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Centre Number						Candidate Number					
Candidate Signature											

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General Certificate of Education  
 June 2004  
 Advanced Level Examination



**PHYSICS (SPECIFICATION A)**  
**Unit 9 Nuclear Instability: Electronics Option**

**PHA9/W**

Thursday 17 June 2004 Morning Session

<p><b>In addition to this paper you will require:</b></p> <ul style="list-style-type: none"> <li>• a calculator;</li> <li>• a pencil and a ruler.</li> </ul>
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Time allowed: 1 hour 15 minutes

**Instructions**

- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** 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 40.
- Mark allocations are shown in brackets.
- The paper carries 10% of the total marks for 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.
- In questions requiring description and explanation you will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary where appropriate. The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
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				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	$\alpha$	$2.90 \times 10^{-3}$	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 $5.5 \times 10^{-4}u$ )				$\theta = \omega_1 t + \frac{1}{2} at^2$		${}_1n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$	
electron charge/mass ratio	$e/m_e$	$1.76 \times 10^{11}$	$\text{C kg}^{-1}$	$\omega_2^2 = \omega_1^2 + 2a\theta$		${}_1n_2 = \frac{n_2}{n_1}$	
proton rest mass	$m_p$	$1.67 \times 10^{-27}$	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	$e/m_p$	$9.58 \times 10^7$	$\text{C kg}^{-1}$	$\text{angular momentum} = I\omega$		$hf = \phi + E_k$	
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>				$\text{work done per cycle} = \text{area of loop}$		$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$	
<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	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$		$E = \frac{1}{2} QV$	
mesons	electron	$e^\pm$	0.510999			$F = BIl$	
		$\mu^\pm$	105.659			$F = BQv$	
	pion	$\pi^\pm$	139.576			$Q = Q_0 e^{-t/RC}$	
		$\pi^0$	134.972				
kaon	$K^\pm$	493.821					
	$K^0$	497.762					
baryons	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 = $4\pi r^2$							
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

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

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

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

$$\Delta Q = ml$$

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

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

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

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

### 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

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

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

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

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

### 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**

**SECTION A: NUCLEAR INSTABILITY**

Answer **all** parts of the question.

- 1 (a) A radioactive source gives an initial count rate of 110 counts per second. After 10 minutes the count rate is 84 counts per second.

background radiation = 3 counts per second

- (i) Give **three** origins of the radiation that contributes to this background radiation.

1 .....

2 .....

3 .....

- (ii) Calculate the decay constant of the radioactive source in  $s^{-1}$ .

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- (iii) Calculate the number of radioactive nuclei in the initial sample assuming that the detector counts all the radiation emitted from the source.

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(7 marks)

- (b) Discuss the dangers of exposing the human body to a source of  $\alpha$  radiation. In particular compare the dangers when the  $\alpha$  source is held outside, but in contact with the body, with those when the source is placed inside the body.

You may be awarded marks for the quality of written communication in your answer.

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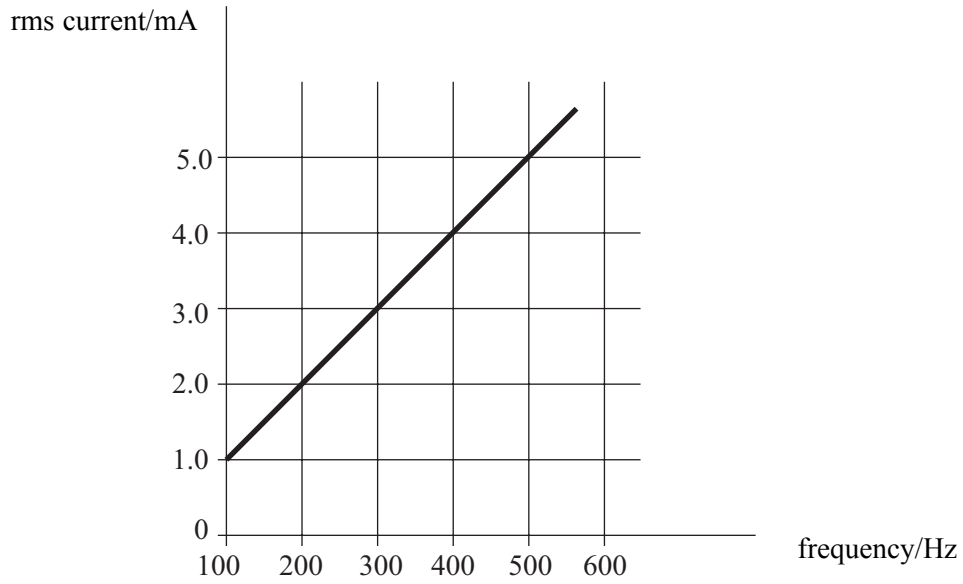
(3 marks)

10

**TURN OVER FOR THE NEXT QUESTION**

**SECTION B: ELECTRONICS**Answer **all** questions.

- 2 (a) The graph shows how the rms current through a capacitor,  $C$ , varied with the frequency of the current. The rms potential difference across  $C$  was  $5.0\text{ V}$  at all frequencies.



Calculate the capacitance of  $C$ .

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(4 marks)



(b) An electrolytic capacitor, marked as  $22\ \mu\text{F}$  20V, when charged and removed from the supply was found to have a small leakage current.

(i) How does the use of an electrolytic capacitor differ from other capacitors?

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(ii) What is the effect of the small leakage current?

.....  
.....

(iii) What does the label 20V tells us about this capacitor?

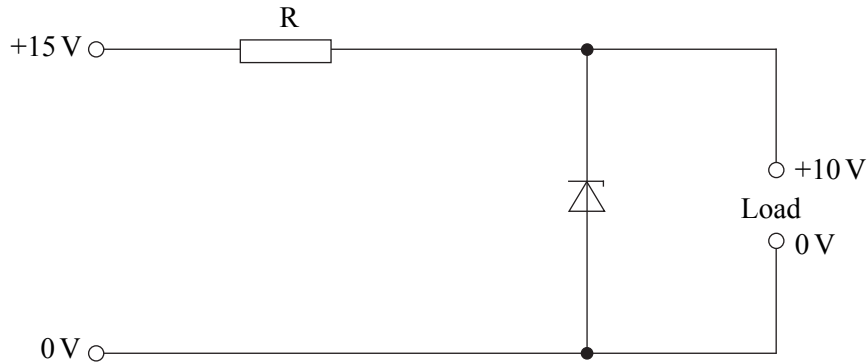
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(3 marks)

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**TURN OVER FOR THE NEXT QUESTION**

3 **Figure 1** shows a zener diode used to produce a stabilised output of 10 V from a nominal 15 V supply.



**Figure 1**

The maximum output current supplied to the load is 100 mA. The zener diode must have a minimum current of 10 mA passing through it to maintain its voltage.

(a) Calculate the ideal value of the resistor R.

.....  
 .....  
 (2 marks)

(b) Calculate the power dissipated by R under these conditions.

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 .....  
 (2 marks)

(c) State, giving a reason, the best value resistor to use from the E24 range.

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 (2 marks)

4 Figure 2 shows an op-amp used in an amplifier circuit.

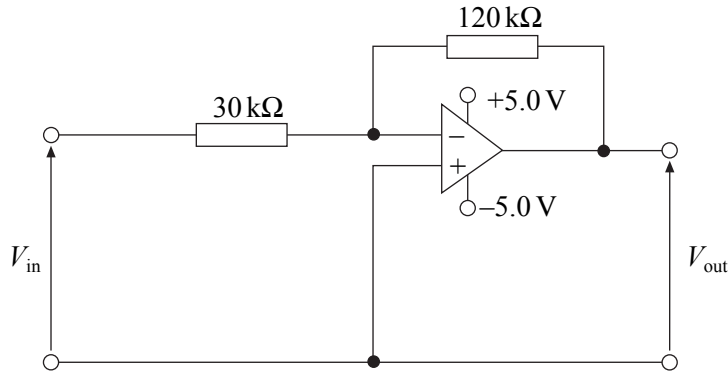


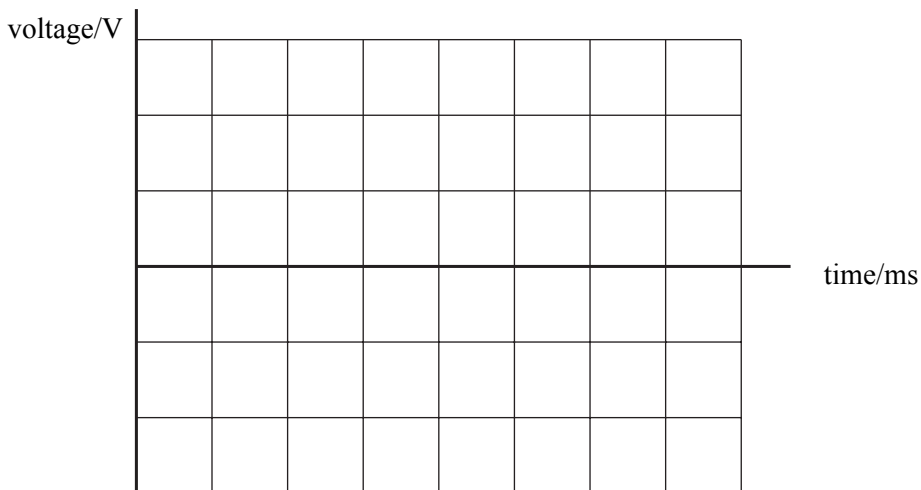
Figure 2

(a) Name the type of amplifier circuit shown. .... (1 mark)

(b) Calculate the output voltage  $V_{out}$  when the input voltage  $V_{in} = 0.50\text{ V}$ .  
 .....  
 ..... (2 marks)

(c) The input is now connected to a sinusoidal source of rms output 2.0 V and frequency 50 Hz.  
 (i) Calculate the peak input voltage.  
 .....

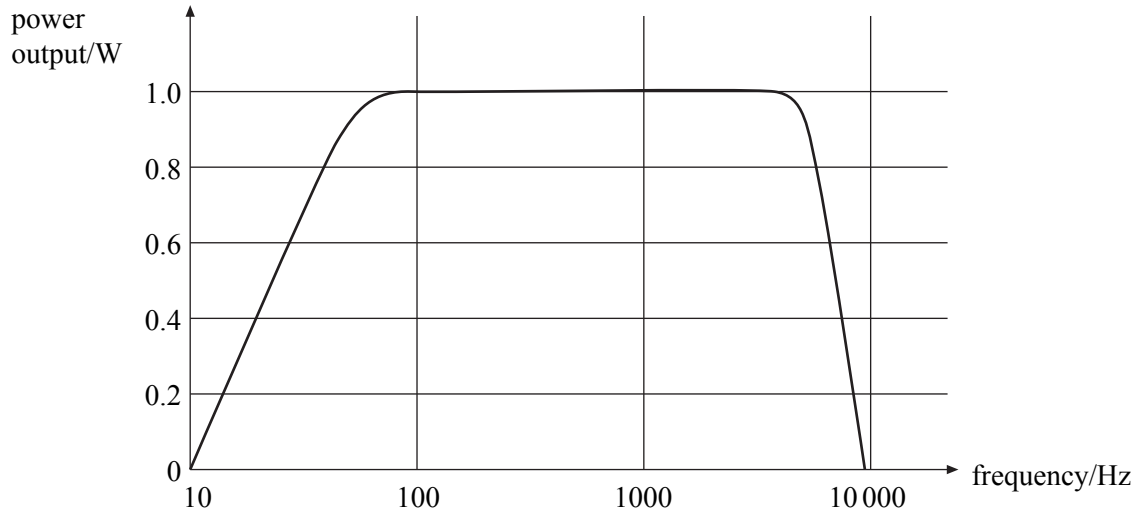
(ii) On the axes below draw a trace showing **two** cycles of the input signal and label it A.  
 On the same axes, draw the **two** corresponding cycles of the output signal and label it B.  
 Add suitable scales to the axes.



(6 marks)

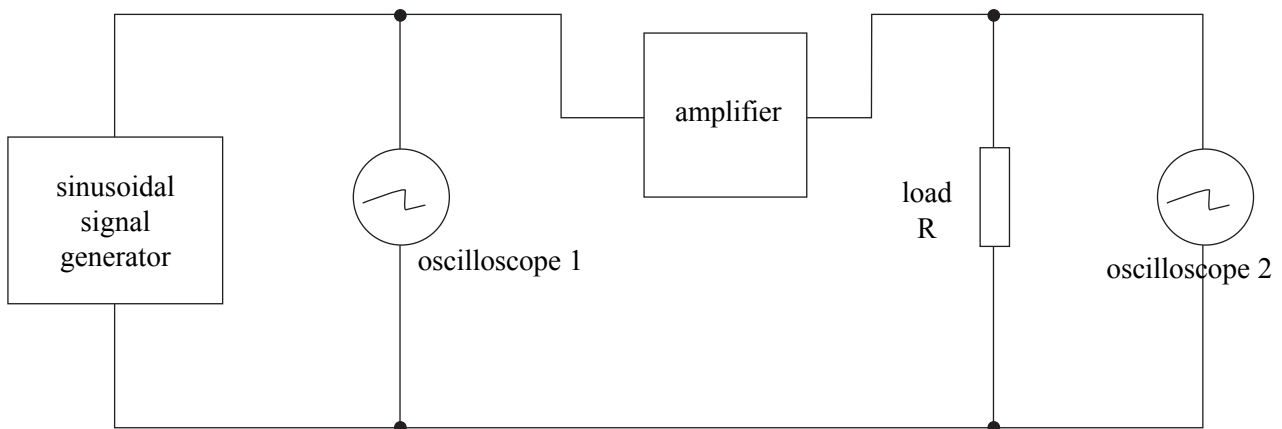
- 5 A student is supplied with an amplifier with a nominal voltage gain of 40. A data sheet shows the variation of power output of the amplifier with frequency, given in **Figure 3**.

power output into  $4\ \Omega$  load for input rms voltage = 50 mV



**Figure 3**

The student sets up the circuit shown in **Figure 4** to test the accuracy of the data sheet.



**Figure 4**

- (a) Discuss what readings must be taken, what must be kept constant and how the readings will be used to plot **Figure 3**.

You may be awarded marks for the quality of written communication in your answer.

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(4 marks)

- (b) In order to give suitable wave displays, the two oscilloscopes must have different input settings. Name the input control which must be adjusted and explain why the settings must be different.

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(2 marks)

**QUALITY OF WRITTEN COMMUNICATION**

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6

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**END OF QUESTIONS**

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