

Surname						Other Names					
Centre Number						Candidate Number					
Candidate Signature											

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General Certificate of Education  
 June 2004  
 Advanced Subsidiary Examination



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

**PHA3/P**

Wednesday 19 May 2004 Morning Session

**In addition to this paper you will require:**

- a calculator;
- a pencil and a 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 in the spaces provided. All working must be shown.
- 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.
- Mark allocations are shown in brackets.
- The paper carries 15% of the total marks for Physics Advanced Subsidiary and carries 7½% of the total marks for the Physics Advanced.
- 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.

**Fundamental constants and values**

Quantity	Symbol	Value	Units
speed of light in vacuo	$c$	$3.00 \times 10^8$	$\text{m s}^{-1}$
permeability of free space	$\mu_0$	$4\pi \times 10^{-7}$	$\text{H m}^{-1}$
permittivity of free space	$\epsilon_0$	$8.85 \times 10^{-12}$	$\text{F m}^{-1}$
charge of electron	$e$	$1.60 \times 10^{-19}$	C
the Planck constant	$h$	$6.63 \times 10^{-34}$	J s
gravitational constant	$G$	$6.67 \times 10^{-11}$	$\text{N m}^2 \text{kg}^{-2}$
the Avogadro constant	$N_A$	$6.02 \times 10^{23}$	$\text{mol}^{-1}$
molar gas constant	$R$	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
the Boltzmann constant	$k$	$1.38 \times 10^{-23}$	$\text{J K}^{-1}$
the Stefan constant	$\sigma$	$5.67 \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$
the Wien constant	$\alpha$	$2.90 \times 10^{-3}$	m K
electron rest mass	$m_e$	$9.11 \times 10^{-31}$	kg
(equivalent to $5.5 \times 10^{-4}\text{u}$ )			
electron charge/mass ratio	$e/m_e$	$1.76 \times 10^{11}$	$\text{C kg}^{-1}$
proton rest mass	$m_p$	$1.67 \times 10^{-27}$	kg
(equivalent to 1.00728u)			
proton charge/mass ratio	$e/m_p$	$9.58 \times 10^7$	$\text{C kg}^{-1}$
neutron rest mass	$m_n$	$1.67 \times 10^{-27}$	kg
(equivalent to 1.00867u)			
gravitational field strength	$g$	9.81	$\text{N kg}^{-1}$
acceleration due to gravity	$g$	9.81	$\text{m s}^{-2}$
atomic mass unit	$u$	$1.661 \times 10^{-27}$	kg
(1u is equivalent to 931.3 MeV)			

**Fundamental particles**

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

$$\text{arc length} = r\theta$$

$$\text{circumference of circle} = 2\pi r$$

$$\text{area of circle} = \pi r^2$$

$$\text{area of cylinder} = 2\pi rh$$

$$\text{volume of cylinder} = \pi r^2 h$$

$$\text{area of sphere} = 4\pi r^2$$

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

**Mechanics and Applied Physics**

$$v = u + at$$

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

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

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

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

$$P = Fv$$

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

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

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

$$I = \sum mr^2$$

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

$$\omega_2 = \omega_1 + at$$

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

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

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

$$T = I\alpha$$

$$\text{angular momentum} = I\omega$$

$$W = T\theta$$

$$P = T\omega$$

$$\text{angular impulse} = \text{change of angular momentum} = Tt$$

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

$$\Delta W = p\Delta V$$

$$pV^\gamma = \text{constant}$$

$$\text{work done per cycle} = \text{area of loop}$$

$$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$$

$$\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$$

$$\text{friction power} = \text{indicated power} - \text{brake power}$$

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

$$\text{maximum possible}$$

$$\text{efficiency} = \frac{T_H - T_C}{T_H}$$

**Fields, Waves, Quantum Phenomena**

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

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

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

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

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

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

$$x = A \cos 2\pi ft$$

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

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

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

$$d \sin \theta = n\lambda$$

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

$$n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$$

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

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

$$E = hf$$

$$hf = \phi + E_k$$

$$hf = E_1 - E_2$$

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

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

**Electricity**

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

$$\epsilon = I(R + r)$$

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

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

$$P = I^2 R$$

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

$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$$

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

$$F = BIl$$

$$F = BQv$$

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

$$\Phi = BA$$

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

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

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

### Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

### 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	$6.00 \times 10^{24}$	$6.40 \times 10^6$

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

### 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

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

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

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

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

Answer **both** questions.

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

- 1 The resistance experienced by an object moving through a liquid is caused by a property of the liquid called *viscosity*. If a ball bearing of density,  $\rho_{\text{bb}}$ , falls through a viscous liquid it will quickly reach terminal velocity,  $v$ .

It can be shown that if the diameter of the ball bearing is much less than the diameter of the container through which it falls, the coefficient of viscosity,  $\eta$ , of the liquid, is given by

$$\eta = k \frac{(\rho_{\text{bb}} - \rho_0)}{v} ,$$

where  $\rho_0$  is the density of the liquid and  $k$  is a constant that depends on the ball bearing used. For a particular type of ball bearing **the values of  $\rho_{\text{bb}}$  and  $k$  are known.**

The viscosity of some oils is known to change very rapidly with the temperature of the oil.

Design an experiment to determine how the coefficient of viscosity of a certain type of oil changes with temperature in the range 20 °C to 90 °C.

The density,  $\rho_{\text{bb}}$ , of the ball bearing will not vary significantly over this temperature range but **this will not be the case for the density,  $\rho_0$ , of the oil.**

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

You may wish to use a diagram to illustrate your solution to this problem.

You should also include the following in your answer:

- The quantities you intend to measure and how you will measure them.
- How you propose to use your measurements to obtain reliable results for the coefficient of viscosity of the oil.
- The factors you will need to control and how you will do this.
- How you could overcome any difficulties in obtaining reliable results.

Write your answers to Question 1 on **pages 6 and 7** of this booklet.

(8 marks)

A series of horizontal dotted lines for writing, spanning the width of the page.

Handwriting practice area with 25 horizontal dotted lines.

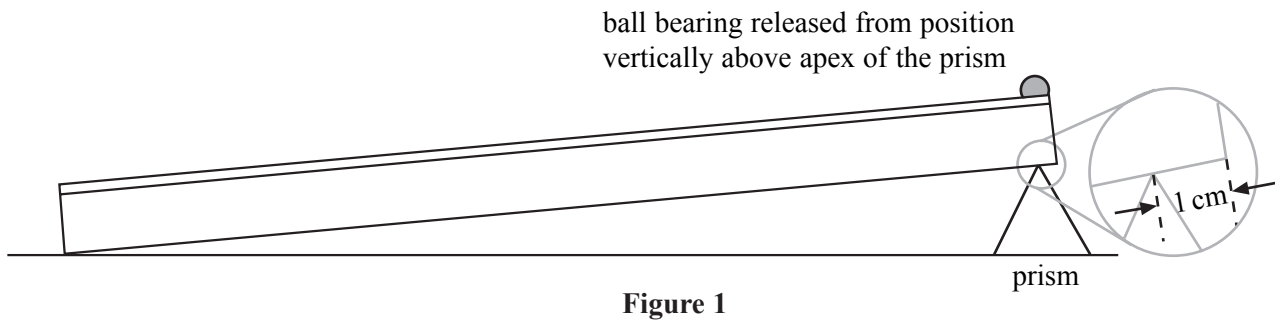


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- 2 In this experiment you are required to investigate how the time for a ball bearing rolling down an inclined track, consisting of a pair of parallel rails, varies as the slope of the track is changed. **No description of the experiment is required.**

- (a) You are provided with two ball bearings of different diameters. Position the apex of the prism approximately 1 cm from the right-hand end of the track, as shown in **Figure 1**. Place the ball bearing of **larger** diameter vertically above the apex of the prism.



- (i) Release the ball bearing from rest and at the same time start the stopwatch. Measure and record the time,  $t_1$ , for this ball bearing to roll to the end of the inclined track.

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$t_1 =$  .....

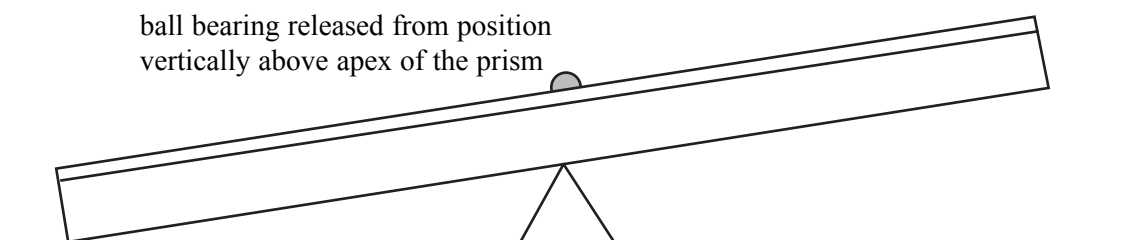
- (ii) Repeat the procedure using the ball bearing of **smaller** diameter. Measure and record the time,  $t_2$ , for this ball bearing to roll to the end of the inclined track.

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$t_2 =$  .....

(1 mark)

- (b) Using the arrangement shown in **Figure 1**, a student measures the time for a particular ball bearing to roll to the end of the track.  
Realising that moving the prism will change the slope of the inclined track, the student rearranges the apparatus with the prism close to the middle of the track, as shown in **Figure 2**. This produces the largest possible slope of the inclined track.



**Figure 2**

Releasing the ball bearing from a position vertically above the apex of the prism as before, the student measures the new time for the ball bearing to reach the end of the track.  
The student claims that the results produced by these measurements show that if the ball bearing rolls a distance,  $s$ , along the inclined track to the end, then

$$t \propto s,$$

where  $t$  is the time for the ball bearing to reach the end of the inclined track.

Carry out an experiment to test this theory. Find values of  $s$  and  $t$  for different slopes of the inclined track. The limiting positions are shown in **Figure 1** and **Figure 2**.

You should carry out the experiment using the ball bearing that, **in your opinion**, will provide the more reliable results for the experiment.

Record your measurements and observations below.

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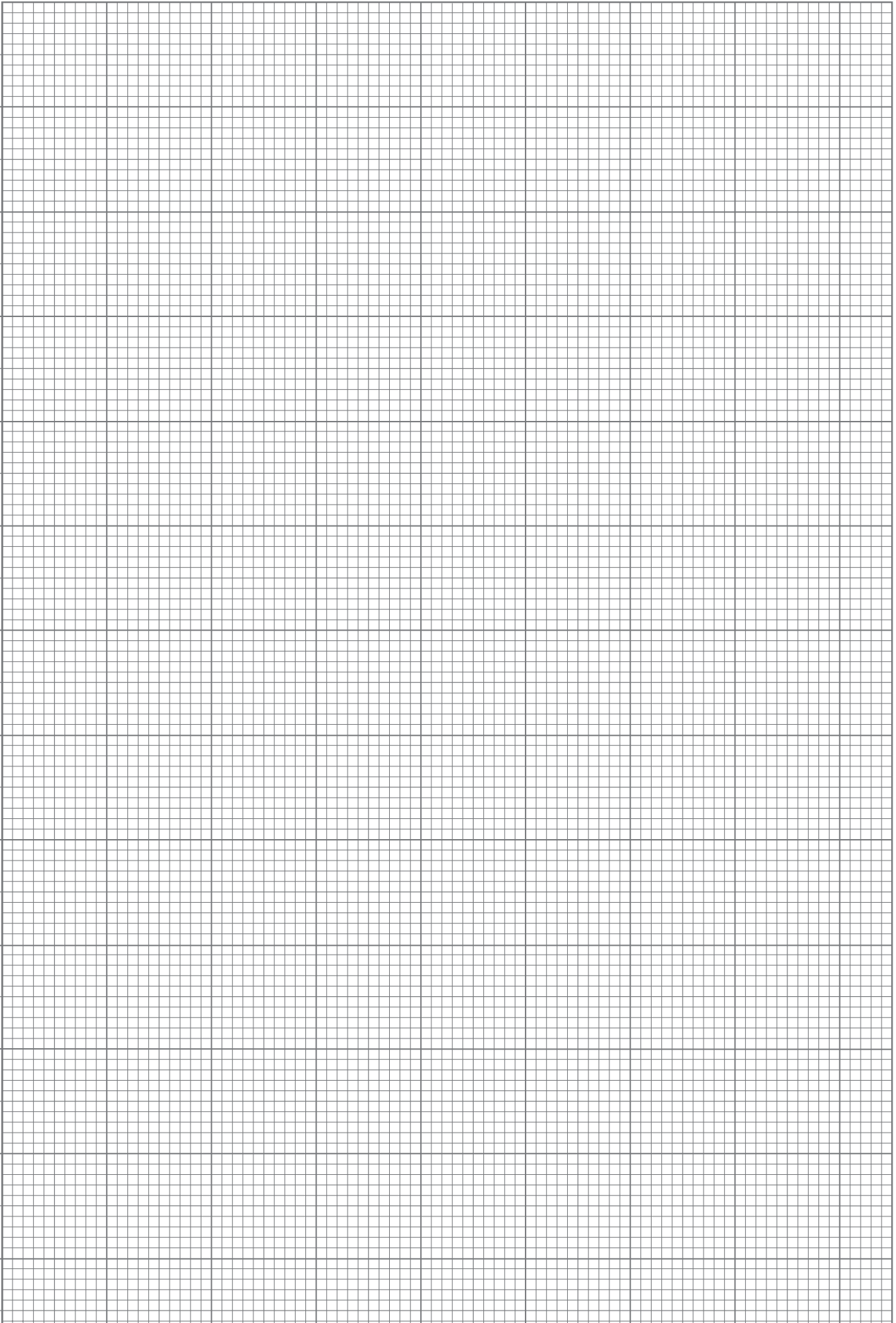
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(7 marks)

- (c) Using the grid on **page 11** of this booklet, plot a suitable graph to test this theory.

(5 marks)



(d) (i) Explain whether the graph you have drawn confirms the student's theory that  $t \propto s$ .

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(ii) In part (a) of the question you measured the times,  $t_1$  and  $t_2$ , for the larger and smaller ball bearings.

Assuming that the student's theory was correct, deduce the length of track that would be required to make the difference between  $t_1$  and  $t_2$  equal to 1.0 s.

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(3 marks)

(e) (i) In part (b) of the question you were instructed to use the ball bearing that, **in your opinion**, would provide the more reliable results for the experiment. State and explain the choice you made about which ball bearing to use.

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(ii) Describe **two additional** precautions you took to reduce the uncertainty in your measurements of  $t$ .

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- (ii) The student's theory assumes that for a track of constant slope, the ball bearing travels down the slope with uniform acceleration.  
Explain, with the aid of a diagram if you wish, how you could test whether this assumption is correct.

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(6 marks)

22

**END OF QUESTIONS**

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