sin ax + C$

Electron arrangements of elements

Key

Key
Atomic number Symbol Electron arrangement Name

Group 1	Group 2											Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
1 **H** 1 Hydrogen																	2 **He** 2 Helium
3 **Li** 2,1 Lithium	4 **Be** 2,2 Beryllium											5 **B** 2,3 Boron	6 **C** 2,4 Carbon	7 **N** 2,5 Nitrogen	8 **O** 2,6 Oxygen	9 **F** 2,7 Fluorine	10 **Ne** 2,8 Neon
11 **Na** 2,8,1 Sodium	12 **Mg** 2,8,2 Magnesium											13 **Al** 2,8,3 Aluminium	14 **Si** 2,8,4 Silicon	15 **P** 2,8,5 Phosphorus	16 **S** 2,8,6 Sulfur	17 **Cl** 2,8,7 Chlorine	18 **Ar** 2,8,8 Argon
19 **K** 2,8,8,1 Potassium	20 **Ca** 2,8,8,2 Calcium	21 **Sc** 2,8,9,2 Scandium	22 **Ti** 2,8,10,2 Titanium	23 **V** 2,8,11,2 Vanadium	24 **Cr** 2,8,13,1 Chromium	25 **Mn** 2,8,13,2 Manganese	26 **Fe** 2,8,14,2 Iron	27 **Co** 2,8,15,2 Cobalt	28 **Ni** 2,8,16,2 Nickel	29 **Cu** 2,8,18,1 Copper	30 **Zn** 2,8,18,2 Zinc	31 **Ga** 2,8,18,3 Gallium	32 **Ge** 2,8,18,4 Germanium	33 **As** 2,8,18,5 Arsenic	34 **Se** 2,8,18,6 Selenium	35 **Br** 2,8,18,7 Bromine	36 **Kr** 2,8,18,8 Krypton
37 **Rb** 2,8,18,8,1 Rubidium	38 **Sr** 2,8,18,8,2 Strontium	39 **Y** 2,8,18,9,2 Yttrium	40 **Zr** 2,8,18, 10,2 Zirconium	41 **Nb** 2,8,18, 12,1 Niobium	42 **Mo** 2,8,18,13, 1 Molybdenum	43 **Tc** 2,8,18,13, 2 Technetium	44 **Ru** 2,8,18,15, 1 Ruthenium	45 **Rh** 2,8,18,16, 1 Rhodium	46 **Pd** 2,8,18, 18,0 Palladium	47 **Ag** 2,8,18, 18,1 Silver	48 **Cd** 2,8,18, 18,2 Cadmium	49 **In** 2,8,18, 18,3 Indium	50 **Sn** 2,8,18, 18,4 Tin	51 **Sb** 2,8,18, 18,5 Antimony	52 **Te** 2,8,18, 18,6 Tellurium	53 **I** 2,8,18, 18,7 Iodine	54 **Xe** 2,8,18, 18,8 Xenon
55 **Cs** 2,8,18,18, 8,1 Caesium	56 **Ba** 2,8,18,18, 8,2 Barium	57 **La** 2,8,18,18, 9,2 Lanthanum	72 **Hf** 2,8,18,32, 10,2 Hafnium	73 **Ta** 2,8,18, 32,11,2 Tantalum	74 **W** 2,8,18,32, 12,2 Tungsten	75 **Re** 2,8,18,32, 13,2 Rhenium	76 **Os** 2,8,18,32, 14,2 Osmium	77 **Ir** 2,8,18,32, 15,2 Iridium	78 **Pt** 2,8,18,32, 17,1 Platinum	79 **Au** 2,8,18, 32,18,1 Gold	80 **Hg** 2,8,18, 32,18,2 Mercury	81 **Tl** 2,8,18, 32,18,3 Thallium	82 **Pb** 2,8,18, 32,18,4 Lead	83 **Bi** 2,8,18, 32,18,5 Bismuth	84 **Po** 2,8,18, 32,18,6 Polonium	85 **At** 2,8,18, 32,18,7 Astatine	86 **Rn** 2,8,18, 32,18,8 Radon
87 **Fr** 2,8,18,32, 18,8,1 Francium	88 **Ra** 2,8,18,32, 18,8,2 Radium	89 **Ac** 2,8,18,32, 18,9,2 Actinium	104 **Rf** 2,8,18,32, 32,10,2 Rutherfordium	105 **Db** 2,8,18,32, 32,11,2 Dubnium	106 **Sg** 2,8,18,32, 32,12,2 Seaborgium	107 **Bh** 2,8,18,32, 32,13,2 Bohrium	108 **Hs** 2,8,18,32, 32,14,2 Hassium	109 **Mt** 2,8,18,32, 32,15,2 Meitnerium	110 **Ds** 2,8,18,32, 32,17,1 Darmstadtium	111 **Rg** 2,8,18,32, 32,18,1 Roentgenium	112 **Cn** 2,8,18,32, 32,18,2 Copernicium						

Transition elements: groups (3)–(12)

Lanthanides	57 **La** 2,8,18, 18,9,2 Lanthanum	58 **Ce** 2,8,18, 20,8,2 Cerium	59 **Pr** 2,8,18,21, 8,2 Praseodymium	60 **Nd** 2,8,18,22, 8,2 Neodymium	61 **Pm** 2,8,18,23, 8,2 Promethium	62 **Sm** 2,8,18,24, 8,2 Samarium	63 **Eu** 2,8,18,25, 8,2 Europium	64 **Gd** 2,8,18,25, 9,2 Gadolinium	65 **Tb** 2,8,18,27, 8,2 Terbium	66 **Dy** 2,8,18,28, 8,2 Dysprosium	67 **Ho** 2,8,18,29, 8,2 Holmium	68 **Er** 2,8,18,30, 8,2 Erbium	69 **Tm** 2,8,18,31, 8,2 Thulium	70 **Yb** 2,8,18,32, 8,2 Ytterbium	71 **Lu** 2,8,18,32, 9,2 Lutetium
Actinides	89 **Ac** 2,8,18,32, 18,9,2 Actinium	90 **Th** 2,8,18,32, 18,10,2 Thorium	91 **Pa** 2,8,18,32, 20,9,2 Protactinium	92 **U** 2,8,18,32, 21,9,2 Uranium	93 **Np** 2,8,18,32, 22,9,2 Neptunium	94 **Pu** 2,8,18,32, 24,8,2 Plutonium	95 **Am** 2,8,18,32, 25,8,2 Americium	96 **Cm** 2,8,18,32, 25,9,2 Curium	97 **Bk** 2,8,18,32, 27,8,2 Berkelium	98 **Cf** 2,8,18,32, 28,8,2 Californium	99 **Es** 2,8,18,32, 29,8,2 Einsteinium	100 **Fm** 2,8,18,32, 30,8,2 Fermium	101 **Md** 2,8,18,32, 31,8,2 Mendelevium	102 **No** 2,8,18,32, 32,8,2 Nobelium	103 **Lr** 2,8,18,32, 32,9,2 Lawrencium

AH National Qualifications SPECIMEN ONLY

S857/77/01 **Physics**

Marking Instructions

These marking instructions have been provided to show how SQA would mark this specimen question paper.

General marking principles for Physics Advanced Higher

Always assign marks for each candidate response in line with these marking principles, the Physics: general marking principles (GMPs) (http://www.sqa.org.uk/files_ccc/Physicsgeneralmarkingprinciples.pdf) and the detailed marking instructions for this assessment.

(a) Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted from a maximum on the basis of errors or omissions.

(b) If a specific candidate response does not seem to be covered by either the principles or detailed marking instructions, and you are uncertain how to assess it, you must seek guidance from your team leader.

(c) Where a candidate incorrectly answers part of a question and carries the incorrect answer forward in the following part, award marks if the incorrect answer has then been used correctly in the subsequent part or 'follow-on'. (GMP 17)

(d) Award full marks for a correct final answer (including units if required) on its own, unless a numerical question specifically requires evidence of working to be shown, eg in a 'show' question. (GMP 1)

(e) Award marks where a diagram or sketch correctly conveys the response required by the question. Clear and correct labels (or the use of standard symbols) are usually required for marks to be awarded. (GMP 19)

(f) Award marks for knowledge of relevant relationships alone. When a candidate writes down several relationships and does not select the correct one to continue with, for example by substituting values, do not award a mark. (GMP 3)

(g) Award marks for the use of non-standard symbols where the symbols are defined **and** the relationship is correct, or where the substitution shows that the relationship used is correct. This must be clear and unambiguous. (GMP 22)

(h) Do not award marks if a 'magic triangle' (eg) 

is the only statement in a candidate's response. To gain the mark, the correct relationship must be stated, for example $V = IR$ or $R = \frac{V}{I}$. (GMP 6)

(i) In rounding to an expected number of significant figures, award the mark for responses that have up to two figures more or one figure less than the number in the data with the fewest significant figures. (GMP 10)

For example:

Data in question is given to 3 significant figures.

Correct final answer is 8·16 J.

Final answer 8·2 J or 8·158 J or 8·1576 J – award the final mark.

Final answer 8 J or 8·15761 J – do not award the final mark

(Note: the use of a recurrence dot, eg $0{\cdot}\dot{6}$, would imply an infinite number of significant figures and would therefore not be acceptable).

(j) Award marks where candidates have incorrectly spelled technical terms, provided that responses can be interpreted and understood without any doubt as to the meaning. Where there is ambiguity, do not award the mark. Two specific examples of this would be when the candidate uses a term that might be interpreted as ‘reflection’, ‘refraction’ or ‘diffraction’ (for example ‘defraction’), or one that might be interpreted as either ‘fission’ or ‘fusion’ (for example ‘fussion’). (GMP 25)

(k) **Only award m**arks for a valid response to the question asked. Where candidates are asked to:

- **identify**, **name**, **give**, or **state**, they need only name or present in brief form.
- **describe**, they must provide a statement or structure of characteristics and/or features.
- **explain**, they must relate cause and effect and/or make relationships between things clear.
- **determine** or **calculate**, they must determine a number from given facts, figures or information.
- **estimate**, they must determine an approximate value for something.
- **justify**, they must give reasons to support their suggestions or conclusions. For example this might be by identifying an appropriate relationship and the effect of changing variables.
- **show that**, they must use physics [and mathematics] to prove something, for example a given value – *all steps, including the stated answer, must be shown*.
- **predict**, they must suggest what may happen based on available information.
- **suggest**, they must apply their knowledge and understanding of physics to a new situation. A number of responses are acceptable: award marks for any suggestions that are supported by knowledge and understanding of physics.
- **use their knowledge of physics or aspect of physics to comment on**, they must apply their skills, knowledge and understanding to respond appropriately to the problem/situation presented (for example by making a statement of principle(s) involved and/or a relationship or equation, and applying these to respond to the problem/situation). Candidates are given credit for the breadth and/or depth of their conceptual understanding.

(l) Marking in calculations

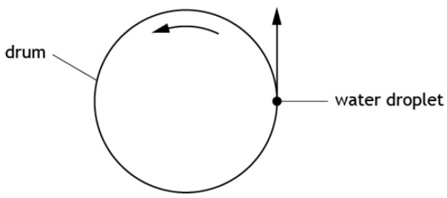
Example question

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. (3 marks)

	Example response	Mark and comment
1.	$V = IR$ $7 \cdot 5 = 1 \cdot 5R$ $R = 5 \cdot 0\ \Omega$	1 mark: relationship 1 mark: substitution 1 mark: correct answer
2.	$5 \cdot 0\ \Omega$	3 marks: correct answer
3.	$5 \cdot 0$	2 marks: unit missing
4.	$4 \cdot 0\ \Omega$	0 marks: no evidence, wrong answer
5.	$\_\_\ \Omega$	0 marks: no working or final answer
6.	$R = \frac{V}{I} = \frac{7 \cdot 5}{1 \cdot 5} = 4 \cdot 0\ \Omega$	2 marks: arithmetic error
7.	$R = \frac{V}{I} = 4 \cdot 0\ \Omega$	1 mark: relationship only
8.	$R = \frac{V}{I} = \_\_\ \Omega$	1 mark: relationship only
9.	$R = \frac{V}{I} = \frac{7 \cdot 5}{1 \cdot 5} = \_\_\ \Omega$	2 marks: relationship and substitution, no final answer
10.	$R = \frac{V}{I} = \frac{7 \cdot 5}{1 \cdot 5} = 4 \cdot 0$	2 marks: relationship and substitution, wrong answer
11.	$R = \frac{V}{I} = \frac{1 \cdot 5}{7 \cdot 5} = 5 \cdot 0\ \Omega$	1 mark: relationship but wrong substitution
12.	$R = \frac{V}{I} = \frac{75}{1 \cdot 5} = 5 \cdot 0\ \Omega$	1 mark: relationship but wrong substitution
13.	$R = \frac{I}{V} = \frac{1 \cdot 5}{7 \cdot 5} = 5 \cdot 0\ \Omega$	0 marks: wrong relationship
14.	$V = IR$ $7 \cdot 5 = 1 \cdot 5 \times R$ $R = 0 \cdot 2\ \Omega$	2 marks: relationship and substitution, arithmetic error
15.	$V = IR$ $R = \frac{I}{V} = \frac{1 \cdot 5}{7 \cdot 5} = 0 \cdot 2\ \Omega$	1 mark: relationship correct but wrong rearrangement of symbols

Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)		$v = 0{\cdot}135t^2 + 1{\cdot}26t$ $a\left(=\frac{dv}{dt}\right) = 0{\cdot}135 \times 2t + 1{\cdot}26$ **(1)** $a = (0{\cdot}135 \times 2 \times 15{\cdot}0) + 1{\cdot}26$ **(1)** $a = 5{\cdot}31\,\text{ms}^{-2}$ **(1)**	**3**	Accept 5·3, 5·310, 5·3100
	(b)		$v = 0{\cdot}135t^2 + 1{\cdot}26t$ $s = \int_0^{15{\cdot}0} v.dt = \left[0{\cdot}045t^3 + 0{\cdot}63t^2\right]_0^{15{\cdot}0}$ **(1)** $s = (0{\cdot}045 \times 15{\cdot}0^3) + (0{\cdot}063 \times 15{\cdot}0^2)$ **(1)** $s = 294\,\text{m}$ **(1)**	**3**	Accept 290, 293·6, 293·63 Constant of integration method acceptable.

Question			Expected response	Max mark	Additional guidance
2.	(a)		$\omega = \frac{\theta}{t}$ **(1)** $\omega = \frac{1250 \times 2 \times \pi}{60}$ **(1)** $\omega = 131 \text{ rad s}^{-1}$	**2**	SHOW question Award a maximum of 1 mark if final answer is not shown.
	(b)	(i)	$\alpha = \frac{\omega - \omega_0}{t}$ **(1)** $\alpha = \frac{131 - 7{\cdot}50}{12{\cdot}0}$ **(1)** $\alpha = 10{\cdot}3 \text{ rad s}^{-2}$ **(1)**	**3**	Accept 10, 10·29, 10·292
	(b)	(ii)	$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ **(1)** $\theta = (7{\cdot}50 \times 12{\cdot}0) + (0{\cdot}5 \times 10{\cdot}3 \times 12{\cdot}0^2)$ **(1)** $\text{revolutions} = \frac{(7{\cdot}50 \times 12{\cdot}0) + (0{\cdot}5 \times 10{\cdot}3 \times 12{\cdot}0^2)}{2\pi}$ **(1)** $\text{revolutions} = 132$ **(1)**	**4**	Or consistent with (b) (i) Accept 130, 132·4, 132·35
	(c)		$F = mr\omega^2$ **(1)** $F = 1{\cdot}5 \times 10^{-2} \times 0{\cdot}28 \times 131^2$ **(1)** $F = 72 \text{ N}$ **(1)**	**3**	Accept 70, 72·1, 72·08
	(d)	(i)	The drum exerts a centripetal/central force on the clothing. **(1)** No centripetal/central force acting on water. **(1)**	**2**	
		(ii)	 (1)	**1**	
		(iii)	Centripetal force decreases **(1)** as mass of wet clothing decreases **(1)**	**2**	

Question			Expected response	Max mark	Additional guidance
3.	(a)		$I = \frac{1}{2}mr^2$ **(1)** $I = 0{\cdot}5 \times 6{\cdot}0 \times 0{\cdot}5^2$ **(1)** $I = 0{\cdot}75\ \text{kgm}^2$	**2**	SHOW question Award a maximum of 1 mark if final answer is not shown.
	(b)	(i)	(For 2·0 kg mass) $I = mr^2$ **(1)** $I = 2{\cdot}0 \times 0{\cdot}40^2$ **(1)** $I_{Total} = (2{\cdot}0 \times 0{\cdot}40^2) + 0{\cdot}75$ $I_{Total} = 1{\cdot}1\ \text{kgm}^2$ **(1)**	**3**	Accept 1, 1·07, 1·070
		(ii)	$I_1\omega_1 = I_2\omega_2$ **(1)** $0{\cdot}75 \times 12 = 1{\cdot}1 \times \omega_2$ **(1)** $\omega_2 = 8{\cdot}2\ \text{rads}^{-1}$ **(1)**	**3**	Or consistent with (b)(i) Accept 8, 8·18, 8·182
		(iii)	No external torque acts on system **or** 2 kg can be considered as a point mass	**1**	
	(c)		The (final) angular velocity will be greater **(1)** The final moment of inertia is less than in (b)(ii) **(1)**	**2**	To be awarded the second mark the candidate must make reference to moment of inertia. It is insufficient to say 'sphere rolls off'.

Question			Expected response	Max mark	Additional guidance
4.	(a)	(i)	$\frac{GMm}{r^2} = mr\omega^2$ **(1)** $\omega = \frac{2\pi}{T}$ **(1)** $\frac{GM_E m}{r^2} = m\frac{4\pi^2}{T^2}r$ $T = 2\pi\sqrt{\frac{r^3}{GM_E}}$	**2**	SHOW question Award a maximum of 1 mark if final answer is not shown.
		(ii)	$T = 2\pi\sqrt{\frac{(6{\cdot}4\times10^6 + 4{\cdot}0\times10^5)^3}{6{\cdot}67\times10^{-11}\times6{\cdot}0\times10^{24}}}$ **(1)** $T = 5{\cdot}6\times10^3\,\text{s}$ **(1)**	**2**	Accept 6, 5·57, 5·569
	(b)	(i)	Value from graph $= 4{\cdot}15\times10^5$ (m) **(1)** $mg = \frac{GMm}{r^2}$ **(1)** $g = \frac{6{\cdot}67\times10^{-11}\times6{\cdot}0\times10^{24}}{(4{\cdot}15\times10^5 + 6{\cdot}4\times10^6)^2}$ **(1)** $\omega_2 = 8{\cdot}6\,\text{Nkg}^{-1}$ **(1)**	**4**	Accept 8, 8·62, 8·617
		(ii)	Less atmospheric drag/friction **or** will reduce running costs.	**1**	
	(c)		The gravitational field is smaller at the ISS (compared to Earth). **(1)** The clocks on ISS will run faster (than those on Earth). **(1)**	**2**	

Question			Expected response	Max mark	Additional guidance
5.	(a)		(Betelgeuse will look) red-orange.	**1**	
	(b)	(i)A	$L = 4\pi r^2 \sigma T^4$ **(1)** $L = 4 \times \pi \times (5\cdot49 \times 10^{10})^2 \times 5\cdot67 \times 10^{-8} \times (1\cdot2 \times 10^4)^4$ **(1)** $L = 4\cdot45 \times 10^{31}$ W **(1)**	**3**	Accept 4·5, 4·453, 4·453
		(i)B	Rigel/stars behave as black body(ies).	**1**	
		(ii)	$\%\Delta r = \frac{0\cdot05}{5\cdot49} \times 100\%$ $\%\Delta T = \frac{0\cdot05}{1\cdot20} \times 100\%$ **(1) (both)** $\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$ **(1)** $\text{Total}\%\Delta = \sqrt{\left(\frac{0\cdot05}{5\cdot49} \times 100 \times 2\right)^2 + \left(\frac{0\cdot05}{1\cdot20} \times 100 \times 4\right)^2}$ **(1)** $\Delta L = 1 \times 10^{31}$ W **(1)**	**4**	Or consistent with (b)(i)A
	(c)		$b = \frac{L}{4\pi d^2}$ **(1)** $b = \frac{4\cdot45 \times 10^{31}}{4 \times \pi \times (773 \times 365\cdot25 \times 24 \times 60 \times 60 \times 3\cdot00 \times 10^8)^2}$ **(1,1)** $b = 6\cdot61 \times 10^{-8}$ Wm^{-2} **(1)**	**4**	Or consistent with (b)(i)A Accept 6·6, 6·612, 6·6122 Independent mark for ly to m conversion (line 2) Accept the use of 365 or 365·24
	(d)		Hydrogen fusion has stopped (in the core) **(1)** The core shrinks **(1)**	**2**	
	(e)		Thermal pressure becomes greater than gravitational force causing Betelgeuse to expand **(1)** As Betelgeuse expands, the thermal pressure and gravitational force eventually return to equilibrium **(1)**	**2**	

Question			Expected response	Max mark	Additional guidance
6.	(a)		Electrostatic force (between the nucleus/proton and the electron).	1	
	(b)	(i)	$\frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$ **(1)** $\frac{e^2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$ $\frac{1}{2}mv^2 = \frac{e^2}{8\pi\varepsilon_0 r}$ **(1)** $E_k = \frac{e^2}{8\pi\varepsilon_0 r}$	2	SHOW question Award a maximum of 1 mark if final answer is not shown.
	(b)	(ii)	$E_k = \frac{e^2}{8\pi\varepsilon_0 r}$ $E_k = \frac{(1{\cdot}60\times10^{-19})^2}{8\times\pi\times8{\cdot}85\times10^{-12}\times0{\cdot}21\times10^{-9}}$ **(1)** $E_k = 5{\cdot}5\times10^{-19}$ J **(1)**	2	Accept 5, 5·48, 5·483
	(c)		$mvr = \frac{nh}{2\pi}$ **(1)** $4{\cdot}22\times10^{-34} = \frac{n\times6{\cdot}63\times10^{-34}}{2\pi}$ **(1)** $n = 4$ (must be an integer) **(1)**	3	
	(d)	(i)	$\Delta x \Delta p_x \geq \frac{h}{4\pi}$ **(1)** $\Delta x \times 1{\cdot}5\times10^{-26} \geq \frac{6{\cdot}63\times10^{-34}}{4\pi}$ **(1)** $\Delta x_{min} = 3{\cdot}5\times10^{-9}$ m **(1)**	3	Accept 4, 3·52, 3·517
		(ii)	$\Delta E \Delta t \geq \frac{h}{4\pi}$ **(1)** If Δt is small then ΔE is large **(1)** Therefore the largest possible energy of the electron may be big enough to overcome the repulsion and cross the gap. **(1)** **or** $\Delta x \Delta p_x \geq \frac{h}{4\pi}$ **(1)** If the momentum is measured with a small uncertainty, the uncertainty in the position of the electron is large enough **(1)** for the electron to exist on the other side of the gap. **(1)**	3	

Question			Expected response	Max mark	Additional guidance
7.	(a)		(Component of) velocity perpendicular to the magnetic field (lines) results in circular motion **or** central force. **(1)** (Component of) velocity parallel to the magnetic field (lines) results in constant velocity **or** no force acting parallel to the magnetic field. **(1)**	2	
	(b)		$\frac{mv^2}{r} = qvB$ **(1+1)** $v = 2{\cdot}6 \times 10^7 \times \sin 50$ **(1)** $\frac{1{\cdot}673 \times 10^{-27} \times (2{\cdot}6 \times 10^7 \times \sin 50)^2}{r}$ $= 1{\cdot}6 \times 10^{-19} \times 2{\cdot}6 \times 10^7 \times \sin 50 \times 58 \times 10^{-6}$ **(1)** $r = 3{\cdot}6 \times 10^3$ m **(1)**	5	Award 1 mark for both relationships Award 1 mark for equating the relationships Accept 4, 3·59, 3·591
	(c)		Any two statements The anti proton path will turn in the opposite direction. The anti proton helix pitch will be greater. Radius of curvature will be smaller.	2	

Question			Expected response	Max mark	Additional guidance
8.	(a)	(i)	Acceleration is proportional to displacement (from a fixed point) and is always directed to (that) fixed point. **or** The unbalanced force is proportional to the displacement (from a fixed point) and is always directed to (that) fixed point.	**1**	Accept $a = -ky$ or $F = -ky$
	(a)	(ii)	From graph $T = 5{\cdot}0$ (s) **(1)** $\omega = \frac{2\pi}{T}$ **(1)** $\omega = \frac{2\times\pi}{5{\cdot}0}$ **(1)** $\omega = 1{\cdot}3$ rads^{-1} **(1)**	**4**	Accept 1, 1·26, 1·257
	(a)	(iii)	$a = -\omega^2 x$ **(1)** $a = (-)1{\cdot}3^2 \times (-)4{\cdot}0$ **(1)** $a = (-)6{\cdot}8\ \text{ms}^{-2}$ **(1)**	**3**	Or consistent with (a)(ii) Accept 7, 6·76, 6·760
	(a)	(iv)	Sine curve **(1)** Period of oscillation 5·0 s **(1)** Maximum speed 5·2 m s^{-1} **(1)**	**3**	Award a maximum of 2 marks if the labels, units are missing.
	(a)	(v)	$E_p = \frac{1}{2} m\omega^2 y^2$ **(1)** $E_p = 0{\cdot}5 \times 85 \times 1{\cdot}3^2 \times 4{\cdot}0^2$ **(1)** $E_p = 1{\cdot}1 \times 10^3$ J **(1)**	**3**	Or consistent with (a)(ii) Accept 1, 1·15, 1·149

Question			Expected response	Max mark	Additional guidance
8.	(b)		**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide 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 application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	3	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

Question			Expected response	Max mark	Additional guidance
9.	(a)		Reflected wave interferes with transmitted wave (to produce points of destructive and constructive interference).	1	
	(b)		Antinode (constructive), high energy, so melted spots. **(1)** Node (destructive), low energy, so no melting. **(1)**	2	
	(c)		$4\times\frac{1}{2}\lambda=0{\cdot}264$ **(1)** $\lambda=0{\cdot}132\text{ m}$ **(1)**	2	Accept 0·13, 0·1320, 0·13200
	(d)		$v=f\lambda$ **(1)** $v=2{\cdot}45\times10^{9}\times0{\cdot}132$ **(1)** $v=3{\cdot}23\times10^{8}\text{ ms}^{-1}$	2	SHOW question Award a maximum of 1 mark if final answer is not shown.
	(e)		The range of the results is small, so the results are precise. **(1)** The difference between the mean value of the results and the accepted value of c is larger than the range, so the results are not accurate. **(1)**	2	

Question			Expected response	Max mark	Additional guidance
10.	(a)		A series of bright and dark spots.	1	Accept fringes.
	(b)		$\lambda = \frac{h}{p}$ **(1)** $\lambda = \frac{6\cdot63\times10^{-34}}{1\cdot20\times10^{-24}\times220}$ **(1)** $\lambda = 2\cdot5\times10^{-12}$ (m) **(1)** Estimate in the range 10^{-12} to 10^{-9} metres **(1)**	4	Statement of value of slit separation must be distinct from value of λ.

Question			Expected response	Max mark	Additional guidance
11.	(a)		3	**1**	
	(b)		$c=\frac{1}{\sqrt{\varepsilon_0\mu_0}}$ **(1)** $c=\frac{1}{\sqrt{8{\cdot}93\times10^{-12}\times1{\cdot}32\times10^{-6}}}$ **(1)** $c=2{\cdot}91\times10^{8}\ \text{ms}^{-1}$ **(1)**	**3**	
	(c)	(i)	$\text{\%uncert in } \mu_0=\frac{5\times10^{-8}}{1{\cdot}32\times10^{-6}}\times100$ $\text{\%uncert in } \mu_0=3{\cdot}8\%$ **(1)** $\text{\%uncert in } \varepsilon_0=\frac{7\times10^{-14}}{8{\cdot}93\times10^{-12}}\times100$ $\text{\%uncert in } \mu_0=0{\cdot}8\%$ **(1)** Uncertainty in μ_0 more significant **(1)**	**3**	
		(ii)	uncert in $\frac{1}{\sqrt{\varepsilon_0\mu_0}}=\frac{1}{2}\times\frac{3{\cdot}8}{100}\times2{\cdot}91\times10^{8}$ **(1)** uncert in $\frac{1}{\sqrt{\varepsilon_0\mu_0}}=6\times10^{6}\ \text{ms}^{-1}$ **(1)**	**2**	

Question			Expected response	Max mark	Additional guidance
12.	(a)	(i)	Force acting per unit positive charge.	1	
		(ii)	$\frac{Q_1}{4\pi\varepsilon_0 r^2} = \frac{Q_2}{4\pi\varepsilon_0 r^2}$ **(1)** $\frac{-8{\cdot}0\times10^{-9}}{4\times\pi\times8{\cdot}85\times10^{-12}\times(0{\cdot}4)^2} = \frac{Q_2}{4\times\pi\times8{\cdot}85\times10^{-12}\times(0{\cdot}2)^2}$ **(1)** $Q_2 = -2{\cdot}0\times10^{-9}$ C	2	SHOW question Award a maximum of 1 mark if final answer is not shown.
		(iii)	$V_1 = \frac{Q}{4\pi\varepsilon_0 r}$ **(1)** $V_1 = \frac{-8{\cdot}0\times10^{-9}}{4\times\pi\times8{\cdot}85\times10^{-12}\times0{\cdot}40}$ **(1)** $V_2 = \frac{-2{\cdot}0\times10^{-9}}{4\times\pi\times8{\cdot}85\times10^{-12}\times0{\cdot}20}$ **(1)** Potential at X $= \frac{-8{\cdot}0\times10^{-9}}{4\times\pi\times8{\cdot}85\times10^{-12}\times0{\cdot}40} + \frac{-2{\cdot}0\times10^{-9}}{4\times\pi\times8{\cdot}85\times10^{-12}\times0{\cdot}20}$ **(1)** Potential at X $= -270$ V **(1)**	5	Accept 300, 269·8
	(b)	(i)	$V_1 = \frac{-8{\cdot}0\times10^{-9}}{4\times\pi\times8{\cdot}85\times10^{-12}\times0{\cdot}50}$ **(1)** $V_2 = \frac{-2{\cdot}0\times10^{-9}}{4\times\pi\times8{\cdot}85\times10^{-12}\times0{\cdot}50}$ **(1)** Potential at P $= \frac{-8{\cdot}0\times10^{-9}}{4\times\pi\times8{\cdot}85\times10^{-12}\times0{\cdot}50} + \frac{-2{\cdot}0\times10^{-9}}{4\times\pi\times8{\cdot}85\times10^{-12}\times0{\cdot}50}$ Potential at P $= -180$ V **(1)**	3	Accept 200, 179·8
		(ii)	Potential difference = –180 – (–270) = 90 (V) **(1)** $E = QV$ **(1)** $E = 1{\cdot}0\times10^{-9}\times90$ **(1)** $E = 9{\cdot}0\times10^{-8}$ J **(1)**	4	Or consistent with a(iii),(b)(i)

Question			Expected response	Max mark	Additional guidance
13.			**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide 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 application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	3	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

Question			Expected response	Max mark	Additional guidance
14.	(a)	(i)	$X_C = \frac{1}{2\pi fC}$ **(1)** $X_C = \frac{1}{2 \times \pi \times 65 \times 5{\cdot}0 \times 10^{-6}}$ **(1)** $X_C = 490\ \Omega$ **(1)**	**3**	Accept 500, 489·7
		(ii)	$I_{RMS} = \frac{V_{RMS}}{X_C}$ **(1)** $I_{RMS} = \frac{15}{490}$ **(1)** $I_{RMS} = 3{\cdot}1 \times 10^{-2}$ A **(1)**	**3**	Or consistent with (a)(i) Accept 3, 3·06, 3·061
	(b)	(i)	Linear scale on both axes. **(1)** Acceptable axes labels (quantities and units). **(1)** Points plotted correctly and acceptable line of best fit. **(1)**	**3**	If either scale is non-linear a maximum of 1 mark can be awarded. Allow $\pm$ half box tolerance when plotting points.
		(ii)	Gradient of best fit line **(1)** Gradient $= \frac{1}{2\pi C}$ Or $C = \frac{1}{2\pi \times \text{gradient}}$ **(1)** Final value of C **(1)**	**3**	If a candidate uses data points that are not on their line of best fit, a maximum of 1 mark can be awarded. A representative gradient value of $3{\cdot}13 \times 10^{7}$ gives a capacitance of $5{\cdot}08 \times 10^{-9}$ F. Final value of C must be consistent with candidate's value for gradient.

[END OF SPECIMEN MARKING INSTRUCTIONS]