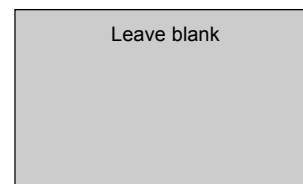


Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			



General Certificate of Education  
January 2006  
Advanced Subsidiary Examination



**PHYSICS (SPECIFICATION A)  
Practical (Unit 3)**

**PHA3/P**

Tuesday 17 January 2006 1.30 pm to 3.15 pm

<p><b>For this paper you must have:</b></p> <ul style="list-style-type: none"> <li>• a calculator</li> <li>• a pencil and ruler</li> </ul>
--

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 **all** 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.
- You are provided with an A3 sheet, INSERT TO PHA3/P/TN, which will be required for Question 2.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
Total (Column 1) →			
Total (Column 2) →			
Quality of Written Communication			
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				Mechanics and Applied Physics		Fields, Waves, Quantum Phenomena	
Quantity	Symbol	Value	Units				
speed of light in vacuo	$c$	$3.00 \times 10^8$	$\text{m s}^{-1}$	$v = u + at$		$g = \frac{F}{m}$	
permeability of free space	$\mu_0$	$4\pi \times 10^{-7}$	$\text{H m}^{-1}$	$s = \left(\frac{u+v}{2}\right)t$		$g = -\frac{GM}{r^2}$	
permittivity of free space	$\epsilon_0$	$8.85 \times 10^{-12}$	$\text{F m}^{-1}$	$s = ut + \frac{at^2}{2}$		$g = -\frac{\Delta V}{\Delta x}$	
charge of electron	$e$	$1.60 \times 10^{-19}$	C	$v^2 = u^2 + 2as$		$V = -\frac{GM}{r}$	
the Planck constant	$h$	$6.63 \times 10^{-34}$	J s	$F = \frac{\Delta(mv)}{\Delta t}$		$a = -(2\pi f)^2 x$	
gravitational constant	$G$	$6.67 \times 10^{-11}$	$\text{N m}^2 \text{kg}^{-2}$	$P = Fv$		$v = \pm 2\pi f \sqrt{A^2 - x^2}$	
the Avogadro constant	$N_A$	$6.02 \times 10^{23}$	$\text{mol}^{-1}$	$\text{efficiency} = \frac{\text{power output}}{\text{power input}}$		$x = A \cos 2\pi ft$	
molar gas constant	$R$	8.31	$\text{J K}^{-1} \text{mol}^{-1}$	$\omega = \frac{v}{r} = 2\pi f$		$T = 2\pi \sqrt{\frac{m}{k}}$	
the Boltzmann constant	$k$	$1.38 \times 10^{-23}$	$\text{J K}^{-1}$	$a = \frac{v^2}{r} = r\omega^2$		$T = 2\pi \sqrt{\frac{L}{g}}$	
the Stefan constant	$\sigma$	$5.67 \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$	$I = \sum mr^2$		$\lambda = \frac{\omega S}{D}$	
the Wien constant	$\alpha$	$2.90 \times 10^{-3}$	m K	$E_k = \frac{1}{2} I\omega^2$		$d \sin \theta = n\lambda$	
electron rest mass	$m_e$	$9.11 \times 10^{-31}$	kg	$\omega_2 = \omega_1 + at$		$\theta \approx \frac{\lambda}{D}$	
(equivalent to $5.5 \times 10^{-4}u$ )				$\theta = \omega_1 t + \frac{1}{2} at^2$		$n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$	
electron charge/mass ratio	$em_e$	$1.76 \times 10^{11}$	$\text{C kg}^{-1}$	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$		$n_2 = \frac{n_2}{n_1}$	
proton rest mass	$m_p$	$1.67 \times 10^{-27}$	kg	$\theta = \frac{1}{2} (\omega_1 + \omega_2)t$		$\sin \theta_c = \frac{1}{n}$	
(equivalent to 1.00728u)				$T = I\alpha$		$E = hf$	
proton charge/mass ratio	$em_p$	$9.58 \times 10^7$	$\text{C kg}^{-1}$	$\text{angular momentum} = I\omega$		$hf = \phi + E_k$	
neutron rest mass	$m_n$	$1.67 \times 10^{-27}$	kg	$W = T\theta$		$hf = E_1 - E_2$	
(equivalent to 1.00867u)				$P = T\omega$		$\lambda = \frac{h}{p} = \frac{h}{mv}$	
gravitational field strength	$g$	9.81	$\text{N kg}^{-1}$	$\text{angular impulse} = \text{change of angular momentum} = Tt$		$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$	
acceleration due to gravity	$g$	9.81	$\text{m s}^{-2}$	$\Delta Q = \Delta U + \Delta W$		<b>Electricity</b>	
atomic mass unit	$u$	$1.661 \times 10^{-27}$	kg	$\Delta W = p\Delta V$		$\epsilon = \frac{E}{Q}$	
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$		$\epsilon = I(R+r)$	
<b>Fundamental particles</b>				$\text{work done per cycle} = \text{area of loop}$		$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$	
Class	Name	Symbol	Rest energy /MeV	$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$		$R_T = R_1 + R_2 + R_3 + \dots$	
photon	photon	$\gamma$	0	$\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$		$P = I^2 R$	
lepton	neutrino	$\nu_e$	0	$\text{friction power} = \text{indicated power} - \text{brake power}$		$E = \frac{F}{Q} = \frac{V}{d}$	
		$\nu_\mu$	0	$\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$		$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$	
	electron	$e^\pm$	0.510999	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$		$E = \frac{1}{2} QV$	
	muon	$\mu^\pm$	105.659			$F = BI$	
mesons	pion	$\pi^\pm$	139.576			$F = BQv$	
		$\pi^0$	134.972			$Q = Q_0 e^{-t/RC}$	
	kaon	$K^\pm$	493.821			$\Phi = BA$	
		$K^0$	497.762				
baryons	proton	p	938.257				
	neutron	n	939.551				
<b>Properties of quarks</b>							
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				
<b>Geometrical equations</b>							
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 = $\frac{4}{3}\pi r^3$							

Turn over ►

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

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

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

### Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

$$pV = \frac{1}{3} Nmc^2$$

$$\frac{1}{2} mc^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$$

### Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

$$\text{work done} = eV$$

$$F = 6\pi\eta rv$$

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

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

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

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

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

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

$$E = mc^2 = \frac{m_0 c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

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

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

### Astrophysics and Medical Physics

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

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

### Medical Physics

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

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

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

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

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

### 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

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

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

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

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

#### Alternating Currents

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

#### Operational amplifier

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

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

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

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

**Turn over for the first question**

**Turn over ▶**

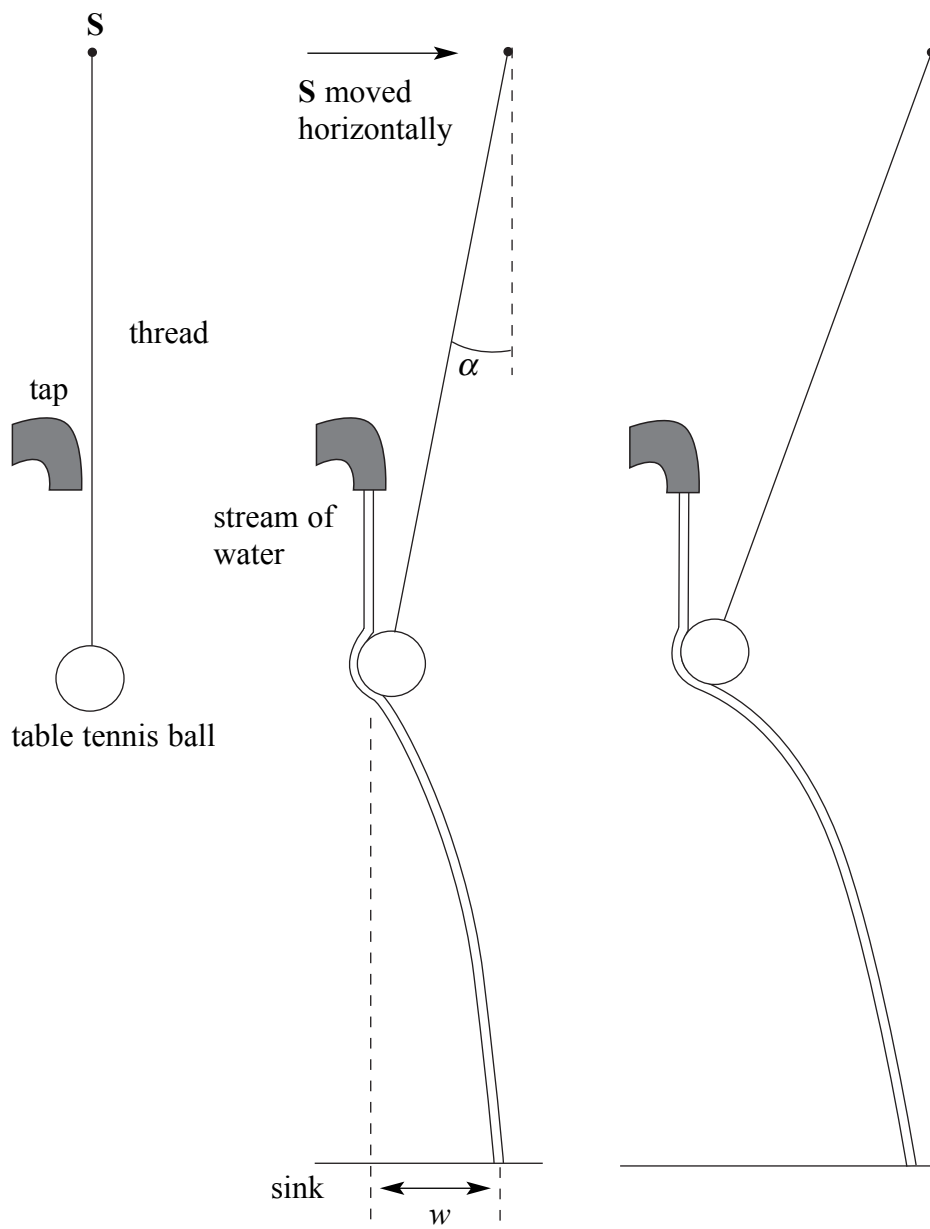
Answer **all** questions.

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

- 1 Two physics students are shown an experiment in which a table tennis ball, suspended by a thread from a point **S**, is positioned under a vertical stream of water falling into a sink. When **S** is moved horizontally the ball remains under the stream. The sideways force pushing the ball towards the stream arises because the water flowing around the surface of the ball is accelerated.

As **S** is moved further in the same direction, the inclination of the thread to the vertical,  $\alpha$ , and the horizontal displacement of the water stream at the sink,  $w$ , both increase, as shown in **Figure 1**.

**Figure 1**



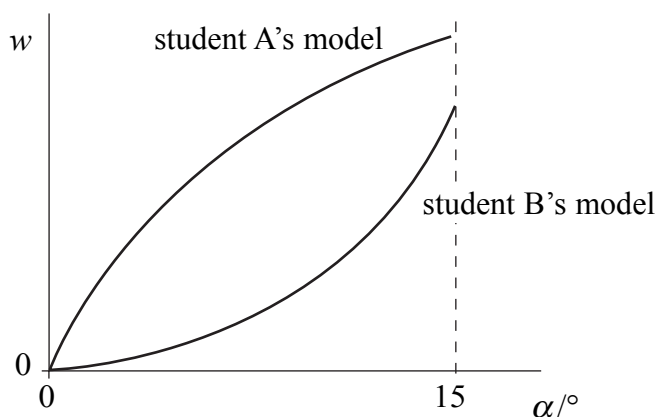
The students each use a computer to model the situation and to predict how  $w$  depends on  $\alpha$ . Both models show that for the water streams that can be produced in their laboratory, the largest value of  $\alpha$  will be no greater than  $15^\circ$ .

Student A's model shows  $w$  increasing at a decreasing rate as  $\alpha$  is increased.

Student B's model shows  $w$  increasing at an increasing rate as  $\alpha$  is increased.

These predictions are shown in **Figure 2**.

**Figure 2**



Design an experiment that the students could perform to discover if the predictions made by either of their computer models are accurate.

You should assume that the normal laboratory apparatus used in schools and colleges is available to the students.

- Identify the quantities you intend to measure and explain how you will measure them. You may wish to use the space below to draw a diagram to illustrate this part of your answer.
- Explain how you propose to use your measurements to determine whether either computer model correctly shows how  $w$  depends on  $\alpha$ .
- List any factors 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 answer to Question 1 on pages 8 and 9 of this booklet.

(8 marks)

Turn over ►





Blank writing area with horizontal dotted lines.

- 2 For Question 2, there is an A3 sheet, (INSERT TO PHA3/P/TN), provided. This sheet will not be sent to the examiner but should be left with the paper at the end of the examination. If you require a further copy of this sheet, ask the supervisor.

You are to investigate the deviation of a light ray passing through a semicircular transparent block.

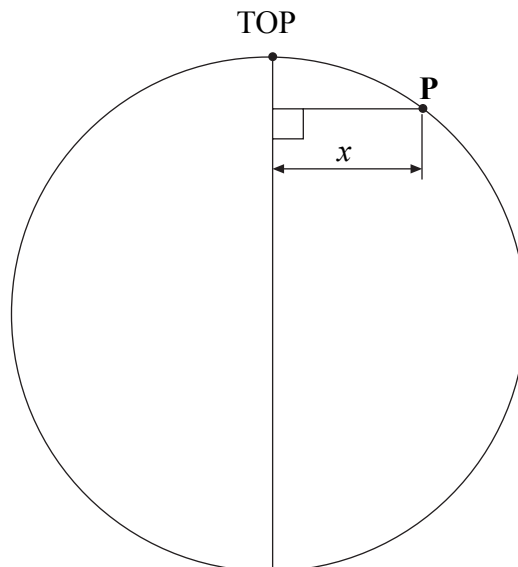
- (a) You are provided with a large sheet of paper showing a diagram of a circle. A diameter of the circle has been marked on the diagram.

- (i) Measure and record below the diameter,  $D$ , of this circle.

$D = \dots\dots\dots$

- (ii) With the point marked TOP furthest from you, measure and record the perpendicular distance,  $x$ , between the point **P** on the circle and the marked diameter, as shown in **Figure 3**.

**Figure 3**

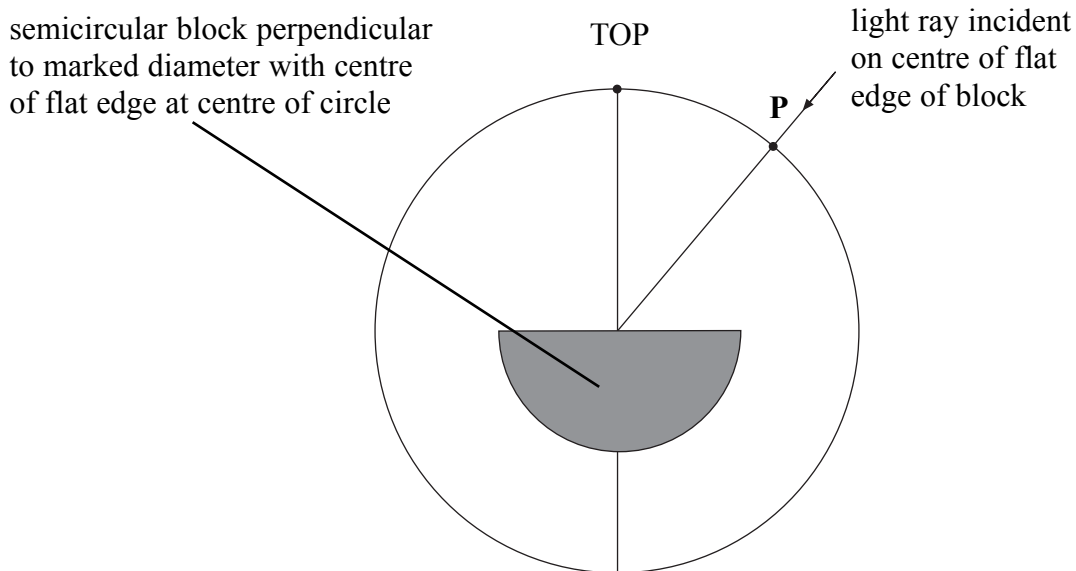


$x = \dots\dots\dots$

(2 marks)

- (b) Position the semicircular block as shown in **Figure 4** so that the centre of the flat edge of the block is perpendicular to the marked diameter. Adjust the position of the block until the centre of the flat edge of the block is at the centre of the circle.

**Figure 4**



Position the ray box so that a ray of light passes through point **P** and is then incident on the centre of the flat edge of the block.

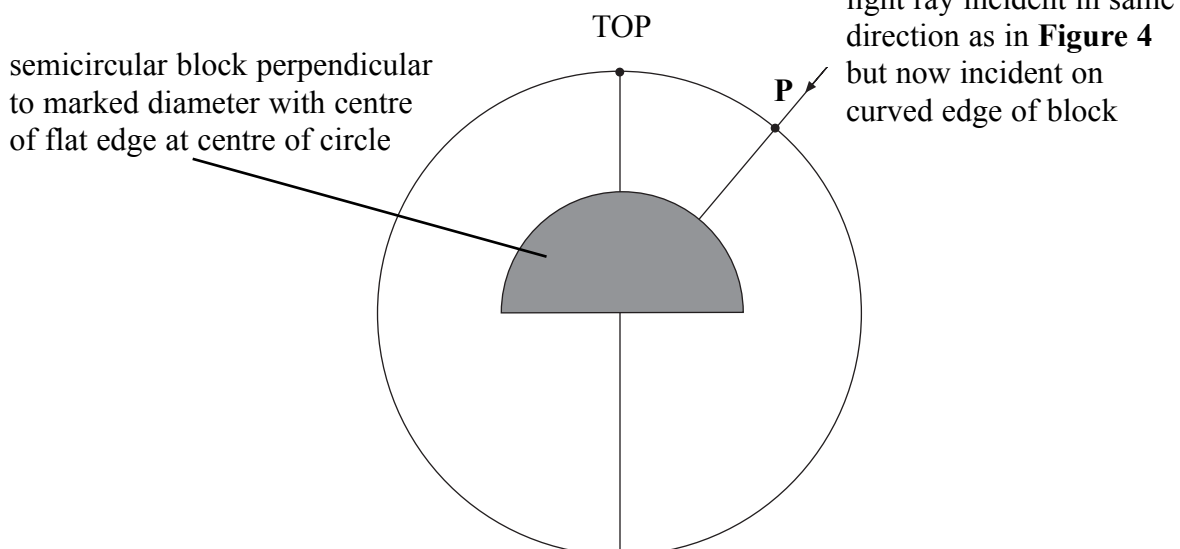
Mark on the diagram the path of the ray emerging from the curved edge of the block. Extend this line to reach the circle.

Measure and record the perpendicular distance,  $y$ , between the point where the emergent ray reaches the circle and the marked diameter.

$$y = \dots\dots\dots$$

Rotate the block to the position shown in **Figure 5**. Note that the centre of the flat edge of the block should still be perpendicular to the marked diameter and the centre of the flat edge of the block should remain at the centre of the circle.

**Figure 5**



Question 2 continues on the next page

Turn over ►

Mark on the diagram the path of the ray emerging from the flat edge of the block. Extend this line to reach the circle. Measure and record the perpendicular distance,  $z$ , between the point where the emergent ray reaches the circle and the marked diameter.

$$z = \dots\dots\dots$$

Replace the block as in **Figure 4** and reposition the ray box so that the ray of light now enters the circle **between** point **P** and the point marked TOP on the marked diameter. Ensure that the ray is once again incident on the centre of the flat edge of the block. Repeating the procedure as before, measure and record additional values of  $y$  corresponding to **five smaller** values of  $x$ . Reposition the block as in **Figure 5** and repeat the procedure to measure and record values of  $z$  corresponding to the **same five smaller** values of  $x$ . You may ask the supervisor for additional sheets of paper, if required.

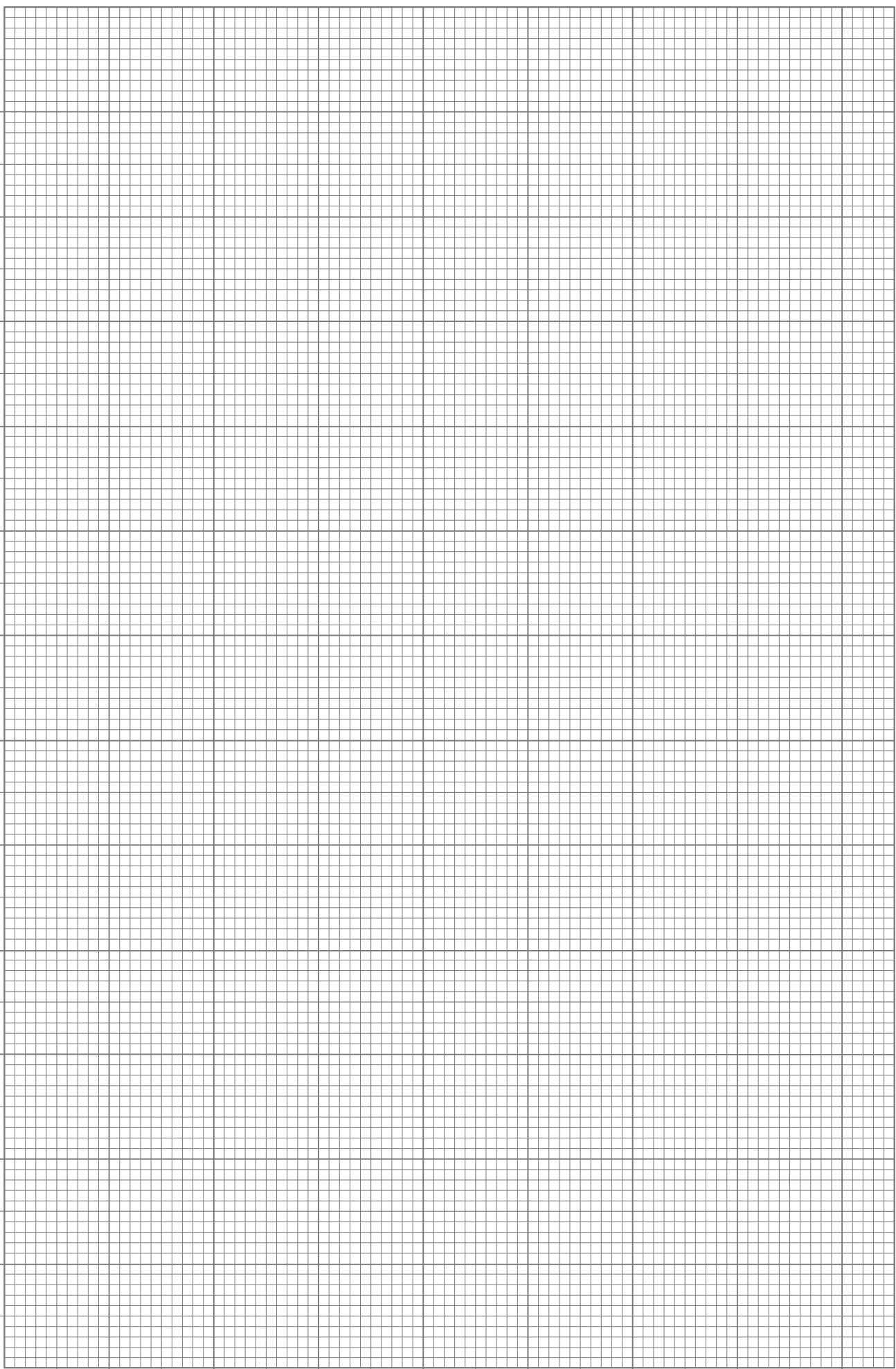
Record all your measurements and observations below.

(6 marks)

- (c) Using the grid on **page 13**, plot a graph with  $z$  on the vertical axis and  $y$  on the horizontal axis. (5 marks)

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

$$G = \dots\dots\dots \quad (3 \text{ marks})$$



- (e) (i) Explain the procedure you used to position the semicircular block as in **Figure 4**.

.....

.....

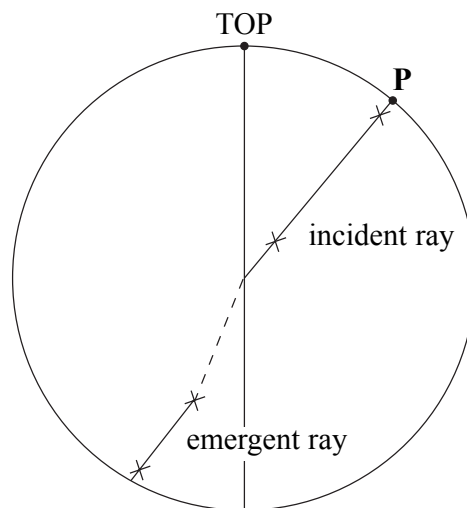
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- (ii) A student, performing the experiment, attempts to arrange the block as shown in **Figure 4**, so that light passes in through the flat edge and traces the paths of the incident and emergent rays to and from the block. When the block is removed, the student draws a line (shown dotted in **Figure 6**) to join the incident and emergent rays.

**Figure 6**



Assuming that the block was of constant radius, state and explain the mistake the student has made.

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(6 marks)

**END OF QUESTIONS**

**There are no questions printed on this page**

**There are no questions printed on this page**



General Certificate of Education  
January 2006

**PHYSICS (SPECIFICATION A)  
Practical (Unit 3)**

**Insert**

**PHA3/P**



**For use in Question 2**

**For use in Question 2**

