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

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General Certificate of Education
 June 2006
 Advanced Subsidiary Examination



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

PHA3/P

Wednesday 17 May 2006 9.00 am to 10.45 am

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| <p>For this paper you must have:</p> <ul style="list-style-type: none"> • 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 **all** questions.
- Answer the 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 | | | | Mechanics and Applied Physics | | Fields, Waves, Quantum Phenomena | |
|---|----------------|-------------------------|-----------------------------------|--|---|----------------------------------|--|
| Quantity | Symbol | Value | Units | | | | |
| speed of light in vacuo | c | 3.00×10^8 | m s^{-1} | $v = u + at$ | $g = \frac{F}{m}$ | | |
| permeability of free space | μ_0 | $4\pi \times 10^{-7}$ | H m^{-1} | $s = \left(\frac{u+v}{2}\right)t$ | $g = -\frac{GM}{r^2}$ | | |
| permittivity of free space | ϵ_0 | 8.85×10^{-12} | F m^{-1} | $s = ut + \frac{at^2}{2}$ | $g = -\frac{\Delta V}{\Delta x}$ | | |
| charge of electron | e | 1.60×10^{-19} | C | $v^2 = u^2 + 2as$ | $V = -\frac{GM}{r}$ | | |
| the Planck constant | h | 6.63×10^{-34} | J s | $F = \frac{\Delta(mv)}{\Delta t}$ | $a = -(2\pi f)^2 x$ | | |
| gravitational constant | G | 6.67×10^{-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 | 6.02×10^{23} | 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 | 1.38×10^{-23} | J K^{-1} | $a = \frac{v^2}{r} = r\omega^2$ | $T = 2\pi\sqrt{\frac{L}{g}}$ | | |
| the Stefan constant | σ | 5.67×10^{-8} | $\text{W m}^{-2} \text{K}^{-4}$ | $I = \sum mr^2$ | $\lambda = \frac{ws}{D}$ | | |
| the Wien constant | a | 2.90×10^{-3} | m K | $E_k = \frac{1}{2} I\omega^2$ | $d \sin \theta = n\lambda$ | | |
| electron rest mass | m_e | 9.11×10^{-31} | kg | $\omega_2 = \omega_1 + at$ | $\theta \approx \frac{\lambda}{D}$ | | |
| (equivalent to $5.5 \times 10^{-4}u$) | | | | $\theta = \omega_1 t + \frac{1}{2} at^2$ | ${}^1n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$ | | |
| electron charge/mass ratio | e/m_e | 1.76×10^{11} | C kg^{-1} | $\omega_2^2 = \omega_1^2 + 2a\theta$ | ${}^1n_2 = \frac{n_2}{n_1}$ | | |
| proton rest mass | m_p | 1.67×10^{-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 | e/m_p | 9.58×10^7 | C kg^{-1} | $\text{angular momentum} = I\omega$ | $hf = \phi + E_k$ | | |
| neutron rest mass | m_n | 1.67×10^{-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 | 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 | m s^{-2} | $\Delta Q = \Delta U + \Delta W$ | | | |
| atomic mass unit | u | 1.661×10^{-27} | kg | $\Delta W = p\Delta V$ | | | |
| (1u is equivalent to 931.3 MeV) | | | | $pV^\gamma = \text{constant}$ | | | |
| Fundamental particles | | | | $\text{work done per cycle} = \text{area of loop}$ | Electricity | | |
| Class | Name | Symbol | Rest energy /MeV | $\text{input power} = \text{calorific value} \times \text{fuel flow rate}$ | $\epsilon = \frac{E}{Q}$ | | |
| photon | photon | γ | 0 | $\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$ | $\epsilon = I(R+r)$ | | |
| lepton | neutrino | ν_e | 0 | $\text{friction power} = \text{indicated power} - \text{brake power}$ | $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$ | | |
| | | ν_μ | 0 | $\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$ | $R_T = R_1 + R_2 + R_3 + \dots$ | | |
| | electron | e^\pm | 0.510999 | $\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$ | $P = I^2 R$ | | |
| | muon | μ^\pm | 105.659 | | $E = \frac{F}{Q} = \frac{V}{d}$ | | |
| mesons | pion | π^\pm | 139.576 | | $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$ | | |
| | | π^0 | 134.972 | | $E = \frac{1}{2} QV$ | | |
| | kaon | K^\pm | 493.821 | | $F = BIl$ | | |
| | | K^0 | 497.762 | | $F = BQv$ | | |
| baryons | proton | p | 938.257 | | $Q = Q_0 e^{-t/RC}$ | | |
| | neutron | n | 939.551 | | $\Phi = BA$ | | |
| 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 = πr^2 | | | | | | | |
| area of cylinder = $2\pi rh$ | | | | | | | |
| volume of cylinder = $\pi r^2 h$ | | | | | | | |
| area of sphere = $4\pi r^2$ | | | | | | | |
| volume of sphere = $\frac{4}{3}\pi r^3$ | | | | | | | |

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

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

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

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

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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 |

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

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

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

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

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

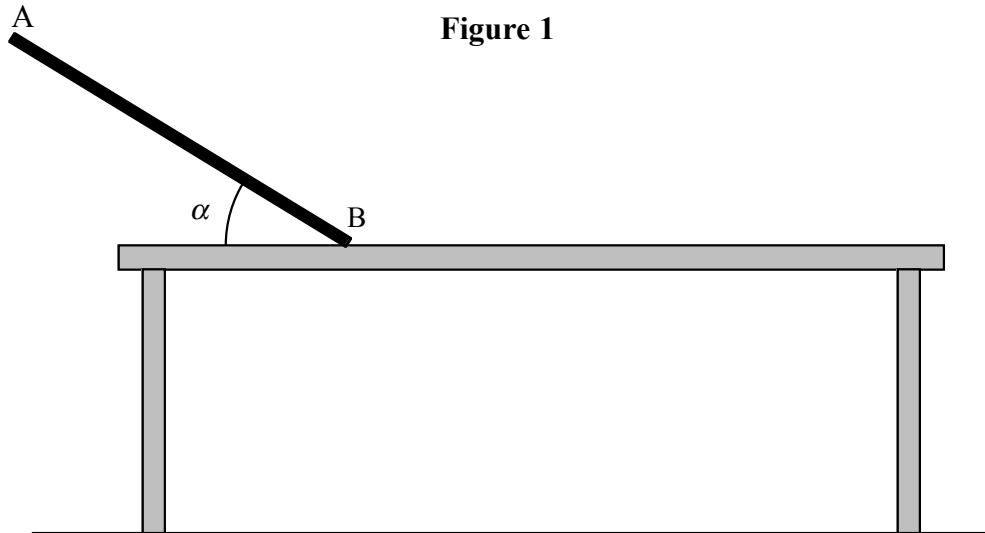
$$V_{\text{out}} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right) \quad \text{summing}$$

Turn over for the first question

Answer **both** questions.

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

- 1 A group of students is provided with a section of straight track, AB, about 1 m long. If the track is placed on the surface of a horizontal table and end A is raised, a ramp is produced forming an angle α between the track and the surface of the table, as shown in **Figure 1**.



A golf ball, released at A, rolls down the ramp to B and travels across the surface of the table.

Design an experiment that the students could perform to determine the value of the angle, α , for which the golf ball travels between B and the edge of the table in the **shortest** time.

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

In your answer you should:

- Identify the quantities the students should measure and explain how they should measure them. You may wish to draw a diagram to illustrate this part of your answer.
- Explain how the students should use these measurements to determine the angle, α , between AB and the surface of the table, for which the golf ball travels between B and the edge of the table in the **shortest** time.
- List any factors the students will need to control and explain how they would do this.
- Identify any difficulties the students might encounter in obtaining reliable results and explain how these could be overcome.

Write your answers to Question 1 on **pages 7 and 8** of this booklet.

(8 marks)

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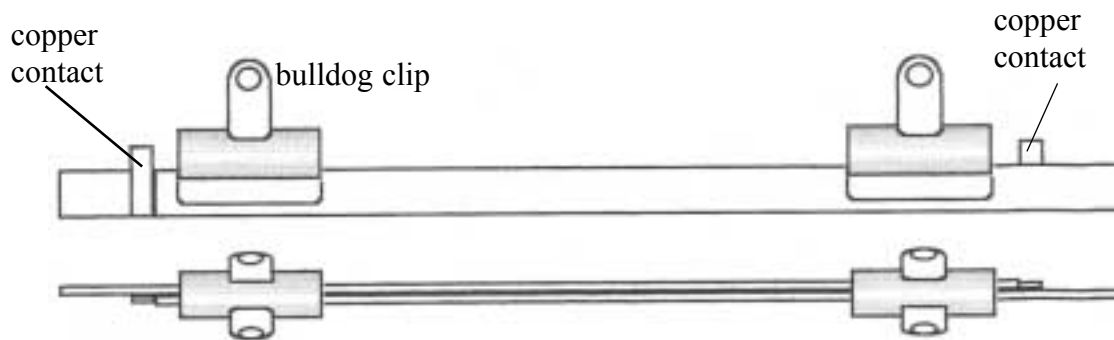
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Dotted lines for writing.

- 2 You are to investigate the characteristics of a circuit containing a resistor made from two rectangular pieces of paper that have electrically-conductive surfaces. The pieces of paper have identical dimensions and are mounted on strips of wood so their conductive surfaces can be placed in contact with each other. This arrangement is secured using bulldog clips and connections to the external circuit are made through copper contacts. Altering the contact area between conductive faces of the paper will change the resistance of this resistor.
- (a) The resistor has already been assembled with the area of contact between the conductive surfaces of the paper at a maximum. Views of the resistor from the side and from above are shown in **Figure 2**.

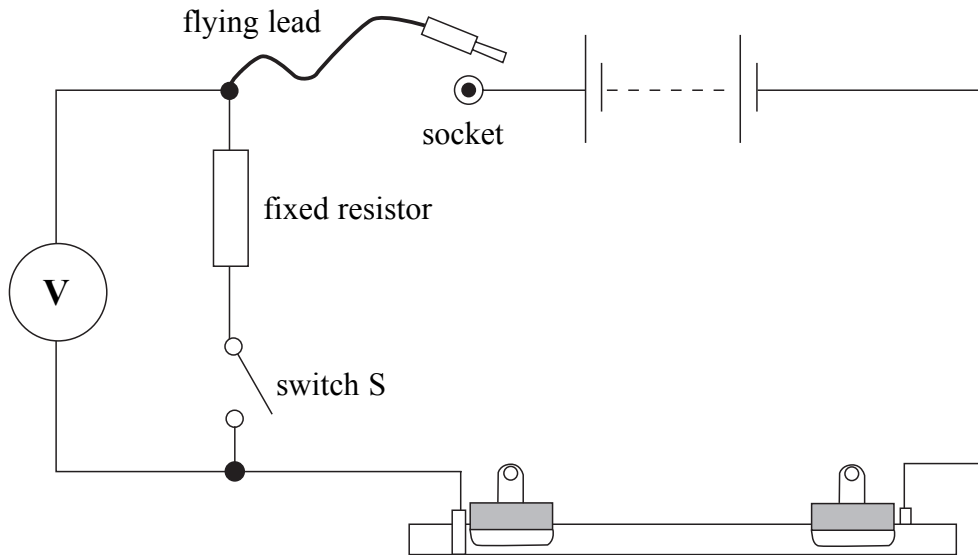
Figure 2



Question 2 continues on the next page

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

Figure 3



- (i) With switch S in the open (off) position, connect the flying lead to the socket. Read and record the voltmeter reading, E .

$$E = \dots\dots\dots$$

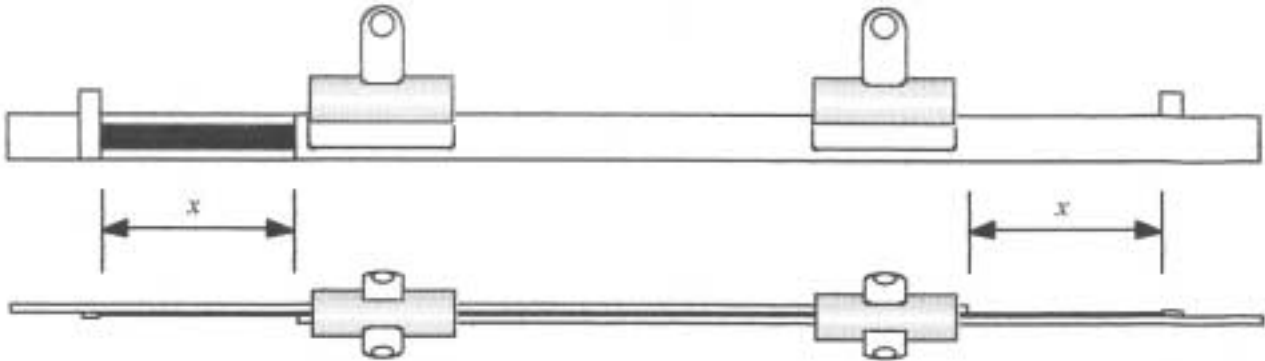
- (ii) Move switch S to the closed (on) position and then read and record the new voltmeter reading, V_0 .

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

(1 mark)

- (b) Disconnect the flying lead from the socket and remove the bulldog clips. Reassemble the variable resistor so the contact area between the conductive faces of the paper is reduced and the exposed length of each piece of paper, x , is about 5.0 cm. Replace the bulldog clips to secure this arrangement, as shown in **Figure 4**.

Figure 4



Reconnect the flying lead to the socket and ensure that the switch, S , remains in the closed (on) position.

Measure and record the distance, x , and the voltmeter reading, V .

Repeating the procedure as before, measure and record additional values of x and V corresponding to **four larger** values of x . Throughout part (b) ensure that the flying lead is disconnected before making changes to the variable resistor.

Record all your measurements and observations below.

(5 marks)

Question 2 continues on the next page

- (c) Using the grid on **page 13**, plot a graph with $\frac{E - V}{V}$ on the vertical axis and x on the horizontal axis.
Record below the data you will plot on your graph.

(7 marks)

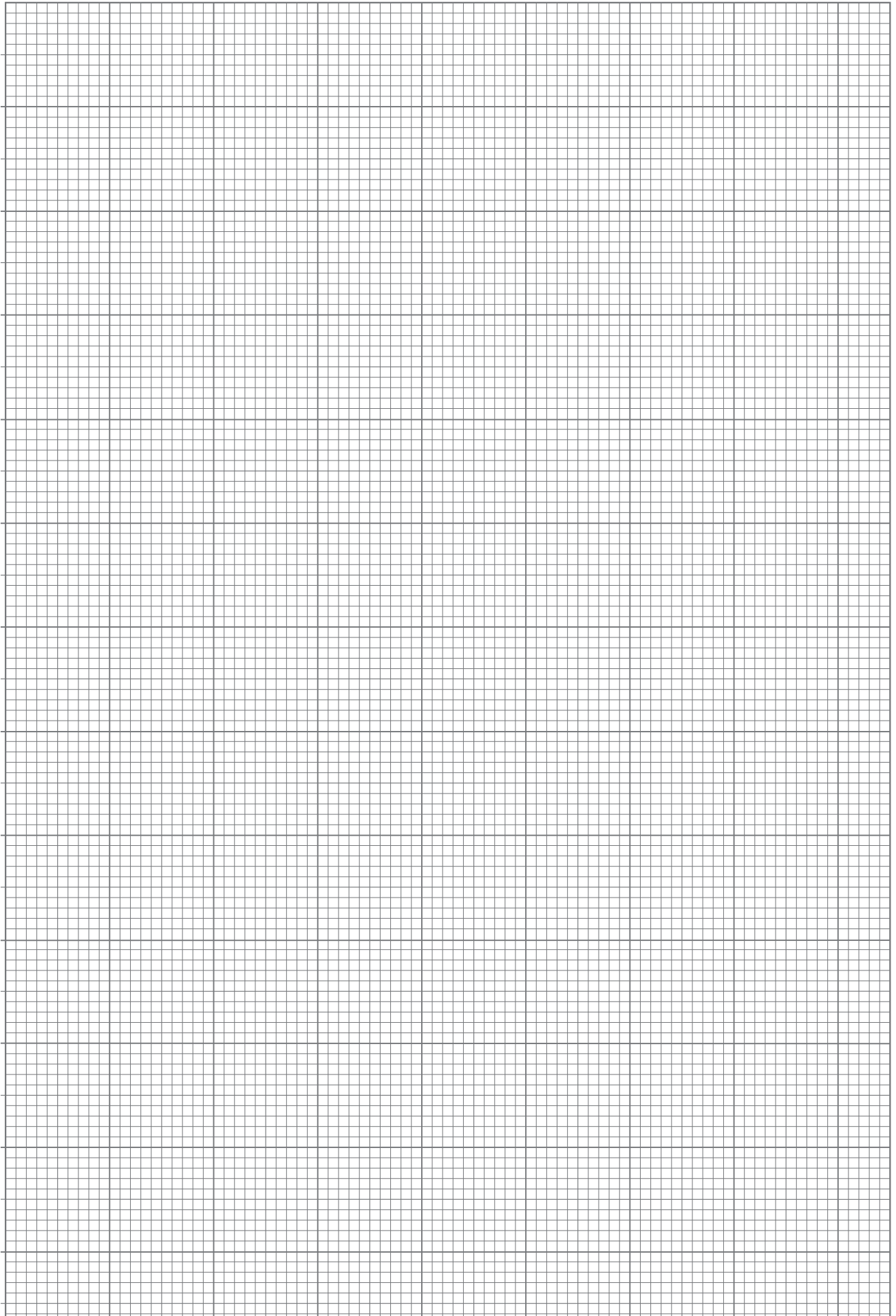
- (d) (i) Measure and record the gradient, G , of your graph.

$$G = \dots\dots\dots$$

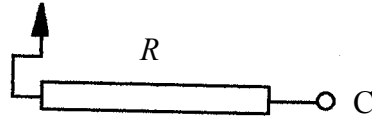
- (ii) Evaluate $\frac{3(E - V_0)}{GV_0}$.

$$\frac{3(E - V_0)}{GV_0} = \dots\dots\dots$$

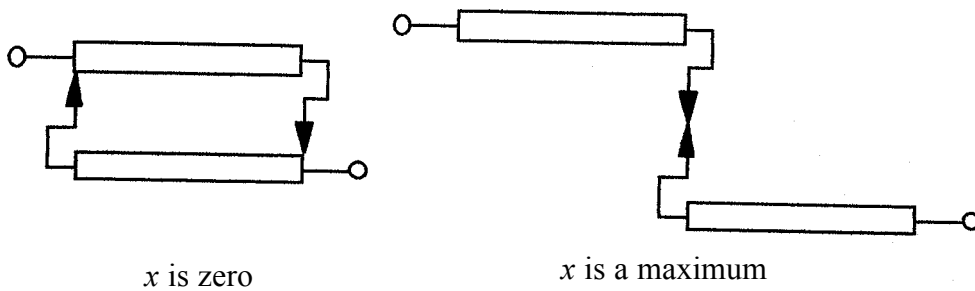
(3 marks)



- (e) A teacher makes the sketch, shown below, to explain how the resistance of the variable resistor varies with x .
Each rectangle of conductive paper is represented in the sketch by a resistor of resistance R , the ends of which are joined to a copper contact, C , and a sliding contact, marked with an arrow.



Two further sketches show the settings of the variable resistor when x is zero and when x is a maximum.



Deduce, in terms of R , the resistance of the variable resistor

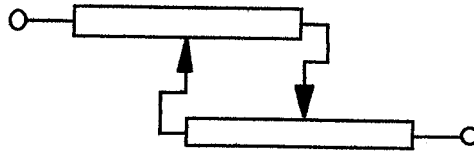
- (i) when x is zero,

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- (ii) when x is a maximum.

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The sketch below shows the setting of the variable resistor when x is **exactly half** the maximum value.



(iii) By drawing a simplified circuit diagram, deduce, in terms of R , the resistance of the variable resistor for this setting.

(iv) The teacher claims that the resistance of the variable resistor increases **uniformly** as x increases from zero. Use your deductions to decide if the teacher's claim might be correct.

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(6 marks)

END OF QUESTIONS

There are no questions printed on this page