FOR OFFICIAL USE

National Qualifications 2025

Mark

X857/77/01 Physics

THURSDAY, 15 MAY

9:00 AM – 12:00 NOON

X857701

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 X857/77/11 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.

SQA ©

X857701 01

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Gravitational acceleration on Earth	g	$9.8\ \text{m s}^{-2}$	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 Moon	M_M	7.3×10^{22} kg	Mass of proton	m_p	1.673×10^{-27} kg
Radius of Moon	R_M	1.7×10^6 m	Mass of positron	m_{e^+}	9.11×10^{-31} kg
Mean Radius of Moon Orbit		3.84×10^8 m	Charge on positron	e^+	1.60×10^{-19} C
Solar radius		6.955×10^8 m	Charge on copper nucleus		4.64×10^{-18} C
Mass of Sun		2.0×10^{30} kg	Planck's constant	h	6.63×10^{-34} J s
Mass of Mars	M_{Mars}	6.42×10^{23} kg	Permittivity of free space	ε_0	$8.85 \times 10^{-12}\ \text{F m}^{-1}$
Radius of Mars	R_{Mars}	3.39×10^6 m	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \text{H m}^{-1}$
1 AU		1.5×10^{11} m	Speed of light in vacuum	c	$3.00 \times 10^8\ \text{m s}^{-1}$
Stefan-Boltzmann constant	σ	$5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	Speed of sound in air	v	$3.4 \times 10^2\ \text{m s}^{-1}$
Universal constant of gravitation	G	$6.67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$			

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	2.70×10^3	933	2623	9.02×10^2	3.95×10^5	. . . .
Copper	8.96×10^3	1357	2853	3.86×10^2	2.05×10^5	. . . .
Glass	2.60×10^3	1400	. . . .	6.70×10^2	. . . .	. . . .
Ice	9.20×10^2	273	. . . .	2.10×10^3	3.34×10^5	. . . .
Glycerol	1.26×10^3	291	563	2.43×10^3	1.81×10^5	8.30×10^5
Methanol	7.91×10^2	175	338	2.52×10^3	9.9×10^4	1.12×10^6
Sea Water	1.02×10^3	264	377	3.93×10^3	. . . .	. . . .
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	. . . .	4.50×10^5
Nitrogen	1.25	63	77	1.04×10^3	. . . .	2.00×10^5
Oxygen	1.43	55	90	9.18×10^2	. . . .	2.40×10^4

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

[Turn over for next question

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Total marks — 155 marks

Attempt ALL questions

1. A Space Transportation System craft uses a parachute to assist with braking after touchdown.

The velocity of the craft, from touchdown at $t = 0$ s to coming to rest, is shown in **Figure 1A**.

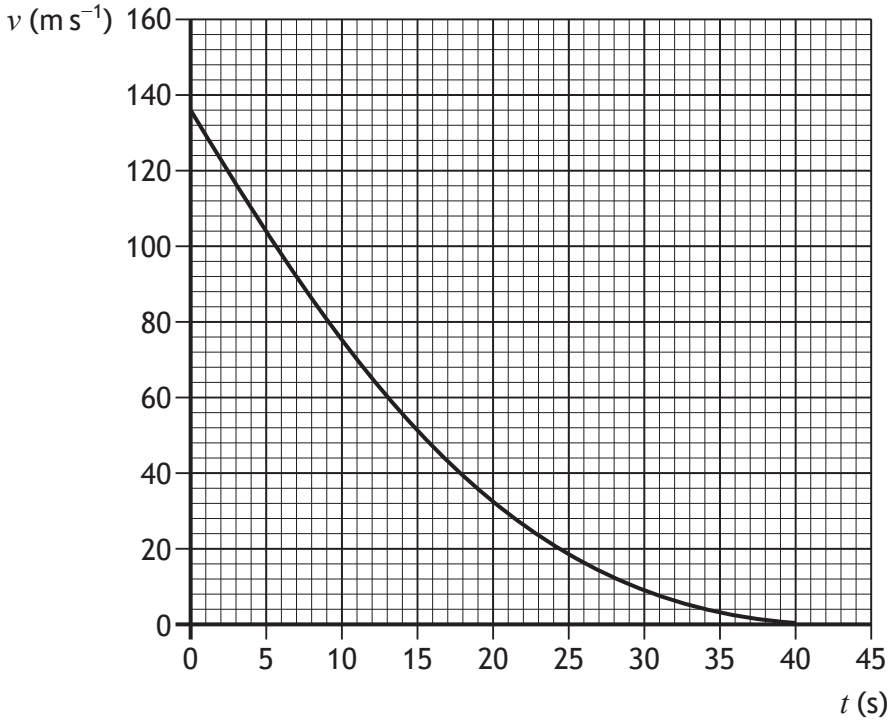

Figure 1A

The velocity v at time t is given by

$$v = 0.09t^2 - 7.0t + 136$$

1. (continued)

Using calculus methods:

(a) determine the acceleration of the craft 15 s after touchdown **3**

Space for working and answer

(b) determine the displacement of the craft between touchdown and coming to rest. **4**

Space for working and answer

2. A fairground ride consists of a rotating drum with a moveable floor.

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

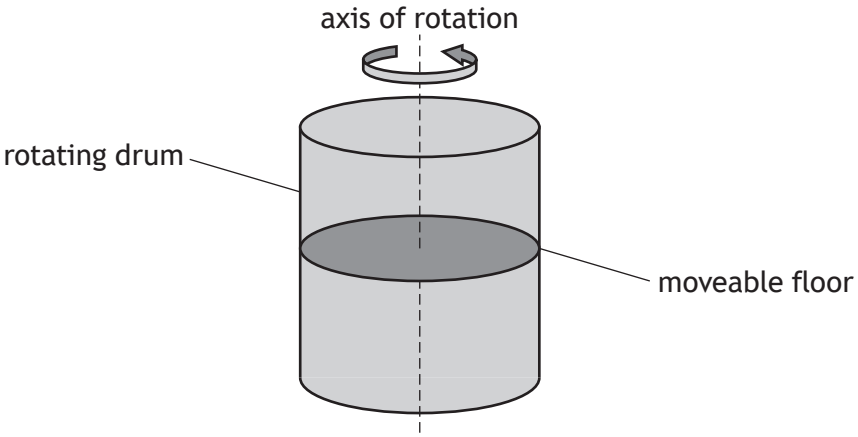

Figure 2A

(a) During a test of the fairground ride, the drum is initially at rest. It then accelerates at 0.12 rad s^{-2} for 34 s.

(i) Calculate the angular velocity of the drum at 34 s. **3**

Space for working and answer

(ii) The moment of the inertia of the ride during the test is 2.4×10^4 kg m^2.

Calculate the unbalanced torque required to produce an acceleration of 0.12 rad s^{-2}. **3**

Space for working and answer

2. (continued)

(b) The ride is now operated with people standing against the inside wall of the drum.

State how the unbalanced torque required to produce an acceleration of 0.12 rad s^{-2} compares with the value calculated in part (a) (ii).

Justify your answer. **2**

(c) When the ride reaches its maximum angular velocity, the moveable floor is lowered. The people remain 'stuck' to the wall, as shown in **Figure 2B**.

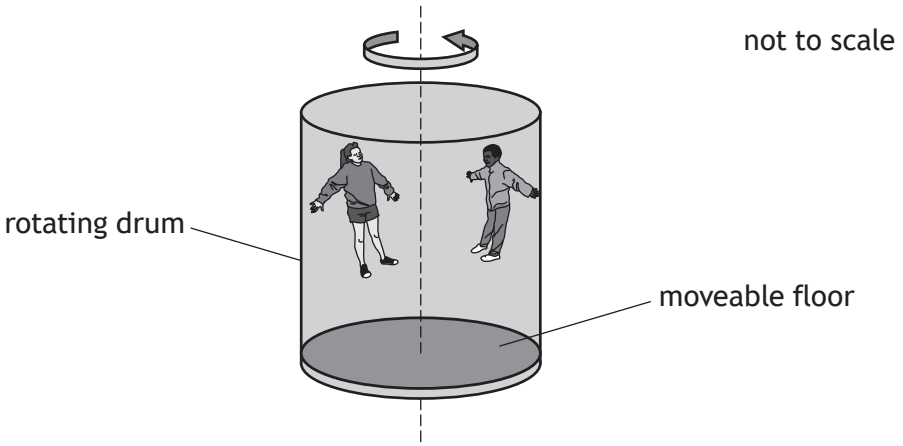

Figure 2B

The rotating drum then slows down and the people slide down the wall.

Explain, in terms of forces, why the people slide down the wall. **1**

[Turn over

3. A pulsar is a rotating neutron star that emits radio waves from its magnetic poles. An artist's impression of this is shown in **Figure 3A**.

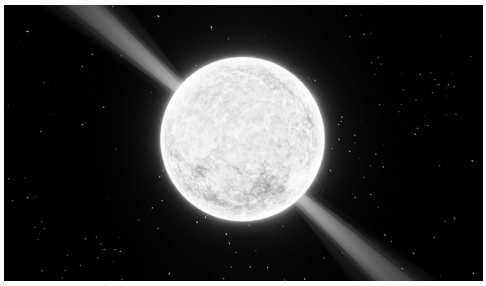

Figure 3A

PSR B1919+21 is a spherical pulsar of approximately uniform density, with the following properties:

period of rotation = 1.34 s

mass = 2.8×10^{30} kg

radius = 9.74×10^{3} m

(a) Show that the angular velocity of PSR B1919+21 is 4.69 rad s^{-1}. **2**

Space for working and answer

(b) Calculate the moment of inertia of PSR B1919+21. **3**

Space for working and answer

3. (continued)

(c) The pulsar was formed when the core of its rotating parent star collapsed under its own gravity.

When this occurred, the loss of mass from the core of the parent star was negligible.

(i) State the principle of conservation of angular momentum. **1**

(ii) The core of the parent star had a moment of inertia of 2.7×10^{42} kg m^2.

Determine the angular velocity of the core of the parent star immediately before it collapsed. **3**

Space for working and answer

[Turn over

3. (continued)

(d) Using your knowledge of physics, comment on the similarities and differences in the evolution of stars into neutron stars, black holes, and white dwarfs. **3**

3. (d) (continued)

[Turn over

4. Spacecraft can be manoeuvred into trajectories passing close to planets in our Solar System, as shown in **Figure 4A**.

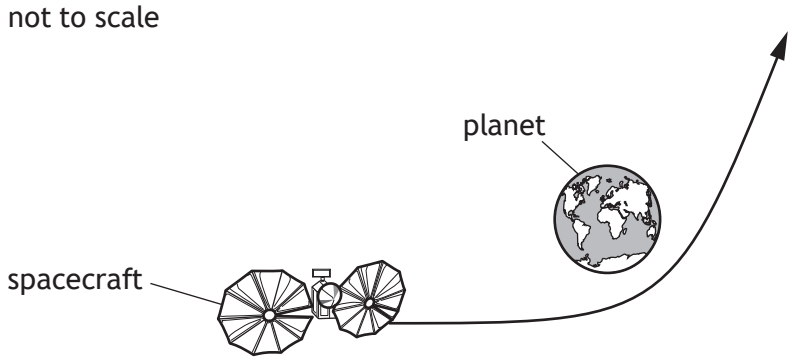

Figure 4A

In following such a trajectory, the speed of the spacecraft can be increased due to a gravity assist effect.

The NASA mission Lucy launched in 2021. The purpose of the mission is to explore asteroids in the outer Solar System.

In 2022, the Lucy spacecraft experienced a gravity assist effect from the Earth. The spacecraft passed 3.6×10^5 m above Earth's surface at its closest approach.

(a) (i) Determine the escape velocity at the point of closest approach of the Lucy spacecraft. **3**

Space for working and answer

(ii) Explain why the speed of the spacecraft at its closest approach should exceed the escape velocity. **1**

4. (continued)

(b) The maximum gain in speed Δv_{max} for this gravity assist manoeuvre can be calculated using the relationship

$$\Delta v_{max} = \frac{2ugr}{gr + u^2}$$

where: u is the approach speed

r is the distance from the centre of the planet to the point of closest approach

g is the gravitational field strength at the surface of the planet.

The approach speed of the spacecraft towards Earth was 1.7×10^4 m s^{-1}.

Determine the maximum speed of the spacecraft after the gravity assist manoeuvre. **3**

Space for working and answer

(c) State how the rate at which time passes on the spacecraft, relative to an observer on the Earth, changes as the spacecraft moves away from Earth.

Justify your answer. **2**

[Turn over

5. The spectrum of a star can be approximated as a black-body spectrum.

The star Sirius A, and the stars Betelgeuse and Rigel in the constellation Orion, can be seen in the winter night sky from Scotland.

Sirius A is the brightest observed star in the night sky.

This is represented in **Figure 5A**.

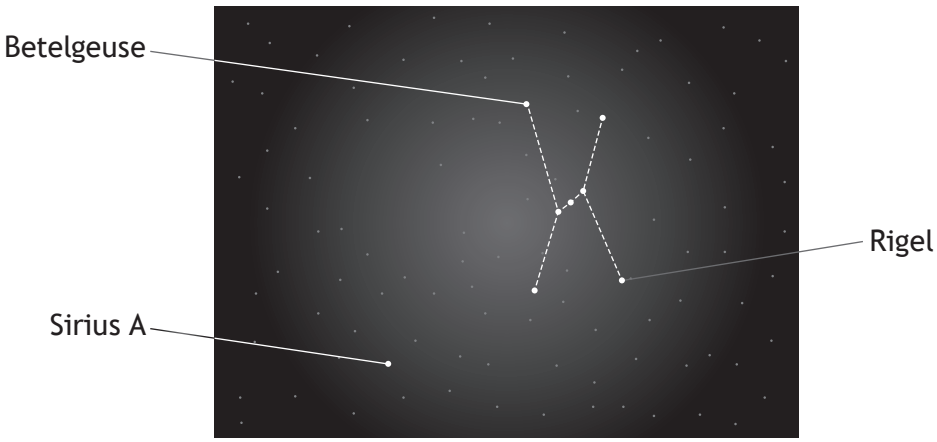

Figure 5A

(a) Sirius A has a companion star, Sirius B, which is a white dwarf.

Sirius B has a radius of 5.6×10^6 m and a luminosity of 9.4×10^{24} W.

Calculate the surface temperature of Sirius B. **3**

Space for working and answer

5. (continued)

(b) Orion's two brightest stars are the blue supergiant Rigel and the red supergiant Betelgeuse.

Rigel is 8.0×10^{18} m from Earth and has an apparent brightness of 5.8×10^{-8} W m^{-2}.

(i) Show that the luminosity of Rigel is 4.7×10^{31} W. **2**

Space for working and answer

(ii) The luminosity of Betelgeuse is the same order of magnitude as the luminosity of Rigel.

Rigel has a surface temperature of 1.2×10^{4} K.

Betelgeuse has a surface temperature of 3.5×10^{3} K.

State whether the radius of Betelgeuse is greater than, less than or equal to that of Rigel.

Justify your answer. **2**

[Turn over

5. (continued)

(c) The black-body spectra of Betelgeuse, Rigel, Sirius B, and the Sun (a main sequence star) are shown in **Figure 5B** below.

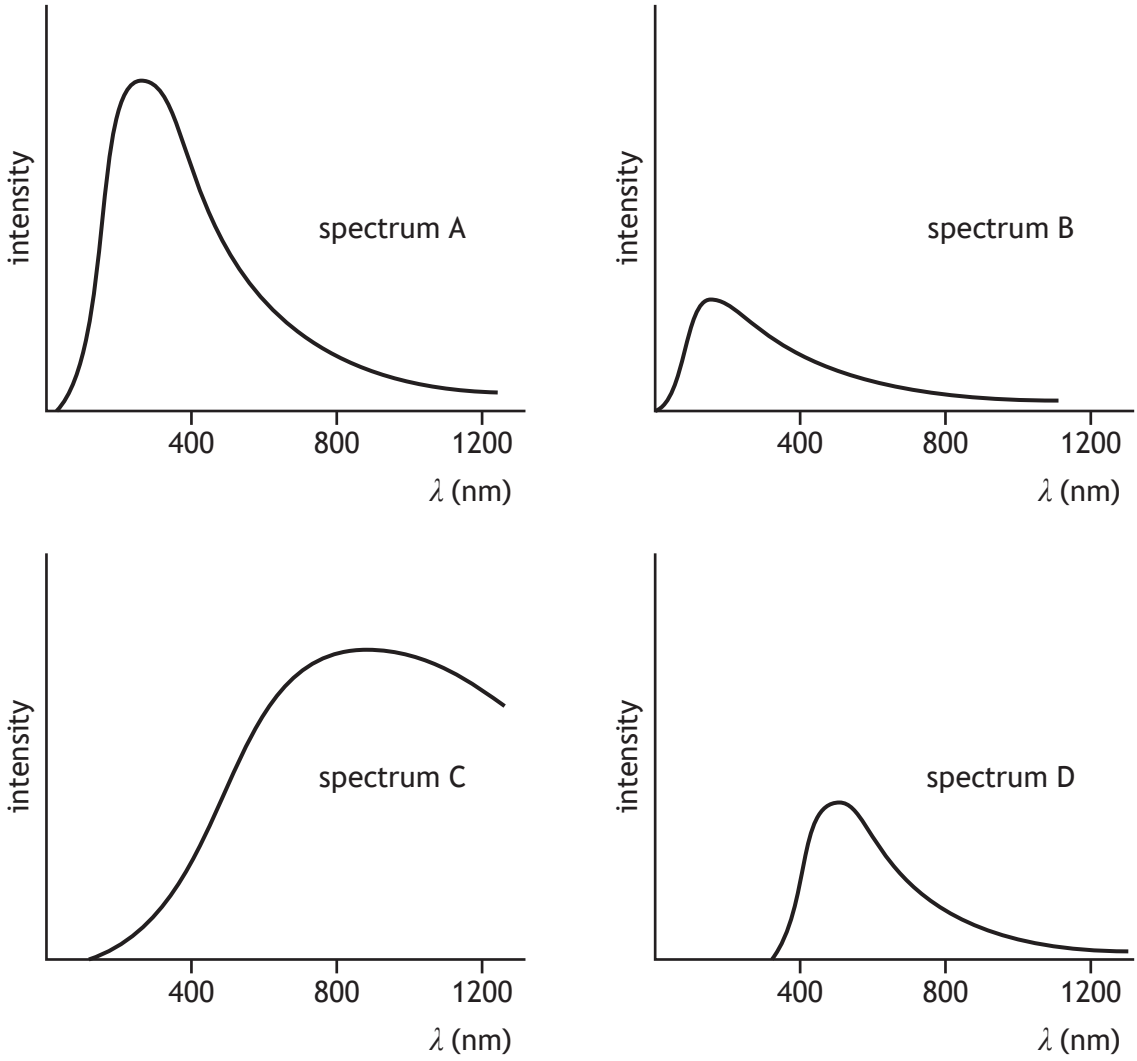

Figure 5B

By considering the peak wavelength of each spectrum, complete the table to identify the correct spectrum for each star. **3**

Star	Spectrum
Betelgeuse	
Rigel	
Sirius B	
Sun	

6. Classical physics theory predicts incorrectly that, at certain wavelengths, the energy emitted by black-body radiators tends to infinity.

(a) (i) State the name given to this prediction. **1**

(ii) The spectrum obtained from an experiment into the properties of black-body radiators is shown in **Figure 6A**.

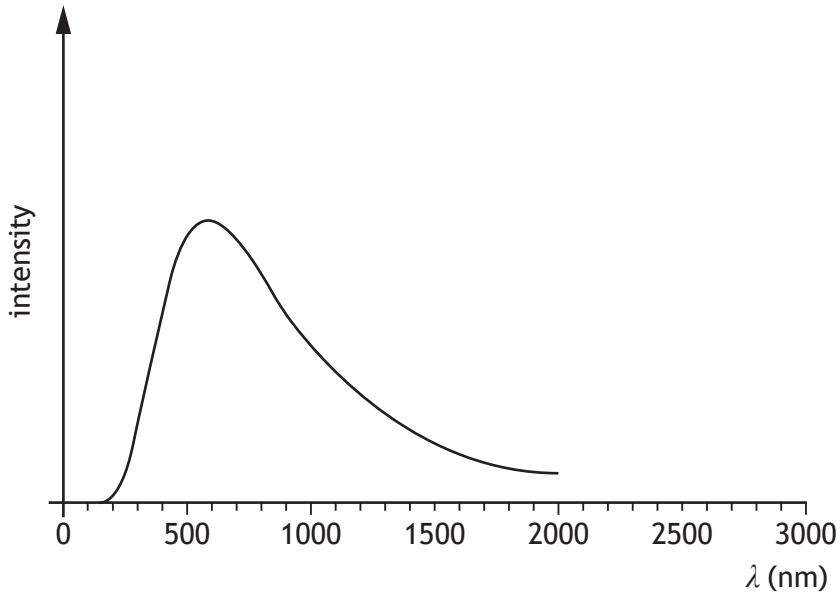

Figure 6A

On **Figure 6A**, add a line to represent the spectrum predicted by classical theory. **1**

(An additional diagram, if required, can be found on *page 53*.)

[Turn over

MARKS

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(b) The relationship between peak wavelength λ_{peak} and temperature T for a black-body radiator is shown in **Figure 6B**.

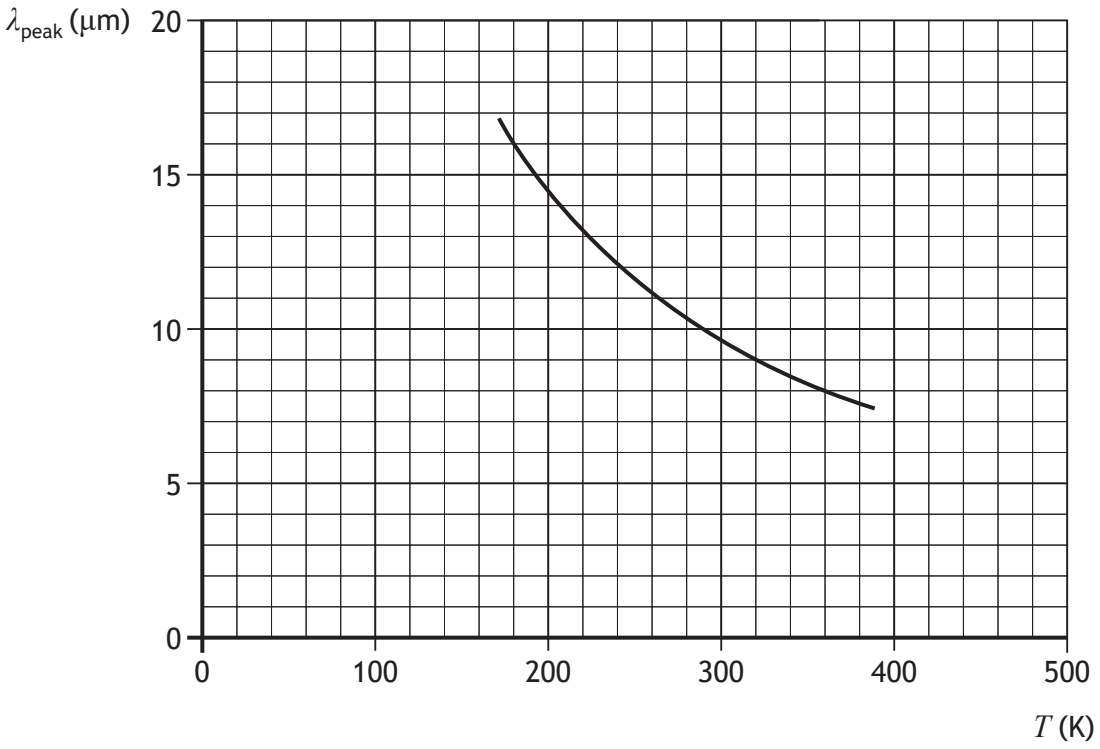


Figure 6B

(i) The peak wavelength emitted by a black-body radiator is 8.5 μm.

Determine the temperature of the black-body radiator. **1**

(ii) Calculate the power per unit area emitted from a black-body radiator at this temperature. **3**

Space for working and answer

6. (b) (continued)

(iii) In a laboratory experiment, the measured power per unit area emitted from an object at this temperature is less than the value calculated in (b) (ii).

Suggest a reason why this is the case. **1**

(c) Infrared thermometers detect photons emitted by an object to determine the temperature of the object.

(i) Calculate the momentum of a photon of wavelength 5.6 μm. **3**

Space for working and answer

(ii) Explain the implication of the phrase *the momentum of a photon*. **1**

[Turn over

7. Cosmic rays consist of charged and uncharged particles.

As the charged particles approach Earth, they interact with the magnetic field of Earth.

(a) State the origin of cosmic rays. **1**

(b) Some of the charged particles will follow a helical path due to their interaction with the magnetic field.

Explain why these charged particles follow a helical path. **2**

7. (continued)

(c) Some of these cosmic rays will collide with the nuclei of atoms in the upper atmosphere of the Earth.

These collisions create new particles, such as muons, which have short lifetimes.

(i) A muon created in one such collision has an energy of 5.56 GeV.

Determine the energy of this muon in joules. **1**

Space for working and answer

(ii) The Heisenberg uncertainty principle states that the uncertainty in the energy of a short-lived quantum particle is related to its lifetime.

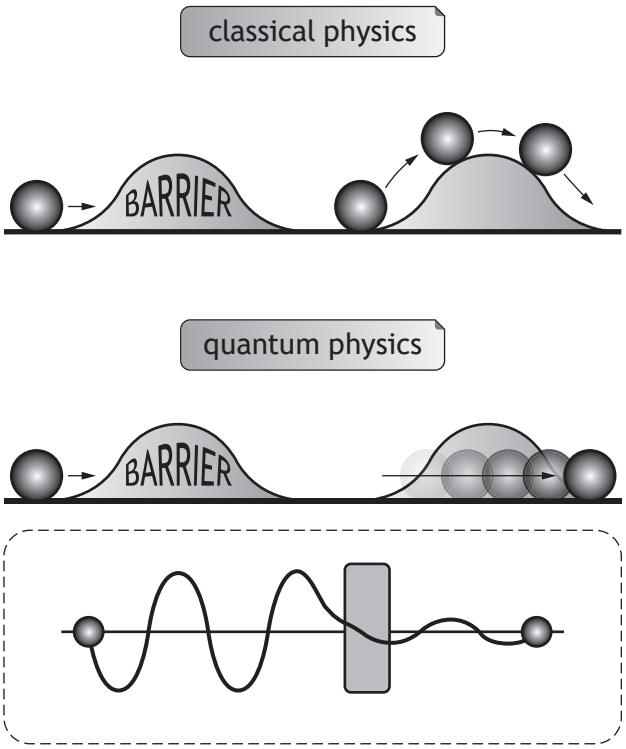
The uncertainty in the energy of a muon is 4.55×10^{-31} J.

Determine the lifetime of this muon. **3**

Space for working and answer

[Turn over

8. The diagram shown is part of a website article that discusses the differences and similarities between classical and quantum physics.



Using your knowledge of physics, comment on the concepts represented in the diagram. **3**

8. (continued)

[Turn over

9. An adult takes a child to a play park.

The child sits on one side of a seesaw, at a distance of 1.8 m from the pivot point, creating a torque.

The adult applies a vertical force to the opposite side of the seesaw to balance that torque, keeping the seesaw level. This force is applied at a distance of 2.3 m from the pivot point.

This is shown in **Figure 9A**.

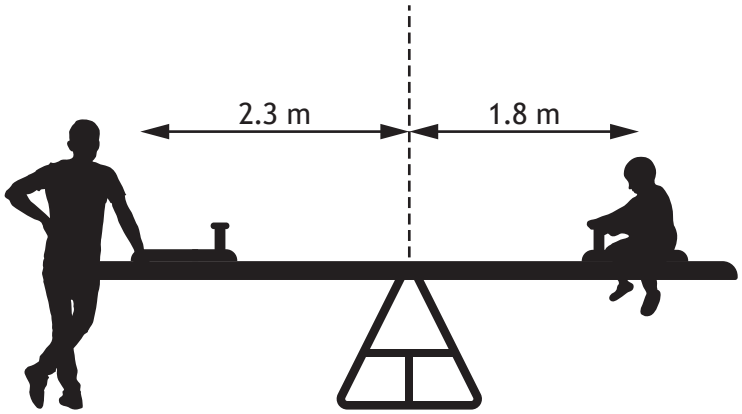


Figure 9A not to scale

(a) The mass of the child is 19 kg.

Determine the magnitude of the force applied by the adult to keep the seesaw level. **4**

Space for working and answer

9. (continued)

(b) The adult now applies a force that varies continuously with time t. This causes the seesaw and child to move up and down. The vertical displacement of the child can be approximated to simple harmonic motion (SHM).

(i) The vertical displacement, in metres, of the child from their starting position is given by the relationship

$$y = 0.33 \sin 2.2t$$

Using calculus methods, show that this relationship is consistent with SHM. **3**

Space for working and answer

(ii) Calculate the period of the motion of the child. **3**

Space for working and answer

[Turn over

9. (b) (continued)

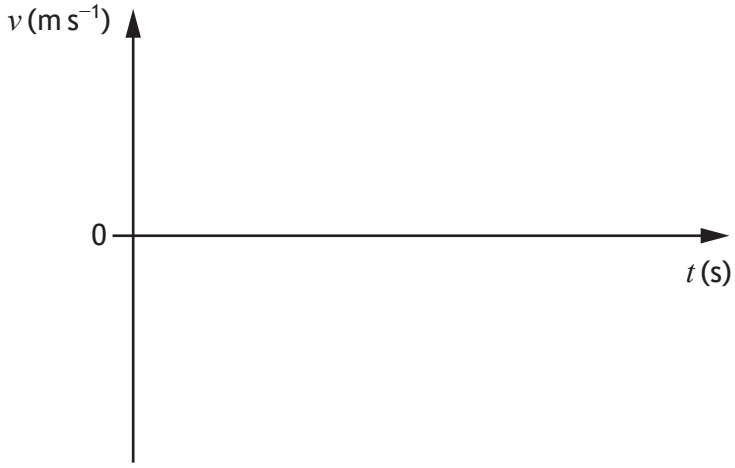
(iii) Calculate the maximum vertical velocity of the child during this motion. **3**

Space for working and answer

(iv) On the axes below, sketch a graph showing how the vertical velocity v of the child varies over **one full period** of their motion, beginning as they pass through the equilibrium position.

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

(An additional diagram, if required, can be found on *page 53*.)



9. (continued)

(c) A second child also wants to play on the seesaw.

The two children take turns pushing on the ground to move the seesaw.

This is shown in **Figure 9B**.

Figure 9B

Explain why the vertical movement of the first child no longer approximates to SHM. **1**

10. Parking sensors are used in cars to assist the driver during parking. The sensors emit and detect waves of specific frequencies. Emitted waves are reflected back to the sensor by nearby objects. The car's onboard computer then determines the distance between the car and the objects.

One model of sensor emits a wave which is described by the relationship

$$y = 7.17 \times 10^{-5} \sin 2\pi \left(3.94 \times 10^{4} t - \frac{x}{8.63 \times 10^{-3}} \right)$$

where the symbols have their usual meanings.

(a) State whether the wave being emitted by the sensor is a sound wave or an electromagnetic wave.

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

Space for working and answer

(b) The wave now reflects from an object and 40% of the initial energy of the wave returns to the sensor.

Determine a relationship that fully describes the reflected wave as it arrives at the sensor. **4**

Space for working and answer

10. (continued)

(c) A sensor on the car detects the reflected wave. A simplified diagram of the detecting circuit is shown in **Figure 10A**.

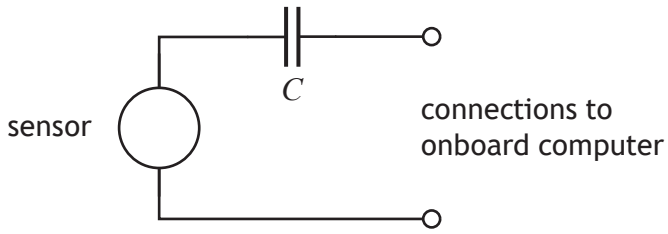


Figure 10A

When the sensor detects the wave, an alternating current is generated in the circuit. This alternating current has the same frequency as the detected wave. Sufficient current will only pass to the onboard computer if the frequency is high enough.

Explain why the frequency needs to be high enough for sufficient current to pass to the onboard computer. **1**

[Turn over

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11. 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 11A**.

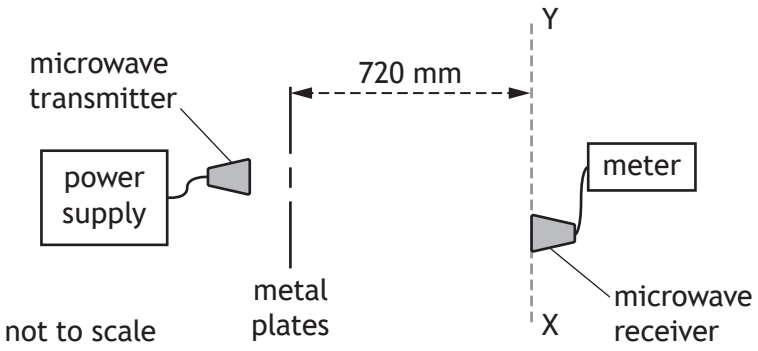

Figure 11A

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**

[Turn over

MARKS

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(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

(b) The student now investigates another aspect of interference to determine if it is suitable to include in their project. The student finds some notes about thin film interference and non-reflective coatings.

The notes include the diagram shown in **Figure 11B**.

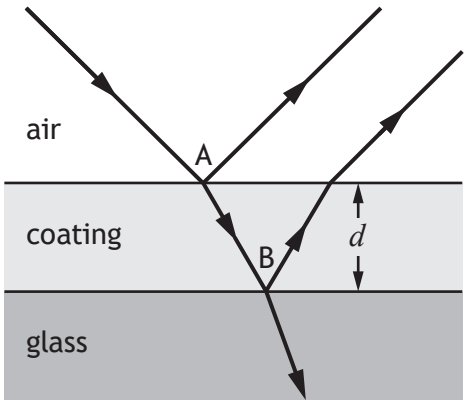

Figure 11B

The refractive index of the coating is less than the refractive index of the glass.

(i) (A) State the phase change, in radians, experienced by a light wave when it reflects at the air-coating boundary at A. **1**

(B) State the phase change, in radians, experienced by a light wave when it reflects at the coating-glass boundary at B. **1**

11. (b) (continued)

(ii) Derive the relationship

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

where d is the minimum thickness for a coating of refractive index n to be non-reflecting for light of wavelength λ. **2**

Space for working and answer

(c) The student considers setting up an experiment to investigate the relationship derived in (b) (ii).

The student plans to form a non-reflecting layer of ice on top of a glass slide. A helium-neon laser will be used as the light source for this experiment.

(i) Calculate the minimum thickness of the layer of ice required for this experiment. **2**

Space for working and answer

(ii) After calculating the minimum thickness of ice required, the student decides against carrying out this experiment.

Based on this calculation, suggest a reason why the student makes this decision. **1**

12. A technician carries out an experiment to measure Brewster's angle for a type of plastic.

A laser beam passes through a polariser and then reflects from a plastic prism on a platform. The platform can be rotated to change the angle θ. The reflected beam is detected by a light meter.

This experimental setup is shown in **Figure 12A**.

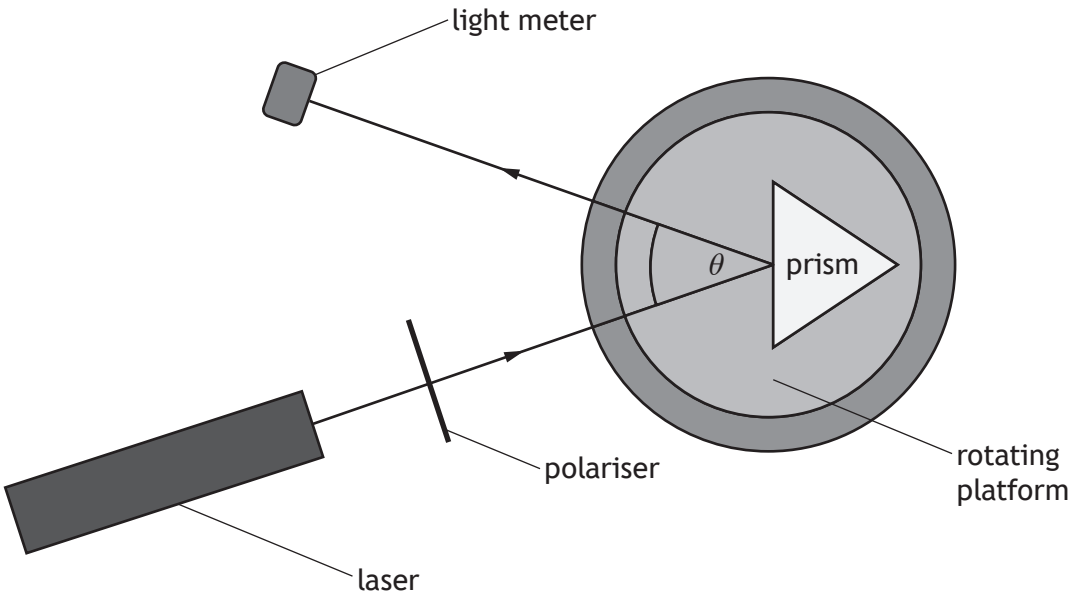

Figure 12A

The polariser ensures that the light reaching the prism is plane-polarised.

As the platform rotates, the light meter is moved to measure the irradiance I of the reflected beam.

At Brewster's angle there is no reflection of the beam from the prism.

(a) State what is meant by *plane-polarised light*. **1**

12. (continued)

(b) **Figure 12B** shows a graph produced from this experiment.

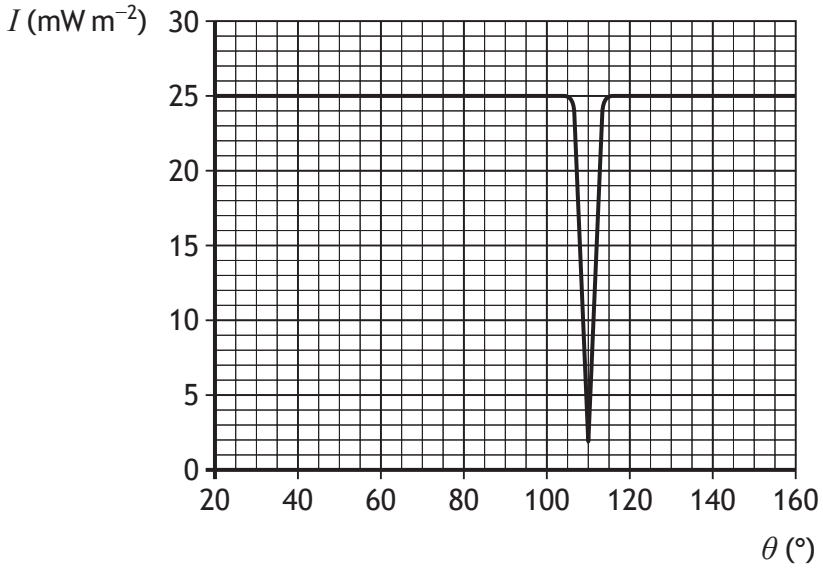

Figure 12B

(i) Determine the refractive index of the plastic. **4**

Space for working and answer

(ii) Suggest a reason why the irradiance detected by the light meter does not reach zero. **1**

[Turn over

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13. A small, positively charged sphere is fixed to an insulated stand, as shown in **Figure 13A**.

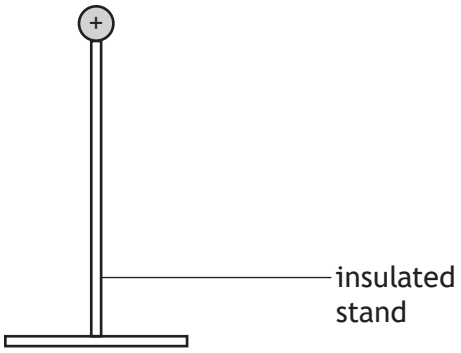

Figure 13A

(a) On **Figure 13A**, sketch the electric field pattern around the charged sphere. **1**

(An additional diagram, if required, can be found on *page 54*.)

(b) The charge on the sphere is +12 nC.

Show that the electric field strength at a distance of 0.15 m from the centre of the charged sphere is 4800 N C^{-1}. **2**

Space for working and answer

13. (continued)

(c) Another charged sphere of mass 16 g is suspended by a thin, insulating cord.

This suspended sphere is moved towards the fixed sphere. When the distance between the two spheres is 0.15 m the deflection of the cord is 5.0° from the vertical.

This is shown in **Figure 13B**.

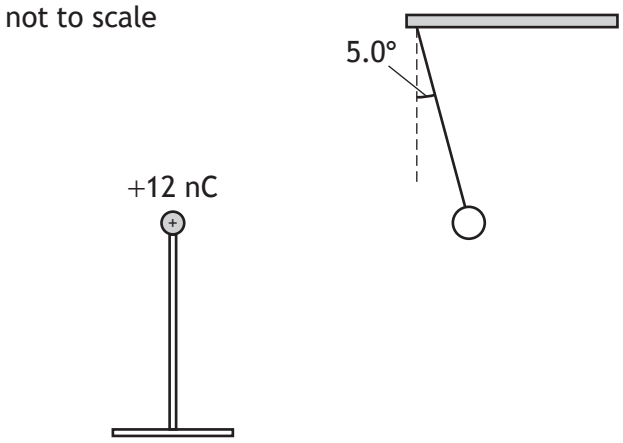

Figure 13B

(i) Determine the magnitude of the electrostatic force acting on the suspended sphere. **3**

Space for working and answer

13. (c) (continued)

(ii) Calculate the charge on the suspended sphere. **3**

Space for working and answer

(d) The suspended sphere is moved to a distance of 0.30 m from the fixed sphere. The charge on the suspended sphere is now doubled.

State whether the angle of the cord from the vertical will be greater than, less than or equal to 5.0°.

Justify your answer. **2**

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14. A mass spectrometer is an instrument that is used to investigate some properties of charged particles.

A simplified illustration showing the path of an ion as it passes through the mass spectrometer is shown in **Figure 14A**.

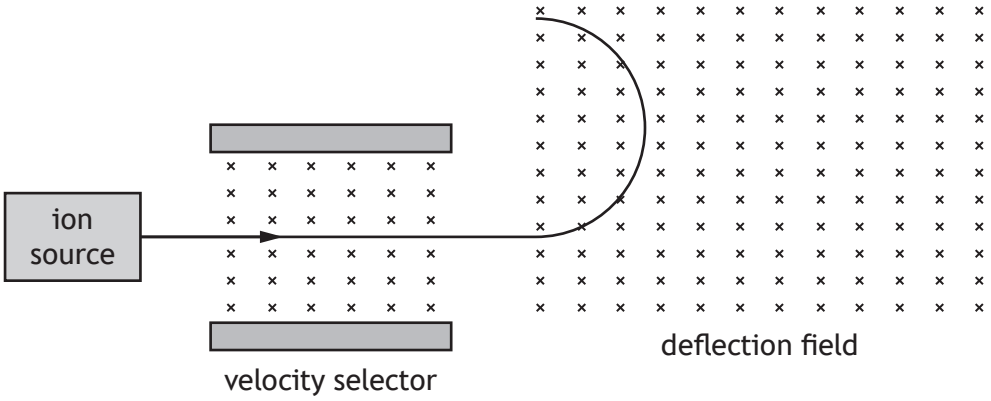

Figure 14A

The velocity selector contains a region in which there is both a uniform electric field and a uniform magnetic field. These fields are perpendicular to each other and also perpendicular to the initial velocity v of the ions.

The electric field is produced by a potential difference of 4.80 kV between two parallel plates. The plates are separated by a distance of 10.0 mm.

This is shown in **Figure 14B**.

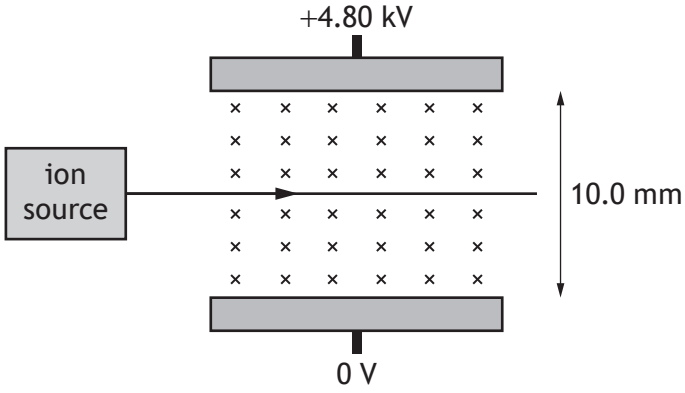

Figure 14B

The magnetic induction in the velocity selector is 225 mT.

14. (continued)

(a) (i) By considering the electric and magnetic forces acting on an ion, show that the velocity v of an ion passing undeflected through the velocity selector is given by the relationship

$$v = \frac{E}{B}$$

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

Space for working and answer

(ii) Determine the velocity of an ion that passes through the velocity selector undeflected. **3**

Space for working and answer

(iii) Explain why different types of ion passing through the velocity selector undeflected have the same velocity. **1**

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14. (continued)

(b) The mass spectrometer is now used to investigate the paths followed by two types of hydrogen ion.

Data for the hydrogen ions are shown below.

Ion	Symbol	Mass ($\times 10^{-27}$ kg)	Charge ($\times 10^{-19}$ C)
Deuterium	$^{2}H^{+}$	3.34	1.60
Tritium	$^{3}H^{+}$	5.01	1.60

These ions enter the deflection field with the velocity determined in (a) (ii) and follow semi-circular paths in the field.

One type of ion leaves the field at point Y and the other type of ion leaves at point Z.

This is shown in **Figure 14C**.

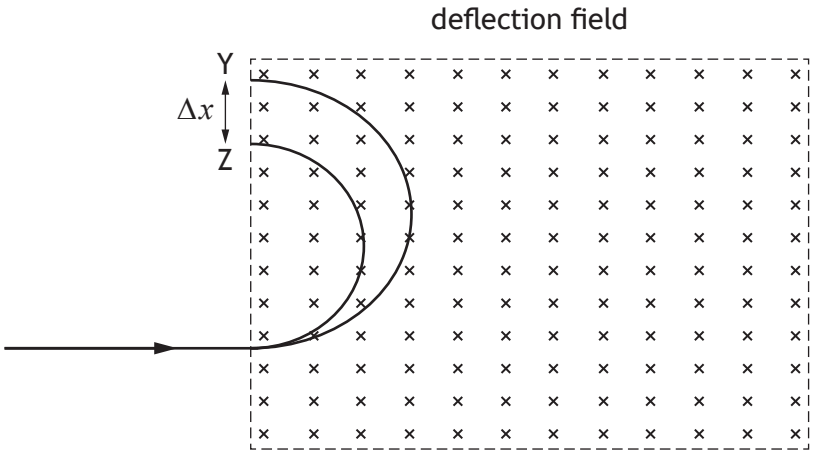

Figure 14C

The magnetic induction in the deflection field is 0.65 T.

14. (b) (continued)

The radius of the curved path of the ions is given by the relationship

$$r = \frac{mv}{qB}$$

where the symbols have their usual meanings.

Determine the separation Δx of the ions when they leave the deflection field. **4**

Space for working and answer

(c) The potential difference between the parallel plates in the velocity selector is now increased. The magnetic inductions of both the velocity selector and the deflection field are unchanged.

State the change to the paths of the ions in the deflection field.

Justify your answer. **2**

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15. A circuit is set up to investigate some properties of inductors. The circuit diagram is shown in **Figure 15A**.

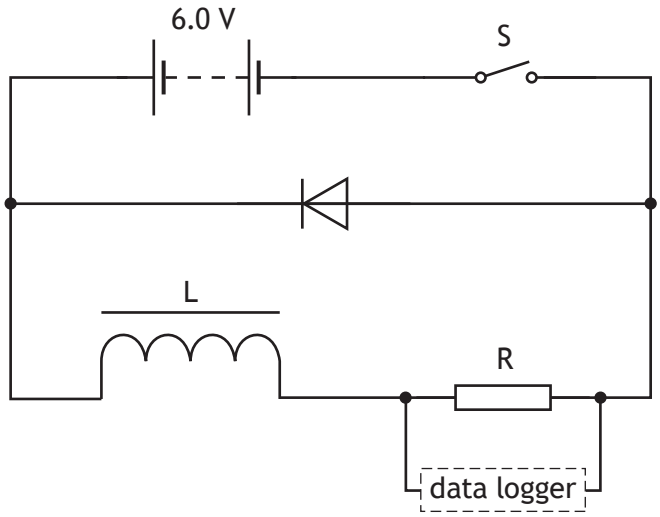

Figure 15A

The resistance of both the battery and inductor can be considered negligible.

(a) Switch S is closed and the data logger records data.

The data is used to produce a graph of current I against time t.

The graph is shown in **Figure 15B**.

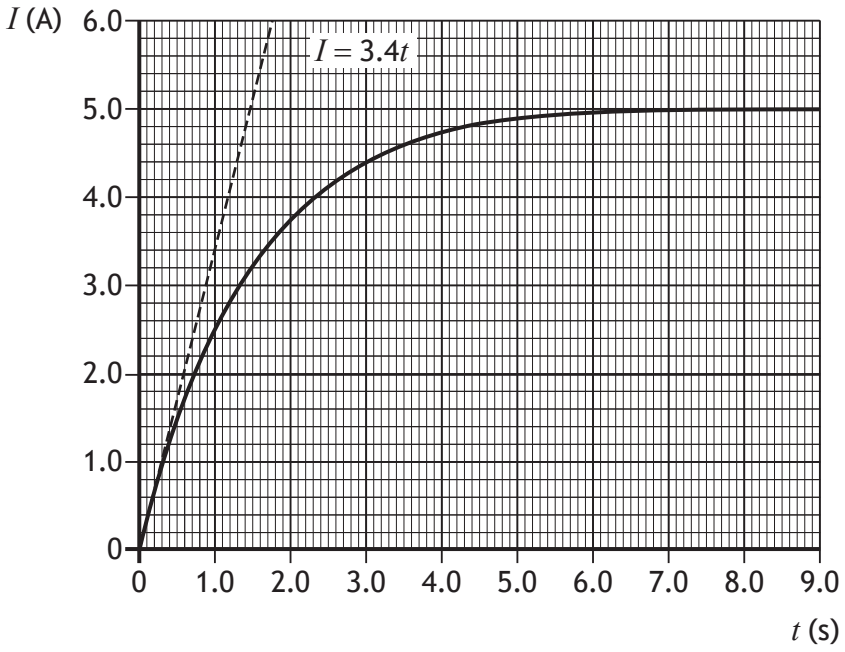

Figure 15B

The dashed line is the tangent to the curve at the origin and indicates the initial rate of change of current.

15. (a) (continued)

(i) Explain fully why the current does not immediately reach its maximum value. **2**

(ii) Calculate the self-inductance of inductor L. **3**

Space for working and answer

(iii) Calculate the maximum energy stored in the inductor. **3**

Space for working and answer

[Turn over

15. (continued)

(b) The iron core is now removed from inductor L. The resistance of the circuit remains the same.

State whether the time taken to reach the maximum current will be greater than, less than or equal to the time taken for inductor L.

Justify your answer. **2**

15. (continued)

(c) The quality factor Q is a property of an AC circuit.

In a series AC circuit containing an inductor and a resistor the quality factor is given by the relationship

$$Q = \frac{\omega L}{R}$$

where the symbols have their usual meanings.

An inductor of inductance 2.4 mH is connected in the circuit shown in **Figure 15C**.

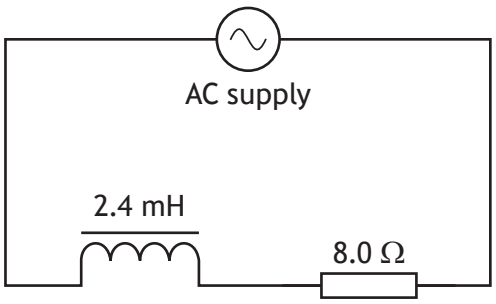

Figure 15C

The quality factor of the circuit is 44.2.

Determine the frequency of the AC supply. **3**

Space for working and answer

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16. As part of their project, a student conducts an experiment to determine a value for Young's modulus of steel using a steel beam. Young's modulus of a material is a measure of how easily it can be stretched and deformed.

The initial experimental set up is shown in **Figure 16A**.

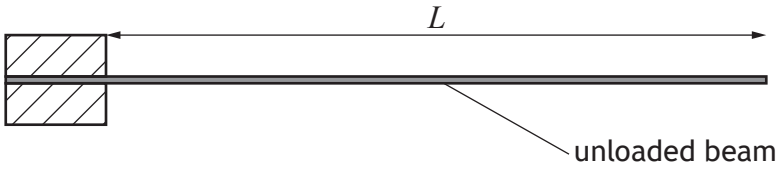

Figure 16A

The student applies a force F to the beam, by attaching a mass to the end of the beam. This causes the beam to be deflected by a displacement s, as shown in **Figure 16B**.

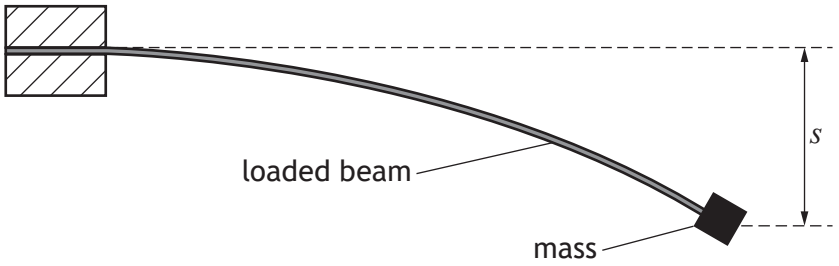

Figure 16B

The force is now varied by attaching additional masses to the end of the beam. The resulting displacements are measured.

The student then uses an app to plot a graph of force against displacement. The graph is shown in **Figure 16C**.

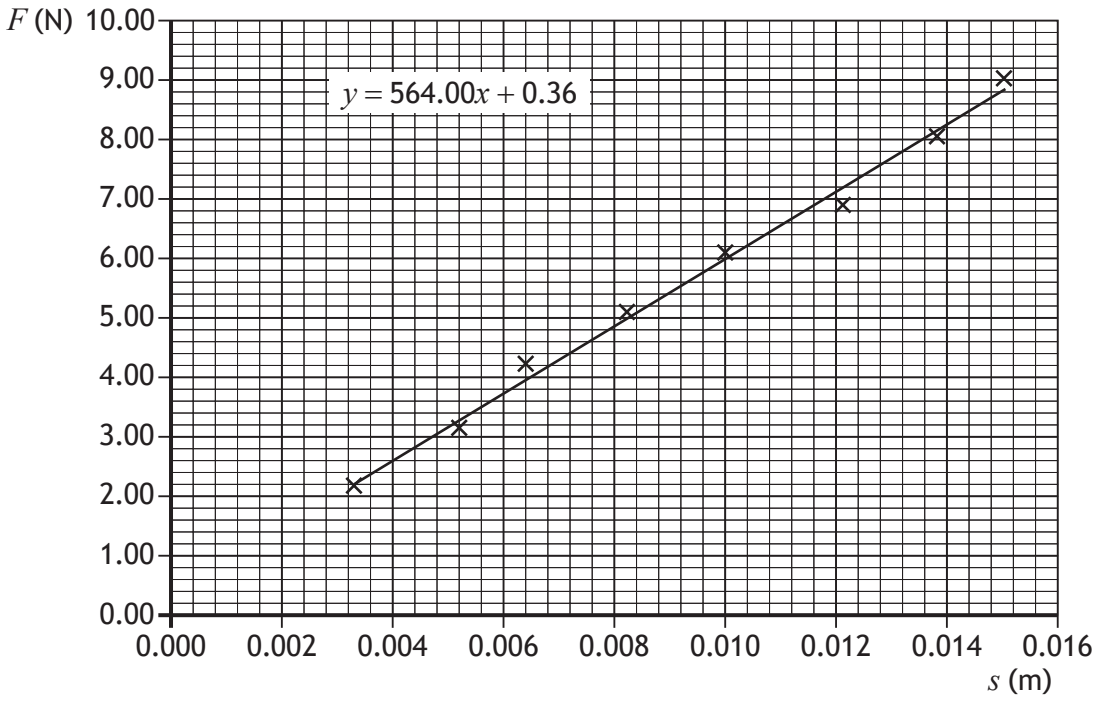

Figure 16C

16. (continued)

(a) Young's modulus E, in pascals, is given by the relationship

$$E = \frac{F}{s} \times \frac{L^3}{3I}$$

The second moment of inertia I of the steel beam is 7.2×10^{-10} m^4.

The length L of the unloaded beam is 0.90 m.

Using information from the graph, determine a value for Young's modulus of the steel used in this experiment. **3**

Space for working and answer

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(b) Data from the app are shown in the table.

Gradient	y-intercept
564.00	0.36
Uncertainty in gradient	**Uncertainty in y-intercept**
8.47	0.19

The student notes the following uncertainties in each quantity:

$$\Delta s = \pm 0.0005 \text{ m}$$
$$\Delta F = \pm 0.01 \text{ N}$$
$$\Delta L = \pm 0.005 \text{ m}$$
$$\Delta I = \pm 0.01 \times 10^{-10} \text{ kg m}^2$$

(i) Determine the absolute uncertainty in the value of Young's modulus obtained in (a). **4**

(ii) The line of best fit does not pass through the origin as theory predicts.

Suggest a source for this systematic uncertainty. **1**

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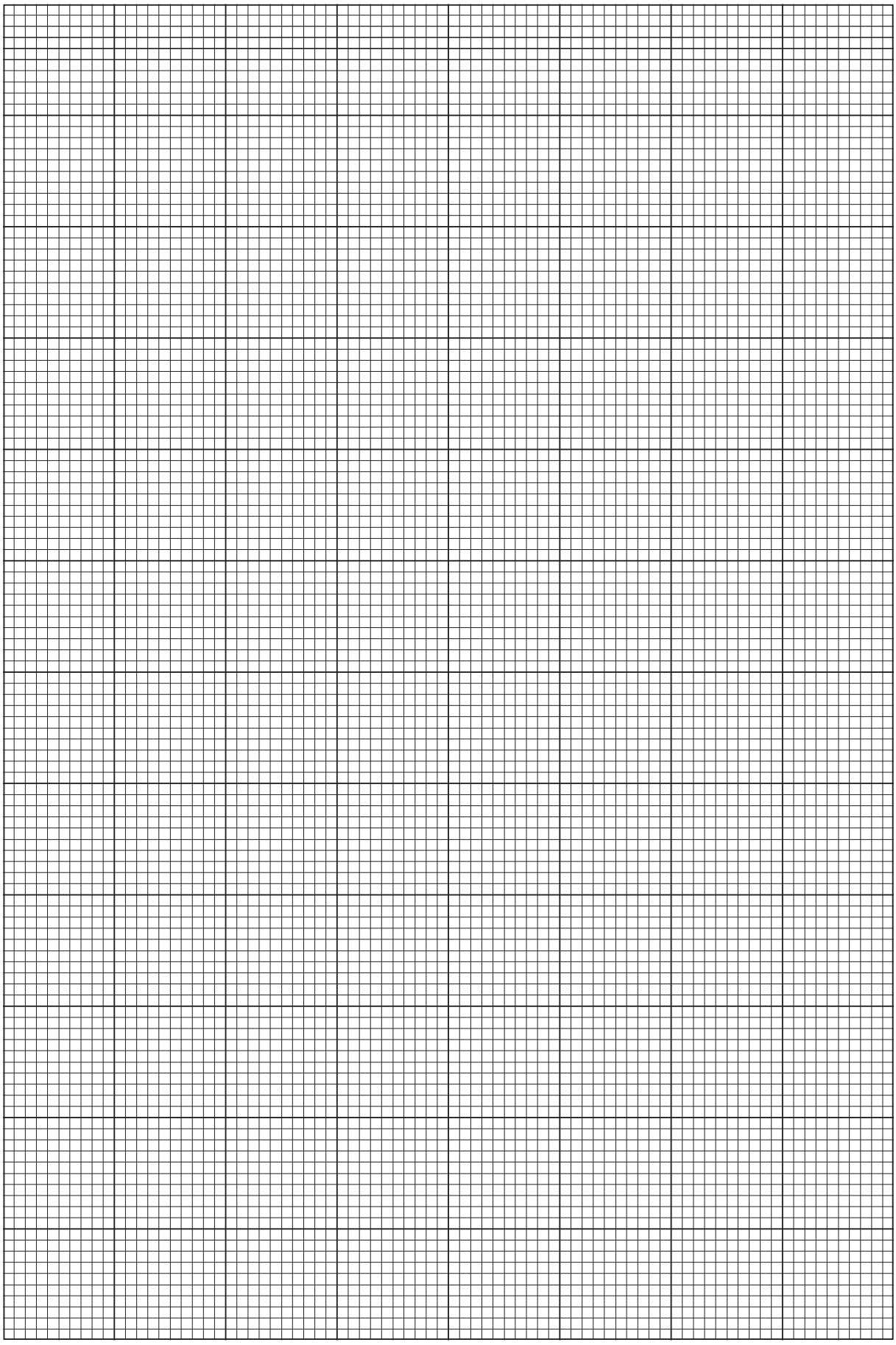
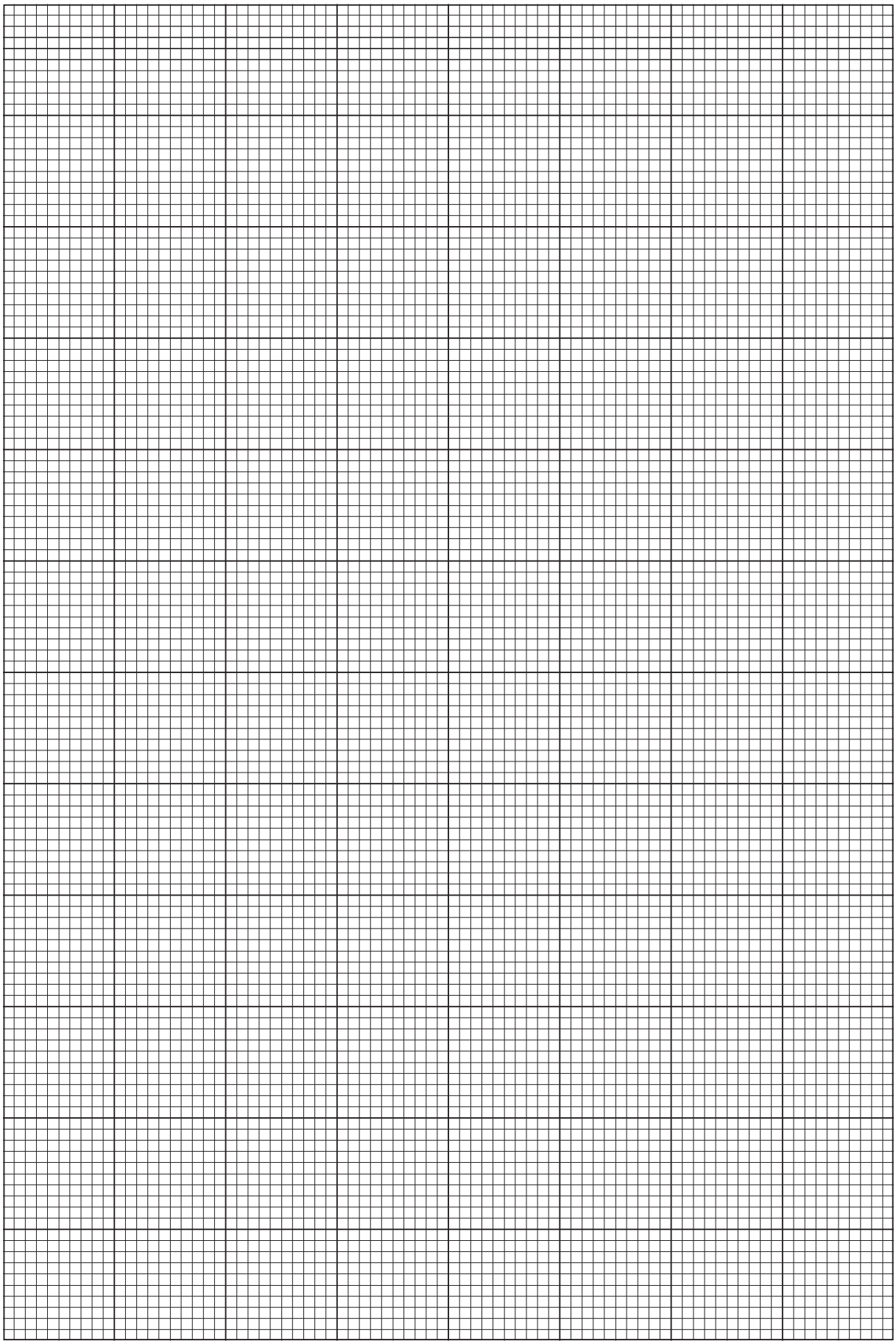




ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for use with question 6 (a) (ii)

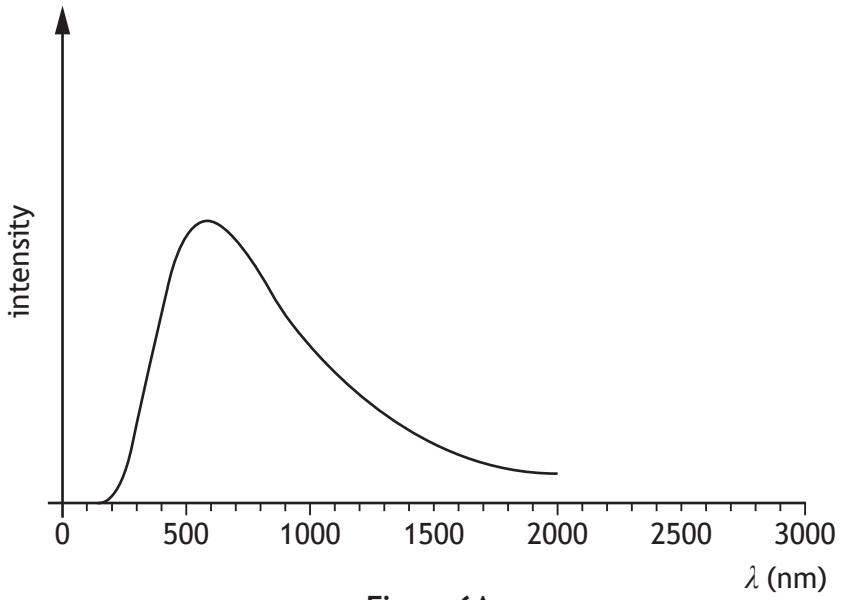
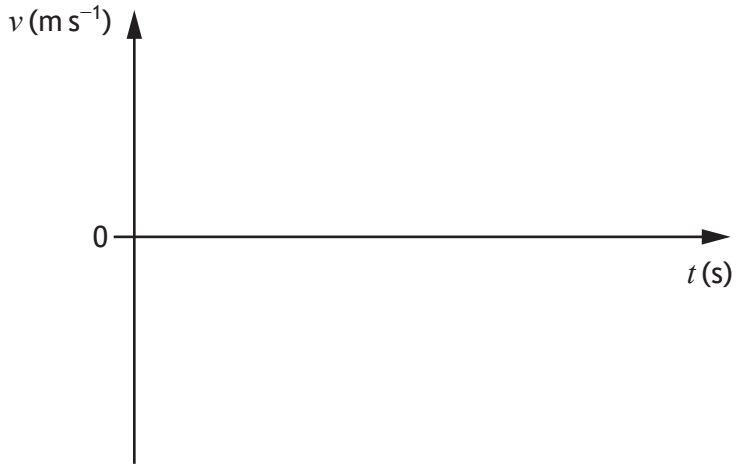


Figure 6A

Additional diagram for use with question 9 (b) (iv)



ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for use with question 13 (a)

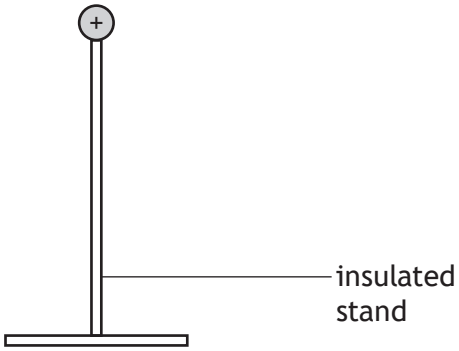


Figure 13A

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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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