Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS
9749/02

Paper 2 Structured Questions

12 September 2024

2 hours

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the question paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	8
2	11
3	5
4	10
5	7
6	9
7	10
8	20
Total	80

This document consists of **22** printed pages and **2** blank pages.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall,	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	T/°C + 273.15
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** questions in the spaces provided.

1 Fig. 1.1 shows a bomber flying horizontally at a speed of 72 m s^{-1} and at a height of 100 m above the ground. When directly flying over the origin O, bomb B is released and it strikes a truck T, which is moving along a level road with a constant speed v. At the instant the bomb is released, the truck T is at a distance x_o = 125 m from origin O.

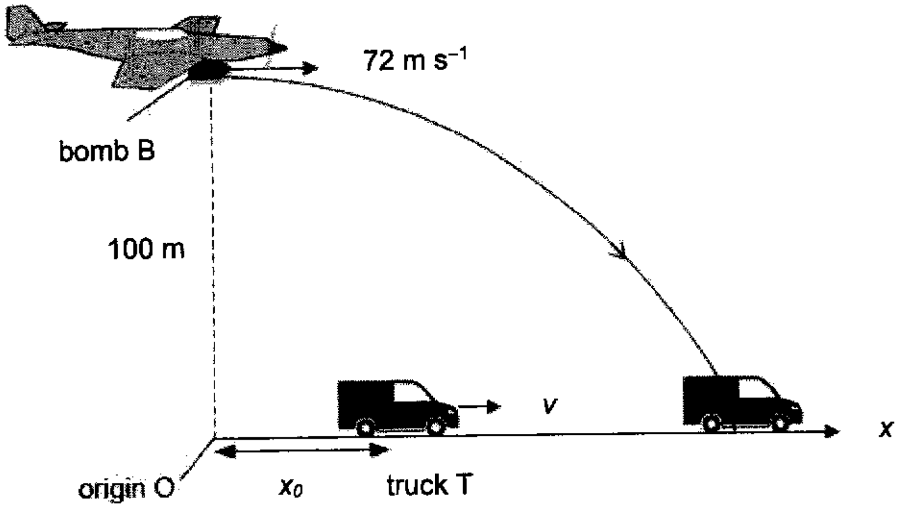


Fig. 1.1

(a) The trajectory of bomb B after it is released from the bomber is said to be *parabolic*. Explain qualitatively why the path taken is *parabolic*.

....

....

.... [2]

(b) Calculate the time of flight of bomb B upon striking the truck T.

time of flight = ... s [2]

(c) **(i)** On Fig. 1.2, sketch graphs showing the variation with time t of the horizontal displacement x, for the bomb B and the truck T. Label the graphs B and T respectively, indicating appropriate values on the graphs.

Fig. 1.2

[2]

(ii) Use your graphs in **(c)(i)** or otherwise, determine the speed v of the truck T.

v = ... m s^{-1} [2]

[Total: 8]

2 (a) Fig. 2.1 shows the head-on collision of two blocks on a frictionless surface.

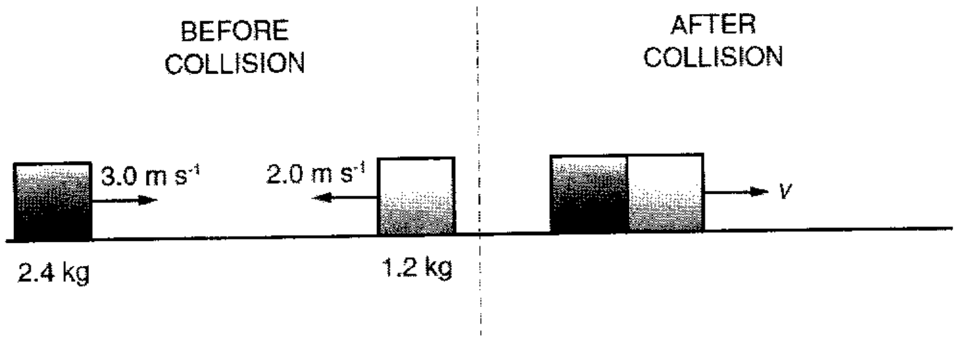


Fig. 2.1

Before the collision, the 2.4 kg block is moving to the right with a speed of 3.0 m s^{-1} and the 1.2 kg block is moving to the left at a speed of 2.0 m s^{-1}. During the collision, the blocks stick together. Immediately after the collision the blocks have a common speed *v*.

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

....

.... [1]

(ii) Calculate the speed *v*.

v = ... m s^{-1} [2]

(iii) Use your answer in **(a)(ii)** to show that the collision is inelastic.

[2]

(b) Fig. 2.2 shows a helicopter viewed from above.

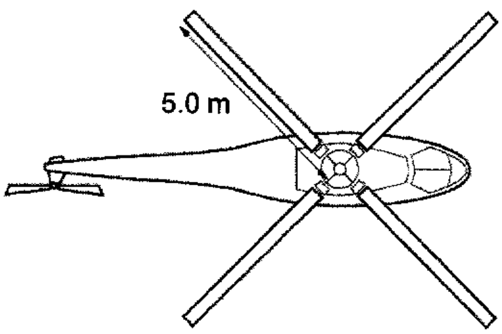


Fig. 2.2

The blades of the helicopter rotate in a circle of radius 5.0 m. When the helicopter is hovering, the blades propel air vertically downwards with a constant speed of 12 m s^{-1}.

Assume that the descending air occupies a uniform cylinder of radius 5.0 m.
The density of air is 1.3 kg m^{-3}.

(i) Explain, in terms of Newton's laws of motion, the forces on the helicopter as it is hovering.

....

....

....

....

....

.... [3]

(ii) Show that the mass of air propelled downwards is 6100 kg in a time of 5.0 seconds.

[1]

(iii) Hence or otherwise, determine the force provided by the rotating helicopter blades to propel this air downwards,

force = ... N [2]

[Total: 11]

3 A cylindrical tube, containing some sand, floats upright in a liquid of density ρ, as shown in Fig. 3.1.

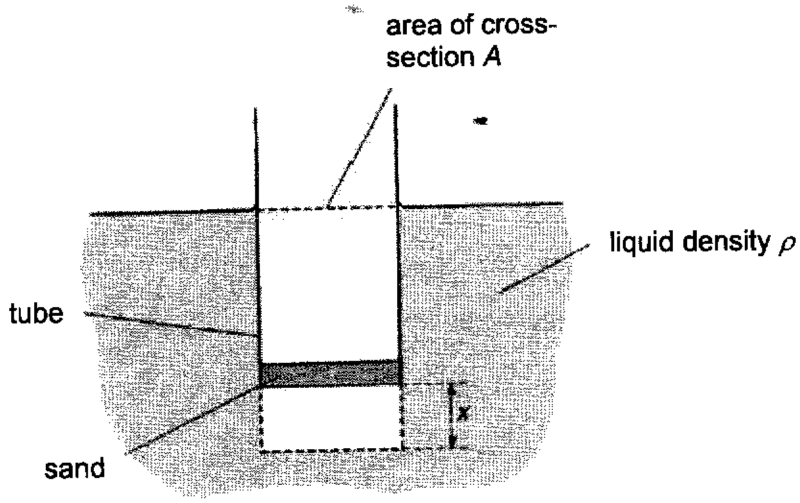


Fig. 3.1

The tube has a uniform cross-sectional area A. The total mass of the tube and sand is M.

The tube is displaced vertically downwards and then released. The tube oscillates vertically.

For a displacement x, the acceleration a of the tube is given by the expression

$$a = -\left(\frac{\rho A g}{M}\right)x$$

where g is the acceleration of free fall.

(a) Explain why the expression leads to the conclusion that the tube is performing simple harmonic motion.

....

....

....

....

.... [3]

(b) The mass M of the tube and sand is 130 g. The area of cross-section A of the tube is 5.3 cm^2. Calculate the frequency of oscillation of the tube when floating in a liquid of density ρ of 1.2×10^3 kg m^{-3}.

frequency = ... Hz [2]

[Total: 5]

4 **(a)** A circuit consists of four resistors, R_1, R_2, R_3 and R_4 of the same resistance R and two ammeters, A_1 and A_2, as shown in Fig. 4.1.

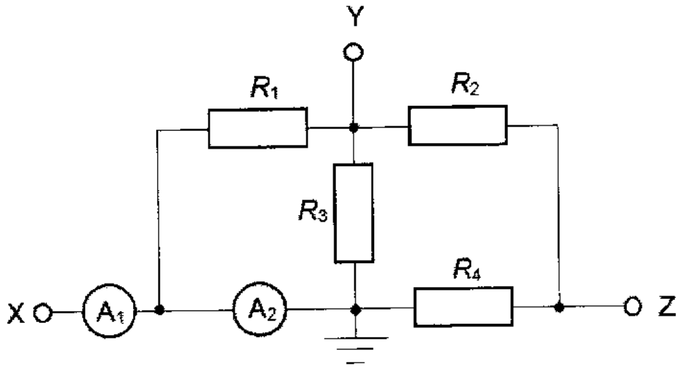


Fig. 4.1

The resistance measured between terminals X and Y is 2.4 Ω.

Show that the value of resistance R is 6.0 Ω. [1]

(b) A cell of e.m.f. 1.5 V and internal resistance 0.60 Ω is connected across the terminals X and Y.

(i) Calculate the current reading in ammeter A_1.

current reading in A_1 = ... A [2]

(ii) Calculate the current reading in ammeter A_2.

current reading in A_2 = ... A [3]

(iii) The positive terminal of the cell is connected to X.

Determine the electric potential at terminal Z.

electric potential at Z = ... V [2]

(iv) An additional circuit consisting of a similar cell of e.m.f 1.5 V and internal resistance 0.60 Ω, a resistor S and a sensitive galvanometer G, as shown in Fig. 4.2 , is now connected to the terminals X and Z.

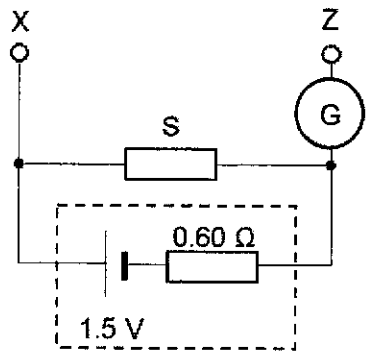


Fig. 4.2

The reading on galvanometer G is zero.

Determine the resistance of S.

resistance of S = ... Ω [2]

[Total: 10]

5 Fig. 5.1 shows a particle of charge -5.0×10^{-6} C undergoing uniform circular motion horizontally clockwise direction. The motion takes place in a region with a uniform magnetic field and uniform electric field, with both fields directed downwards in the plane of the paper.

The magnetic flux density is 0.50 T and the electric field strength is 150 N C^{-1}.

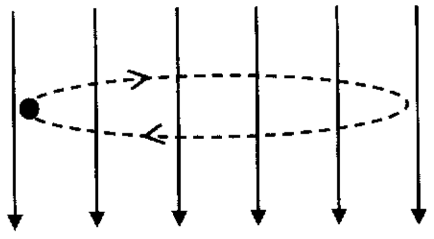


Fig. 5.1

(a) **(i)** Show that the period of revolution, T, of the charged particle is given by

$$T = \frac{2\pi E}{Bg}$$

where g is the acceleration of free fall. [3]

(ii) Hence determine the period T.

T = ... s [1]

(b) The electric field is now removed.

Describe the motion of the charged particle. Explain your answer.

....

....

....

....

....

.... [3]

[Total: 7]

6 In a particular experimental X-ray tube, a copper target is used. Electrons in the tube are accelerated by a potential difference of 10.0 kV before striking the copper target. The first three energy levels of an isolated copper atom and the X-ray spectrum are as shown in Fig. 6.1.

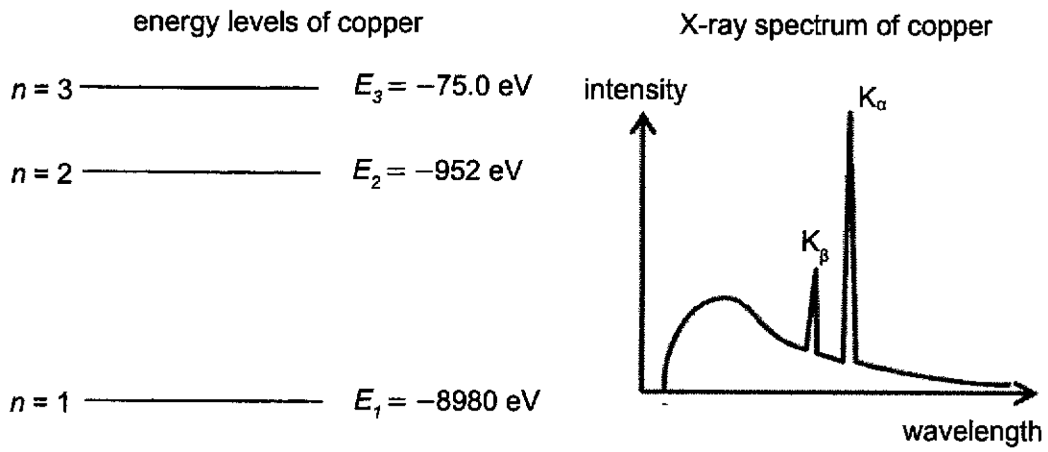


Fig. 6.1

(a) Explain the origin of the continuous background spectrum.

....

....

....

.... [2]

(b) Determine,

(i) the minimum wavelength of the X-ray photons,

wavelength = ... m [2]

(ii) the wavelengths of the K_α and K_β characteristic emissions.

K_α wavelength = ... m

K_β wavelength = ... m [3]

(c) The diameter of a nucleus is in the order of magnitude of 10^{-15} m. Show, using the Heisenberg uncertainty principle, that the electron does not exist inside the nucleus.

[2]

[Total: 9]

7 A nucleus of Uranium-235 may be made to undergo fission when bombarded by a neutron. When Uranium-235 nuclei undergo fission with a slow-moving neutron, two possible reactions that may occur are

Reaction 1: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{139}_{54}Xe + ^{95}_{38}Sr + 2^{1}_{0}n +$ energy

Reaction 2: $^{235}_{92}U + ^{1}_{0}n \rightarrow 2^{116}_{46}Pd + xc +$ energy

(a) For reaction 2, identify the particle c and the number x of such particle(s) produced in this reaction.

particle c = ...

x = ... [2]

(b) The binding energy per nucleon *E* for a number of nuclides is given in Fig. 7.1.

Nuclide	*E* / MeV
$^{95}_{38}Sr$	8.74
$^{139}_{54}Xe$	8.39
$^{235}_{92}U$	7.60

Fig. 7.1

(i) Explain what is meant by *binding energy* of a nucleus.

....

.... [1]

(ii) Determine the energy released in reaction 1.

energy released = ... J [2]

(iii) Hence, calculate the loss in mass in reaction 1.

loss in mass = ... kg [2]

(iv) The energy released in reaction 2 is 163 MeV. Suggest, with a reason, which of the two reactions is more likely to occur.

....

....

....

....

.... [3]

[Total: 10]

8 In 1798, Henry Cavendish performed an experiment to determine a value for the average density of the Earth.

The experiment can also be used to determine G, the gravitational constant.

Cavendish carried out the measurements using the method and torsion balance apparatus devised by John Michell in 1783.

Fig. 8.1 shows the torsion balance in its equilibrium position.

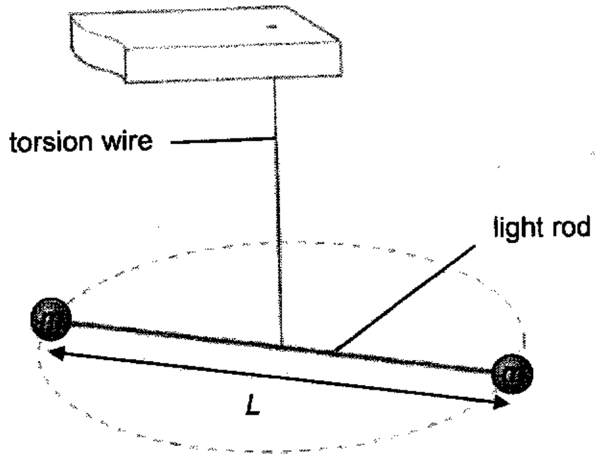


Fig. 8.1 (not to scale)

A stiff torsion wire was used to suspend a light horizontal rod from its midpoint.

Small lead spheres of mass m = 0.730 kg and diameter d = 50 mm were attached to the ends of the light rod.

The centre-to-centre separation of the spheres was L = 1.80 m.

(a) State what is meant by a *gravitational field*.

....

.... [1]

(b) **(i)** Determine the density ρ of lead.

ρ = ... kg m^{-3} [2]

(ii) The rod was turned by a small angle θ from its equilibrium position in a horizontal plane, as shown in Fig. 8.2.

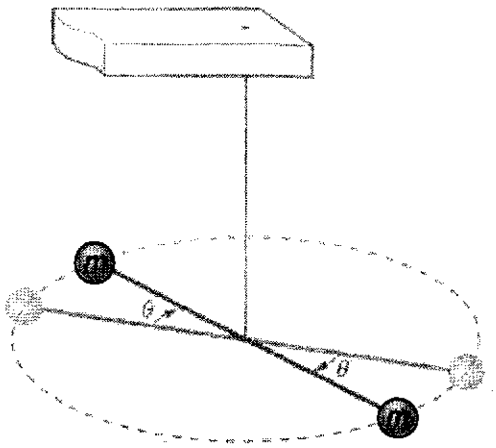


Fig. 8.2 (not to scale)

When released, the rod oscillated with simple harmonic motion about the equilibrium position with a period T.

The torque τ exerted on the rod by the torsion wire was given by the equation:

$$\tau = \frac{2\pi^2 mL^2\theta}{T^2}$$

In an experiment conducted by Cavendish, the pendulum has a period of oscillation of T = 14.0 min when τ = 1.2 x 10^{-5} N m.

Determine the corresponding value of θ.

θ = ... ° [3]

(iii) The rod was returned to its equilibrium position.

Next, Cavendish placed large lead spheres of mass M = 158 kg and diameter D = 30.0 cm near the small lead spheres.

A gravitational attraction force F between each pair of spheres caused the rod to rotate through an angle θ_1 as shown in Fig. 8.3.

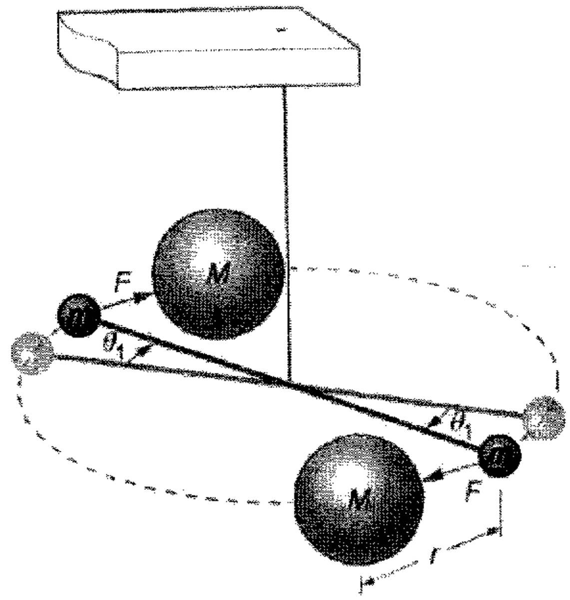


Fig. 8.3 (not to scale)

At this angle, the torque caused by the gravitational attraction was equal to the opposing torque caused by the torsion in the wire.

The centre-to-centre separation of one of the large lead spheres and the small lead sphere next to it was r.

The air gap between each large lead sphere and the small lead sphere next to it was 1.0 mm.

Show that r = 17.6 cm.

[2]

(iv) The angle of rotation θ_1 was too small to be measured directly.

Using a vernier scale, Cavendish was able to determine the displacement of the smaller lead spheres to be 4.1 mm ± 0.1 mm.

The centre-to-centre separation of the two small lead spheres, L was measured to be (1.80 ± 0.01) m.

Determine the angle θ_1 and its corresponding uncertainty.

θ_1 = ... ± .... rad [3]

(v) The large lead spheres were then removed, and the system oscillated with simple harmonic motion as before.

Show that the gravitational constant G is related to the period T by the relationship:

$$G = \frac{2\pi^2 L r^2 \theta_1}{MT^2}$$

[2]

(c) During a lecture, a professor performs a modern version of the Cavendish experiment. The professor uses the same torsion balance method but adds a mirror, laser and screen to measure the rotation.

Fig. 8.4 shows the torsion balance in its equilibrium position.

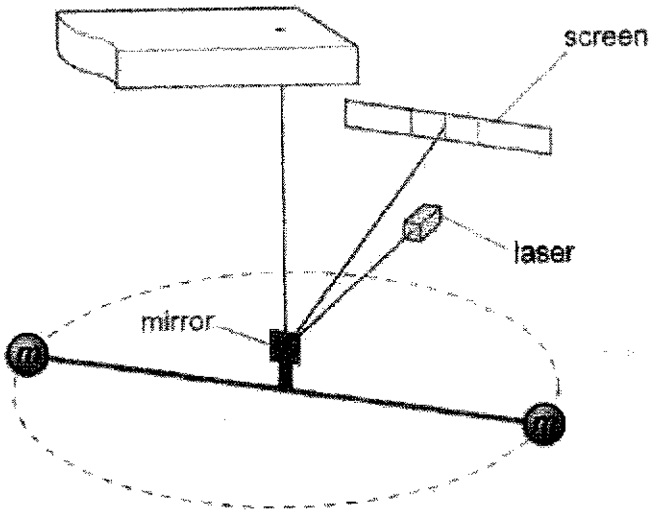


Fig. 8.4 (not to scale)

When the professor brings the large lead spheres near to the small lead spheres, the light rod rotates and the laser beam is deflected, as shown in Fig. 8.5.

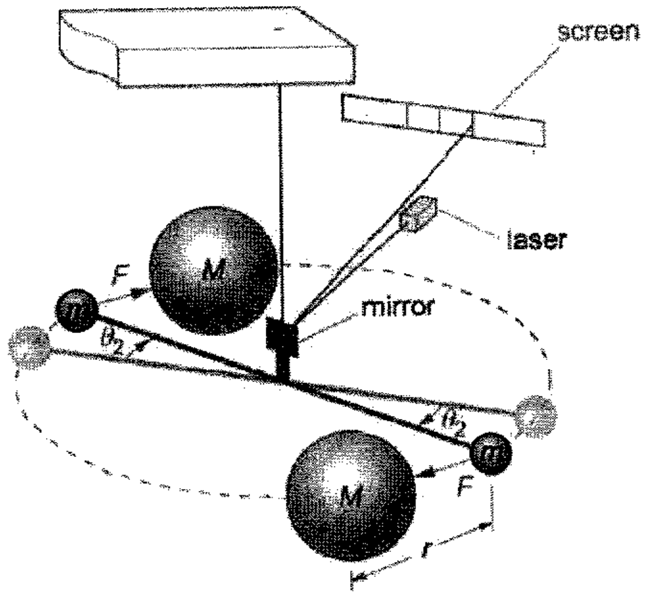


Fig. 8.5 (not to scale)

(i) When the rod rotates by an angle of θ_2, the laser beam deflects by an angle of $2\theta_2$ since the angle of incidence of the laser beam is equal to its angle of reflection.

The mirror is a distance 12.00 m from the screen. The professor measures the deflection of the laser beam on the screen as 15.6 cm.

Show that the corresponding angle of rotation $\theta_2 = 0.372\ °$.

[1]

(ii) The professor removes the large lead spheres and simultaneously starts a timer.

The professor records a time of 10 minutes 22 seconds for the laser beam to move from the maximum deflection, through the equilibrium position to the opposite maximum deflection, and back to the equilibrium position again.

Use this measurement and the expression in **(b)(v)** to determine a value and the S.I. base unit for the gravitational constant *G*.

G = ... [3]

S.I. base unit = ... [1]

(iii) The professor switches off the laser but leaves the system oscillating and the timer running overnight.

The next morning, the professor switches the laser back on and records the time when the laser beam next passes through the equilibrium position, traveling from the right, as t = 13 hours 48 minutes 18 seconds.

By considering uncertainty, explain qualitatively why using this value of t will lead to a more accurate determination of the value for the period T.

....

.... [1]

(iv) The professor calculates a new value for G using the value for T from **(b)(iii)**.

This new value for G is slightly lower than the accepted value of G.

Suggest the main reason for this difference.

....

.... [1]

[Total: 20]

BLANK PAGE

BLANK PAGE

BLANK PAGE

2024 DHS H2 Physics Prelim Paper 2 Suggested Solutions

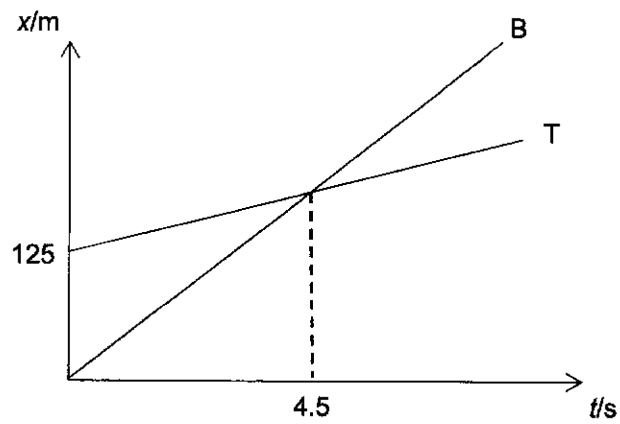
1 **(a)** The bomb is travelling at constant speed in the horizontal direction **B1**
and is accelerating uniformly in the perpendicular (vertical) direction at a rate of 9.81 m s^{-2} (acceleration of free fall) **B1**

MC:	*Generally well answered. Most candidates were able to link their explanations to the definition of projectile motion and hence were able to attain full or minimally partial credit. Most who attained partial credit typically only stated that there is an acceleration in the vertical direction but did not explicitly mention that it is constant.*

(b) $100 = 4.91\,t^2$ **C1**
$t = 4.5$ s **A1**

MC:	*Generally well answered. Some candidate forgot to square in their working.*

(c) **(i)** 2 straight line graphs to show intersect at $t = 4.5$ s **A1**
and when t = 0, $x_{bomb} = 0$ and $x_{truck} = 125$ m **A1**
No indication of values or graph labels: deduct 1 mark



MC:	*Decent attempt. Most candidates were able to obtain the graph above. Common errors included having both graphs start at the origin.*

(ii) v = gradient of truck graph = [(72 x 4.5) – 125] / (4.5) **C1**
= 44 m s^{-1} **A1**

MC:	*Generally well answered. Ecf was should their answers in (b) or (c)(i) be wrong.*

2 (a) (i) It states that the total momentum of a system of bodies is constant provided no *external resultant* force acts on the system. **B1**

MC:	*This principle applies not only to collision problems e.g. applies during alpha decay as well. In addition, students must explain the meaning of conserve in their answers. It is also not necessary to mention that the system is isolated as no external force would imply such as.*

(ii) By conservation of momentum, **C1**

$(2.4\times3.0) - (1.2\times2.0) = 3.6v$

$v = 1.3 \text{ m s}^{-1}$ **A1**

(iii) Initial total kinetic energy calculated correctly (10.8 + 2.4 = **13.2 J**) and

Final total kinetic energy calculated correctly (**3.2 J**) **M1**

Since total kinetic energy of system is not constant, the collision is inelastic. **B1**

OR

relative speed of approach = 5.0 m s^{-1}, relative speed of separation = 0 m s^{-1} **M1**

Since relative speed of approach is not equal to relative speed of separation, the collision is inelastic. **B1**

MC:	*As it is a 'show' type of question, answers need to be written in full with no short form used, i.e. KE is not accepted but have to spell out as kinetic energy.*

(b) (i) By Newton's second law, there is a net downward force by the rotor on the air to increase the momentum of air. **B1**

By Newton's third law, the air exerts a force of equal magnitude but upward direction (i.e. lift force) on the rotor. **B1**

Since the helicopter is hovering, by Newton's first law, the net force on helicopter is zero, that is, lift force = weight of helicopter. **B1**

(ii) volume of air displaced downwards V

= cross-section area of air x distance moved by the air in 5 seconds

$= \pi(5.0^2)(12)(5.0)$

mass of air displaced downwards in 5 seconds

= volume of air x density of air

$= \pi(5.0^2)(12)(5.0)(1.3)$ **C1**

= 6100 kg (2 s.f.) **A0**

MC:	*As it is a 'show' type of question, answers need to be written in full, before any substitution of values. Any symbols used must be defined.*

(iii) By Newton's second law, F = rate of change of momentum

$= \frac{6000}{5.0}(12)$ **C1**

$= 1.4 \times 10^4$ N **A1**

MC:	*Some students mistakenly took the mass of air propelled downwards as the mass of the helicopter.*

3 (a) The density of fluid ρ, the cross-section area A of tube, the total mass M of tube and sand and g is constant, **B1**
hence acceleration a is proportional to displacement x from the equilibrium position. **B1**
The negative sign indicates that acceleration a is in opposite direction to displacement x from the equilibrium position. **B1**
These indicate that the motion of the tube is simple harmonic where $a = -\omega^2 x$. **A0**

(b) $\omega^2 = \frac{\rho A g}{M}$

$= \frac{(1.2 \times 10^3)(5.3 \times 10^{-4})9.81}{130 \times 10^{-3}}$

$= 48$ rad^2 s^{-2} **C1**

$f = \frac{\omega}{2\pi} = 1.1$ Hz **A1**

MC:	*There were some careless mistakes in converting cm^2 to SI units. In addition, some students mistakenly thought* ω = 48 rad s^{-1}.

4 (a) The re-drawn Fig. 4.1 is as follows i.e. R_1, R_3 and (R_2, R_4 in series) are in parallel across X and Y.

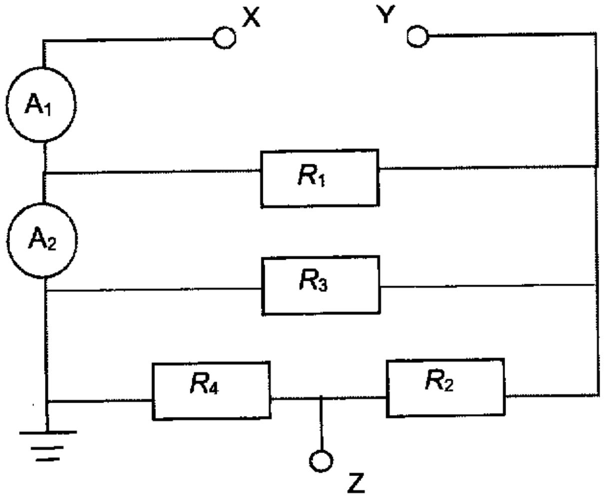


Fig. 4

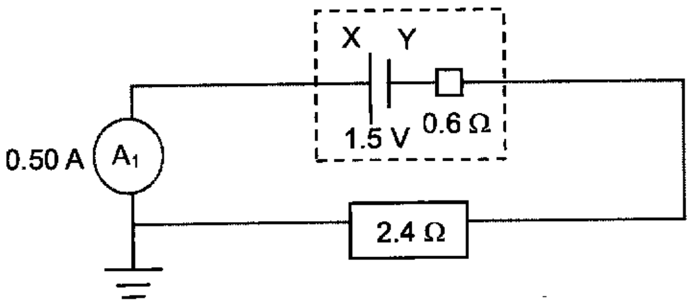
The effective resistance is $\left(\frac{1}{R}+\frac{1}{R}+\frac{1}{2R}\right)^{-1} = 0.4R$ **M1**

$0.4R = 2.4$

$R = 6.0\ \Omega$ **A0**

MC:	*There are different ways to view the re-drawn Fig. 4 to solve the (b)(i) to (iii). Below is the working that should be clear enough for you to understand.*

(b) (i)



Total resistance = $2.4+0.6 = 3.0\ \Omega$ **M1**

Current in $A_1 = \frac{E}{R} = \frac{1.5}{3.0} = 0.50$ A **A1**

(ii) Terminal potential difference between X and Y

$= \frac{2.4}{3.0} \times 1.5 = 1.2 \text{ V}$ **M1**

Current through resistor $R_1 = \frac{V}{R} = \frac{1.2}{6.0} = 0.20 \text{ A}$ **B1**

Thus, current in $A_2 = 0.50 - 0.20 = 0.30 \text{ A}$ **A1**

(iii) Potential difference across $R_4 = \frac{6.0}{6.0+6.0} = \times 1.2 = 0.60 \text{ V}$ **M1**

Potential at $Z = 0 - 0.60 = -0.60 \text{ V}$ **A1**

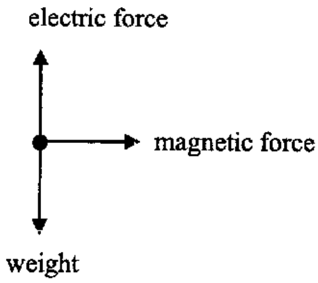
(iv) As reading is zero, the potential difference across S is 0.6 V. **C1**

The potential difference across $S = \frac{S}{S+0.60} \times 1.5 = 0.60 \text{ V}$

Hence $S = 0.4\ \Omega$ **A1**

5(a)(i)

The **magnetic force** acting on the charged particle provides the **centripetal force** for the charged particle to move in uniform circular motion. **B1**



$$Bqv\sin\theta = ma_c = mv\left(\frac{2\pi}{T}\right)$$

$$T = \frac{2\pi m}{Bq}$$

The circular motion is horizontal, so the net vertical force is zero.

$$mg = qE$$ **C1**

Combining both equations,

$$T = \frac{2\pi m}{Bq}$$ **C1**

$$= \frac{2\pi E}{Bg} \quad \text{(Shown)}$$ **A0**

CKW MC	• Some students stated that both the magnetic force **and** electric force (or sometimes even just the electric force) provide the centripetal force, which was a misconception! Though not credited, an initial free body diagram to identify the correct forces acting on the charged particle in the problem will be a useful starting approach. • The equation based on vertical equilibrium i.e. (1) could not be derived or was not shown separately by quite a number of students. • Some students wrote $F = ma = mg$ for the vertical direction, which is conceptually incorrect application of Newton's 2nd law, since there is no acceleration in the vertical direction i.e. $a = 0$. Thus, $mg = qE$ means that the magnitude of the weight of the particle, mg is equal to the magnitude of the electric force, qE on the particle	
5(a)(ii)	From (i), $T = \frac{2\pi E}{Bg} = \frac{2\pi(150)}{(0.50)(9.81)}$ = **192 s**	**A1**
CKW MC	This part is well done, except for a few students who make careless mistakes.	
5(b)	When the electric field is removed, the only **vertical force** acting on the charged particle is its **weight**. Hence, the particle ***falls with uniform acceleration*** *g*. The magnetic force still provides the centripetal force for the charged particle to movie in uniform horizontal circular motion, resulting in the charged particle moving in a **helical** path in which the ***distance between adjacent loops increases*** as the particle falls. Using Fleming's Left-hand Rule, the charged particle will continue to move in a **clockwise circle when viewed from the top** of its helical path.	**B1** **B1** **B1**
CKW MC	• Many students use inappropriate terms such as "spiral" or did not state the consequences of a net force due to weight based on Newton's 2nd Law. • Most students did not state the direction of the charged particle in its helical motion and from the correct perspective.	

6 (a) Photons are produced whenever a **charged particle** such as electrons **decelerates**. **B1**

The electrons produced from the cathode will strike the metal target and decelerates. Since the electrons has a **distribution of decelerations**, the X-ray photons produced also has a distribution of wavelengths. Hence a continuous spectrum is produced. **B1**

MC:	*Generally very poorly done. Many candidates quoted either the explanation for characteristic emissions or phenomena completely unrelated to X-ray production such as line spectra, discrete energy levels, radioactive decay or photoelectric effect.* *Amongst those that managed to produce some semblance of the above answer, most did not state explicitly the mechanism in which photons can be produced using charged particles. However, most were able to identify that the electrons will decelerate to different extents (or lose different amounts of KE) which gives rise to the continuous background.*

(b) (i)

$$\frac{hc}{\lambda_{min}} = eV$$

$$\lambda_{min} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{1.6\times10^{-19}\times10000}$$ **C1**

$$=1.2431\times10^{-10}$$

$$=1.24\times10^{-10}\text{m}$$ **A1**

MC:	*Generally very poorly done. Most candidates could not link the minimum wavelength to the accelerating potential but instead attempted to use energy differences in the energy level diagram to calculate their answers.*

(ii) For K_α line,

$$|E_2 - E_1| = \frac{hc}{\lambda_\alpha}$$

$$\lambda_\alpha = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{(-952+8980)\times1.6\times10^{-19}}$$ **C1**

$$=1.5485\times10^{-10}\text{ m}$$

$$=1.55\times10^{-10}\text{ m}$$ **A1**

For K_β line,

$$|E_3 - E_1| = \frac{hc}{\lambda_\beta}$$

$$\lambda_\beta = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{(-75.0+8980)\times1.6\times10^{-19}}$$

$$=1.39599\times10^{-10}\ \text{m}$$

$$=1.40\times10^{-10}\ \text{m}$$ **A1**

Note: C1 awarded for any correct substitution for either K_α or K_β.

MC:	*Generally very poorly done. Most students were not aware of the energy level transitions that produces the K_α and K_β lines. Despite it being labelled in the diagram to further aid students, many ended up with a $\lambda_\alpha < \lambda_\beta$.*

(c) By Heisenberg's Uncertainty principle,

$$\Delta p\Delta x \geq h$$

$$m\Delta v\Delta x \geq h$$

$$\Delta v \geq \frac{h}{m\Delta x} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times10^{-15}} = 7.3\times10^{11}\ \text{m s}^{-1}$$ **C1**

Since the required velocity of electrons Δv is greater than the speed of light of 3.0×10^{8} m s^{-1}, the electrons does not exist inside the nucleus. **A1**

MC:	*Generally very poorly done. Quite a significant number did not attempt the question. Most candidates who attempted the question were also unable to make connections to the speed of light.* ***<u>Common errors:</u>*** • *Using the de Broglie wavelength equation to do the calculations. (either to compute p or λ to be used in the Heisenberg's Uncertainty relation)* • *Stating that the electron has a momentum of $\sqrt{2mE} = \sqrt{2mqV}$ where V is the accelerating potential in the earlier part. (This is incorrect as the V is an externally applied potential difference. The electron will not exist in the nucleus even in the absence of this potential difference.)*

7 (a) Neutron **A1**

$x = 4$ **A1**

(b) (i) The binding energy of a nucleus is the <u>minimum energy</u> required to <u>completely separate the nucleus into its constituent nucleons</u> (protons and neutrons) <u>to infinity</u>. **B1**

MC:	*Generally very poorly done. Most students were lacking in keywords in their definitions*

(ii) $E_{released} = BE_{products} - BE_{reactants}$

$= 139\ (8.39) + (5\ (8.74) - 235\ (7.60)$ **C1**

$= 210.51$ MeV

$= 3.36816 \times 10^{-11}$ J

$= 3.37 \times 10^{-11}$ J **A1**

MC:	*Generally not very well done. Most students missed out that the information given is the binding energy* ***<u>per nucleon</u>****, and hence did not multiply the mass numbers in their workings.* *A small handful had erroneous conversion of MeV into J.*

(iii) (loss in mass) $c^2 = E_{released}$

(loss in mass) $(3.00 \times 10^8)^2 = 3.36816 \times 10^{-11}$ **C1**

(loss in mass) $= 3.74 \times 10^{-28}$ kg **A1**

MC:	*Generally well done. Ecf was given should their answer in (ii) be incorrect.*

(iv) When more energy is being released in a nuclear reaction, more stable daughter nuclei are formed as a result. **B1**

Since reaction 1 releases more energy than reaction 2, **B1**

reaction 1 is more likely to occur. **B1**

MC:	*Generally well done. Ecf was given should their answer in (ii) be incorrect. Students' conclusion and explanations should be adjusted according to their answer in (b)(ii). (i.e. if the energy released obtained in (ii) is lower than reaction 2, students must conclude that reaction 2 is more likely to occur to attain credit)* *A small handful of students mixed up the concepts of spontaneity of reactions with the likelihood of reactions. Students are advised not to haphazardly introduce scientific terms outside of what the question has stated or is required to answer the question to avoid being marked down unnecessarily.*

8(a)	Gravitational field is a **region of space** in which a **mass** will experience a **non-contact gravitational** force.	**A1**
CKW MC	• This definition was assessed in 2017 & 2018 H2 P3. • Refer to DHS "Gravitational Field" notes for reference. • Many candidates confused *gravitational field* with *gravitational field strength.* • An *area* is not the same as a *volume* or *region.* • For definitions, avoid using the root words again. Thus, candidates should explain the words *gravitational* and *field* separately.	
8(b)(i)	$\rho = \frac{M}{V} = \frac{M}{\left(\frac{4}{3}\pi r^3\right)} = \frac{0.73}{\left(\frac{4}{3}\pi(25 \times 10^{-3})^3\right)}$ $= 11000 \text{ kg m}^{-3}$	**C1** **A1**
CKW MC	There was quite a number of students who did not use the correct formula for the volume of a sphere or know the importance of the word "diameter".	
8(b)(ii)	Unit of τ = Unit of $\frac{2\pi^2 mL^2\theta}{T^2}$ $\text{N m} = \text{kg m s}^{-2}\text{ m} = \frac{\text{kg m}^2}{\text{s}^2}$ Unit of θ Unit of $\theta = 1$ $\tau = \frac{2\pi^2 mL^2\theta}{T^2}$ $1.2 \times 10^{-5} = \frac{2\pi^2(0.730)(1.80)^2\theta}{(14.0 \times 60)^2}$ $\theta = 0.18136$ rad $= 0.18136\left(\frac{360}{2\pi}\right)^{\circ} = 10(.4)^{\circ}$	**C1** **A1** **A1**
CKW MC	• Most students did not realise the unit of θ in the given equation is in radians. • Some students used 2*m* instead of *m*.	

8(b)(iii)	Radius of large sphere, $R = D/2 = 15.0\text{ cm}$ Radius of small sphere, $r' = d/2 = 25\text{ mm} = 2.5\text{ cm}$ Thus, $r = r' + R + \text{air gap width}$ $= 15.0 + 2.5 + 0.1$ $= 17.6\text{ cm}$	**B1** **C1** **A0**
CKW **MC**	• Quite a number of students attempted to use Newton's law of gravitation for this part using the given value of torque! • It is also not possible to use the given torque in **(b)(ii)** for this part since it is a different experiment, and the torque is different for M = 158 kg as can be shown that $LF_g = L\left(\frac{GMm}{r^2}\right) = 1.2 \times 10^{-5}$ $r = \sqrt{\frac{LGMm}{1.2 \times 10^{-5}}} = \sqrt{\frac{(1.8)(6.67 \times 10^{-11})(158)(0.73)}{1.2 \times 10^{-5}}} \neq 0.176\text{ m}$	
8(b)(iv)	Using $s = (L/2)\theta_1$, $4.1 \times 10^{-3} = (1.8/2)\theta_1$ $\theta_1 = 4.\dot{5} \times 10^{-3}\text{ rad}$ The uncertainty equation is given by $\frac{\Delta\theta_1}{\theta_1} = \frac{\Delta s}{s} + \frac{\Delta L}{L}$ $\frac{\Delta\theta_1}{4.\dot{5} \times 10^{-3}} = \frac{0.1}{4.1} + \frac{0.01}{1.80}$ $\Delta\theta_1 = 0.1 \times 10^{-3}\text{ rad}$ $\theta_1 = (4.6 \pm 0.1) \times 10^{-3}\text{ rad}$	 **A1** **C1** **A1**
CKW **MC**	The max-min method will lead to the same answer.	

8(b)(v)	At θ_1, the torque caused by the gravitational attraction (between *M* and *m*) was equal to the opposing torque caused by the torsion in the wire. Thus, from **(b)(ii)**, $LF_g = \frac{2\pi^2 mL^2\theta}{T^2}$ $L\frac{GMm}{r^2} = \left(\frac{2\pi^2 mL^2}{T^2}\right)\theta_1$ $G = \frac{2\pi^2 Lr^2\theta_1}{MT^2}$ (Shown)	B1 C1 A0
	OR The maximum **restoring force** is equal to the **gravitational force between the large and small spheres** at a separation of *r*.. Thus, $\lvert F_g \rvert = ma = m\omega^2 x_o$ $\frac{GMm}{r^2} = m\left(\frac{2\pi}{T}\right)^2 x_o$ $G = \left(\frac{4\pi^2}{T^2}\right)\frac{r^2}{M}x_o$ The amplitude x_o of the simple harmonic motion is approximately equal to $\frac{L}{2}\theta_1$. Thus, $G = \left(\frac{4\pi^2}{T^2}\right)\frac{r^2}{M}\left(\frac{L}{2}\theta_1\right)$ $G = \frac{2\pi^2 Lr^2\theta_1}{MT^2}$ (Shown)	B1 C1 A0

CKW MC	Many candidates seem to have the misconception that gravitational force *is* the torque **and/or** the squared term for *L* gets omitted or incorrectly simplified in one step e.g. $$\frac{GMm}{r^2}=\left(\frac{2\pi^2 mL^2}{T^2}\right)\theta_1$$ $$G=\frac{2\pi^2 Lr^2\theta_1}{MT^2}$$	
8(c)(i)	When the rod rotates by an angle of θ_2, the laser beam deflects by an angle of $2\theta_2$ since the angle of incidence of the laser beam is equal to its angle of reflection. Thus, Using $s_2 = D_2(2\theta_2)$, $15.6/100=(12.00)(2\theta_2)$ $\theta_2 = 0.00650$ rad $=0.00650\left(\frac{360}{2\pi}\right)^{\circ}$ $=0.372^{\circ}$	**C1** **A0**
	OR Using small angle approximation, $2\theta_2 \approx \frac{s_2}{D_2} \quad \rightarrow \quad \tan(2\theta_2)=\sin(2\theta_2)=\frac{s_2}{D_2}$ $\tan(2\theta_2)=\sin(2\theta_2)=\frac{15.6/100}{12.00}$ $\theta_2 = 0.372^{\circ}$	**C1** **A0**
CKW MC	Candidates should show all relevant substitutions and conversion.	

8(c)(ii)	¾ of a period is equal to 10 mins 22 s. Thus, $\frac{3}{4}T = ((10)(60)+22)$ s $T = \frac{2488}{3}$ s From **(b)(v)**, $G = \frac{2\pi^2 L r^2 \theta_2}{MT^2}$ $= \frac{2\pi^2(1.80)(17.6/100)^2(0.00650)}{(158)(2488/3)^2}$ $= 6.58 \times 10^{-11}$ m^3 kg^{-1} s^{-2} Unit of G = Unit of $\frac{2\pi^2 L r^2 \theta_2}{MT^2}$ $= \frac{\text{m m}^2}{\text{kg s}^2}$ $=$ m^3 kg^{-1} s^{-2}	**M1** **C1** **A1** **A1**
CKW MC	• Most students did not realise the unit of θ_2 is in radians, and conversion needs to be performed for the θ_2 in degrees in **(c)(i)** if used. • Radian is not an SI base unit.	
8(c)(iii)	*T* will be determined by **taking the average of a large number** of oscillations (about 60 instead of about 1 oscillation as in (b)(ii)) with the **same actual uncertainty**, thus the **percentage (or fractional)** uncertainty of *T* will be **reduced** significantly.	**A1**
CKW MC	Quite a number of students did not use appropriate and specific terms in their answers such percentage and/or actual uncertainty.	
8(c)(iv)	The rod was assumed to be light.	**A1**
CKW MC	• Most candidates did not provide the **main** reason for the difference in *T* leading to a difference in *G*. • The system rotates so slowly in 1 oscillation (*T* = 14 min) that the damping of air resistance is negligible.	