| Surname | | Other Names | |
|---|---|---|---|
| Centre Number | | Candidate Number | |
| Candidate Signature | | | |

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General Certificate of Education
June 2006
Advanced Level Examination

**PHYSICS (SPECIFICATION A)** **PHAP**
**Practical (Units 5–9)**

Wednesday 24 May 2006 9.00 am to 10.45 am

**For this paper you must have:**
- a calculator
- a pencil and ruler

Time allowed: 1 hour 45 minutes

**Instructions**
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **both** questions
- Answer questions in the spaces provided.
- Show all your working
- Do all rough work in this book. Cross through any work you do not want marked.

**Information**
- The maximum mark for this paper is 30.
- The marks for questions are shown in brackets.
- *A Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are expected to use a calculator where appropriate.
- You are advised to spend no more than 30 minutes on Question 1.

| For Examiner's Use | | | |
|---|---|---|---|
| Number | Mark | Number | Mark |
| 1 | | | |
| 2 | | | |
| Total (Column 1) → | | | |
| Total (Column 2) → | | | |
| TOTAL | | | |
| Examiner's Initials | | | |

**Data Sheet**

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

# Data Sheet

## Fundamental constants and values

| *Quantity* | *Symbol* | *Value* | *Units* |
|---|---|---|---|
| speed of light in vacuo | $c$ | $3.00 \times 10^{8}$ | $m\ s^{-1}$ |
| permeability of free space | $\mu_0$ | $4\pi \times 10^{-7}$ | $H\ m^{-1}$ |
| permittivity of free space | $\varepsilon_0$ | $8.85 \times 10^{-12}$ | $F\ m^{-1}$ |
| charge of electron | $e$ | $1.60 \times 10^{-19}$ | C |
| the Planck constant | $h$ | $6.63 \times 10^{-34}$ | J s |
| gravitational constant | $G$ | $6.67 \times 10^{-11}$ | $N\ m^2\ kg^{-2}$ |
| the Avogadro constant | $N_A$ | $6.02 \times 10^{23}$ | $mol^{-1}$ |
| molar gas constant | $R$ | 8.31 | $J\ K^{-1}\ mol^{-1}$ |
| the Boltzmann constant | $k$ | $1.38 \times 10^{-23}$ | $J\ K^{-1}$ |
| the Stefan constant | $\sigma$ | $5.67 \times 10^{-8}$ | $W\ m^{-2}\ K^{-4}$ |
| the Wien constant | $\alpha$ | $2.90 \times 10^{-3}$ | m K |
| electron rest mass (equivalent to $5.5 \times 10^{-4}$u) | $m_e$ | $9.11 \times 10^{-31}$ | kg |
| electron charge/mass ratio | $e/m_e$ | $1.76 \times 10^{11}$ | $C\ kg^{-1}$ |
| proton rest mass (equivalent to 1.00728u) | $m_p$ | $1.67 \times 10^{-27}$ | kg |
| proton charge/mass ratio | $e/m_p$ | $9.58 \times 10^{7}$ | $C\ kg^{-1}$ |
| neutron rest mass (equivalent to 1.00867u) | $m_n$ | $1.67 \times 10^{-27}$ | kg |
| gravitational field strength | $g$ | 9.81 | $N\ kg^{-1}$ |
| acceleration due to gravity | $g$ | 9.81 | $m\ s^{-2}$ |
| atomic mass unit (1u is equivalent to 931.3 MeV) | u | $1.661 \times 10^{-27}$ | kg |

## Fundamental particles

| *Class* | *Name* | *Symbol* | *Rest energy* /MeV |
|---|---|---|---|
| photon | photon | $\gamma$ | 0 |
| lepton | neutrino | $\nu_e$ | 0 |
| | | $\nu_\mu$ | 0 |
| | electron | $e^{\pm}$ | 0.510999 |
| | muon | $\mu^{\pm}$ | 105.659 |
| mesons | pion | $\pi^{\pm}$ | 139.576 |
| | | $\pi^{0}$ | 134.972 |
| | kaon | $K^{\pm}$ | 493.821 |
| | | $K^{0}$ | 497.762 |
| baryons | proton | p | 938.257 |
| | neutron | n | 939.551 |

## Properties of quarks

| *Type* | *Charge* | *Baryon number* | *Strangeness* |
|---|---|---|---|
| u | $+\frac{2}{3}$ | $+\frac{1}{3}$ | 0 |
| d | $-\frac{1}{3}$ | $+\frac{1}{3}$ | 0 |
| s | $-\frac{1}{3}$ | $+\frac{1}{3}$ | –1 |

## Geometrical equations

*arc length* $= r\theta$

*circumference of circle* $= 2\pi r$

*area of circle* $= \pi r^2$

*area of cylinder* $= 2\pi rh$

*volume of cylinder* $= \pi r^2 h$

*area of sphere* $= 4\pi r^2$

*volume of sphere* $= \frac{4}{3}\pi r^3$

## Mechanics and Applied Physics

$v = u + at$

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

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

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

$F = \frac{\Delta(mv)}{\Delta t}$

$P = Fv$

$efficiency = \frac{power\ output}{power\ input}$

$\omega = \frac{v}{r} = 2\pi f$

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

$I = \sum mr^2$

$E_k = \frac{1}{2} I\omega^2$

$\omega_2 = \omega_1 + \alpha t$

$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$

$\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$

$T = I\alpha$

*angular momentum* $= I\omega$

$W = T\theta$

$P = T\omega$

*angular impulse = change of angular momentum* $= Tt$

$\Delta Q = \Delta U + \Delta W$

$\Delta W = p\Delta V$

$pV^{\gamma} =$ constant

*work done per cycle = area of loop*

*input power = calorific value × fuel flow rate*

*indicated power as (area of p – V loop) × (no. of cycles/s) × (no. of cylinders)*

*friction power = indicated power – brake power*

$efficiency = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

*maximum possible efficiency* $= \frac{T_H - T_C}{T_H}$

## Fields, Waves, Quantum Phenomena

$g = \frac{F}{m}$

$g = -\frac{GM}{r^2}$

$g = -\frac{\Delta V}{\Delta x}$

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

$a = -(2\pi f)^2 x$

$v = \pm 2\pi f\sqrt{A^2 - x^2}$

$x = A\cos 2\pi ft$

$T = 2\pi\sqrt{\frac{m}{k}}$

$T = 2\pi\sqrt{\frac{l}{g}}$

$\lambda = \frac{\omega s}{D}$

$d\sin\theta = n\lambda$

$\theta \approx \frac{\lambda}{D}$

${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$

${}_1n_2 = \frac{n_2}{n_1}$

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

$E = hf$

$hf = \phi + E_k$

$hf = E_1 - E_2$

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

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

## Electricity

$\epsilon = \frac{E}{Q}$

$\epsilon = I(R + r)$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

$R_T = R_1 + R_2 + R_3 + \cdots$

$P = I^2 R$

$E = \frac{F}{Q} = \frac{V}{d}$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

$E = \frac{1}{2}QV$

$F = BIl$

$F = BQv$

$Q = Q_0 e^{-t/RC}$

$\Phi = BA$

Turn over ▶

$magnitude\ of\ induced\ e.m.f. = N\frac{\Delta\Phi}{\Delta t}$

$I_{rms} = \frac{I_0}{\sqrt{2}}$

$V_{rms} = \frac{V_0}{\sqrt{2}}$

**Mechanical and Thermal Properties**

$the\ Young\ modulus = \frac{tensile\ stress}{tensile\ strain} = \frac{F}{A}\frac{l}{e}$

$energy\ stored = \frac{1}{2}Fe$

$\Delta Q = mc\,\Delta\theta$

$\Delta Q = ml$

$pV = \frac{1}{3}Nm\overline{c^2}$

$\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT = \frac{3RT}{2N_A}$

**Nuclear Physics and Turning Points in Physics**

$force = \frac{eV_p}{d}$

$force = Bev$

$radius\ of\ curvature = \frac{mv}{Be}$

$\frac{eV}{d} = mg$

$work\ done = eV$

$F = 6\pi\eta rv$

$I = k\frac{I_0}{x^2}$

$\frac{\Delta N}{\Delta t} = -\lambda N$

$\lambda = \frac{h}{\sqrt{2meV}}$

$N = N_0 e^{-\lambda t}$

$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

$R = r_0 A^{\frac{1}{3}}$

$E = mc^2 = \frac{m_0c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

$l = l_0\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$

$t = \frac{t_0}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

**Astrophysics and Medical Physics**

| Body | Mass/kg | Mean radius/m |
|---|---|---|
| Sun | $2.00 \times 10^{30}$ | $7.00 \times 10^{8}$ |
| Earth | $6.00 \times 10^{24}$ | $6.40 \times 10^{6}$ |

1 astronomical unit = $1.50 \times 10^{11}$ m

1 parsec = 206265 AU = $3.08 \times 10^{16}$ m = 3.26 ly

1 light year = $9.45 \times 10^{15}$ m

Hubble constant ($H$) = 65 km s$^{-1}$ Mpc$^{-1}$

$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$

$M = \frac{f_o}{f_e}$

$m - M = 5\log\frac{d}{10}$

$\lambda_{max}T = \text{constant} = 0.0029\text{ m K}$

$v = Hd$

$P = \sigma AT^4$

$\frac{\Delta f}{f} = \frac{v}{c}$

$\frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$

$R_s \approx \frac{2GM}{c^2}$

**Medical Physics**

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

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ and $m = \frac{v}{u}$

$intensity\ level = 10\log\frac{I}{I_0}$

$I = I_0 e^{-\mu x}$

$\mu_m = \frac{\mu}{\rho}$

**Electronics**

Resistors

Preferred values for resistors (E24)
Series: 1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2 2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 ohms
and multiples that are ten times greater

$Z = \frac{V_{rms}}{I_{rms}}$

$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$

$C_T = C_1 + C_2 + C_3 + \cdots$

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

**Alternating Currents**

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

**Operational amplifier**

$G = \frac{V_{out}}{V_{in}}$ voltage gain

$G = -\frac{R_f}{R_1}$ inverting

$G = 1 + \frac{R_f}{R_1}$ non-inverting

$V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$ summing

**Turn over for the first question**

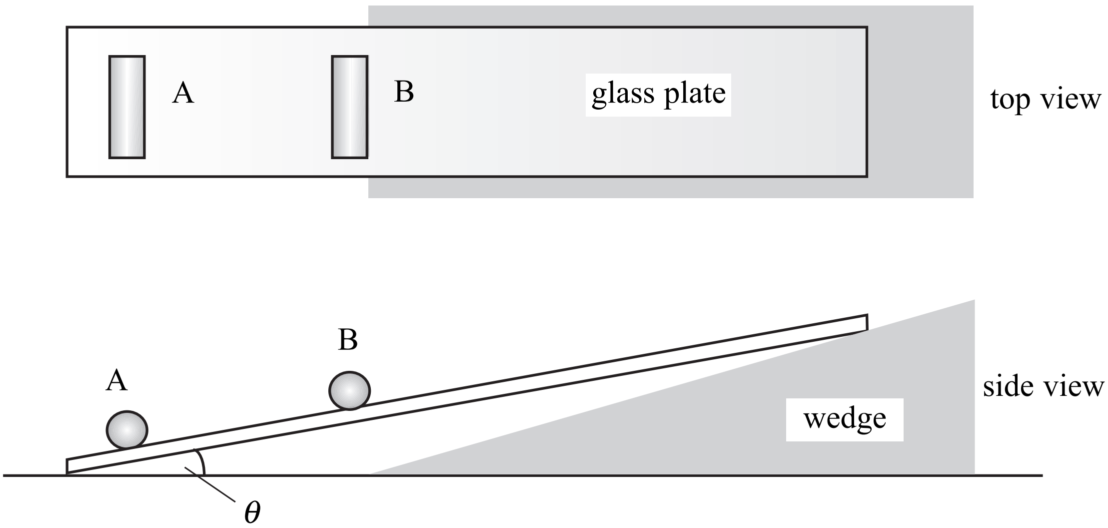
**Turn over ▶**

Answer **both** questions.

You are advised to spend no more than 30 minutes on Question 1.

**1** A student discovers a novel way of measuring the force that acts between two cylindrical bar magnets.
Two such magnets, A and B, are placed on a smooth, flat glass plate with the poles aligned so that the magnets repel one another. Magnet A is glued in place. A wedge is then introduced under one edge of the glass plate so that the plate is inclined at an angle, $\theta$, to the desk.
Magnet B, which is free to roll, comes to rest in the position shown by the views given in **Figure 1**.

**Figure 1**

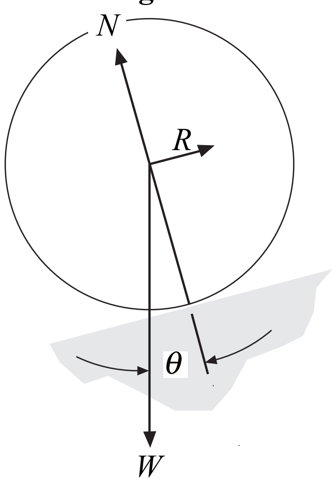



The student sketches a force diagram, shown in **Figure 2**, for the forces acting on magnet B. These are

- $W$, the weight of the rolling magnet,
- $N$, the contact force **normal to** the glass plate and
- $R$, the repulsive force due to the fixed magnet, acting **parallel to** the glass plate.

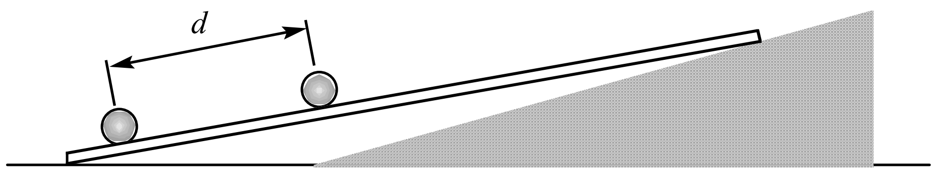
Realising that these forces are in equilibrium, the student plans to use this diagram to determine the magnitude of $R$.

**Figure 2**



It is suggested that $R$ might vary as $\frac{1}{d^2}$, where $d$ is the separation of the magnets, as shown in **Figure 3**.

**Figure 3**




Design an experiment that enables the student to determine whether $R$ varies as $\frac{1}{d^2}$.

You should assume that the normal laboratory apparatus used in schools and colleges is available. You may wish to draw a diagram to illustrate your answer.

In your answer you should:

- Identify the quantities you intend to measure and explain how you will measure them.
- Explain how you propose to use your measurements to determine if $R$ varies as $\frac{1}{d^2}$. You may wish to draw a diagram to illustrate this part of your answer.
- List any factor(s) you will need to control and explain how you will do this.
- Identify any difficulties you might encounter in obtaining reliable results and explain how these could be overcome.

Write your answers to Question 1 on **pages 8 and 9** of this booklet.

*(8 marks)*

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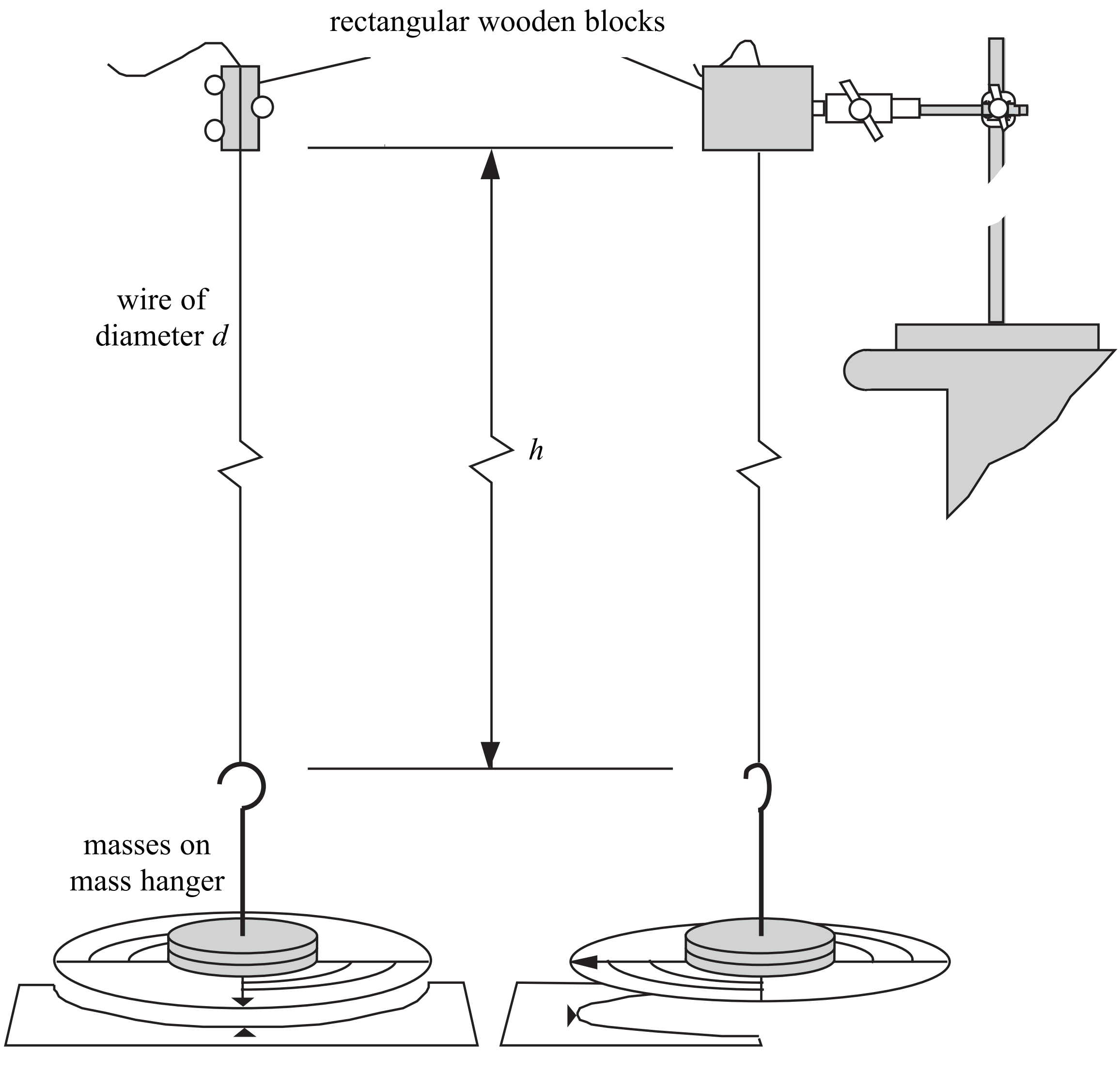
8

Turn over

**2** You are to investigate the rotational oscillations of a mass suspended from a wire, as the length, *h*, of the wire is varied.
The arrangement of the apparatus is shown in front view and side view in **Figure 4**.

**Figure 4**




(a) Use the micrometer screw gauge to determine the mean diameter, *d*, of the wire.

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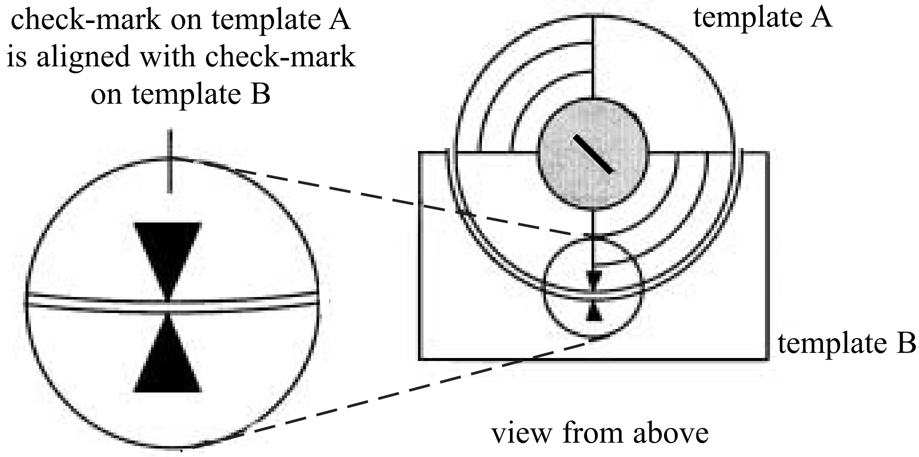
*d* =......................................

*(1 mark)*

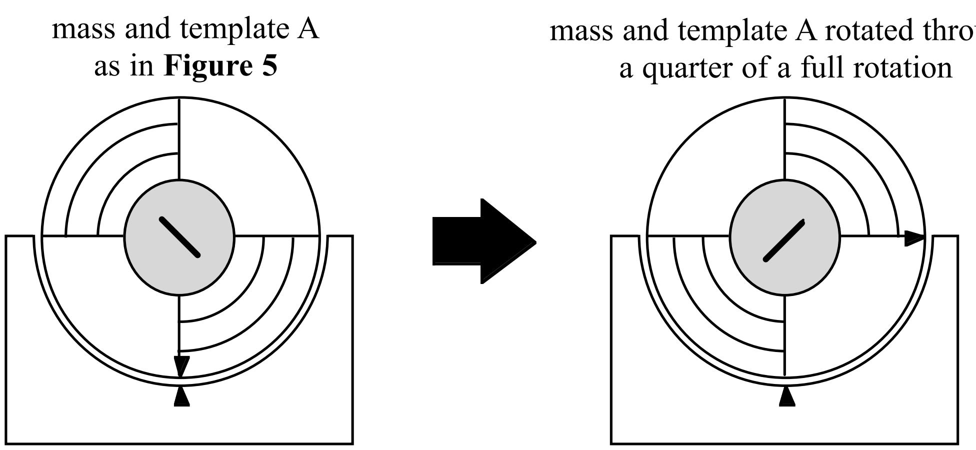
(b) Template A is a piece of card that is trapped between the mass hanger and slotted masses. Template B is another piece of card that can be placed on the floor below the suspended mass. Printed on both templates are check marks that you should use when measuring the period of rotational oscillations of the suspended mass. Rotate template A on its own until the check-mark is pointing away from the edge of the bench. Position template B so that it is directly below the suspended mass and the check-mark is aligned with that on template A, as shown in **Figure 5**.

**Figure 5**




Keeping the wire vertical, rotate the stem of the mass hanger so that the suspended mass turns through approximately a quarter of a full rotation, i.e. 90°, as shown in **Figure 6**.

**Figure 6**




Release the stem of the mass hanger so that the suspended mass performs rotational oscillations.
Make suitable measurements to determine the period, $T$, of the rotational oscillations and the length of wire, $h$, as defined in **Figure 4**.

Repeat the procedure to find values of $T$ for four smaller values of $h$.
Record all the measurements you make on the following page.

**Turn over ▶**

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Measurements and observations.

*(4 marks)*

(c) Using the grid on **page 13**, plot a graph with $\log_{10}$ ($h$/m) on the vertical axis and $\log_{10}$ ($T$/s) on the horizontal axis.
Tabulate below the data you will plot on your graph.

*(8 marks)*

(d) Measure and record the gradient, $G$, of your graph.

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$G$ = ..........................................

*(3 marks)*

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(e) Theory shows that for a given length of wire, $T \propto \frac{1}{d^2}$ .

Suppose the experiment is repeated using a wire of the same material but half the diameter. If the values of $h$ used were the same as in the original experiment, state, without explanation, what effect this change would have on

(i) the values of $T$,

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(ii) the result for $G$.

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*(3 marks)*

(f) It is suggested that, in common with other examples of oscillating systems you may have studied, the amplitude of the rotational oscillation decays exponentially as the energy of the system decreases due to damping.
Outline how you would verify whether this suggestion is correct.

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*(3 marks)*

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**END OF QUESTIONS**

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