

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
 June 2005
 Advanced Subsidiary Examination



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

PHA3/P

Wednesday 18 May 2005 Morning Session

In addition to this paper you will require:

- a calculator;
- a pencil and a ruler.

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

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.

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	3.00×10^8	m s^{-1}
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}
charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass	m_e	9.11×10^{-31}	kg
(equivalent to $5.5 \times 10^{-4} \text{u}$)			
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}
proton rest mass	m_p	1.67×10^{-27}	kg
(equivalent to 1.00728u)			
proton charge/mass ratio	e/m_p	9.58×10^7	C kg^{-1}
neutron rest mass	m_n	1.67×10^{-27}	kg
(equivalent to 1.00867u)			
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	m s^{-2}
atomic mass unit	u	1.661×10^{-27}	kg
(1u is equivalent to 931.3 MeV)			

Fundamental particles

Class	Name	Symbol	Rest energy /MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	e^\pm	0.510999
	muon	μ^\pm	105.659
mesons	pion	π^\pm	139.576
		π^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

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

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

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

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

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

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

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

Mechanics and Applied Physics

$$v = u + at$$

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

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

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

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

$$P = Fv$$

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

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

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

$$I = \sum mr^2$$

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

$$\omega_2 = \omega_1 + at$$

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

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

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

$$T = I\alpha$$

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

$$W = T\theta$$

$$P = T\omega$$

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

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

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

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

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

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

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

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

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

$$\text{maximum possible}$$

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

Fields, Waves, Quantum Phenomena

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

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

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

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

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

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

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

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

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

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

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

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

$$n_1 \lambda_1 = n_2 \lambda_2 = \frac{c_1}{c_2}$$

$$n_1 \lambda_1 = \frac{n_2}{n_1}$$

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

$$E = hf$$

$$hf = \phi + E_k$$

$$hf = E_1 - E_2$$

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

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

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	2.00×10^{30}	7.00×10^8
Earth	6.00×10^{24}	6.40×10^6

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

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

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

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

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

$$X_C = \frac{1}{2\pi f C}$$

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 An aerosol spray can produces paint droplets which have a range of speeds. A student decides to use the apparatus illustrated in **Figure 1** to find the range of speed of the droplets.

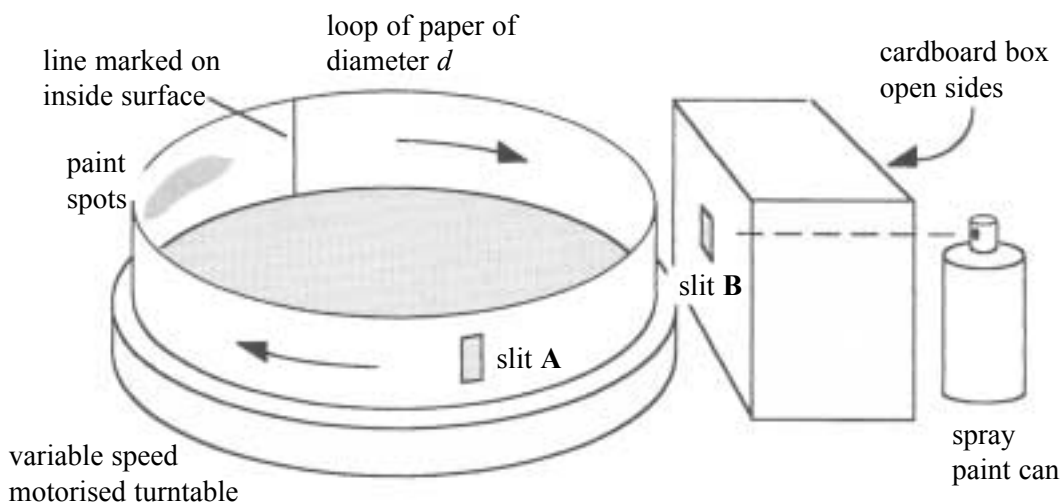


Figure 1

A strip of paper is made into a circular loop of diameter d and placed on a stationary variable speed motorised turntable. A slit, **A**, is made in the loop and directly opposite, a line is marked on the inside surface. The turntable is set in motion and reaches a steady rate of rotation.

When paint is sprayed into the open side of the cardboard box some of the paint passes through slit **A** when this becomes aligned with slit **B** and a pattern of paint spots appears on the inside of the loop. The paper loop is removed from the turntable and laid on a flat surface with the pattern of paint spots uppermost, as shown in **Figure 2**.

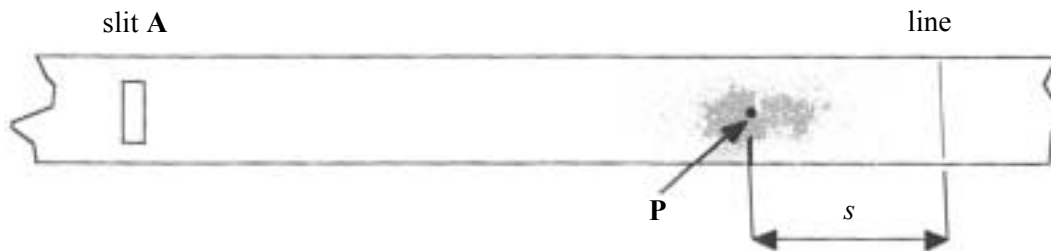


Figure 2

The student deduces that the time, t , for the particular paint spot, **P**, to have travelled across the diameter of the loop, d , is given by

$$t = \frac{sT}{\pi d}.$$

T is the time for one rotation of the turntable and s is the distance between paint spot **P** and the line marked on the inside surface of the loop, as defined in **Figure 2**.

Design an experiment to enable the student to find the range of speed of the droplets in the paint spray.

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

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 range of speeds of the droplets in the paint spray.
- 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 answer to Question 1 on **pages 7 and 8** of this booklet.

(8 marks)

Handwriting practice area with 20 horizontal dotted lines.

Handwriting practice area with horizontal dashed lines.

- 2 In this experiment you are required to investigate currents and voltages in a circuit containing two power supplies, E_1 and E_2 , the negative terminals of which are joined together.
No description of the experiment is required.

You are provided with the partly completed circuit shown in **Figure 3**.

Terminal **A** is connected to the positive side of E_1 and terminal **B** is connected to the positive side of E_2 .

The positive lead of the voltmeter should be **permanently connected** to terminal **A** throughout the experiment.

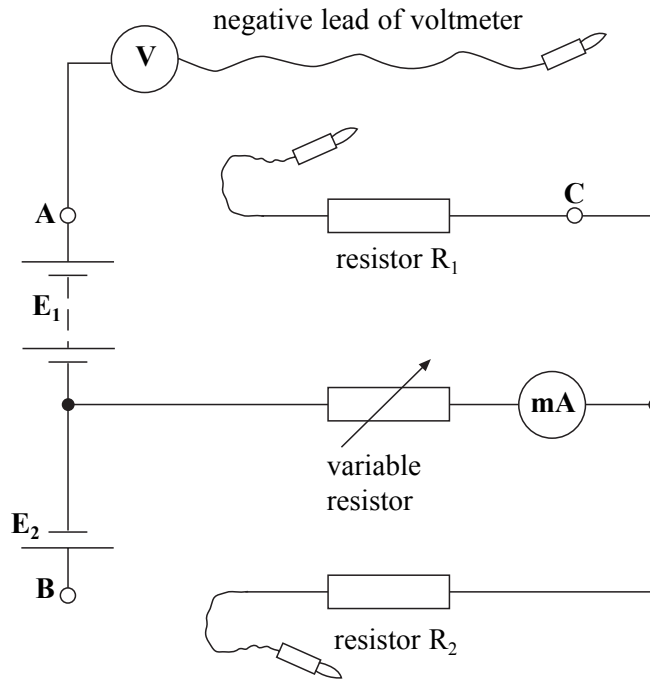


Figure 3

- (a) Connect the negative lead of the voltmeter to terminal **B**.
Read and record the voltmeter reading V_{AB} .

$$V_{AB} = \dots\dots\dots$$

(1 mark)

- (b) **Figure 3** shows flying leads joined to the resistors R_1 and R_2 .
Connect the flying lead joined to R_1 to terminal **A**.
Connect the flying lead joined to R_2 to terminal **B**.
Connect the negative lead of the voltmeter to terminal **C**.
Adjust the setting of the variable resistor until the voltmeter reading V_{AC} is at a minimum.
Read and record V_{AC} and the milliammeter reading, I .
By adjusting the setting of the variable resistor, read and record further readings of V_{AC} and I up to and including the maximum values that can be obtained.
Record all your measurements in the space provided on page 10.

Measurements and observations.

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(7 marks)

(c) Using the grid on page 11 of this booklet plot a graph of your results with V_{AC} on the vertical axis and I on the horizontal axis.

(5 marks)

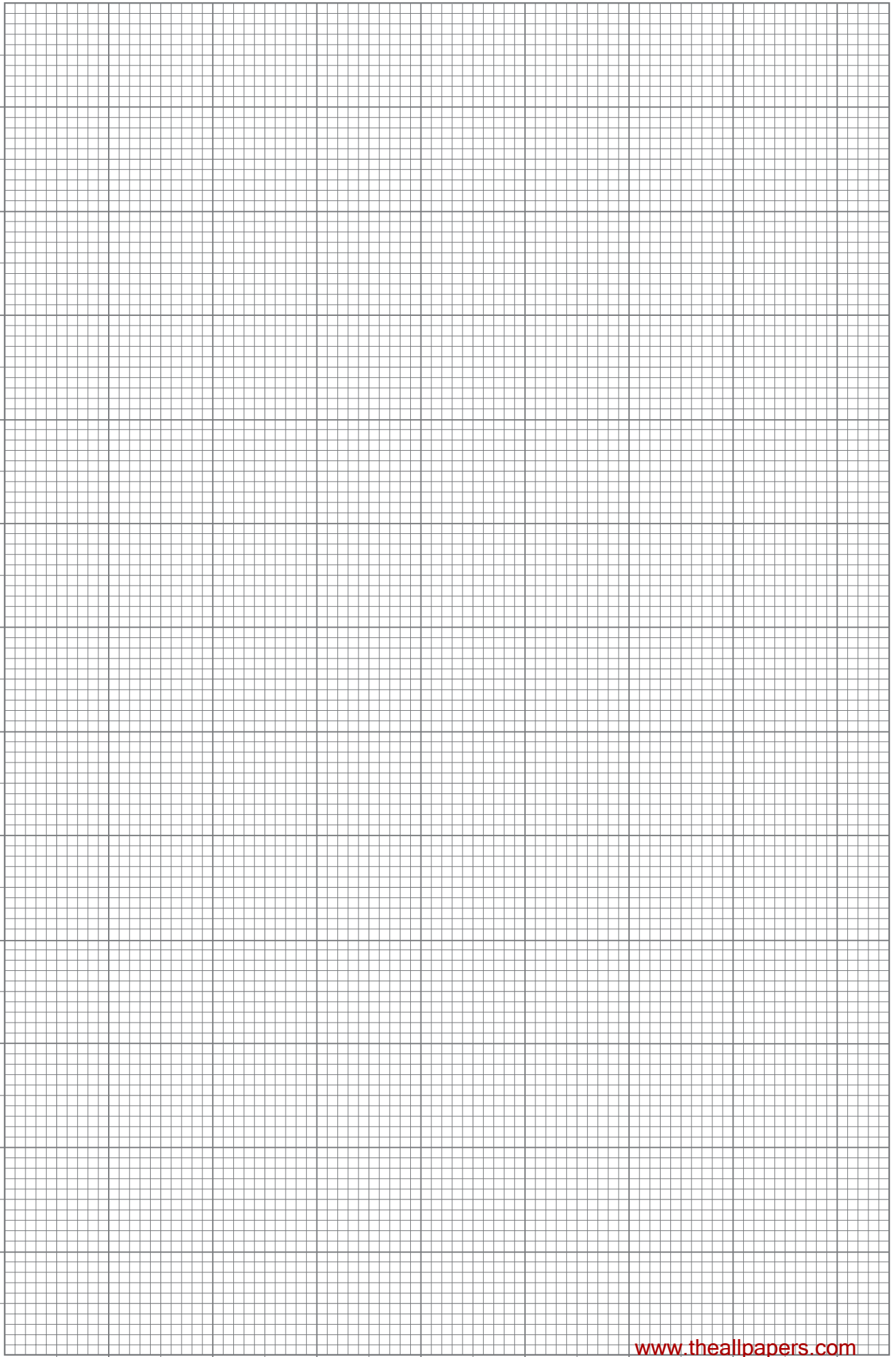
(d) (i) Read and record the intercept, V_0 , on the vertical axis of your graph.

$$V_0 = \dots\dots\dots$$

(ii) Evaluate $\frac{V_{AB}}{V_0}$.

$$\frac{V_{AB}}{V_0} = \dots\dots\dots$$

(3 marks)



- (e) Student A produces a graph with a conventional origin, as shown in **Figure 4**. Student B produces the graph with a false origin on the **vertical axis**, as shown in **Figure 5**. Explain how the graph drawn by student B reduces the uncertainty in V_0 .

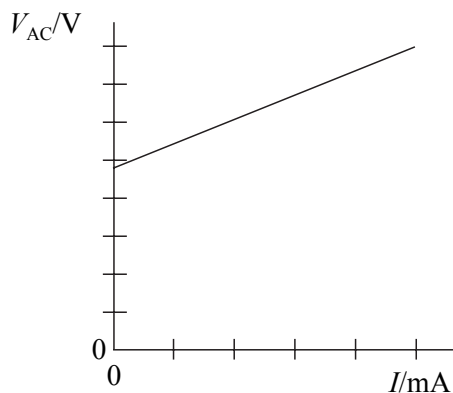


Figure 4

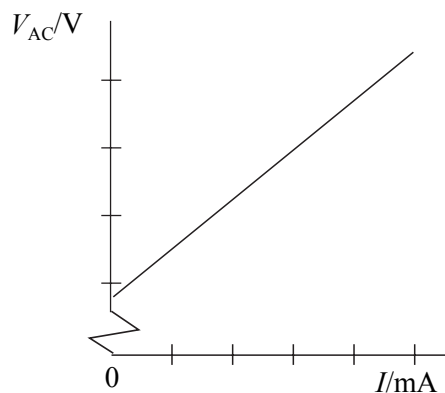


Figure 5

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(1 mark)

- (f) What evidence does the experiment provide that current through resistor R_1 is always in the direction from terminal **A** to terminal **C**?

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(1 mark)

(g) The voltage, V_{AC} , across resistor R_1 determines the **direction** of the current through resistor R_2 .
When V_{AC} is **greater than** V_{AB} the current direction through R_2 is away from terminal **B**.
When V_{AC} is **less than** V_{AB} the current direction through R_2 is towards terminal **B**.

(i) What can you say about the current in resistor R_2 when V_{AC} **is the same as** V_{AB} .

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(ii) Read from your graph the millimeter reading when $V_{AC} = V_{AB}$.

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(iii) By considering your answers to part (g)(i) and part (g)(ii), deduce the current through resistor R_1 when $V_{AC} = V_{AB}$.

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(iv) Deduce the resistance of resistor R_1 .

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(4 marks)

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END OF QUESTIONS

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