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.

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Data

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

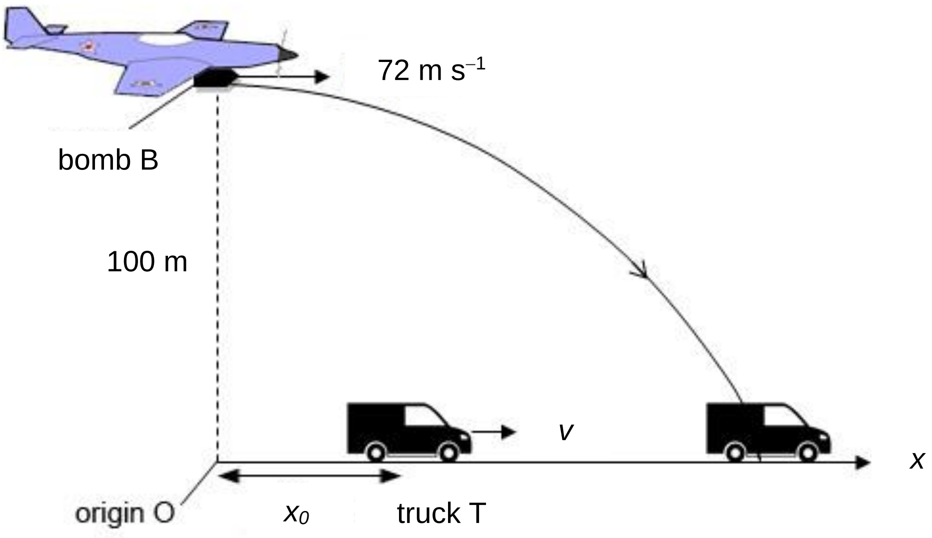

Fig. 1.1

(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.

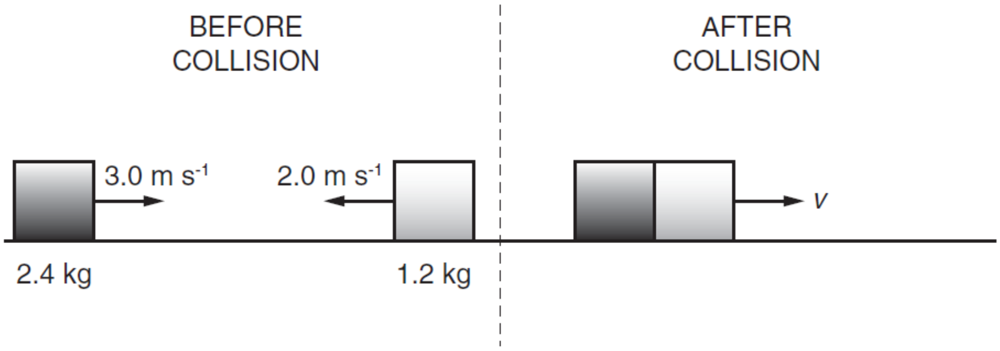

Fig. 2.1

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.

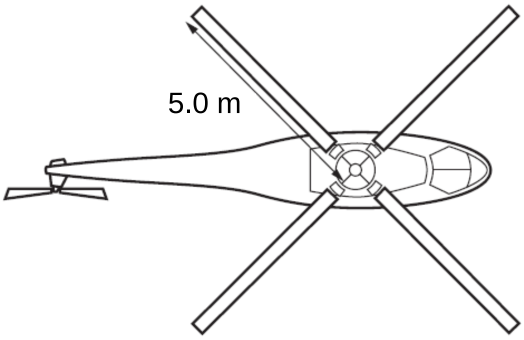

Fig. 2.2

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.

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…………………………………………………………………………………………… [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.

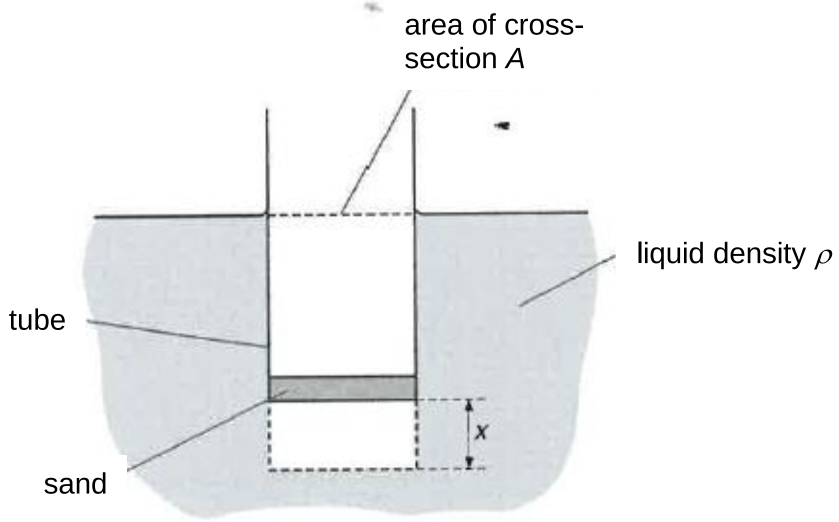

Fig. 3.1

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.

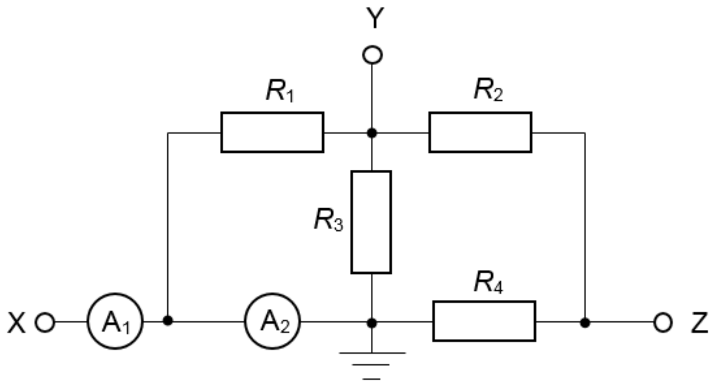

Fig. 4.1

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.

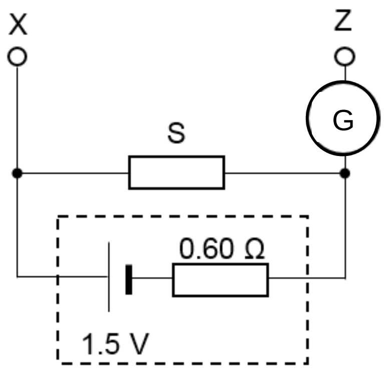

Fig. 4.2

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}.

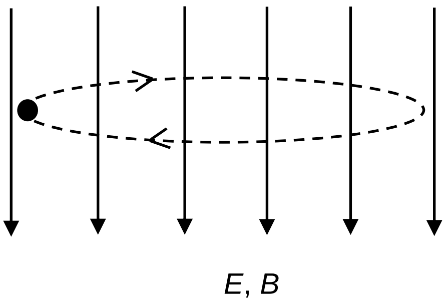

Fig. 5.1

(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.

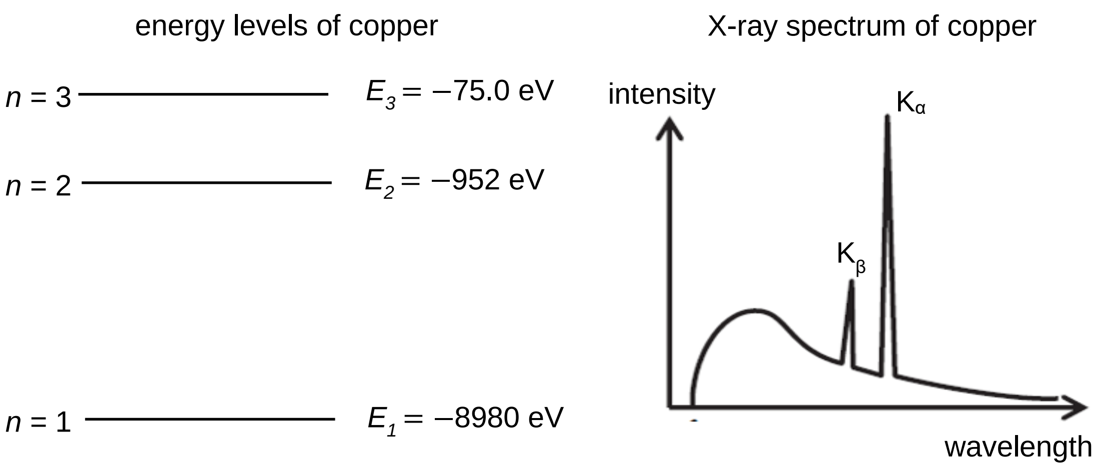

Fig. 6.1

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

Reaction 2: ${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow 2\,{}^{116}_{46}\text{Pd} + x\text{c} +$ 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.

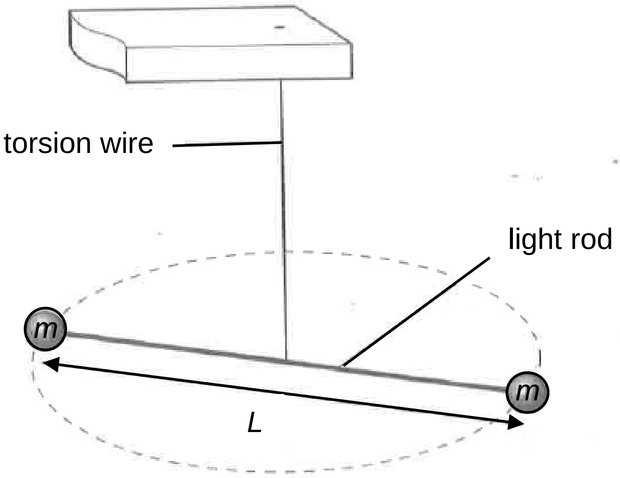

Fig. 8.1 (not to scale)

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.

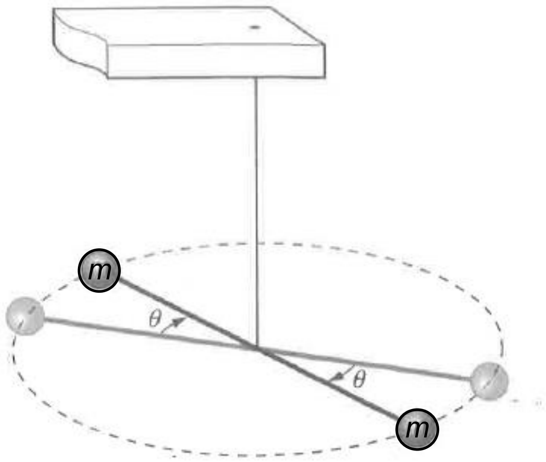

Fig. 8.2 (not to scale)

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.

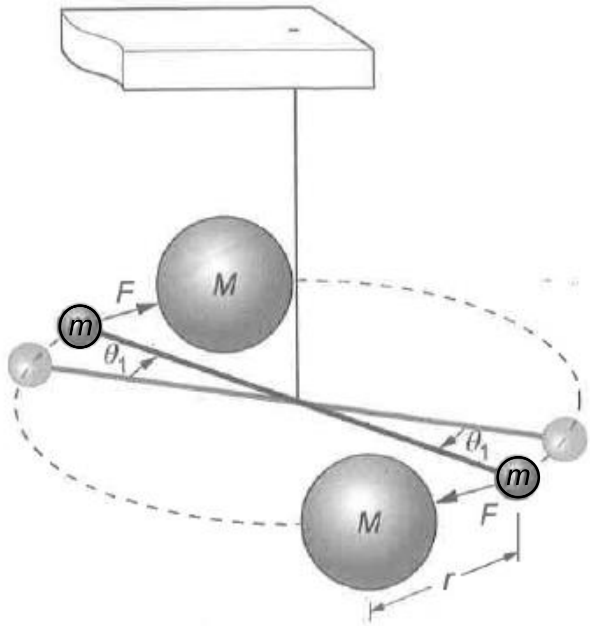

Fig. 8.3 (not to scale)

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:

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

[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.

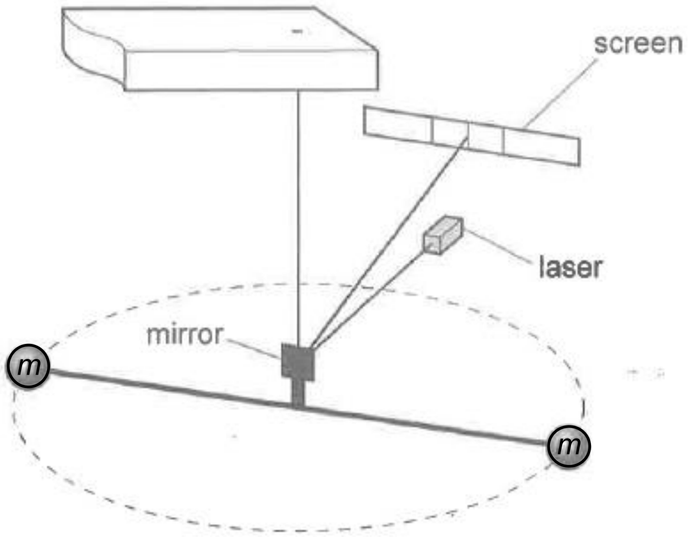

Fig. 8.4 (not to scale)

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.

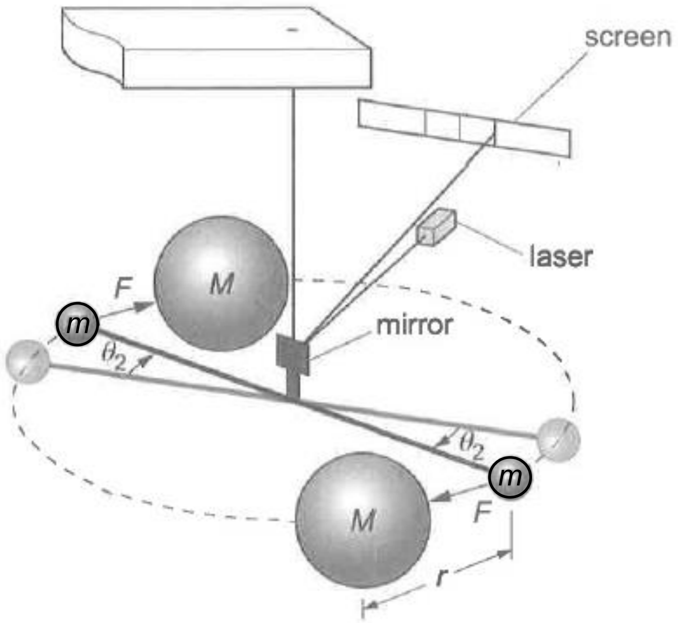

Fig. 8.5 (not to scale)

(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 θ_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]

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