

Surname						Other Names					
Centre Number						Candidate Number					
Candidate Signature											

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General Certificate of Education  
 January 2007  
 Advanced Subsidiary Examination



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

**PHA3/P**

Wednesday 17 January 2007 1.30 pm to 3.15 pm

**For this paper you must have:**

- 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 **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 to be 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			
Question	Mark	Question	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	$c$	$3.00 \times 10^8$	$\text{m s}^{-1}$	$v = u + at$		$g = \frac{F}{m}$	
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	$\sigma$	$5.67 \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$	$I = \sum mr^2$		$\lambda = \frac{ws}{D}$	
the Wien constant	$\alpha$	$2.90 \times 10^{-3}$	$\text{m K}$	$E_k = \frac{1}{2} I\omega^2$		$d \sin \theta = n\lambda$	
electron rest mass	$m_e$	$9.11 \times 10^{-31}$	kg	$\omega_2 = \omega_1 + \alpha t$		$\theta \approx \frac{\lambda}{D}$	
(equivalent to $5.5 \times 10^{-4}u$ )				$\theta = \omega_1 t + \frac{1}{2} \alpha t^2$		${}^1n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$	
electron charge/mass ratio	$elm_e$	$1.76 \times 10^{11}$	$\text{C kg}^{-1}$	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$		${}^1n_2 = \frac{n_2}{n_1}$	
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	$elm_p$	$9.58 \times 10^7$	$\text{C kg}^{-1}$	$\text{angular momentum} = I\omega$		$hf = \phi + E_k$	
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	$\Delta W = p\Delta V$		$e = \frac{E}{Q}$	
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$		$e = I(R + r)$	
<b>Fundamental particles</b>				$\text{work done per cycle} = \text{area of loop}$		$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$	
<i>Class</i>	<i>Name</i>	<i>Symbol</i>	<i>Rest energy</i>	$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$		$R_T = R_1 + R_2 + R_3 + \dots$	
			/MeV	$\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$		$P = I^2 R$	
photon	photon	$\gamma$	0	$\text{friction power} = \text{indicated power} - \text{brake power}$		$E = \frac{F}{Q} = \frac{V}{d}$	
lepton	neutrino	$\nu_e$	0	$\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$		$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$	
		$\nu_\mu$	0	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_C}$		$E = \frac{1}{2} QV$	
		electron	$e^\pm$	0.510999		$F = BIl$	
mesons	pion	$\mu^\pm$	105.659		$F = BQv$		
		$\pi^\pm$	139.576				
		$\pi^0$	134.972				
baryons	kaon	$K^\pm$	493.821				
		$K^0$	497.762				
		proton	$p$	938.257			
	neutron	$n$	939.551				
<b>Properties of quarks</b>							
<i>Type</i>	<i>Charge</i>	<i>Baryon number</i>	<i>Strangeness</i>				
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 = $4\pi r^2$							

$$\text{magnitude of induced emf} = N \frac{\Delta\Phi}{\Delta t}$$

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

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

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

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

### 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

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

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

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

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

**Turn over for the first question**

Answer **both** questions.

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

- 1** A physics student has constructed the system, shown in **Figure 1**, to investigate the transfer of sound waves through a wire.

The student's idea is based on a 'string telephone' in which a piece of string or wire is held in tension between two metal cans. When sound waves are incident on the base of can A, they are transmitted through the wire connecting can A to can B. In the system shown, the sound waves are clearly audible when the student places his ear close to the open end of can B. The incident sound waves are produced by a small loudspeaker placed in contact with the base of can A. The loudspeaker is connected to a signal generator that produces an output of fixed frequency.

A cord is used to suspend a container of sand from can B: by adjusting the amount of sand in this container the tension in the wire can be varied.

Design an experiment that the student could perform to investigate how the tension in the wire affects the loudness of the sound produced by can B. You should assume that the normal laboratory apparatus used in schools and colleges is available for the student answering the question to use. A microphone, capable of converting sound waves into an ac voltage signal, is also available.

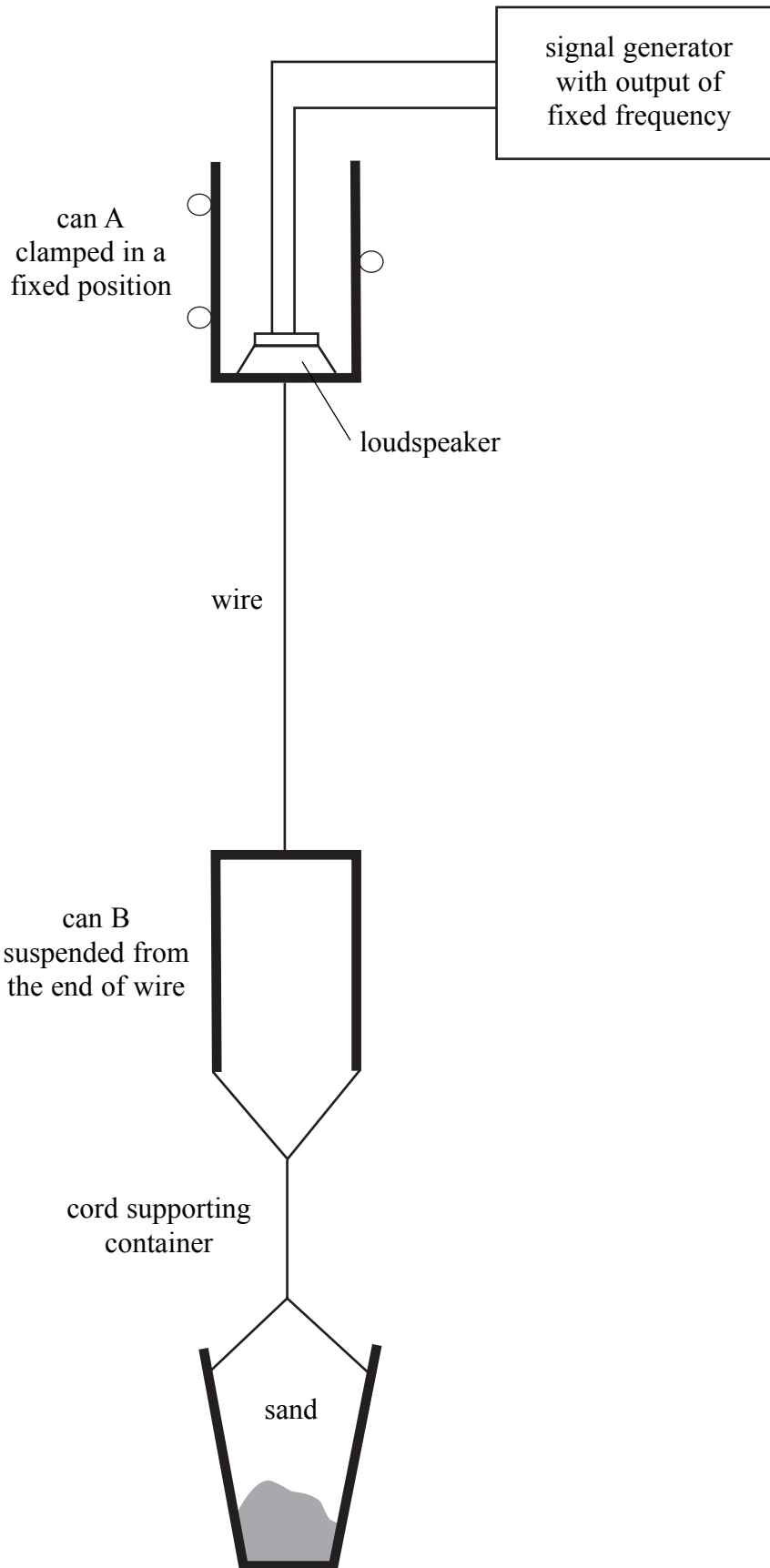
Your answer should

- identify the quantities that should be measured and explain how these measurements will be made: you may add detail to **Figure 1** to illustrate this part of your answer,
- explain how the measurements will be used to investigate how the tension in the wire affects the loudness of the sound transmitted through the wire,
- list any factor(s) that should be controlled during the proposed experiment and explain how this will be done,
- identify any difficulties in obtaining reliable results that might be encountered and explain relevant procedures to show how these difficulties could be overcome.

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

*(8 marks)*

Figure 1







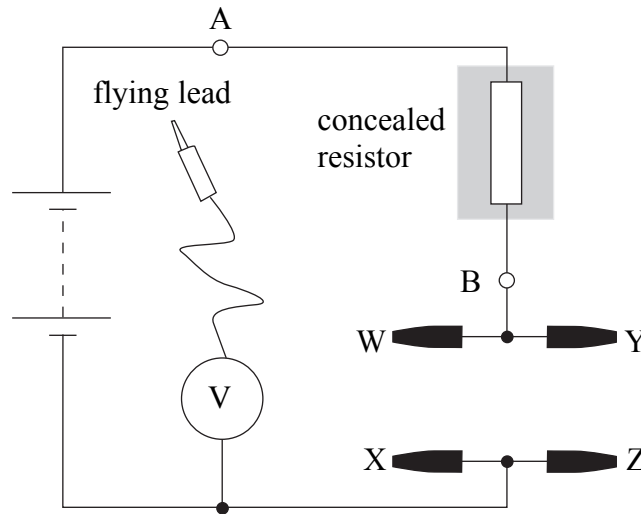
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- 2 You are to investigate the characteristics of a potential divider circuit. The potential divider consists of a concealed resistor and combinations of other known resistors that can be connected into the circuit using the clips W, X, Y and Z. **No description of the experiment is required.**

You are provided with the circuit shown in **Figure 2**.

**Figure 2**



- (a) (i) Connect the  $1000\ \Omega$  resistor between clip W and clip X. Connect the flying lead to socket A. Read and record the voltmeter reading,  $V_0$ .

$V_0 = \dots\dots\dots$

- (ii) Connect the flying lead to socket B. **Do not remove this lead for the remainder of the experiment.** Read and record the new voltmeter reading  $V_1$ .

$V_1 = \dots\dots\dots$

- (iii) Explain, **without detailed calculation**, how your results for  $V_0$  and  $V_1$  show that the resistance of the concealed resistor is less than  $1000\ \Omega$ .

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(3 marks)

Question 2 continues on the next page

- (b) You are also provided with seven additional resistors with resistances,  $R$ , between  $4700\ \Omega$  and  $100\ \Omega$ . Connect the  $4700\ \Omega$  resistor between clip Y and clip Z so that it is **in parallel** with the  $1000\ \Omega$  resistor.

Read the voltmeter reading,  $V$ , recording the reading corresponding to this value of  $R$  in the table below.

Repeat the procedure, replacing the  $4700\ \Omega$  resistor with each of the additional resistors in turn, until you have readings of  $V$  for each value of  $R$ .

**When you have completed your readings, remove any resistors still connected between clips W and X or between clips Y and Z.**

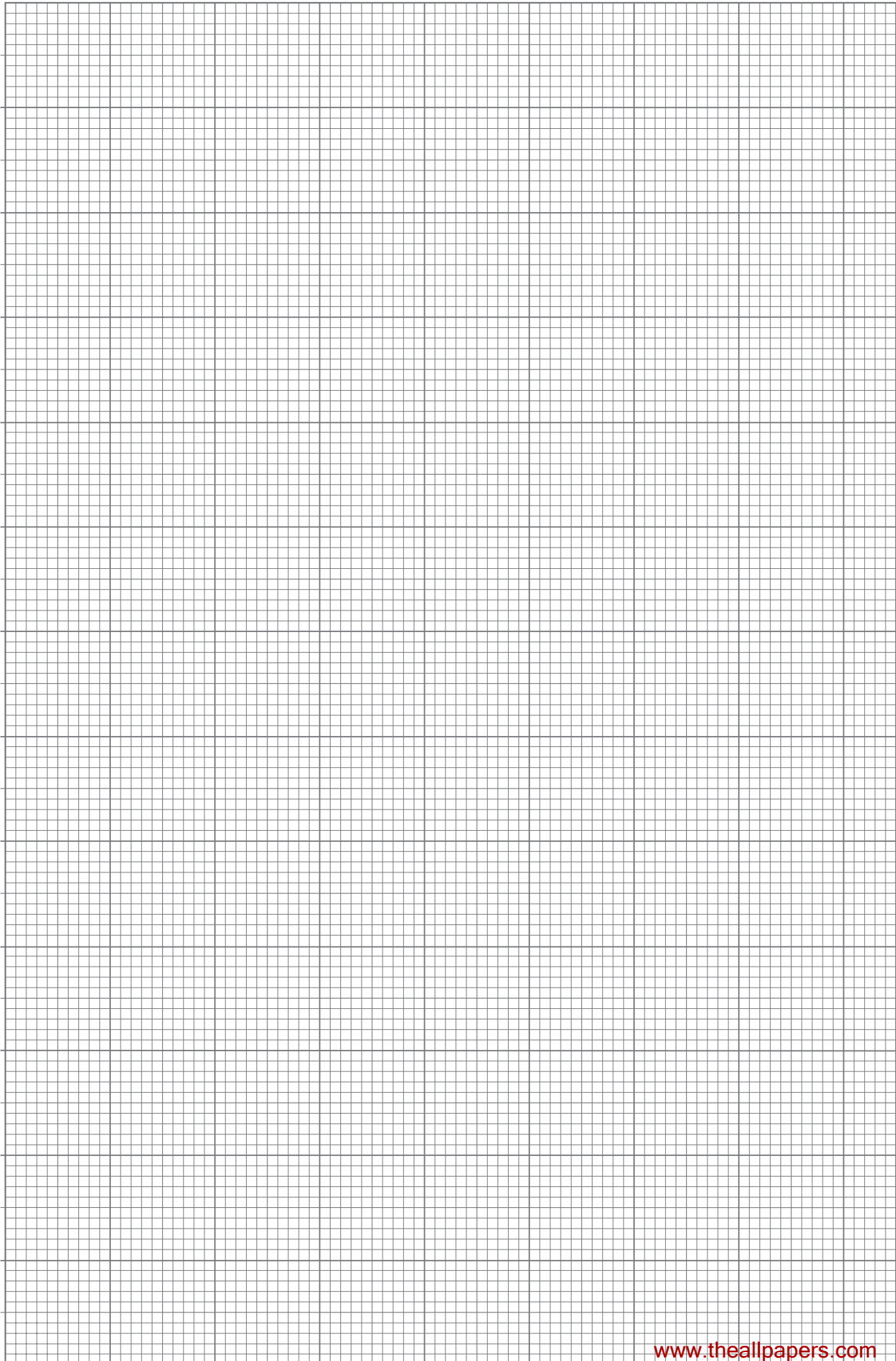
$R/\ \Omega$	$V/V$
4700	
820	
470	
330	
220	
150	
100	

(2 marks)

- (c) Plot a graph with  $\frac{1}{V}$  on the vertical axis and  $\frac{(1000 + R)}{R}$  on the horizontal axis.

Tabulate below the data you will plot on your graph.

(8 marks)



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

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(ii) Evaluate  $GV_0$ .

$GV_0 =$  ..... (3 marks)

(e) (i) Explain how you decided on the number of significant figures to use in your data for  $\frac{1}{V}$ .

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(ii) A student claims that the voltmeter reading,  $V_0$ , represents the emf of the power supply.  
Explaining your reasoning, discuss whether this claim is correct.

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- (iii) Six of the additional resistors provided have a resistance less than  $1000\ \Omega$ . Suppose that the concealed resistor has the same resistance as one of these six resistors. Outline a simple procedure that would allow you, **without calculation**, to determine which of these resistors has the same resistance as the concealed resistor. The procedure you describe must **not** involve removing or shorting-out the concealed resistor in the circuit.

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(6 marks)

**END OF QUESTIONS**

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