

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
 January 2004
 Advanced Level Examination



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

PHA9/W

Monday 26 January 2004 Morning Session

In addition to this paper you will require:

- a calculator;
- a pencil and a ruler.

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.

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}	$\text{W m}^{-2} \text{K}^{-4}$	$I = \sum mr^2$	$\lambda = \frac{\omega s}{D}$		
the Wien constant	α	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}	$\Delta Q = \Delta U + \Delta W$	Electricity		
atomic mass unit	u	1.661×10^{-27}	kg	$\Delta W = p\Delta V$	$\epsilon = \frac{E}{Q}$		
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$	$\epsilon = I(R+r)$		
Fundamental particles				$\text{work done per cycle} = \text{area of loop}$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$		
<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	γ	0	$\text{friction power} = \text{indicated power} - \text{brake power}$	$E = \frac{F}{Q} = \frac{V}{d}$		
lepton	neutrino	ν_e	0	$\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$	$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$		
		ν_μ	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	μ^\pm	105.659		$F = BQv$		
mesons	pion	π^\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							
<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				
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 = $4\pi r^2$							

Data Sheet

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

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

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

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

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

Astrophysics and Medical Physics

Body	Mass/kg	Mean radius/m
Sun	2.00×10^{30}	7.00×10^8
Earth	6.00×10^{24}	6.40×10^6

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

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

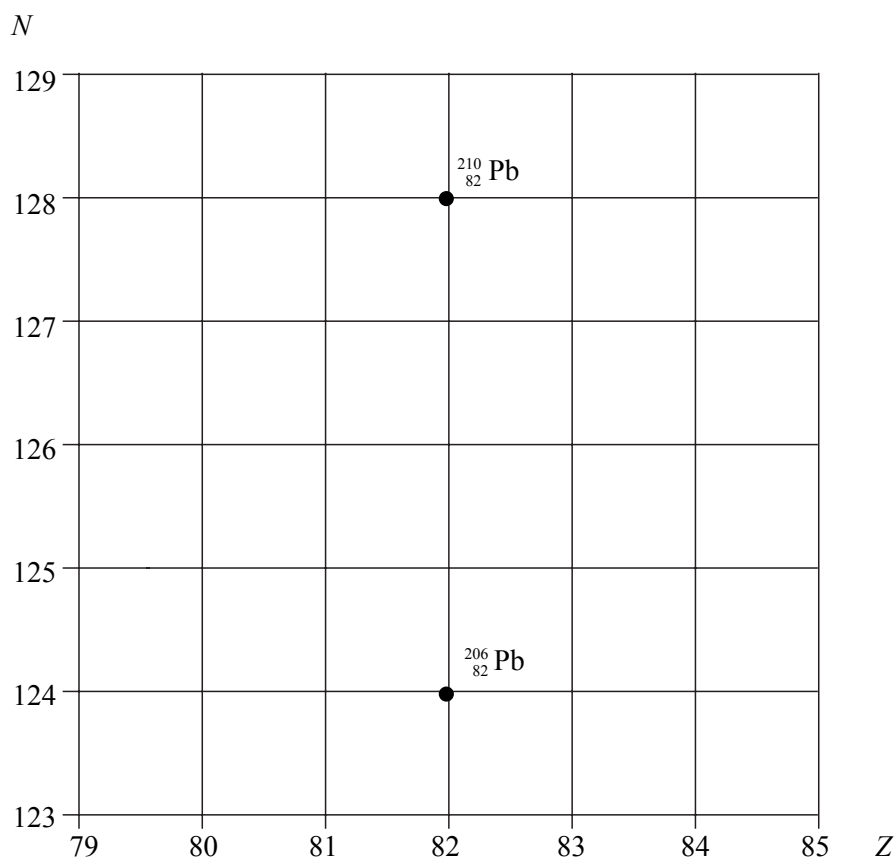
$$G = 1 + \frac{R_f}{R_i} \quad \text{non-inverting}$$

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

SECTION A: NUCLEAR INSTABILITY

Answer **all** of this question

- 1 (a) The lead nuclide ${}^{210}_{82}\text{Pb}$ is unstable and decays in three stages through α and β emissions to a different lead nuclide ${}^{206}_{82}\text{Pb}$. The position of these lead nuclides on a grid of neutron number, N , against proton number, Z , is shown below.



On the grid draw **three** arrows to represent one possible decay route.
Label each arrow with the decay taking place.

(3 marks)

- (b) The copper nuclide ${}^{64}_{29}\text{Cu}$ may decay by positron emission or by electron capture to form a nickel (Ni) nuclide.
Complete the two equations that represent these two possible modes of decay.

positron emission ${}^{64}_{29}\text{Cu}$

electron capture ${}^{64}_{29}\text{Cu}$

(4 marks)

- (c) The nucleus of an atom may be investigated by scattering experiments in which radiation or particles bombard the nucleus.

Name **one** type of radiation or particle that may be used in this investigation and describe the main physical principle of the scattering process.

State the information which can be obtained from the results of this scattering.

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

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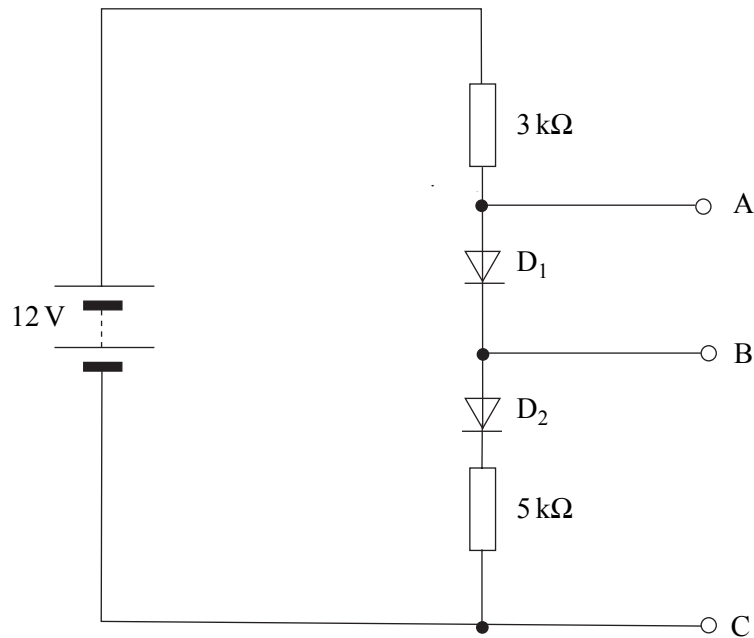
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(3 marks)

10

TURN OVER FOR THE NEXT QUESTION

SECTION B: ELECTRONICS

Answer **all** questions.2 **Figure 1** shows a series circuit containing resistors and silicon diodes.**Figure 1**

(a) Calculate

(i) the voltage between A and C,

.....

.....

.....

.....

(ii) the voltage between B and C.

.....

.....

.....

.....

(4 marks)

(b) A student connects diode D_2 the opposite way round to that shown in **Figure 1**.

State, giving reasons,

(i) the new voltage between A and C,

.....
.....
.....
.....

(ii) the new voltage between B and C.

.....
.....
.....
.....

(3 marks)

7

TURN OVER FOR THE NEXT QUESTION

(b) The resistor R has a resistance of $10\text{ k}\Omega$. Estimate a value for the capacitance of C.

time base setting = 2 ms/division

.....

.....

.....

.....

.....

.....

(4 marks)



TURN OVER FOR THE NEXT QUESTION

- 4 The circuit shown in **Figure 4** uses an ideal op-amp as a voltage comparator. It is used in a frost warning device in which the LED lights when the temperature falls to 0°C . **Figure 5** shows the variation of resistance with temperature of the thermistor.

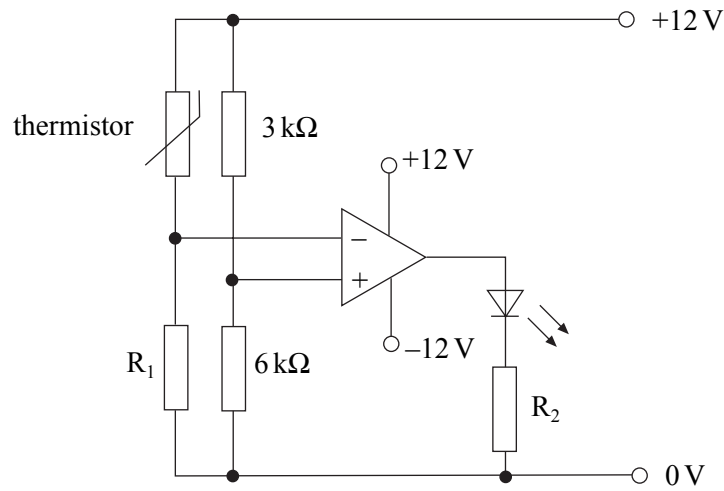


Figure 4

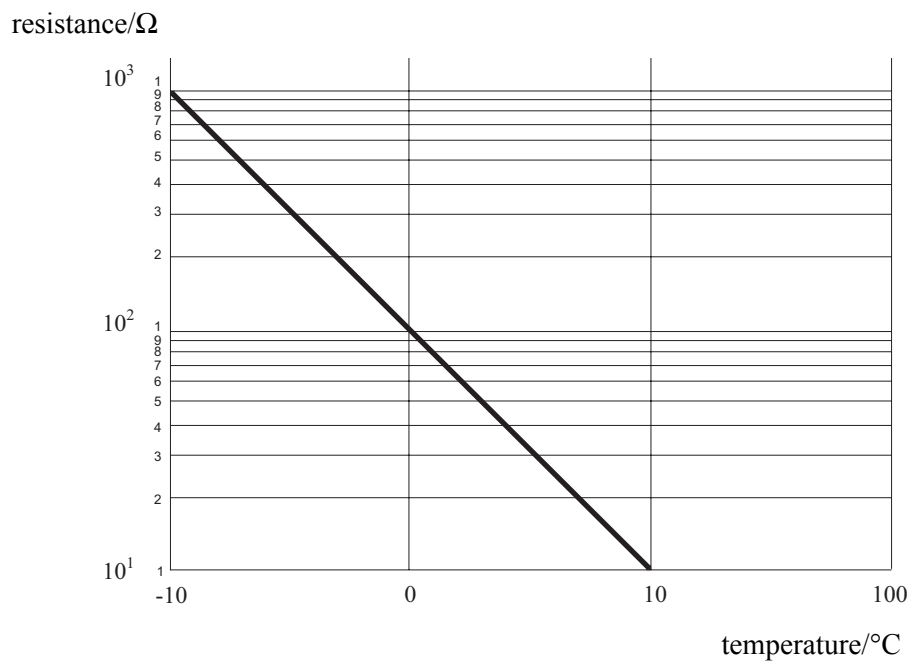


Figure 5

(a) Calculate the voltage at the non-inverting input of the op-amp.

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.....
.....
.....

(1 mark)

(b) Calculate the resistance of R_1 to allow the output to switch at 0°C .

.....
.....
.....
.....

(2 marks)

(c) When the LED is on, the current through it is 20 mA and the p.d. across it is 2.0 V.

Calculate

(i) the resistance of resistor R_2 ,

.....
.....

(ii) the power dissipated in this resistor.

.....
.....

(4 marks)

(d) In practice, what value of resistor from the E24 series should be used for R_2 ?

.....

(1 mark)

TURN OVER FOR THE NEXT QUESTION

5 The circuit in **Figure 6** is used to switch on a mains powered light. The input V_{in} is supplied from an op-amp and switches from -5 V to $+5\text{ V}$.

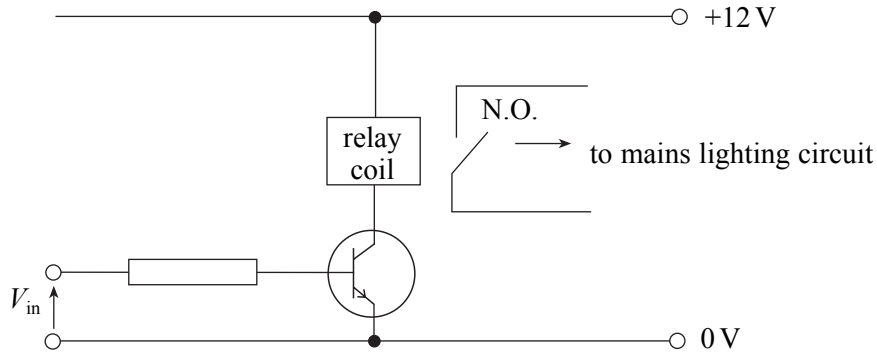


Figure 6

(a) Describe the action of the transistor and the relay as V_{in} changes from -5 V to $+5\text{ V}$.

.....

.....

.....

.....

.....

.....

(3 marks)

(b) Add to the circuit in **Figure 6** a diode which would protect the transistor.

(2 marks)

QUALITY OF WRITTEN COMMUNICATION

(2 marks)

5

2

END OF QUESTIONS