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National
Qualifications
SPECIMEN ONLY

Mark

S857/77/01 **Physics**

Date — Not applicable

Duration — 2 hours 30 minutes

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 — 130

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.

Do not remove any exam materials. You must leave this booklet on your desk; if you do not, you could lose all the marks for this paper.

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DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Gravitational acceleration on Earth	g	$9.8\ \text{m}\,\text{s}^{-2}$	Mass of electron	m_e	9.11×10^{-31} kg
Radius of Earth	R_E	6.4×10^{6} m	Charge on electron	e	-1.60×10^{-19} C
Mass of Earth	M_E	6.0×10^{24} kg	Mass of neutron	m_n	1.675×10^{-27} kg
Mass of Jupiter	M_J	1.90×10^{27} kg	Mass of proton	m_p	1.673×10^{-27} kg
Radius of Jupiter	R_J	7.15×10^{7} m	Mass of alpha particle	m_α	6.645×10^{-27} kg
Mean Radius of Jupiter Orbit		7.79×10^{11} m	Charge on alpha particle		3.20×10^{-19} C
Solar radius		6.955×10^{8} m	Planck's constant	h	6.63×10^{-34} J s
Mass of Sun		2.0×10^{30} kg	Permittivity of free space	ε_0	$8.85 \times 10^{-12}\ \text{F}\,\text{m}^{-1}$
1 AU		1.5×10^{11} m	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \text{H}\,\text{m}^{-1}$
Stefan-Boltzmann constant	σ	$5.67 \times 10^{-8}\ \text{W}\,\text{m}^{-2}\,\text{K}^{-4}$	Speed of light in vacuum	c	$3.00 \times 10^{8}\ \text{m}\,\text{s}^{-1}$
Universal constant of gravitation	G	$6.67 \times 10^{-11}\ \text{m}^{3}\,\text{kg}^{-1}\,\text{s}^{-2}$	Speed of sound in air	v	$3.4 \times 10^{2}\ \text{m}\,\text{s}^{-1}$

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 ($\text{kg}\,\text{m}^{-3}$)	Melting Point (K)	Boiling Point (K)	Specific Heat Capacity ($\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$)	Specific Latent Heat of Fusion ($\text{J}\,\text{kg}^{-1}$)	Specific Latent Heat of Vaporisation ($\text{J}\,\text{kg}^{-1}$)
Aluminium	2.70×10^{3}	933	2792	8.97×10^{2}	3.96×10^{5}	....
Copper	8.96×10^{3}	1357	2833	3.85×10^{2}	2.06×10^{5}	....
Glass	2.60×10^{3}	1400	....	6.70×10^{2}	....	....
Ice	9.20×10^{2}	273	....	2.09×10^{3}	3.34×10^{5}	....
Glycerol	1.26×10^{3}	291	563	2.43×10^{3}	1.99×10^{5}	6.70×10^{5}
Methanol	7.91×10^{2}	175	338	2.53×10^{3}	9.9×10^{4}	1.10×10^{6}
Sea Water	1.02×10^{3}	264	377	3.99×10^{3}	....	....
Water	1.00×10^{3}	273	373	4.18×10^{3}	3.34×10^{5}	2.26×10^{6}
Air	1.29	....	....	....	....	....
Hydrogen	9.0×10^{-2}	14	20	1.43×10^{4}	....	2.23×10^{5}
Nitrogen	1.25	63	77	1.04×10^{3}	....	2.00×10^{5}
Oxygen	1.43	54	90	9.18×10^{2}	....	2.13×10^{4}

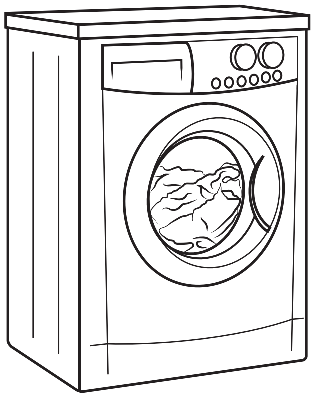
The gas densities refer to a temperature of 273 K and a pressure of 1.01×10^{5} Pa.

S857770102

Total marks — 130 marks

Attempt ALL questions

1. 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.



(a) 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 its maximum angular velocity of 131 rad s^{-1}.

(i) Calculate the angular acceleration of the drum during the 12.0 s, assuming the acceleration is uniform. **3**

Space for working and answer

[Turn over

1. (a) (continued)

(ii) Determine how many revolutions the drum will make during the 12.0 seconds. **4**

Space for working and answer

(b) When the drum is rotating at maximum angular velocity, an item of wet clothing of mass 1.5×10^{-2} kg rotates at a distance of 0.28 m from the axis of rotation, as shown in **Figure 1A**.

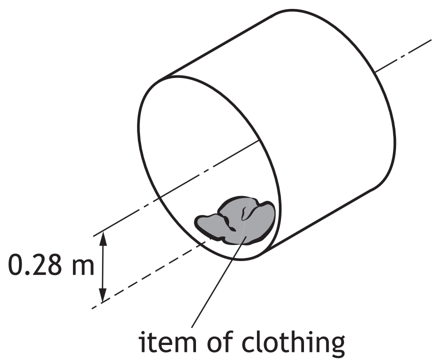


Figure 1A

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

Space for working and answer

1. (continued)

(c) The outer surface of the drum has small holes, as shown in **Figure 1B**.

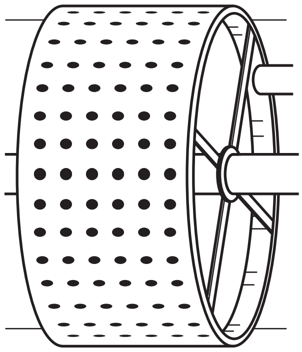


Figure 1B

These holes allow most of the water to be removed.

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

(ii) The drum rotates in an anticlockwise direction.

On **Figure 1C**, show the direction of the water droplet as it leaves the drum. **1**

(An additional diagram, if required, can be found on *page 40*.)

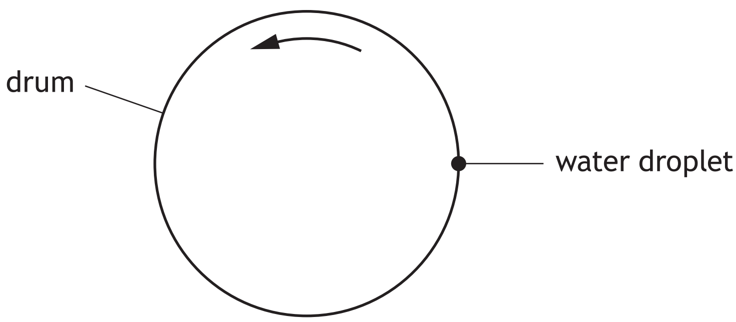


Figure 1C

1. (c) (continued)

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

You must justify your answer. **2**

2. A student uses a solid, uniform circular disc of radius 290 mm and mass 0.40 kg as part of an investigation into rotational motion.

This disc is shown in **Figure 2A**.

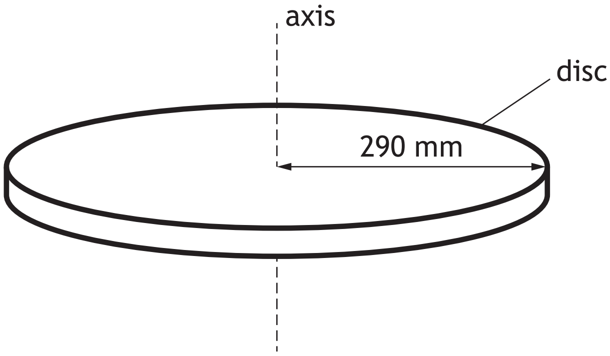


Figure 2A

(a) Show that the moment of inertia of the disc about the axis shown in **Figure 2A** is 0.017 kg m^2. **2**

Space for working and answer

[Turn over

2. (continued)

(b) The disc is now mounted horizontally on the axle of a rotational motion sensor, as shown in **Figure 2B**.

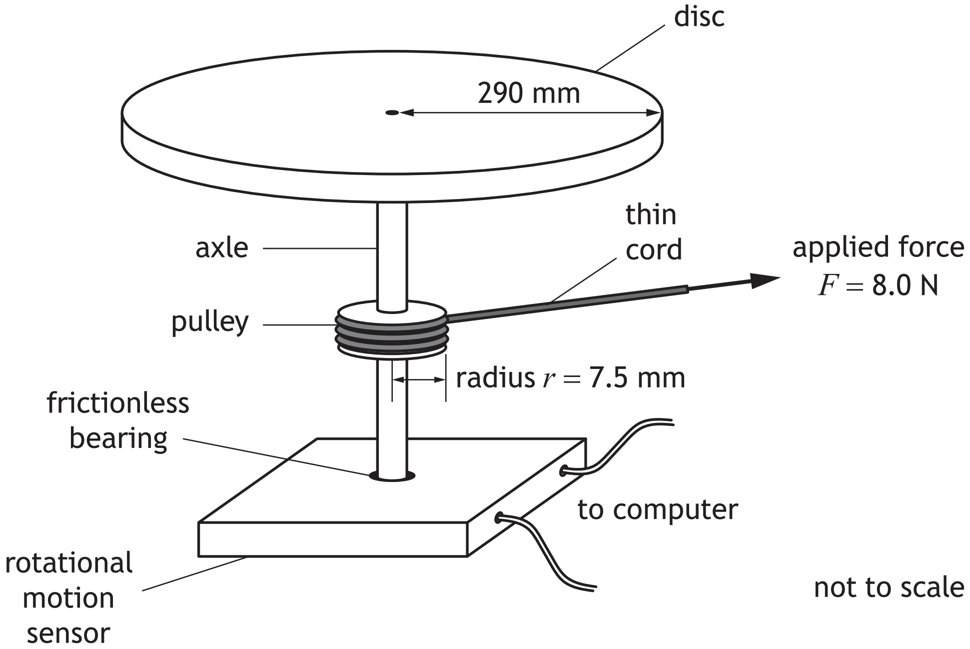


Figure 2B

The axle is on a frictionless bearing. A thin cord is wound around a stationary pulley, which is attached to the axle.

The moment of inertia of the pulley and axle can be considered negligible.

The pulley has a radius of 7.5 mm and a force of 8.0 N is applied to the free end of the cord.

(i) Calculate the torque applied to the pulley. **3**

Space for working and answer

(ii) Calculate the angular acceleration produced by this torque. **3**

Space for working and answer

2. (continued)

(c) In a second experiment, the disc has an angular velocity of 12 rad s^{-1}.

The student now drops a small 25 g cube vertically onto the disc. The cube sticks to the disc.

The centre of mass of the cube is 220 mm from the axis of rotation, as shown in **Figure 2C**.

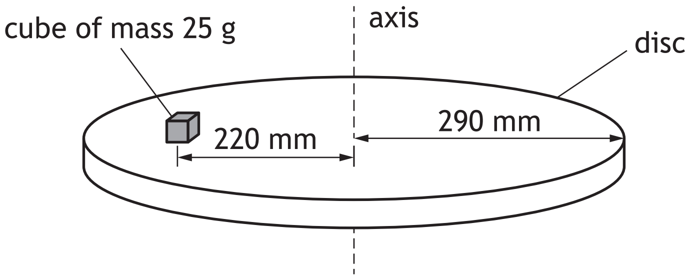


Figure 2C

Determine the angular velocity of the system immediately after the cube was dropped onto the disc. **5**

Space for working and answer

[Turn over

3. The NASA space probe Dawn has travelled to and orbited large asteroids in the Solar System. Dawn has a mass of 1240 kg.

The table gives information about two large asteroids orbited by Dawn. Both asteroids can be considered to be spherical and remote from other large objects.

Name	Mass ($\times 10^{20}$ kg)	Radius (km)
Vesta	2.59	263
Ceres	9.39	473

(a) Dawn began orbiting Vesta, in a circular orbit, at a height of 680 km above the surface of the asteroid. The gravitational force acting on Dawn at this altitude was 24.1 N.

(i) Show that the tangential velocity of Dawn in this orbit is 135 m s^{-1}. **2**

Space for working and answer

(ii) Calculate the orbital period of Dawn. **3**

Space for working and answer

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MARKS DO NOT WRITE IN THIS MARGIN

3. (continued)

(b) Later in its mission, Dawn entered orbit around Ceres. It then moved from a high orbit to a lower orbit around the asteroid.

(i) State what is meant by the *gravitational potential of a point in space*. **1**

(ii) Dawn has a gravitational potential of $-1.29 \times 10^{4}\ \mathrm{J\,kg^{-1}}$ in the high orbit and a gravitational potential of $-3.22 \times 10^{4}\ \mathrm{J\,kg^{-1}}$ in the lower orbit.

Determine the change in the potential energy of Dawn as a result of this change in orbit. **4**

Space for working and answer

[Turn over

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4. The constellation Orion, shown in **Figure 4A**, is a common sight in the winter sky above Scotland.

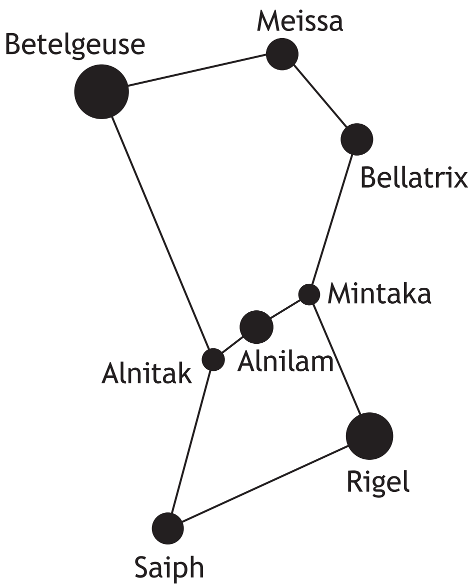

Figure 4A

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 4B**.

4. (continued)

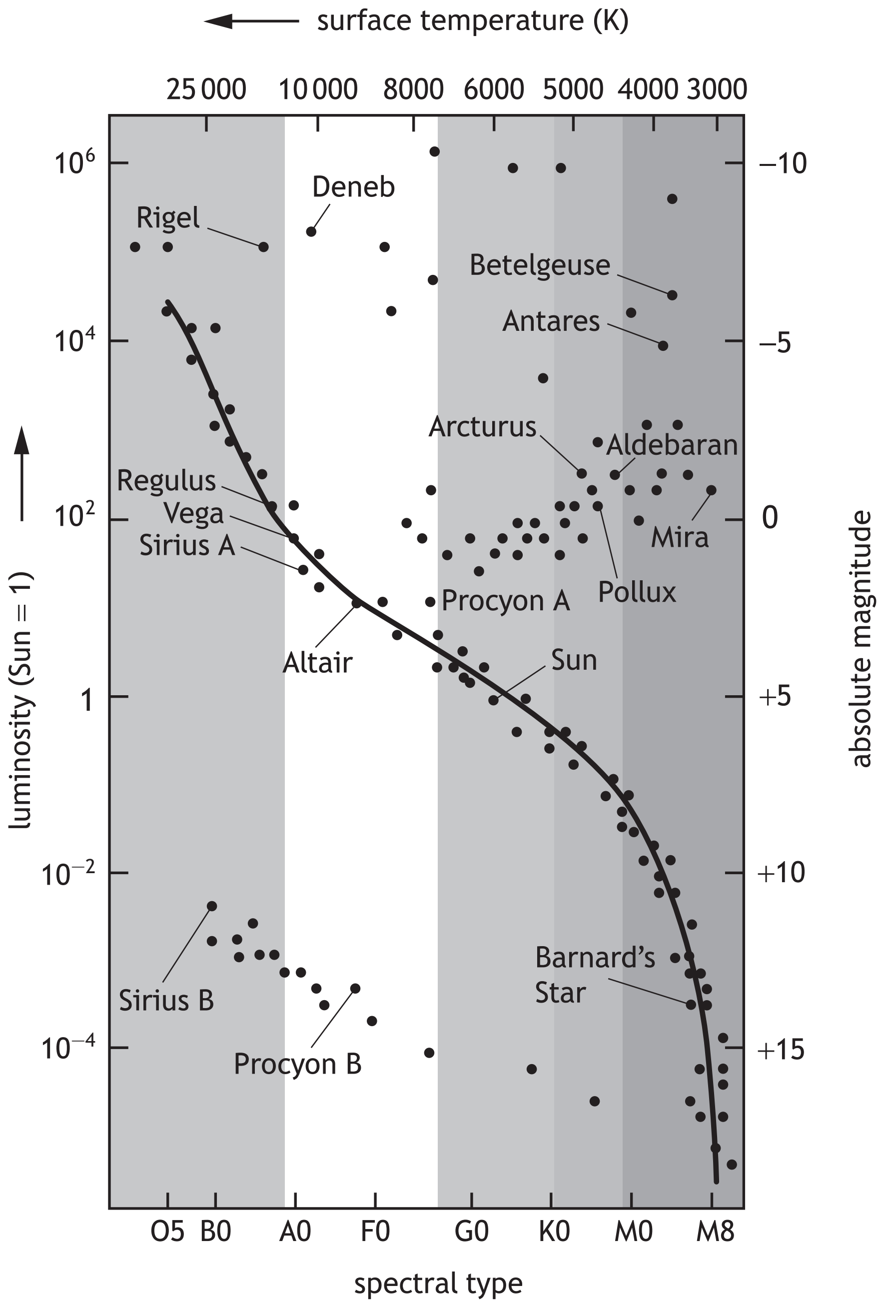

Figure 4B

(a) Using the H-R diagram, state the class of stars to which Betelgeuse belongs. **1**

[Turn over

4. (continued)

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

Property of Rigel	
Surface temperature	$(1.20 \pm 0.05) \times 10^4$ K
Radius	$(5.49 \pm 0.50) \times 10^{10}$ 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**

4. (b) (continued)

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

Space for working and answer

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

Space for working and answer

(d) Betelgeuse is not on the main sequence region of the H-R diagram.

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**

[Turn over

5. 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 since 1870 is shown in **Figure 5**.

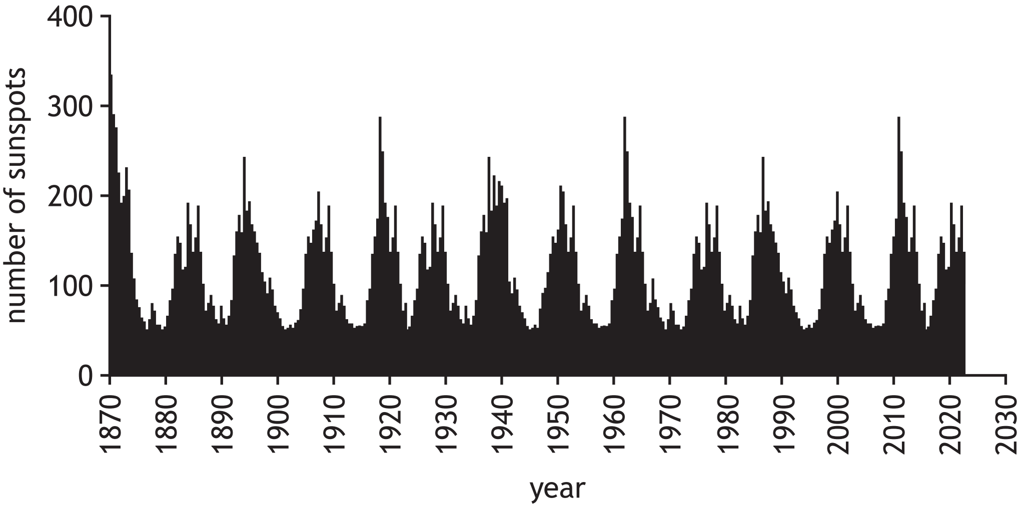

Figure 5

Coronal mass ejections (CME) are one type of solar activity that originate near sunspots. 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 comment on the potential effects that solar activity could have over the next few years. **3**

DO NOT WRITE IN THIS MARGIN

5. (continued)

[Turn over

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MARKS | DO NOT WRITE IN THIS MARGIN

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 $n = 1$.

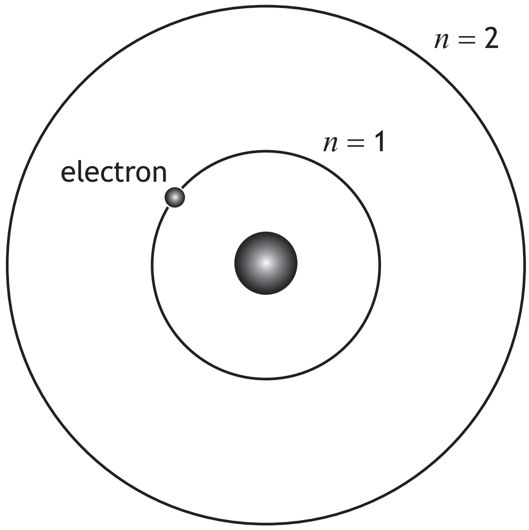

Figure 6A

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

(b) (i) By considering the force acting on the electron, 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**

Space for working and answer

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 4.22×10^{-34} 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 the momentum of an electron in a hydrogen atom was determined to be $\pm 1.5 \times 10^{-26}$ 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**.

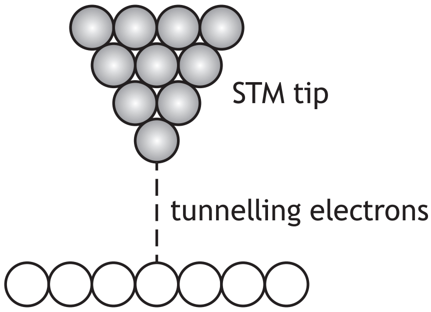

Figure 6B

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

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

7. (a) The Earth can be modelled as a black body radiator.

The average surface temperature of the Earth can be estimated using the relationship.

$$T = \frac{b}{\lambda_{\text{peak}}}$$

where: T is the average surface temperature of the Earth in kelvin

b is Wien's Displacement Constant equal to 2.89×10^{-3} K m

λ_{peak} is the peak wavelength of the radiation emitted by a black body radiator.

The average surface temperature of Earth is 15 °C.

(i) Estimate the peak wavelength of the radiation emitted by Earth. **3**

Space for working and answer

(ii) State the part of the electromagnetic spectrum to which this peak wavelength corresponds. **1**

[Turn over

7. **(continued)**

MARKS | DO NOT WRITE IN THIS MARGIN

(b) In order to investigate the properties of black body radiators, a student makes measurements from the spectra produced by a filament lamp.

Measurements are made when the lamp is operated at its rated voltage and when it is operated at a lower voltage.

The filament lamp can be considered to be a black body radiator.

A graph of the results obtained is shown in **Figure 7**.

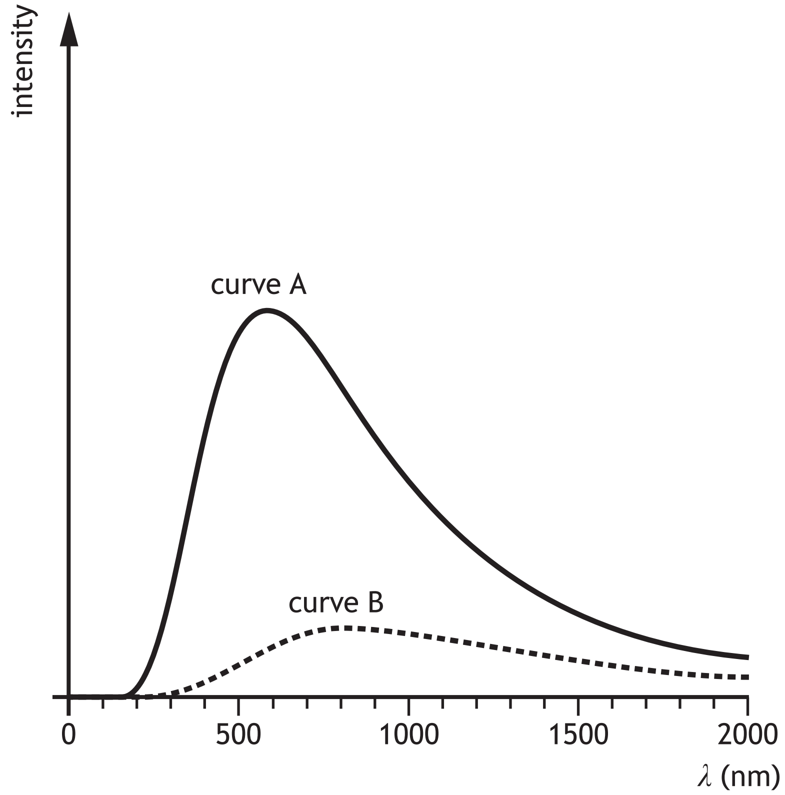

Figure 7

(i) State which curve corresponds to the radiation emitted when the filament lamp is operating at its rated voltage.

You must justify your answer. **2**

(ii) The shape of the curves on the graph on **Figure 7** is not as predicted by classical physics.

On **Figure 7**, sketch a curve to show the result predicted by classical physics. **1**

(An additional graph, if required, can be found on *page 40*.)

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

8. 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 8A**.

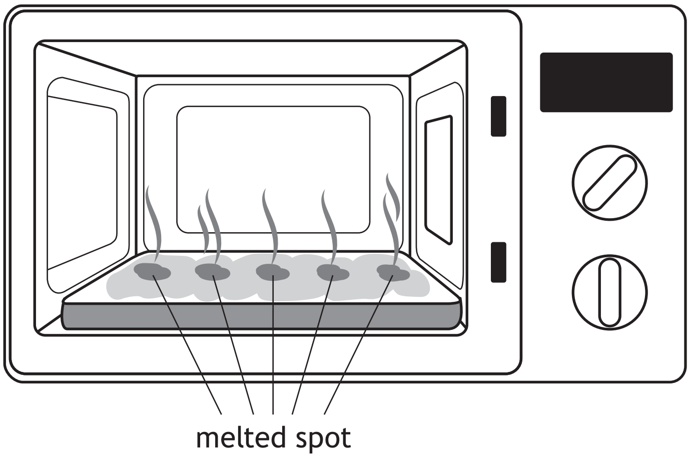

Figure 8A

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

8. (continued)

(c) The student measures the distance between the first melted spot and the fifth melted spot as 264 mm, as shown in **Figure 8B**.

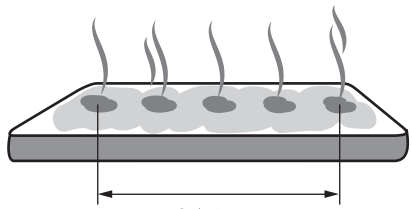

Figure 8B

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.

Calculate the value obtained by the student for the speed of light. **3**

Space for working and answer

8. (continued)

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

$3.26 \times 10^8\ \mathrm{m\,s^{-1}}$, $3.19 \times 10^8\ \mathrm{m\,s^{-1}}$, $3.23 \times 10^8\ \mathrm{m\,s^{-1}}$, $3.21 \times 10^8\ \mathrm{m\,s^{-1}}$

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

[Turn over

9. A student is investigating interference as part of their Advanced Higher Physics project.

The student sets up an experiment using a microwave transmitter and a double slit constructed from three metal plates. The apparatus is set up as shown in **Figure 9A**.

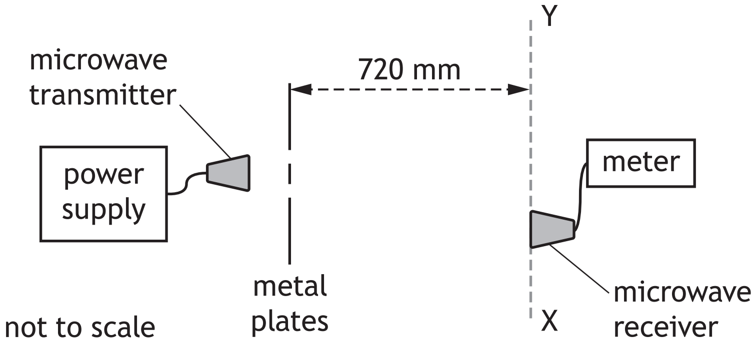

Figure 9A

The double slit has a slit separation of 42 mm.

The student slowly moves the microwave receiver from X to Y and detects regions of constructive interference.

(a) (i) State the **two** required conditions for the waves to produce regions of constructive interference. **1**

(ii) Explain how the student was able to identify the regions of constructive interference from this experimental set up. **1**

9. (a) (continued)

(iii) Two adjacent regions of constructive interference are detected. The regions are separated by a distance of 470 mm.

Calculate the wavelength of the microwaves. **3**

Space for working and answer

[Turn over

9. **(continued)**

(b) The student now sets up a second experiment.

A thin air wedge is formed between two glass plates of length 75 mm, which are in contact at one end and separated by a thin metal wire at the other end.

Figure 9B shows sodium light being reflected down onto the air wedge.

A travelling microscope is used to view the resulting interference pattern.

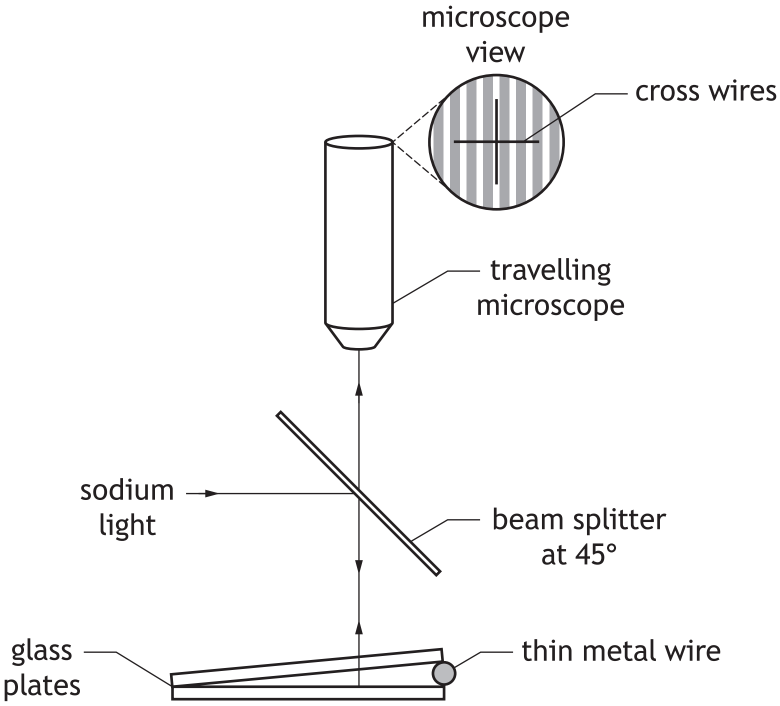

Figure 9B

The student observes the image shown in **Figure 9C**.

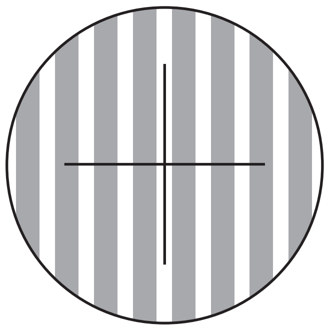

Figure 9C

The student aligns the cross-hairs to a bright fringe and then moves the travelling microscope until 20 further bright fringes have passed through the cross-hairs and notes that the travelling microscope has moved a distance of 9.8×10^{-4} m.

The student uses this data to determine the thickness of the thin metal wire between the glass plates.

9. (b) (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

(i) State whether the interference pattern is produced by division of amplitude or by division of wavefront. **1**

(ii) Determine the diameter of the thin metal wire. **4**

Space for working and answer.

(iii) By measuring across multiple fringe separations rather than just one, the student states that they have more confidence in the value of diameter of the wire which was obtained.

Suggest one reason why the student's statement is correct. **1**

(iv) A current is now passed through the thin metal wire and its temperature increases.

The fringes are observed to get closer together.

Suggest a possible explanation for this observation. **2**

[Turn over

10. A student is observing the effect of passing light through polarising filters.

Two polarising filters, the polariser and the analyser, are placed between a lamp and the student, as shown in **Figure 10A**.

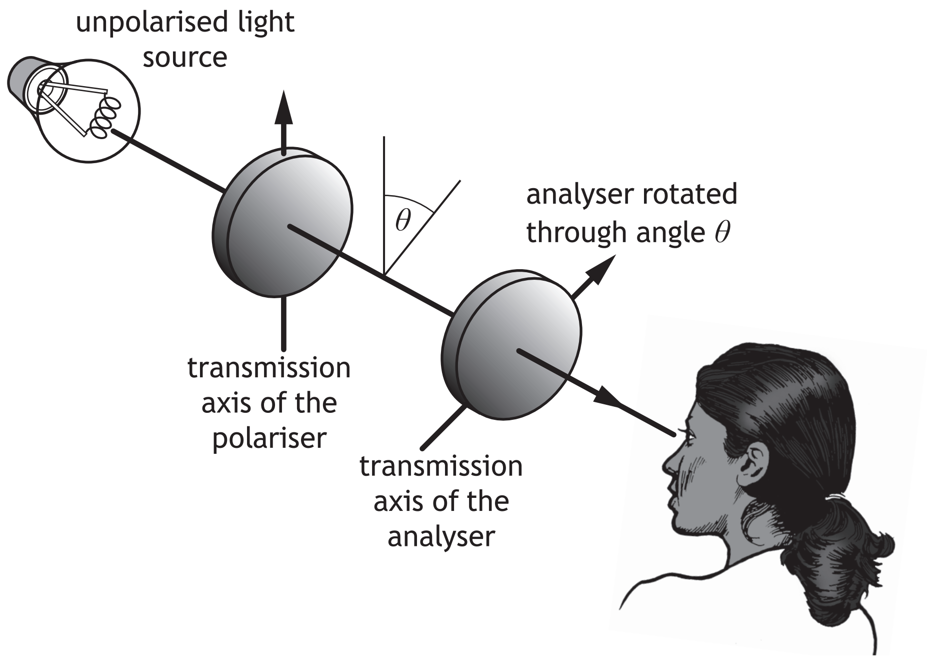

Figure 10A

The polariser is held in a fixed position, and the analyser can be rotated.

Angle θ is the angle between the transmission axes of the two filters. When the transmission axes of the polariser and the analyser are parallel, θ is 0° and the student observes bright light from the lamp.

(a) (i) Describe, in terms of brightness, what the student observes as the analyser is again slowly rotated from 0° to 180°. **2**

(ii) The polariser is now removed.

Describe, in terms of brightness, what the student observes as the analyser is again slowly rotated from 0° to 180°. **1**

10. (continued)

(b) Sunlight reflected from a wet road can cause glare, which is hazardous for drivers. This is shown in **Figure 10B**.

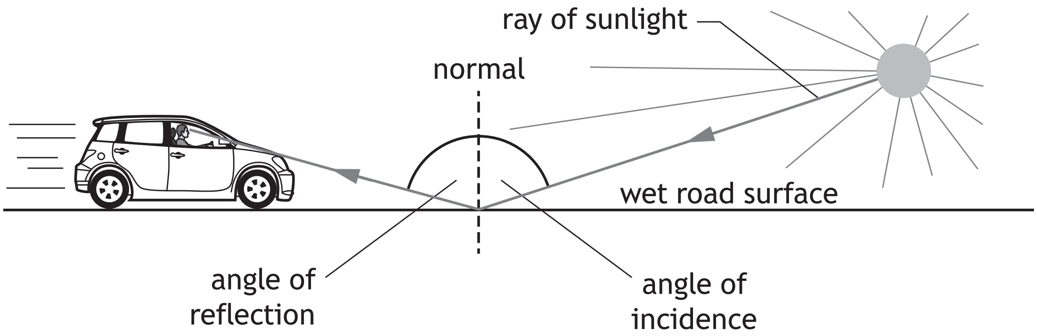

Figure 10B

Reflected sunlight is polarised when the light is incident on the wet road surface at the Brewster angle.

(i) Calculate the Brewster angle for light reflected from water. **3**

Space for working and answer

(ii) A driver is wearing polarising sunglasses.

Explain how wearing polarising sunglasses rather than non-polarising sunglasses will reduce the glare experienced by the driver. **1**

[Turn over

11. Two point charges Q_1 and Q_2 are separated by a distance of 0.60 m, as shown in **Figure 11**.

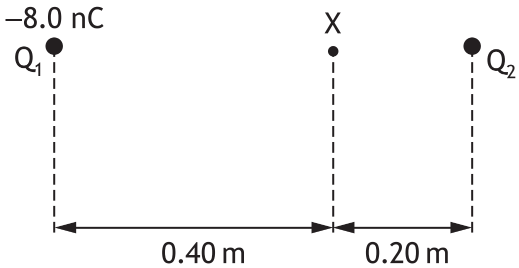

Figure 11

The charge on Q_1 is −8.0 nC. The electric field strength at point X is zero.

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

(b) Show that the charge on Q_2 is −2.0 nC. **2**

Space for working and answer

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

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

12. 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 12A**.

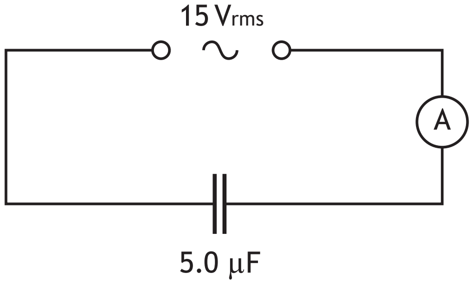

Figure 12A

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

[Turn over

S857770133

12. **(continued)**

MARKS DO NOT WRITE IN THIS MARGIN

(b) The student uses the following circuit to determine the capacitance of a second capacitor, as shown in **Figure 12B**.

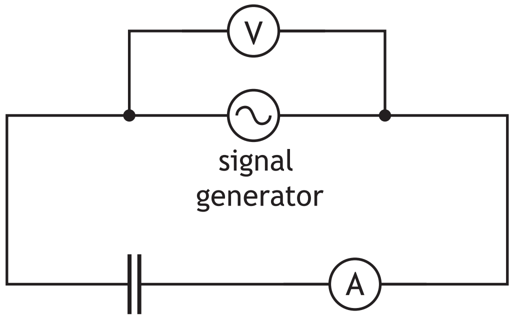

Figure 12B

The student obtains the following data.

X_c (Ω)	f (Hz)	$\frac{1}{f}$ (s)
6.47×10^5	40	0.025
2.99×10^5	100	0.010
1.52×10^5	200	0.005
6.35×10^4	500	0.002
3.18×10^4	1000	0.001

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

(The table of results is also shown on *page 38*, after the square-ruled paper.)

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

Space for working and answer

13. A group of students were evaluating an experiment to investigate the relationship between the mass on a spring and its period of oscillation.

Figure 13 shows some of the apparatus used.

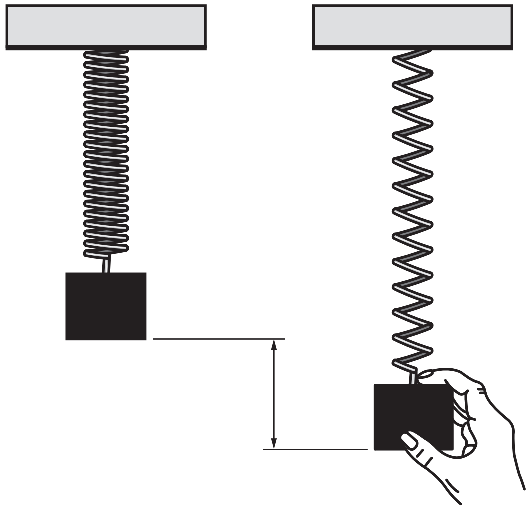

Figure 13

Student A stated '*I think we should use a balance that reads to 0.001 g instead of 0.1 g. This will give a more accurate answer.*'

Student B stated '*I think we should repeat the time measurement and calculate a mean value.*'

Student C stated '*I think we should measure the time for 10 oscillations and divide this value by 10 to get the time for one complete oscillation. This will give us a more precise answer.*'

Student D stated '*I think it would be good to check the mass on another balance.*'

Using your knowledge of experimental analysis, comment on these statements. **3**

DO NOT WRITE IN THIS MARGIN

13. (continued)

[END OF SPECIMEN QUESTION PAPER]

S857770136

X_c (Ω)	f (Hz)	$\frac{1}{f}$ (s)
6.47×10^5	40	0.025
2.99×10^5	100	0.010
1.52×10^5	200	0.005
6.35×10^4	500	0.002
3.18×10^4	1000	0.001

DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for question 1 (c) (ii)

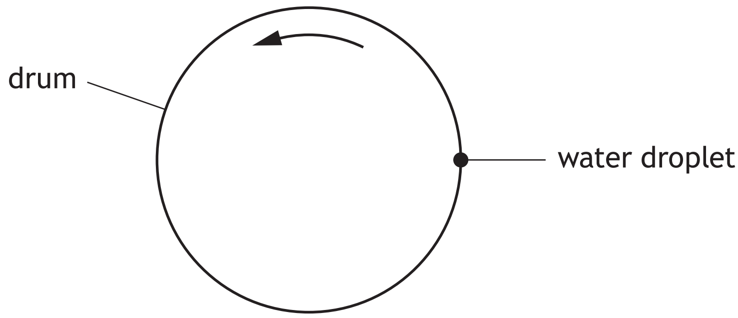

Figure 1C

Additional graph for question 7 (b) (ii)

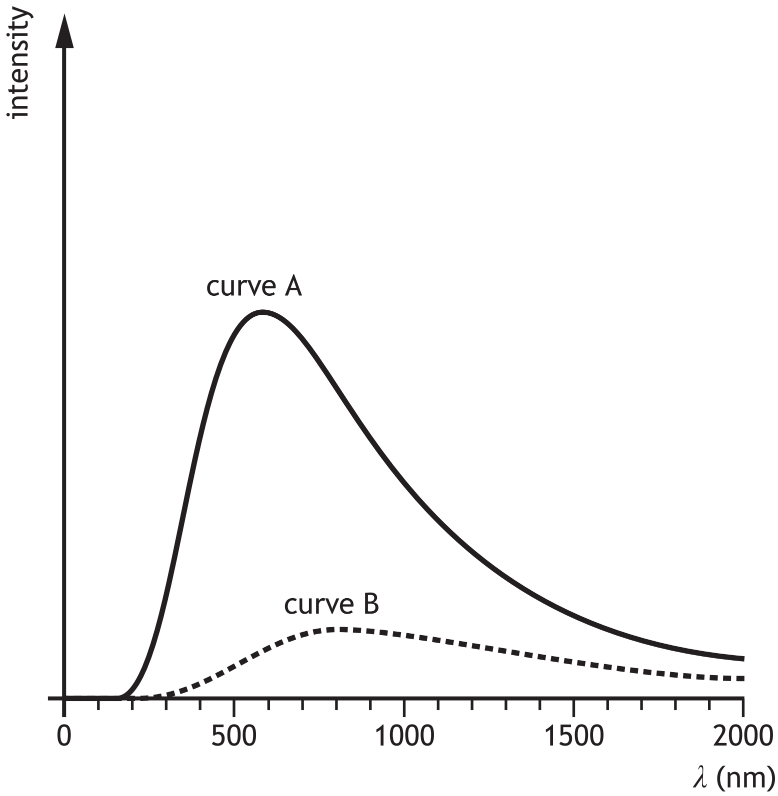

Figure 7

S857770140

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

S857770142

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S857/77/11

Physics
Relationships sheet

Date — Not applicable

Duration — 2 hours 30 minutes

S857711

Relationships required for Physics Advanced Higher

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

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

$$v = u + at$$

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

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

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

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

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

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

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

$$s = r\theta$$

$$v = r\omega$$

$$a_t = r\alpha$$

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

$$\omega = 2\pi f$$

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

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

$$I = \sum mr^2$$

$$\tau = Fr$$

$$\tau = I\alpha$$

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

$$L = I\omega$$

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

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

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

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

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

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

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

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

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

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

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

$$E = hf$$

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

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

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

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

$$F = qvB$$

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

$F = -ky$

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

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

$y = A\cos\omega t$ or $y = A\sin\omega t$

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

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

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

$E = kA^2$ or $\frac{E_1}{A_1^2} = \frac{E_2}{A_2^2}$

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

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

$opd = n \times gpd$

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

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

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

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

$n = \tan i_P$

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

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

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

$F = QE$

$V = Ed$

$W = QV$

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

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

$F = IlB\sin\theta$

$F = qvB$

$\tau = RC$

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

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

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

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

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

$X_L = 2\pi fL$

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

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

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

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

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

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

$$v = u + at$$

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

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

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

$$W = mg$$

$$F = ma$$

$$E_W = Fd$$

$$E_P = mgh$$

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

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

$$p = mv$$

$$Ft = mv - mu$$

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

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

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

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

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

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

$$v = H_0 d$$

$$W = QV$$

$$E = mc^2$$

$$E = hf$$

$$E_K = hf - hf_0$$

$$E_2 - E_1 = hf$$

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

$$v = f\lambda$$

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

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

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

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

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

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

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

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

$$Q = It$$

$$V = IR$$

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

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

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

$$E = V + Ir$$

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

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

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

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

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

Atomic number
Symbol
Electron arrangement
Name

Transition elements

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						

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

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S857/77/01

Physics

Marking Instructions

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

Qualifications Scotland
Teisteanasan Alba

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) ([Physics: general marking principles - National 3 to Advanced Higher (qualifications.gov.scot)]) 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.

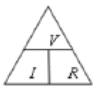
(c) Where a candidate incorrectly answers part of a question and carries the incorrect answer forward in the following part, award marks if the incorrect answer has then been used correctly in the subsequent part or 'follow-on'. (GMP 16)

(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 1a)

(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 1c)

(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 20)

(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 2)

(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 6)

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 $0.\dot{6}$, 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 22)

(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.

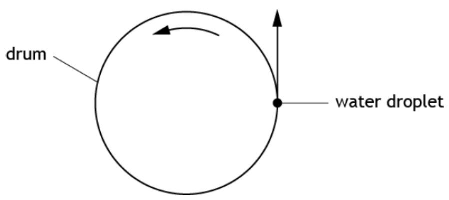
(l) Marking in calculations

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.	$V = IR$ $7.5 = 1.5R$ $R = 5.0\ \Omega$	1 mark: relationship 1 mark: substitution 1 mark: correct answer
2.	$5.0\ \Omega$	3 marks: correct answer
3.	5.0	2 marks: unit missing
4.	$4.0\ \Omega$	0 marks: no evidence, wrong answer
5.	$\_\_\ \Omega$	0 marks: no working or final answer
6.	$R = \frac{V}{I} = \frac{7.5}{1.5} = 4.0\ \Omega$	2 marks: arithmetic error
7.	$R = \frac{V}{I} = 4.0\ \Omega$	1 mark: relationship only
8.	$R = \frac{V}{I} = \_\_\ \Omega$	1 mark: relationship only
9.	$R = \frac{V}{I} = \frac{7.5}{1.5} = \_\_\ \Omega$	2 marks: relationship and substitution, no final answer
10.	$R = \frac{V}{I} = \frac{7.5}{1.5} = 4.0$	2 marks: relationship and substitution, wrong answer
11.	$R = \frac{V}{I} = \frac{1.5}{7.5} = 5.0\ \Omega$	1 mark: relationship but wrong substitution
12.	$R = \frac{V}{I} = \frac{75}{1.5} = 5.0\ \Omega$	1 mark: relationship but wrong substitution
13.	$R = \frac{I}{V} = \frac{1.5}{7.5} = 5.0\ \Omega$	0 marks: wrong relationship
14.	$V = IR$ $7.5 = 1.5 \times R$ $R = 0.2\ \Omega$	2 marks: relationship and substitution, arithmetic error
15.	$V = IR$ $R = \frac{I}{V} = \frac{1.5}{7.5} = 0.2\ \Omega$	1 mark: relationship correct but wrong rearrangement of symbols

Marking Instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)	(i)	$\alpha = \dfrac{\omega - \omega_0}{t}$ **(1)** $\alpha = \dfrac{131 - 7.50}{12.0}$ **(1)** $\alpha = 10.3\ \text{rad}\,\text{s}^{-2}$ **(1)**	**3**	Accept: 10, 10.29, 10.292
		(ii)	$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ **(1)** $\theta = (7.50 \times 12.0) + (0.5 \times 10.3 \times 12.0^2)$ **(1)** **revolutions** $= \dfrac{(7.50 \times 12.0) + (0.5 \times 10.3 \times 12.0^2)}{2\pi}$ **(1)** **revolutions** $= 132$ **(1)**	**4**	Accept: 130, 132.4, 132.35 Or consistent with (a)(i)
	(b)		$F = mr\omega^2$ **(1)** $F = 1.5 \times 10^{-2} \times 0.28 \times 131^2$ **(1)** $F = 72\ \text{N}$ **(1)**	**3**	Accept: 70, 72.1, 72.08
	(c)	(i)	The drum exerts a centripetal/central force on the clothing. **(1)** No centripetal/central force acting on water. **(1)**	**2**	
		(ii)		**1**	
		(iii)	Centripetal force decreases **(1)** as mass of wet clothing decreases. **(1)**	**2**	MUST JUSTIFY

Question			Expected response	Max mark	Additional guidance
2.	(a)		$I=\frac{1}{2}mr^2$ **(1)** $I=\frac{1}{2}\times 0.40\times\left(290\times 10^{-3}\right)^2$ **(1)** $I=0.017\ \text{kg m}^2$	**2**	SHOW question
	(b)	(i)	$\tau=Fr$ **(1)** $\tau=8.0\times 7.5\times 10^{-3}$ **(1)** $\tau=0.060\ \text{Nm}$ **(1)**	**3**	Accept: 0.06, 0.0600, 0.06000
		(ii)	$\tau=I\alpha$ **(1)** $0.060=0.017\times\alpha$ **(1)** $\alpha=3.5\ \text{rad s}^{-2}$ **(1)**	**3**	Or consistent with (b)(i) Accept: 4, 5.53, 3.529
	(c)		$I_{cube}=mr^2$ **(1)** $I_{cube}=25\times 10^{-3}\times\left(220\times 10^{-3}\right)^2$ **(1)** $I_1\omega_1=\left(I_1+I_{cube}\right)\omega_2$ **(1)** $0.017\times 12=\left(0.017+\left(25\times 10^{-3}\times\left(220\times 10^{-3}\right)^2\right)\right)\omega_2$ **(1)** $\omega_2=11\ \text{rad s}^{-1}$ **(1)**	**5**	Accept: 10, 11.2, 11.20

Question			Expected response	Max mark	Additional guidance
3.	(a)	(i)	$F = \frac{mv^2}{r}$ **(1)** $24.1 = \frac{1240 \times v^2}{(263 \times 10^3 + 680 \times 10^3)}$ **(1)** $v = 135 \text{ ms}^{-1}$	**2**	SHOW question Alternative: $\frac{mv^2}{r} = \frac{GMm}{r^2}$ **(1)** $v = \sqrt{\frac{GM}{r}}$ $v = \sqrt{\frac{6.67 \times 10^{-11} \times 2.59 \times 10^{20}}{(263 \times 10^3 + 680 \times 10^3)}}$ **(1)** $v = 135 \text{ ms}^{-1}$
		(ii)	$v = \frac{2\pi r}{T}$ **(1)** $135 = \frac{2\pi(263 \times 10^3 + 680 \times 10^3)}{T}$ **(1)** $T = 4.39 \times 10^4 \text{ s}$ **(1)**	**3**	Accept: 4.4, 4.389, 4.3889
	(b)	(i)	The work done in moving unit mass from infinity (to that point).	**1**	
		(ii)	$V_{low} - V_{high} = -3.22 \times 10^4 - (-1.29 \times 10^4)$ **(1)** $(V_{low} - V_{high} = -1.93 \times 10^4)$ $(\Delta)E = (\Delta)Vm$ **(1)** $(\Delta)E = -1.93 \times 10^4 \times 1240$ **(1)** $(\Delta)E = -2.39 \times 10^7 \text{ J}$ **(1)**	**4**	Accept: 2.4, 2.393, 2.3932 Can also be done by calculating potential energy in each orbit and subtracting. **1** mark for relationship. **1** mark for all substitutions. **1** mark for subtraction. **1** mark for final answer including unit.

Question			Expected response	Max mark	Additional guidance
4.	(a)		Red giant	**1**	
	(b)	(i) (A)	$L = 4\pi r^2 \sigma T^4$ (1) $L = 4 \times \pi \times (5.49 \times 10^{10})^2 \times 5.67 \times 10^{-8} \times (1.20 \times 10^4)^4$ (1) $L = 4 \cdot 45 \times 10^{31}$ W (1)	**3**	Accept: 4.5, 4.453, 4.4531
		(i) (B)	Rigel behaves as a black body. **OR** Stars behave as black bodies.	**1**	Accept: Rigel has a uniform radius Rigel is spherical Rigel has a uniform surface temperature
		(ii)	$\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$ (1) $\frac{\Delta L}{4.45 \times 10^{31}} = \sqrt{\left(\frac{0.05}{5.49} \times 2\right)^2 + \left(\frac{0.05}{1.20} \times 4\right)^2}$ (1), (1) $\Delta L = 1 \times 10^{31}$ W (1)	**4**	Or consistent with (b)(i)(A) Suspend sig fig rule 1 mark for relationship 1 mark for substitution of data 1 mark for applying indices rule 1 mark for final answer
	(c)		$b = \frac{L}{4\pi d^2}$ (1) $b = \frac{4.45 \times 10^{31}}{4 \times \pi \times \left(773 \times 365.25 \times 24 \times 60 \times 60 \times 3.00 \times 10^8\right)^2}$ (1,1) $b = 6.61 \times 10^{-8}$ Wm^{-2} (1)	**4**	Or consistent with (b)(i)(A) Accept: 6.6, 6.612, 6.61222 Independent mark for ly to m conversion (line 2). The use of 365 or 365.24 is acceptable.
	(d)		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
5.			**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
6.	(a)		Electrostatic force (between the nucleus/proton and the electron).	1	
	(b)	(i)	$\frac{Q_1Q_2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$ **(1)** $\frac{e^2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$ $\frac{1}{2}mv^2 = \frac{e^2}{8\pi\varepsilon_0 r^2}$ **(1)** $E_k = \frac{e^2}{8\pi\varepsilon_0 r^2}$	2	SHOW question
		(ii)	$E_k = \frac{e^2}{8\pi\varepsilon_0 r}$ $E_k = \frac{(1.60\times10^{-19})^2}{8\times\pi\times8.85\times10^{-12}\times0.21\times10^{-9}}$ **(1)** $E_k = 5.5\times10^{-19}$ J **(1)**	2	Accept: 5, 5.48, 5.483
	(c)		$mvr = \frac{nh}{2\pi}$ **(1)** $4.22\times10^{-34} = \frac{n\times6.63\times10^{-34}}{2\pi}$ **(1)** $n = 4$ (must be an integer) **(1)**	3	
	(d)	(i)	$\Delta x\Delta p_x \geq \frac{h}{4\pi}$ **(1)** $\Delta x\times1.5\times10^{-26} \geq \frac{6.63\times10^{-34}}{4\pi}$ **(1)** $\Delta x_{\min} = 3.5\times10^{-9}$ m **(1)**	3	Accept: 4, 3.52, 3.517

Question			Expected response	Max mark	Additional guidance
6.	(d)	(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)	(i)	$T = 15 + 273$ **(1)** $T = \frac{b}{\lambda_{peak}}$ $15 + 273 = \frac{2.89 \times 10^{-3}}{\lambda_{peak}}$ **(1)** $\lambda_{peak} = 1.00 \times 10^{-5}$ m **(1)**	**3**	Accept: 1.0, 1.003 Also accept 1 Incorrect or no conversion to kelvin – **(0)** marks
		(ii)	Infrared	**1**	
	(b)	(i)	(curve) A **(1)** Peak at shorter wavelength/higher frequency (as temperature is higher). **(1)** **OR** Higher/greater (peak) intensity (as greater energy). **(1)**	**2**	
		(ii)	Curve (approximately) asymptotic to y-axis and decreasing with increased wavelength.	**1**	Intercept with y-axis – **(0)** marks

Question			Expected response	Max mark	Additional guidance
8.	(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)		$4\times\frac{1}{2}\lambda = 0.264$ **(1)** $\lambda = 0.132$ m **(1)**	**2**	
	(d)		$v = f\lambda$ **(1)** $v = 2.45\times10^{9}\times0.132$ **(1)** $v = 3.23\times10^{8}\ \text{ms}^{-1}$ **(1)**	**3**	Or consistent with (c) Accept: 3.2, 3.234, 3.2340
	(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/random uncertainty, so the results are not accurate. **(1)**	**2**	

Question			Expected response	Max mark	Additional guidance
9.	(a)	(i)	(When) two <u>coherent</u> waves meet <u>in-phase</u>.	**1**	Both conditions must be stated. Accept: 'path difference $= m\lambda$' in place of 'in-phase'. 'constant phase relationship' in place of 'coherent'.
		(ii)	A maximum reading is displayed on the meter.	**1**	
		(iii)	$\Delta x = \frac{\lambda D}{d}$ **(1)** $470\times10^{-3} = \frac{\lambda\times720\times10^{-3}}{42\times10^{-3}}$ **(1)** $\lambda = 0.027$ m **(1)**	**3**	Accept: 0.03, 0.0274, 0.02742
	(b)	(i)	(Division of) amplitude.	**1**	
		(ii)	$\Delta x = \frac{9.8\times10^{-4}}{20}$ **(1)** $\Delta x = \frac{\lambda l}{2d}$ **(1)** $\frac{9.8\times10^{-4}}{20} = \frac{589\times10^{-9}\times75\times10^{-3}}{2d}$ **(1)** $d = 4.5\times10^{-4}$ m **(1)**	**4**	Accept: 5, 4.51, 4.508 First mark independent
		(iii)	Reduces the uncertainty in the value of Δx or d obtained. **OR** Reduces the impact/significance of any uncertainty on the value obtained for Δx or d.	**1**	
		(iv)	The wire expands/d increases **(1)** $\Delta x = \frac{\lambda l}{2d}$, (and since d increases) while l and λ remain constant, (Δx decreases). **OR** Since d increases and $\Delta x \propto \frac{1}{d}$, Δx decreases. **(1)**	**2**	

Question			Expected response	Max mark	Additional guidance
10.	(a)	(i)	The brightness (starts at a maximum and) decreases to (a minimum at) 90°. **(1)** The brightness then increases (from the minimum back to the maximum at 180°). **(1)**	**2**	Response must indicate a gradual change as the analyser rotates.
		(ii)	The brightness remains constant (throughout).	**1**	
	(b)	(i)	$n = \tan i_p$ **(1)** $1.33 = \tan i_p$ **(1)** $i_p = 53.1°$ **(1)**	**3**	Accept: 53, 53.06, 53.061
		(ii)	The polarising sunglasses will act as an analyser/absorb/block (some of) the glare.	**1**	

Question			Expected response	Max mark	Additional guidance
11.	(a)		Force acting per unit positive charge.	**1**	
	(b)		$\frac{Q_1}{4\pi\varepsilon_0 r^2}=\frac{Q_2}{4\pi\varepsilon_0 r^2}$ (1) $\frac{-8.0\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.40^2}=\frac{Q_2}{4\times\pi\times8.85\times10^{-12}\times0.20^2}$ (1) $\left(Q_2=-2.0\times10^{-9}\right)$ $Q_2=-2.0$ nC	**2**	SHOW question
	(c)		$V_1=\frac{Q}{4\pi\varepsilon_0 r}$ (1) $V_1=\frac{-8.0\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.40}$ (1) $V_2=\frac{-2.0\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.20}$ (1) Potential at X $=\frac{-8.0\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.40}+\frac{-2.0\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.20}$ (1) Potential at X $=-270$ V (1)	**5**	Accept: 300, 269.8

Question			Expected response	Max mark	Additional guidance
12.	(a)	(i)	$X_C = \frac{1}{2\pi fC}$ **(1)** $X_C = \frac{1}{2\times\pi\times65\times5.0\times10^{-6}}$ **(1)** $X_C = 490\ \Omega$ **(1)**	**3**	Accept: 500, 489.7
		(ii)	$X_C = \frac{V}{I}$ **(1)** $490 = \frac{15}{I}$ **(1)** $I = 3.1\times10^{-2}$ A **(1)**	**3**	Or consistent with (a)(i) Accept: 3, 3.06, 3.061
	(b)	(i)	Axes appropriately labelled (quantity and units) and axes linearly scaled. **(1)** [Allow for axes starting at zero or broken axes or an appropriate value]. Data points plotted accurately. **(1)** Appropriate line of best-fit. **(1)**	**3**	If the origin is shown the scale must either be continuous, or the axis must be 'broken'. Otherwise, maximum **(2)** marks. If non-linear scale is used over the range of the data on either axis eg values from the table are used as the scale points, **(0)** marks. Do not penalise if candidates plot $\frac{1}{f}$ against X_C. Accuracy of plotting should be easily checkable with the scale chosen. An appropriate scale to allow the accuracy of plotting to be checked must be linear over the range of the data.
		(ii)	Gradient of line of best fit. **(1)** gradient= $\frac{1}{2\pi C}$ **OR** $C = \frac{1}{2\times\pi\times\text{gradient}}$ **(1)** Final value of C **(1)**	**3**	If candidates use data points not on their line of best fit, then maximum of **(1)** mark available. A representative gradient value of 2.55×10^{7} gives a capacitance of 6.24×10^{-9} F. Final value of C must be consistent with candidate's value for gradient.

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.

[END OF SPECIMEN MARKING INSTRUCTIONS]

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Change since last published:

The duration of the paper has been shortened and the number of marks reduced. Some questions have been removed from the previous specimen question paper, some have been edited or updated, and some have been replaced.