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Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education  
 June 2006  
 Advanced Subsidiary Examination



**PHYSICS (SPECIFICATION A) PHA3/W**  
**Unit 3 Current Electricity and Elastic Properties of Solids**

Friday 9 June 2006 9.00 am to 10.00 am

**For this paper you must have:**

- a calculator
- a pencil and a ruler

Time allowed: 1 hour

**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 50. This includes up to 2 marks for the Quality of Written Communication.
- 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 reminded of the need for good English and clear presentation in your answers. Questions 1(b) and 3(b) should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
Total (Column 1)		→	
Total (Column 2)		→	
Quality of Written Communication			
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	$\sigma$	$5.67 \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$	$I = \sum mr^2$	$\lambda = \frac{\omega s}{D}$		
the Wien constant	$a$	$2.90 \times 10^{-3}$	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	$\omega_2 = \omega_1 + \alpha t$	$\theta \approx \frac{\lambda}{D}$		
(equivalent to $5.5 \times 10^{-4}u$ )				$\theta = \omega_1 t + \frac{1}{2} \alpha t^2$	$n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$		
electron charge/mass ratio	$e/m_e$	$1.76 \times 10^{11}$	$\text{C kg}^{-1}$	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$	$n_2 = \frac{n_2}{n_1}$		
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>				$\text{work done per cycle} = \text{area of loop}$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$		
<b>Class</b>	<b>Name</b>	<b>Symbol</b>	<b>Rest energy</b>	$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$	$R_T = R_1 + R_2 + R_3 + \dots$		
			/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	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$	$E = \frac{1}{2} QV$		
	electron	$e^\pm$	0.510999		$F = BIl$		
	muon	$\mu^\pm$	105.659		$F = BQv$		
mesons	pion	$\pi^\pm$	139.576		$Q = Q_0 e^{-t/RC}$		
		$\pi^0$	134.972		$\Phi = BA$		
	kaon	$K^\pm$	493.821				
		$K^0$	497.762				
baryons	proton	$p$	938.257				
	neutron	$n$	939.551				
<b>Properties of quarks</b>							
<b>Type</b>	<b>Charge</b>	<b>Baryon number</b>	<b>Strangeness</b>				
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

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

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

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

$$\Delta Q = ml$$

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

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

### 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	$2.00 \times 10^{30}$	$7.00 \times 10^8$
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

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

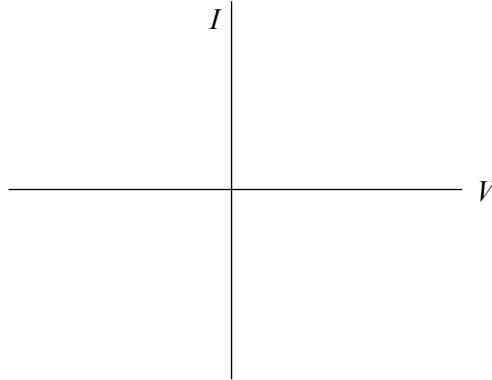
$$G = -\frac{R_f}{R_1} \quad \text{inverting}$$

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

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

Answer **all** questions.

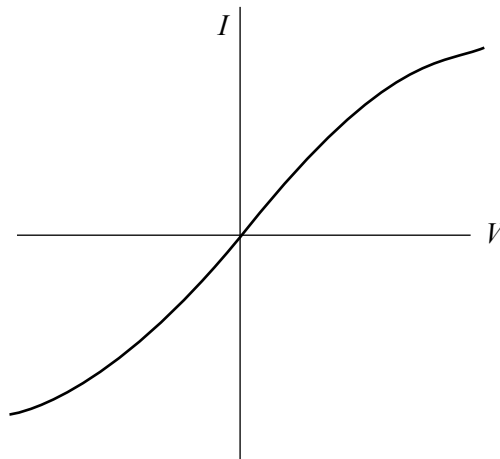
- 1 (a) On the axes below draw the  $I - V$  characteristic for a silicon semiconductor diode in both forward bias and reverse bias. Indicate any relevant voltage values on the axis.



(4 marks)

- (b) **Figure 1** shows the  $I - V$  characteristic for a filament lamp. Explain the shape of the characteristic.

**Figure 1**



You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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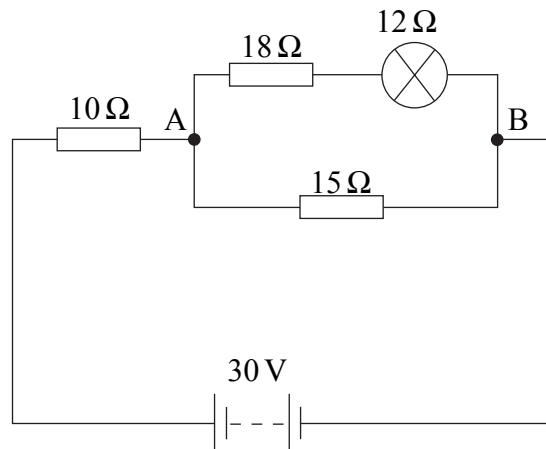
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(4 marks)  
Turn over ▶

- 2 In the circuit shown in **Figure 2**, the battery, of negligible internal resistance, has an emf of 30 V. The pd across the lamp is 6.0 V and its resistance is  $12\ \Omega$ .

**Figure 2**



- (a) Show that the total resistance of the circuit is  $20\ \Omega$ .

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(3 marks)

- (b) Calculate

- (i) the current supplied by the battery,

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- (ii) the pd between the points A and B,

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.....

- (iii) the current in the lamp.

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.....

(4 marks)

(c) (i) What is the power of the lamp, in W?

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.....

(ii) What percentage of the power supplied by the battery is dissipated in the lamp?

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.....

*(3 marks)*

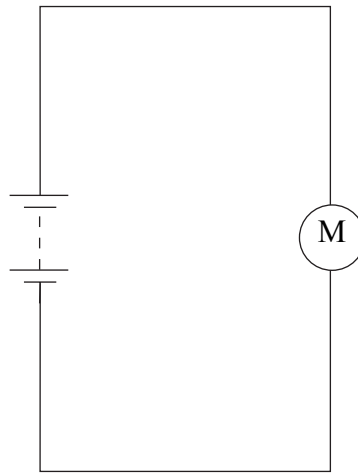
10
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**Turn over for the next question**

**Turn over ▶**

- 3 The battery of an electric car consists of 30 cells, connected in series, to supply current to the motor, as shown in **Figure 3**.

**Figure 3**



- (a) Assume that the internal resistance of each cell is negligible and that the pd across each cell is 6.0 V.

- (i) State the pd across the motor.

.....

- (ii) The battery provides 7.2 kW to the motor when the car is running. Calculate the current in the circuit.

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.....

- (iii) The battery can deliver this current for two hours. Calculate how much charge the battery delivers in this time.

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.....

- (iv) Calculate the energy delivered to the motor in the two hour period.

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(7 marks)



(b) In practice, each cell has a small but finite internal resistance. Explain, without calculation, the effect of this resistance on

- the current in the circuit, and
- the time for which the battery can deliver the current in part (a)(ii).

You may assume that the motor behaves as a constant resistance.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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(3 marks)

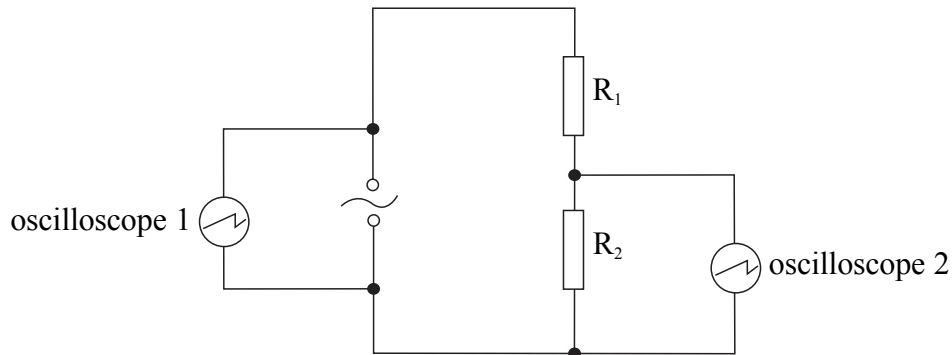
<b>10</b>

**Turn over for the next question**

**Turn over ▶**

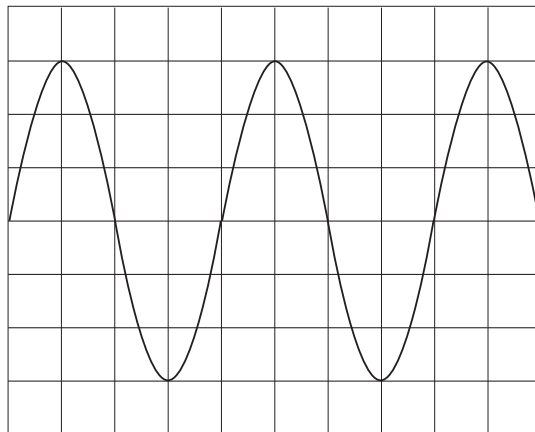
- 4 The circuit in **Figure 4** shows a sinusoidal ac source connected to two resistors,  $R_1$  and  $R_2$ , which form a potential divider. Oscilloscope 1 is connected across the source and oscilloscope 2 is connected across  $R_2$ .

**Figure 4**



- (a) **Figure 5** shows the trace obtained on the screen of oscilloscope 1. The time base of the oscilloscope is set at 10 ms per division and the voltage sensitivity at 15 V per division.

**Figure 5**



For the ac source, calculate

- (i) the frequency,

.....  
 .....

- (ii) the rms voltage.

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 .....

(4 marks)

(b) The resistors have the following values:  $R_1 = 450 \Omega$  and  $R_2 = 90 \Omega$ .  
Calculate

(i) the rms current in the circuit,

.....

(ii) the rms voltage across  $R_2$ .

.....

(2 marks)

(c) Oscilloscope 2 is used to check the calculated value of the voltage across  $R_2$ . The screen of oscilloscope 2 is identical to that of oscilloscope 1 and both are set to the same time base. Oscilloscope 2 has the following range for voltage sensitivity: 1 V per div., 5 V per div., 10 V per div. and 15 V per div.

State which voltage sensitivity would give the most suitable trace. Explain the reasons for your choice.

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(3 marks)

9
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**Turn over for the next question**

**Turn over ▶**

- 5 (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

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- (ii) Explain what is meant by the elastic limit of the wire.

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.....

- (iii) Define the Young modulus of a material and state the unit in which it is measured.

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*(5 marks)*

- (b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire. A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

- (i) What other quantities must be measured before the value of the Young modulus can be obtained?

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- (ii) Explain how the student may obtain a value of the Young modulus.

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- (iii) How would a value for the elastic energy stored in the wire be found from the results?

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*(6 marks)*

<b>11</b>

**Quality of Written Communication** *(2 marks)*

<b>2</b>

**END OF QUESTIONS**

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