FOR OFFICIAL USE

National Qualifications 2024

Mark

X857/77/01 Physics

THURSDAY, 25 APRIL

9:00 AM – 12:00 NOON

X8577701

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.

X857770101

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.

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Total marks — 155

Attempt ALL questions

1. An electric car is travelling at a constant velocity.

The car then accelerates along a straight road.

The car starts accelerating at $t = 0$ s.

While accelerating, the velocity v of the car at time t is given by the relationship

$$v = 2.4 + 13t - 0.69t^2$$

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

Using calculus methods:

(a) determine the acceleration of the car at $t = 2.0$ s **3**

Space for working and answer

(b) determine the distance travelled by the car between $t = 0$ s and $t = 2.0$ s. **3**

Space for working and answer

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X857770104

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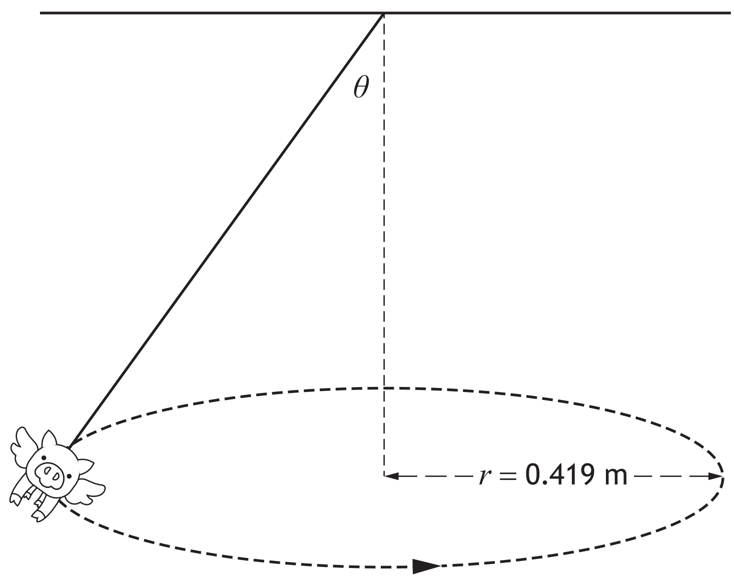
2. The motion of a battery-powered flying toy pig can be modelled as a conical pendulum.

The pig has a mass of 0.230 kg and is attached to a ceiling with a thin string.

The pig is set in motion and moves in a horizontal circle of radius 0.419 m as shown in **Figure 2A**.



not to scale

Figure 2A

The pig has an angular velocity of 3.01 rad s^{-1}.

(a) Show that the tangential speed of the pig is 1.26 m s^{-1}. **2**

Space for working and answer

[Turn over

* X 8 5 7 7 7 0 1 0 5 *

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2. (continued)

(b) (i) On **Figure 2B**, show the forces acting on the pig as it travels at a constant speed in a horizontal circle.

You must name these forces and show their directions. **2**

(An additional diagram, if required, can be found on *page 52*.)

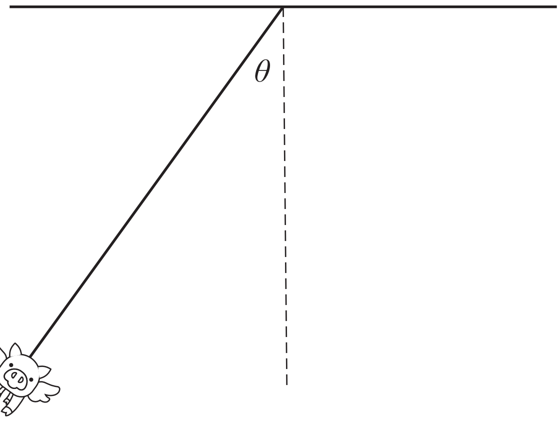

Figure 2B

(ii) By considering the effect of the forces acting on the pig, show that tan θ is given by the relationship

$$\tan\theta = \frac{v^2}{gr}$$

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

Space for working and answer

2. (b) (continued)

(iii) Calculate the angle θ when the tangential speed is $1.26\ \mathrm{m\,s^{-1}}$. **2**

Space for working and answer

(c) The pig is battery powered to keep it moving in a horizontal circle. As the batteries run out, the tangential speed decreases.

State the effect this has on the angle θ.

You must justify your answer. **2**

[Turn over

3. A wind turbine is used to generate electrical energy from the kinetic energy of the wind.

The wind turbine comprises a tower and a rotor assembly.

The rotor assembly consists of three identical blades attached to a central rotating hub as shown in **Figure 3A**.

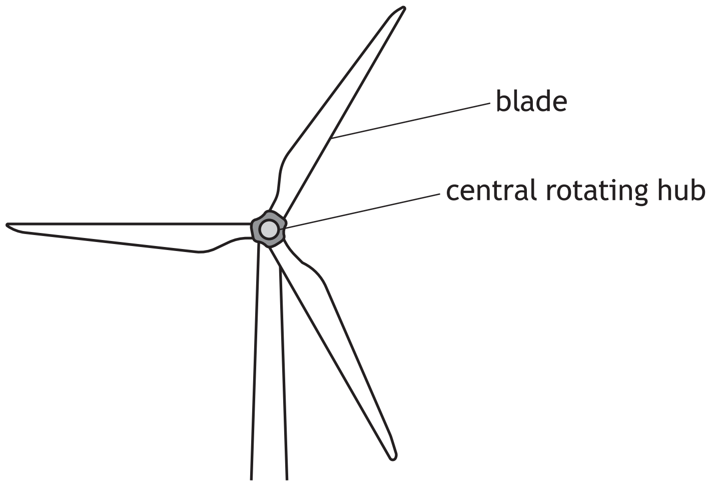

Figure 3A

Each blade has a mass of 2.0×10^4 kg and a length of 54 m. Each blade can be modelled as a solid rod rotating about its end.

The mass of the rotating hub is negligible compared to the mass of the blades.

(a) Show that the moment of inertia of the rotor assembly is $5.8 \times 10^7\ \mathrm{kg\,m^2}$. **2**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

3. (continued)

(b) When the wind speed reaches 25 $m\,s^{-1}$, the angular velocity of the rotor assembly is 3.7 $rad\,s^{-1}$.

At this velocity, brakes are applied to bring the rotor assembly to a stop.

The brakes apply a frictional torque on the rotor assembly.

The rotor assembly comes to rest in 550 s.

(i) Calculate the angular acceleration of the rotor assembly during this time. **3**

Space for working and answer

(ii) Calculate the magnitude of the unbalanced torque acting on the rotor assembly during this time. **3**

Space for working and answer

[Turn over

3. (continued)

(c) In winter, ice forms on the rotor assembly, adding mass to the blades.

As the temperature rises, ice can be thrown from the blades.

(i) On the diagram shown in **Figure 3B**, show the direction of the **initial** velocity of a piece of ice thrown from the tip of a blade at the bottom of its circular path. **1**

(An additional diagram, if required, can be found on *page 52*.)

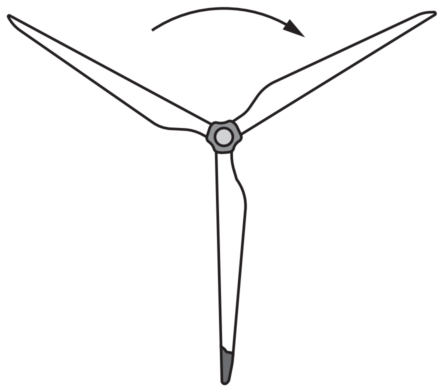

Figure 3B

(ii) As a result of the ice being thrown, mass is removed from the blades.

Explain why, despite this loss of mass, there is no observable change in the angular velocity of the rotor assembly. **1**

3. (continued)

(d) The maximum power P generated by this wind turbine is given by the following relationship

$$P = 0.3\rho A v^3$$

where: ρ is the density of air $= 1.29\ \text{kg m}^{-3}$

A is the area of the circle swept by the rotor assembly in m^2

v is the windspeed in m s^{-1}.

Calculate the maximum power generated when the windspeed is $11.5\ \text{m s}^{-1}$. **2**

Space for working and answer

[Turn over

4. The Double Asteroid Redirection Test (DART) was a recent NASA mission. It was designed to crash a spacecraft into an asteroid to deflect the asteroid from its path.

This was a test to see if a spacecraft could deflect an asteroid that is on a collision course with Earth.

The target of the DART spacecraft was the asteroid Dimorphos, which is in a circular orbit around a larger asteroid Didymos as shown in **Figure 4A**.

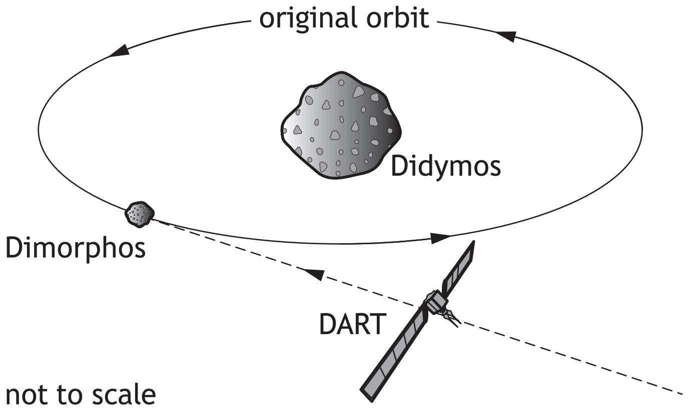

Figure 4A

The radius of orbit of Dimorphos is 1.2×10^3 m.

The period of orbit of Dimorphos is 11.9 hours.

(a) Calculate the mass of Didymos. **3**

Space for working and answer

* X 8 5 7 7 7 0 1 1 2 *

4. (continued)

(b) The mission was planned so that the impact did not knock Dimorphos out of orbit around Didymos and put it on a collision course with Earth.

(i) Calculate the escape velocity from Didymos at the orbit of Dimorphos. **3**

Space for working and answer

(ii) The DART spacecraft collided with Dimorphos, which resulted in the period of orbit of Dimorphos around Didymos decreasing by 30 minutes.

Explain fully the change to the gravitational potential energy of Dimorphos as a result of this collision. **2**

(c) Asteroids on a potential collision course with Earth must be impacted at a large distance away from Earth.

Suggest why this impact must occur at a large distance in order to prevent a collision with Earth. **1**

[Turn over

5. (a) A clock in curved spacetime and a clock in flat spacetime will measure different time intervals between the same two events.

The difference Δt between the time intervals measured by the two clocks is given by the relationship

$$\Delta t = t_G \left(\frac{1}{\sqrt{1 - \left(\frac{r_{schwarzchild}}{r} \right)}} - 1 \right)$$

where t_G is the time interval between two events as measured by the clock in curved spacetime and the other symbols have their usual meaning.

(i) Calculate the Schwarzschild radius of the Earth. **3**

Space for working and answer

(ii) A clock on the surface of the Earth measures a time interval t_G between two events of 24 hours.

Calculate the time difference Δt, in seconds, between the intervals measured by a clock in flat spacetime and the clock on the surface of the Earth, where r is equal to the radius of the Earth. **2**

Space for working and answer

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5. **(continued)**

(b) Clocks onboard global positioning system (GPS) satellites experience the following effects due to special relativity and general relativity.

	Time difference per day (with reference to a clock on the surface of Earth)
Special relativity	7 μs slower
General relativity	46 μs faster

Determine the daily adjustment that must be made to a clock onboard a GPS satellite so that it remains synchronised with a clock on the surface of the Earth. **1**

Space for working and answer

[Turn over

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5. **(continued)**

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(c) The Stanford Torus is a NASA design for a space habitat capable of housing ten thousand permanent residents. The Torus is a doughnut-shaped ring, which is 1.8 km in diameter. The Torus rotates about a central axis of rotation through its hub as shown in **Figure 5A**.

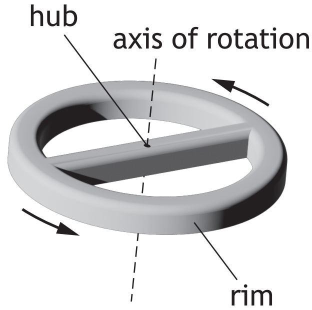


Figure 5A

The rotation of the Torus results in ‘artificial gravity’ on the inside surface of the rim.

The angular velocity of the Torus is chosen so that a resident on the inside surface of the rim will experience an equivalent gravitational effect to that experienced on the surface of the Earth. A resident at the centre of the hub will experience no ‘artificial gravity’.

(i) Calculate the angular velocity of the Torus required to produce this effect. **3**

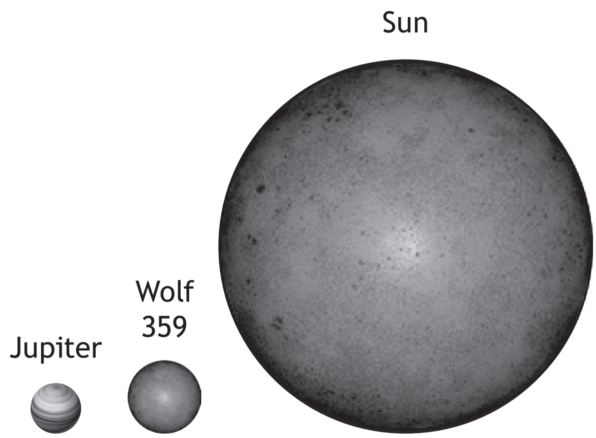
Space for working and answer

(ii) General relativity predicts that a clock at the rim and a clock at the centre of the hub would not stay synchronised.

State which clock would run slower.

You must justify your answer. **2**

6. Wolf 359 is a main sequence star located in the constellation Leo. MARKS | DO NOT WRITE IN THIS MARGIN



Some information about Wolf 359 is given in the table.

Mass	0.11 solar masses
Surface temperature	2800 K
Luminosity	4.38×10^{23} W
Distance from Earth	7.9 ly

(a) (i) Calculate the power per unit area emitted from the surface of Wolf 359. **3**

Space for working and answer

(ii) Calculate the radius of Wolf 359. **3**

Space for working and answer

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6. (continued)

(b) A main sequence star fuses hydrogen in its core.

Figure 6A shows one possible p-p chain in the hydrogen fusion process.

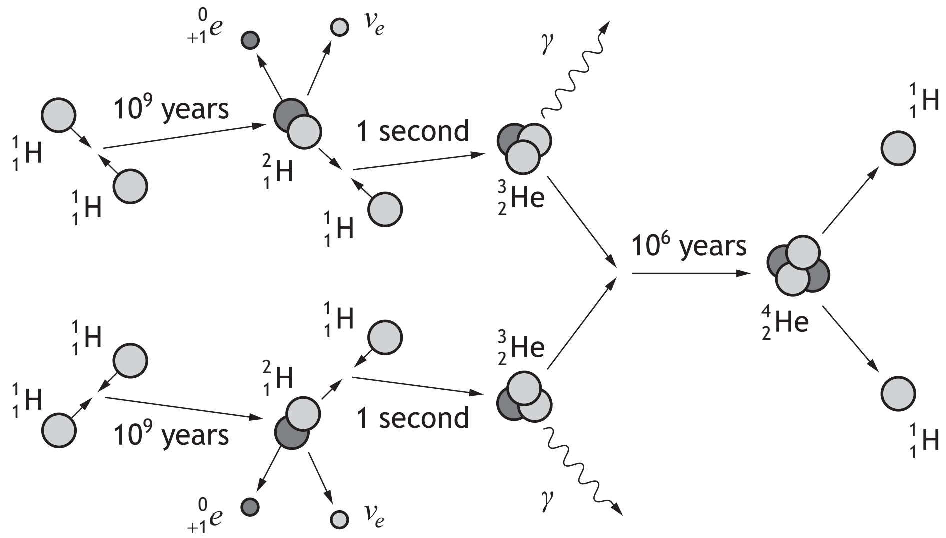

Figure 6A

(i) State the name of the particles represented by the symbols:

v_e

$^{0}_{+1}e$ **1**

(ii) Suggest why deuterium $^{2}_{1}H$ does not build up in the star due to this p-p chain. **1**

(c) Wolf 359 belongs to a class of stars that will stay on the main sequence for thousands of billions of years.

Suggest why, despite knowing the mass of these stars, scientists have not yet observed the fate of these stars. **1**

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7. Wave-particle duality is a key concept in quantum theory.

Louis de Broglie proposed that a particle of matter, which is moving, has an associated wavelength.

(a) State one piece of experimental evidence for a 'particle' showing wave-like behaviour. **1**

(b) A proton is moving with a velocity of $1.50 \times 10^{7}\ \mathrm{m\,s^{-1}}$.

(i) Calculate the de Broglie wavelength of the proton. **3**

Space for working and answer

(ii) Explain why wave-like behaviour is not observed for this proton. **1**

[Turn over

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7. (continued)

(c) Albert Einstein proposed that electromagnetic radiation was comprised of quanta called photons rather than being a continuous wave.

Arthur Compton provided experimental evidence for the existence of photons.

In a similar experiment, X-ray photons are scattered by collisions with stationary electrons as shown in **Figure 7A**.

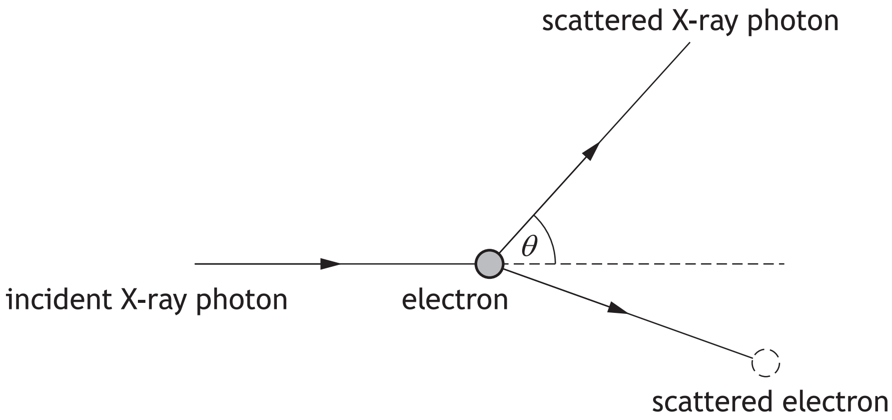

Figure 7A

The electron gains momentum from the collision and is scattered. Therefore, the scattered X-ray photon has less momentum than the incident X-ray photon.

The scattered photon has a longer wavelength than the incident X-ray photon. The difference in wavelength $\Delta\lambda$ is referred to as the Compton shift.

The Compton shift of an X-ray photon scattered through an angle θ is given by the relationship

$$\Delta\lambda = \frac{h}{m_e c}\left(1 - \cos\theta\right)$$

where the symbols have their usual meaning.

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7. (c) (continued)

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(i) An X-ray photon detector is positioned at an angle θ to the path of the incident photon.

A graph showing the variation of intensity with wavelength for the incident and scattered X-ray photons is shown in **Figure 7B**.

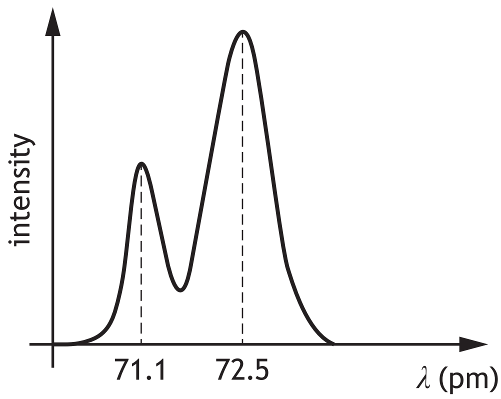

Figure 7B

Determine the scattering angle θ of the X-ray photons. **3**

Space for working and answer

(ii) The X-ray detector is now moved to detect X-ray photons at a smaller scattering angle.

State whether the magnitude of the observed Compton shift will increase, stay the same or decrease.

Justify your answer. **2**

* X 8 5 7 7 7 0 1 2 1 *

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8. A plasma consists of highly energetic charged particles. The plasma has a high temperature and can be contained by a device called a magnetic bottle.

The magnetic bottle uses a non-uniform magnetic field as shown in **Figure 8A**.

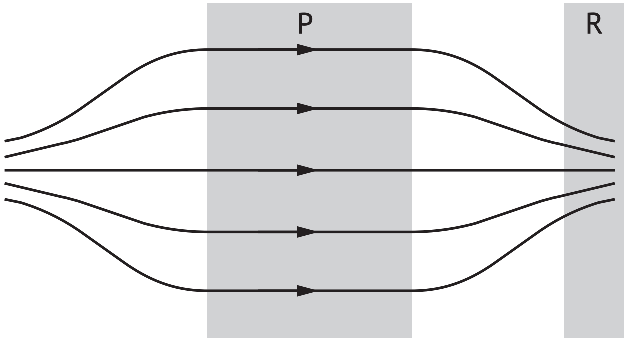

Figure 8A

(a) The magnetic field in region P can be considered to be uniform.

The magnetic induction in region P is 95.0 mT.

A proton is moving through region P with a velocity of $2.40 \times 10^6\ \text{m s}^{-1}$, at an angle of 55.0° to the direction of the magnetic field, as shown in **Figure 8B**.

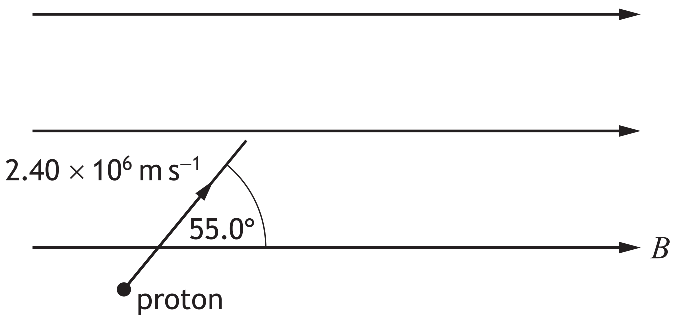

Figure 8B

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8. (a) (continued)

The proton follows a helical path in the magnetic field.

(i) Explain why the proton follows a helical path. **2**

(ii) By considering the forces acting on the proton, determine the radius of the helical path in region P. **5**

Space for working and answer

[Turn over

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8. (continued)

(b) The proton reflects inside the magnetic bottle at a point in region R. The path of the proton after it reflects is shown in **Figure 8C**.

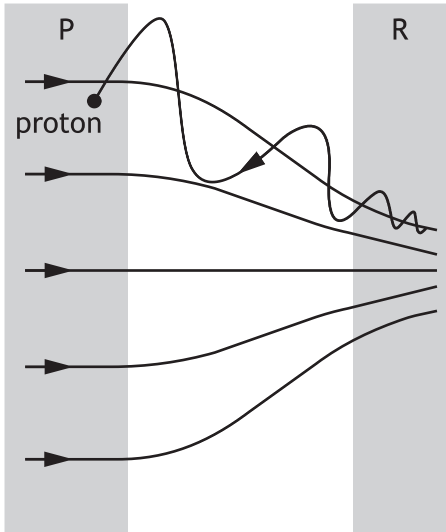

Figure 8C

Apart from direction, state one change to the helical path followed by the proton as it travels between regions R and P.

Justify your answer. **2**

MARKS | DO NOT WRITE IN THIS MARGIN

9. The suspension system of a car is designed to reduce the effects of bumps in a road for the car and its occupants. The suspension system uses coil springs.

An engineer investigates one of the springs used in a car.

The spring has a spring constant of 8.6×10^4 N m^{-1}.

(a) The engineer connects the spring to a lightweight platform.

A block of mass 510 kg is placed on the platform, causing the spring to compress through a distance Δy. This spring and block system is shown in **Figure 9A**.

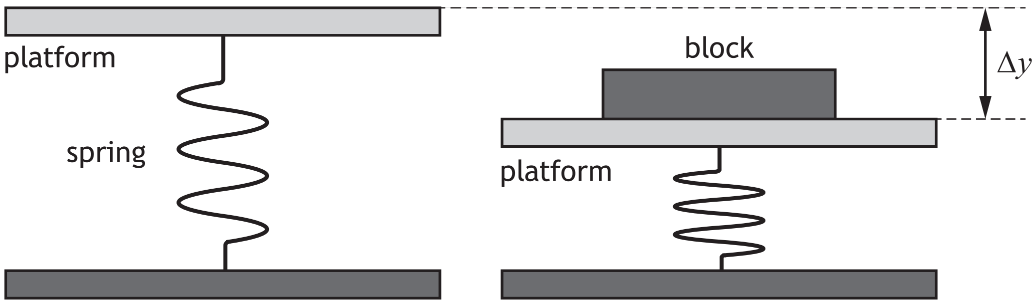

Figure 9A

Determine the compression distance Δy of the spring due to the block. **3**

Space for working and answer

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9. (continued) MARKS | DO NOT WRITE IN THIS MARGIN

(b) The engineer now investigates the oscillation of the spring and block system.

This oscillation can be modelled as simple harmonic motion.

(i) Show that the angular frequency of the oscillation is

$$\omega = \sqrt{\frac{k}{m}}$$

where the symbols have their usual meaning. **3**

Space for working and answer

(ii) Calculate the angular frequency of the oscillation. **2**

Space for working and answer

(iii) Cars designed for motorsport competition typically use stiffer springs, which require a greater force to produce the same compression.

The engineer uses the same system to test a stiffer spring.

State whether the angular frequency of the oscillation of the stiffer spring will be greater than, the same as or less than that of the original spring.

You must justify your answer. **2**

* X 8 5 7 7 7 0 1 2 6 *

9. (continued) MARKS DO NOT WRITE IN THIS MARGIN

(c) For safety and comfort the suspension system should be damped.

The engineer models the damping system by adding a damper as shown in **Figure 9B**.

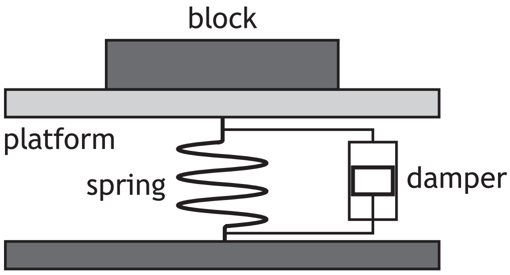

Figure 9B

The damper consists of a piston inside a cylinder filled with oil. The oil provides a resistive force that opposes the motion of the piston.

(i) The damping system is tested by pushing down on the platform and block system, and then releasing it. This causes the suspension system to oscillate.

The results of the test are shown in **Figure 9C**.

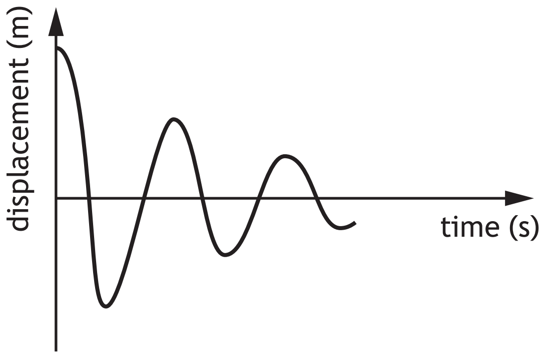

Figure 9C

State the type of damping shown in **Figure 9C**. **1**

(ii) To pass the test, the damping system should not complete more than one full oscillation.

Suggest a change that could be made to this damping system so that the system passes the test. **1**

* X 8 5 7 7 7 0 1 2 7 *

MARKS DO NOT WRITE IN THIS MARGIN

10. Scorpions are able to detect their prey by sensing vibrations travelling through sand.

When a beetle walks across sand it creates vibrations that can be modelled as two travelling waves produced at the same time. One of the waves is a transverse wave and the other is a longitudinal wave.

(a) The transverse wave produced by the beetle can be modelled by the relationship

$$y = 1.95 \times 10^{-5} \sin 2\pi (9.5t - 0.18x)$$

where y is measured in metres.

(i) Determine the speed of the transverse wave. **4**

Space for working and answer

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10. (a) (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

(ii) When the transverse wave reaches the scorpion, the energy of the wave has reduced to one eighth of its original value.

Calculate the amplitude of the wave when it reaches the scorpion. **3**

Space for working and answer

(iii) Explain why there is a maximum distance at which the scorpion can detect the beetle. **1**

(b) The beetle is 0.34 m from the scorpion.

The scorpion detects the longitudinal wave before it detects the transverse wave.

The longitudinal wave travels through the sand at a speed of 150 $m\,s^{-1}$.

Determine the time interval between the scorpion detecting the longitudinal wave and the transverse wave. **3**

Space for working and answer

11. A technician in a laboratory carries out a Young's double slit experiment to verify the operational wavelengths of three lasers.

The technician uses the experimental set up shown in **Figure 11A**.

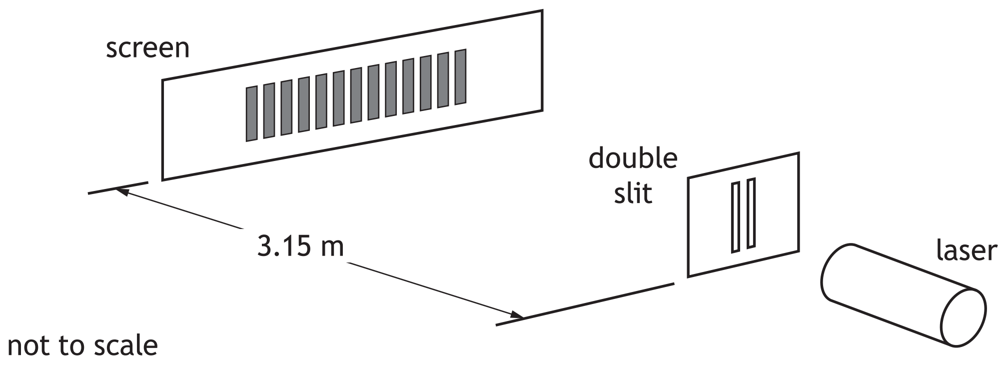

Figure 11A

The types of laser tested and their stated operational wavelengths are shown in the table.

Laser type	Operational wavelength (nm)
Helium-neon	633
Copper vapour	511
Argon	455

(a) State which of the lasers tested should produce an interference pattern with the largest fringe separation.

Justify your answer. **2**

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

(b) The copper vapour laser produced the interference pattern shown in **Figure 11B**.

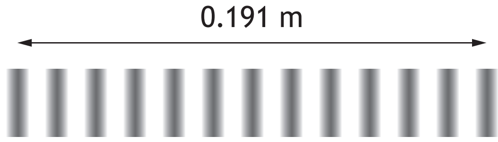

Figure 11B

The technician used a double slit with a slit separation of 1.00×10^{-4} m.

The technician measured a distance of 0.191 m across twelve fringe spacings.

(i) Determine the wavelength obtained by the technician. **4**

Space for working and answer

(ii) Suggest a reason why the wavelength obtained by the technician is **less than** the stated operational wavelength. **1**

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11. (continued)

(c) The technician now uses the helium-neon laser to investigate the separation of the circular tracks on a CD, as shown in **Figure 11C**.

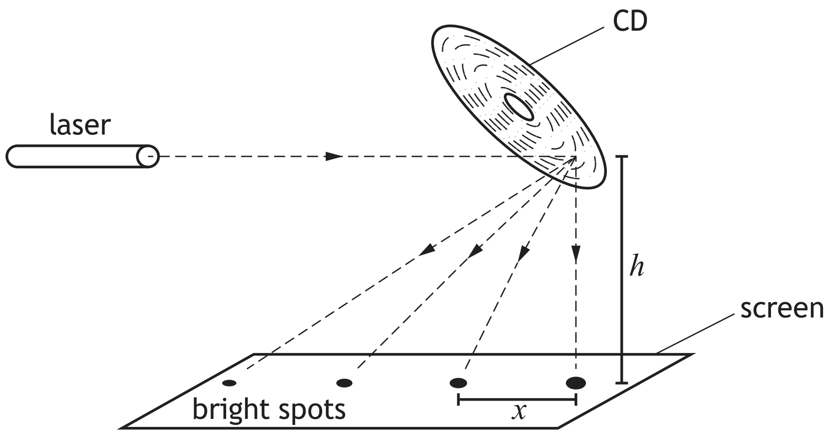

Figure 11C

(i) Explain fully how a series of bright spots is produced on the screen. **2**

(ii) The technician measures the separation x of the bright spots and the height h of the CD above the screen. These results are used to determine the separation of the tracks on the CD.

The technician now moves the screen further away from the CD.

(A) Suggest one advantage for determining the separation of the tracks by moving the screen further away. **1**

(B) Suggest one disadvantage for determining the separation of the tracks by moving the screen further away. **1**

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12. A student is planning a project on polarisation.

(a) Describe an experiment that the student could carry out to determine whether the light from a laptop screen is plane polarised. **2**

(b) As part of their project, the student finds the diagram shown in **Figure 12A**.

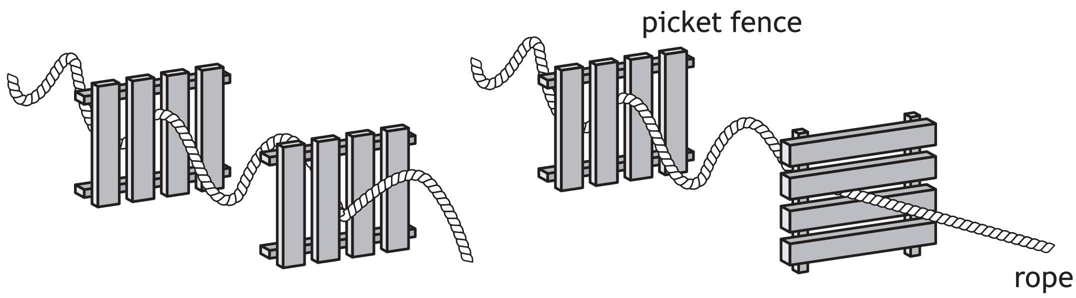

Figure 12A

The diagram represents an analogy for the transmission of light through a polarising filter.

Using your knowledge of physics, comment on this analogy. **3**

12. (b) (continued)

[Turn over

13. (a) An electric field exists around a point charge Q_1. | MARKS | DO NOT WRITE IN THIS MARGIN

The charge of Q_1 is -4.5 nC.

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

(ii) Calculate the electric field strength at a distance of 0.088 m from Q_1. **3**

Space for working and answer

(b) Point S is at a distance of 0.088 m from charge Q_1.

A second identical charge Q_2 is now placed at a distance of 0.088 m from point S as shown in **Figure 13A**.

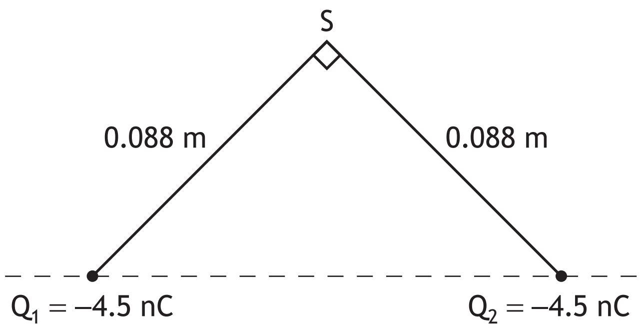

Figure 13A

(i) Determine the magnitude of the resultant electric field strength at point S due to both charges. **2**

Space for working and answer

13. (b) (continued)

(ii) State the direction of the resultant electric field strength at point S due to both charges. **1**

(c) The electric potential at the position of Q_2, due to Q_1, is −325 V.

(i) Determine the maximum work done, in electron volts, in bringing charge Q_2 to this point. **4**

Space for working and answer

(ii) Suggest a reason why the work done to move Q_2 to this point would be less than this maximum value. **1**

[Turn over

14. A solenoid is a helical coil of wire. When there is a current in the wire a magnetic field is produced in and around the solenoid.

(a) **Figure 14A** shows a solenoid.

On **Figure 14A**, sketch the magnetic field pattern produced by the current. **2**

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

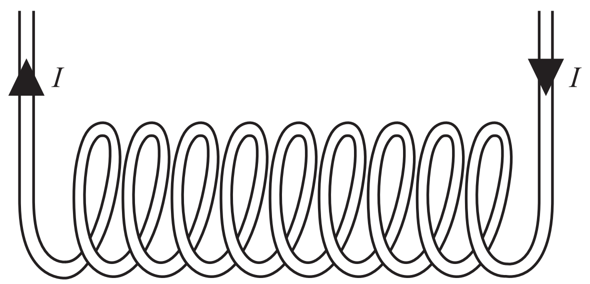

Figure 14A

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(b) For a short, wide solenoid, the magnetic induction produced depends on the current I in the solenoid, the radius R of the solenoid, the number of turns N of the coil, and the distance x along the central axis of the solenoid from the centre of the solenoid.

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

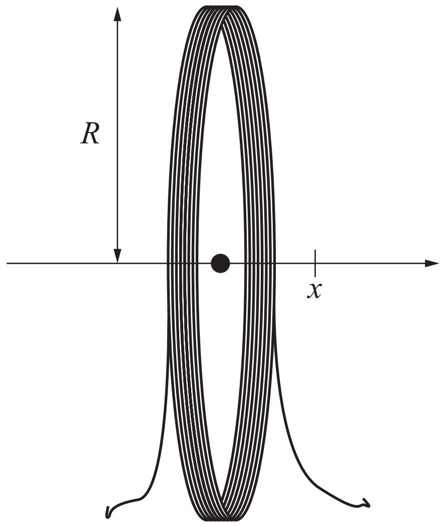

Figure 14B

The magnetic induction of this type of solenoid is given by the relationship

$$B = \frac{\mu_0 INR^2}{2\left(R^2 + x^2\right)^{\frac{3}{2}}}$$

There is a current of 3.5 A in the wire.

The radius of the solenoid is 120 mm.

The solenoid has 64 turns.

The maximum magnetic induction occurs at the centre of the solenoid, where $x = 0$ m.

Determine the maximum magnetic induction produced by this solenoid. **2**

Space for working and answer

* X 8 5 7 7 7 0 1 3 9 *

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14. (continued)

(c) A ferromagnetic material can be inserted into a solenoid, along its central axis, to increase the magnetic induction.

(i) State what is meant by the term *ferromagnetic*. **1**

(ii) Suggest a ferromagnetic material that will increase the magnetic induction. **1**

(iii) Predict the effect that the insertion of this ferromagnetic material will have on the magnetic field lines around the solenoid. **1**

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15. Two tourists are taking an evening walk while on holiday in the north of Scotland. The aurora borealis or 'Northern Lights' are clearly visible in the night sky.

The tourists have the following conversation.

Tourist 1: It's amazing to think that all that light is because of tiny charges accelerating into the atmosphere.

Tourist 2: So where do these tiny charges come from?

Tourist 1: Space somewhere? I'm not really sure, but I think it's because they're coming straight down into the magnetic field of the Earth at the North Pole.

Tourist 2: Does that explain why we don't see them down south?

Using your knowledge of physics, comment on this conversation. **3**

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15. (continued)

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16. A capacitor and resistor are connected in series to a variable DC supply. This combination of components, called an RC circuit, is connected to a signal processing unit in an electronic timer.

The RC circuit is shown in **Figure 16A**.

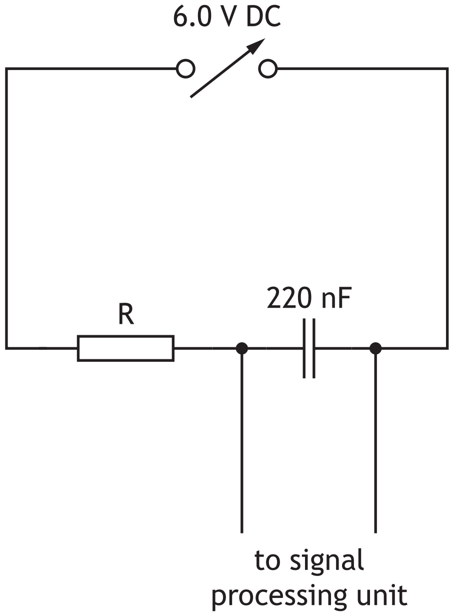

Figure 16A

(a) (i) State the number of time constants required for a capacitor in an RC circuit to be considered fully charged. **1**

(ii) In this RC circuit the capacitor is considered to be fully charged 1.0 ms after charging commences.

Determine the resistance of resistor R. **3**

Space for working and answer

* X 8 5 7 7 7 0 1 4 4 *

16. (continued)

(b) The capacitor is now fully discharged and the voltage of the variable DC supply is halved. The capacitor is then charged again.

State whether the time taken to fully charge the capacitor is now less than, equal to or greater than 1.0 ms.

You must justify your answer. **2**

(c) The RC circuit is now connected to a 6.0 V rms, 77 Hz AC supply.

(i) State what is meant by the term *capacitive reactance*. **1**

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

Space for working and answer

[Turn over

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17. A compound pendulum consists of a thin rectangular bar with holes at regular intervals. These holes can be used as pivot points for oscillations of the compound pendulum.

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This is shown in **Figure 17A**.

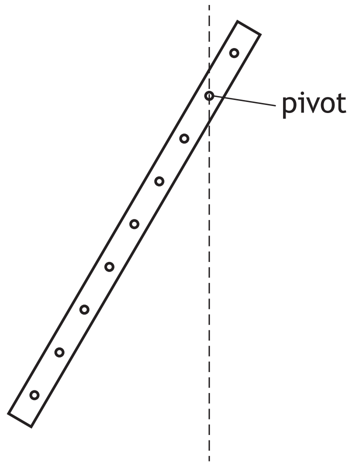

Figure 17A

(a) A student is using the compound pendulum in an experiment to determine the acceleration due to gravity. At one pivot point the student measures the time for ten oscillations of the pendulum. The student repeats this measurement another four times.

The times measured are:

16.09 s, 16.26 s, 16.15 s, 16.48 s, 16.22 s.

(i) Determine the mean period of the pendulum for this pivot point. **1**

Space for working and answer

(ii) Determine the absolute uncertainty in the period of the pendulum for this pivot point. **2**

Space for working and answer

* X 8 5 7 7 7 0 1 4 7 *

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17. (continued)

(b) The student now repeats the experiment for a number of different pivot points on the pendulum. The student varies the distance l between the pivot point and the centre of mass of the pendulum. This causes the period of the pendulum T to change.

The relationship between l and T for a compound pendulum is

$$T^2 l = \frac{4\pi^2}{g} l^2 + k$$

where k is a constant.

Acceleration due to gravity can be determined from of a graph of $T^2 l$ against l^2.

The graph obtained from the student's results is shown in **Figure 17B**.

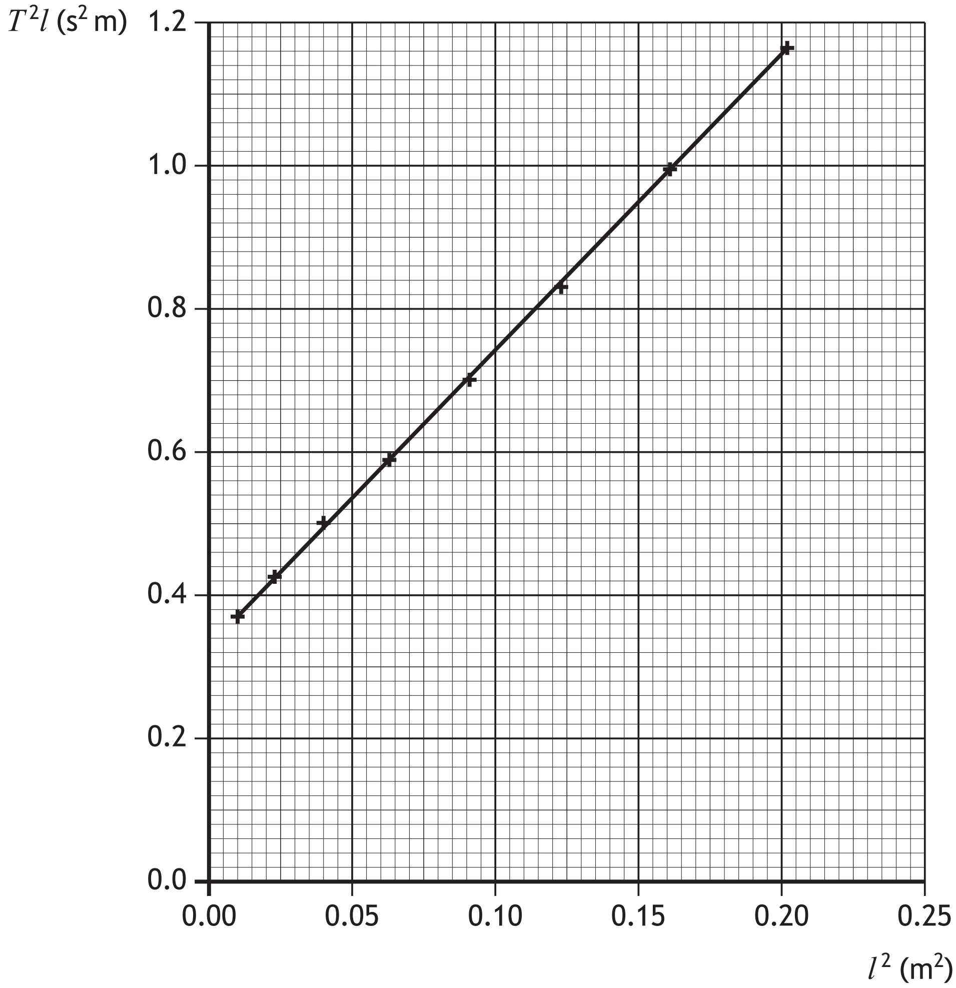

Figure 17B

* X 8 5 7 7 7 0 1 4 8 *

17. (b) (continued)

Using information from the graph, determine the value for acceleration due to gravity obtained from this experiment. **3**

Space for working and answer

(c) After analysing all of the data, the student states that the experiment has been, 'very precise, but not accurate'.

Explain whether the student's statement is correct. **2**

[END OF QUESTION PAPER]

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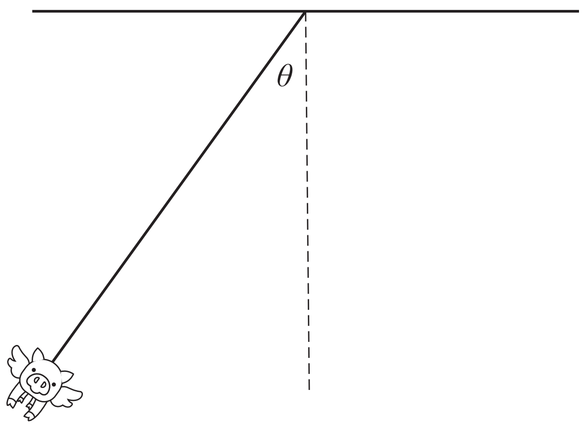
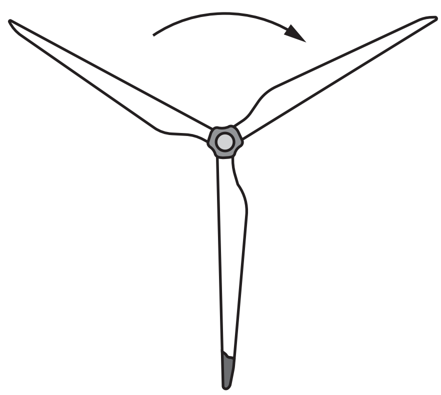
ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for use with question 2 (b) (i)

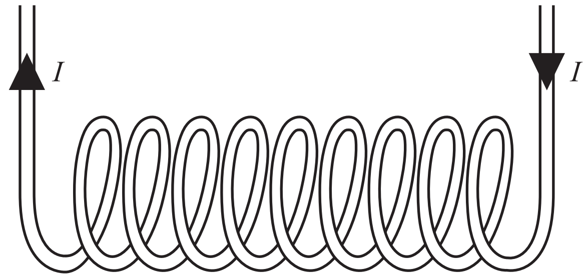


Additional diagram for use with question 3 (c) (i)



ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for use with question 14 (a)



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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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