Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
January 2008
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Friday 11 January 2008 1.30 pm to 2.30 pm

For this paper you must have:
- a pencil and a ruler
- a calculator.

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 to be 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 expected to use a calculator where appropriate.
- Questions 3(b) and 5(b) should be answered in continuous prose. In these questions you may be marked on your ability to use good English, to organise information clearly and to use specialist vocabulary where appropriate.

For Examiner's Use			
Question	Mark	Question	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.

Data Sheet

Fundamental constants and values

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

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	$\mu^{\pm}$	105.659
mesons	pion	$\pi^{\pm}$	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

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 $= \frac{4}{3}\pi r^3$

Mechanics and Applied Physics

$v = u + at$

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

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

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

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

$P = Fv$

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

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

angular momentum $= I\omega$

$W = T\theta$

$P = T\omega$

angular impulse = change of angular momentum $= Tt$

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

$\Delta W = p\Delta V$

$pV^{\gamma} =$ constant

work done per cycle = area of loop

input power = calorific value × fuel flow rate

indicated power as (area of p – V loop) × (no. of cycles/s) × (no. of cylinders)

friction power = indicated power – brake power

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

maximum possible efficiency $= \frac{T_H - T_C}{T_H}$

Fields, Waves, Quantum Phenomena

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

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

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

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

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

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

$x = A\cos 2\pi ft$

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

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

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

$d\sin\theta = n\lambda$

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

${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$

${}_1n_2 = \frac{n_2}{n_1}$

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

$E = hf$

$hf = \phi + E_k$

$hf = E_1 - E_2$

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

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Electricity

$\epsilon = \frac{E}{Q}$

$\epsilon = I(R + r)$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

$R_T = R_1 + R_2 + R_3 + \cdots$

$P = I^2 R$

$E = \frac{F}{Q} = \frac{V}{d}$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

$E = \frac{1}{2}QV$

$F = BIl$

$F = BQv$

$Q = Q_0 e^{-t/RC}$

$\Phi = BA$

Turn over ▶

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

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

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

Mechanical and Thermal Properties

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

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

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

$\Delta Q = ml$

$pV = \frac{1}{3}Nm\overline{c^2}$

$\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT = \frac{3RT}{2N_A}$

Nuclear Physics and Turning Points in Physics

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

force $= Bev$

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

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

work done $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

$E = mc^2 = \frac{m_0c^2}{\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

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

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

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

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

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

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

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

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

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

$\lambda_{max}T$ = constant = 0.0029 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

power $= \frac{1}{f}$

$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ and $m = \frac{v}{u}$

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

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

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

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

$X_C = \frac{1}{2\pi fC}$

Alternating Currents

$f = \frac{1}{T}$

Operational amplifier

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

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

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

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

There are no questions printed on this page

Answer **all** questions in the spaces provided.

1 (a) (i) A cable of length 8.0 m consists of a single strand of copper wire of cross-sectional area $7.8 \times 10^{-7}\,\text{m}^2$.
When the current through the cable is 5.0 A, calculate the voltage between the ends of the cable.

resistivity of copper = $1.7 \times 10^{-8}\,\Omega\,\text{m}$

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(ii) Calculate the energy dissipated when the current flows through the cable for 6 minutes.

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(5 marks)

(b) (i) A second cable, also 8.0 m long, consists of three strands of copper. Each strand has the same cross-sectional area as the single copper strand in part (a) and the total current through the cable is the same as that in part (a).

If the voltage between the ends of the cable in part (a) was *V*, obtain without calculation, an expression for the voltage between the ends of the second cable, in terms of *V*.

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(ii) Compare the heating effect of the same current passing through the two cables.

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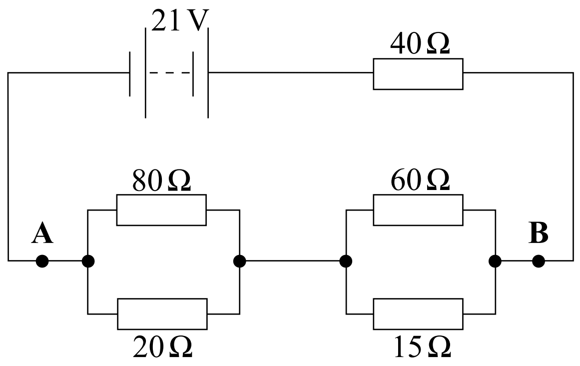
(4 marks)

9

Turn over for the next question

2 (a) A battery of emf 21 V and negligible internal resistance is connected to a resistor network as shown in **Figure 1**.

Figure 1



(i) Calculate the resistance of the single equivalent resistor that could replace the four resistors between the points **A** and **B**.

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(ii) Calculate the current through the 40 Ω resistor.

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(iii) Calculate the current through the 60 Ω resistor.

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(6 marks)

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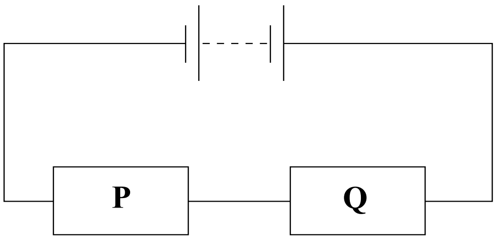
(b) A student is provided with the circuit shown in **Figure 2**, where **P** and **Q** are sealed boxes.

Figure 2



The student is told that

- each of the boxes **P** and **Q** contains two resistors in parallel
- one of these four resistors has a value of 1.0 Ω
- each of the other three resistors have values much greater than 1.0 Ω.

(i) State what measurements the student, with the aid of a voltmeter, must make in order to determine which box contains the 1.0 Ω resistor.

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(ii) Explain how the measurements you describe would enable the student to make the correct identification of the box containing the 1.0 Ω resistor.

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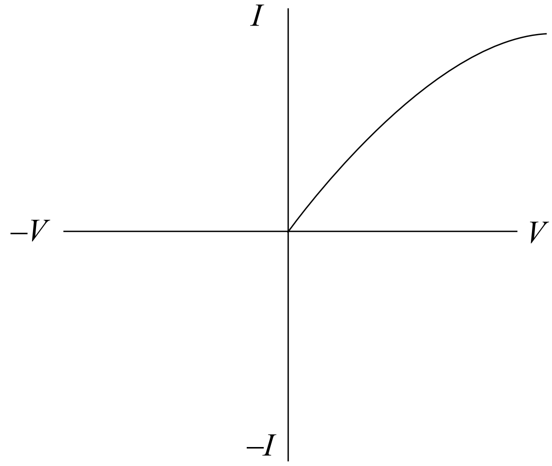
(4 marks)

10

Turn over

3 **Figure 3** shows the positive part of the $I - V$ characteristic for a filament lamp when the current through it is in the positive direction.

Figure 3



(a) (i) Draw the circuit diagram of an experimental arrangement which could be used to collect the data necessary to produce this graph. Your circuit should include a potential divider and a data logger. Label the filament lamp clearly.

(ii) On **Figure 3** complete the characteristic when the current through the filament lamp is reversed.

(5 marks)

(b) Explain the shape of the complete $I - V$ characteristic.

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

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(4 marks)

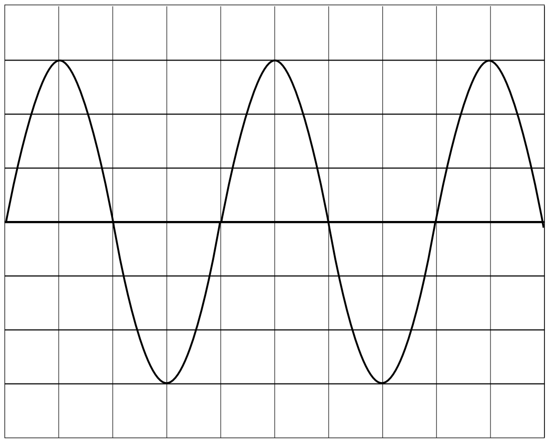
9

Turn over for the next question

4 An oscilloscope is connected to a sinusoidal ac source whose frequency and voltage output can be varied.

(a) At a certain frequency the ac signal has an rms output of 21.2 V. **Figure 4** shows the trace obtained on the screen of the oscilloscope when one horizontal division corresponds to a time of 20 ms.

Figure 4



Calculate, for the signal shown,

(i) the peak voltage,

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....

(ii) the frequency.

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(3 marks)

(b) The voltage output and frequency of the ac signal are now changed so that the peak voltage is 60V and the frequency is 100 Hz.

State which **two** controls on the oscilloscope have to be altered so that the screen shows the same number of cycles as in **Figure 4**, but with the peak to peak distance occupying the **full** screen.

Determine also the values at which these two controls have to be set.

control 1 ....

value of setting..

....

control 2 ....

value of setting..

....

(5 marks)

8

Turn over for the next question

5 (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire. State the meaning of

tensile stress ....

....

tensile strain ....

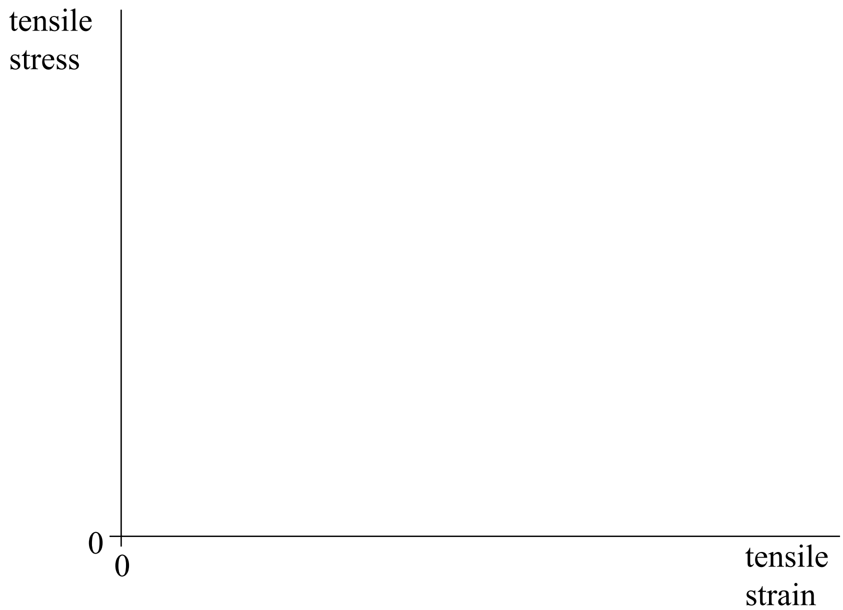
....

(2 marks)

(b) Two wires, **A** and **B**, of equal length and diameter are to be compared. Each of the two wires is subjected, in turn, to an increasing tensile stress until the wire breaks.

Wire **A** is made from a brittle material and wire **B** from a ductile material. The Young modulus for the brittle material is greater than that for the ductile material.

(i) On the axes provided, sketch the graphs you would expect for each wire. Label the graphs **A** and **B** respectively.



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(ii) Describe how the behaviour of each wire relates to the shape of each graph.

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

graph **A** ....

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....

graph **B** ....

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(8 marks)

(c) A uniform wire of length 1.5 m and cross-sectional area $2.4 \times 10^{-6}\,m^2$, hangs vertically from a fixed support. A mass of 10 kg is suspended from its lower end.

Calculate the extension of the wire.

the Young modulus for the material of the wire = 2.0×10^{11} Pa

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(2 marks)

12

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

There are no questions printed on this page