

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

Leave blank

General Certificate of Education
 June 2004
 Advanced Level Examination



PHYSICS (SPECIFICATION A) PHA8/W
Unit 8 Nuclear Instability: Turning Points in Physics Option

Thursday 17 June 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.

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	$\omega_2 = \omega_1 + at$		$\theta = \frac{\lambda}{D}$	
(equivalent to $5.5 \times 10^{-4}u$)				$\theta = \omega_1 t + \frac{1}{2} at^2$		${}^{1}n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$	
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$		${}^{1}n_2 = \frac{n_2}{n_1}$	
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}	<i>angular momentum</i> = $I\omega$		$hf = \phi + E_k$	
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}	<i>angular impulse</i> = change of <i>angular momentum</i> = 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				<i>work done per cycle</i> = 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>	<i>input power</i> = calorific value \times fuel flow rate		$R_T = R_1 + R_2 + R_3 + \dots$	
			/MeV	<i>indicated power</i> as (area of $p - V$ loop) \times (no. of cycles/s) \times (no. of cylinders)		$P = I^2 R$	
photon	photon	γ	0	<i>friction power</i> = indicated power - 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	<i>maximum possible efficiency</i> = $\frac{T_H - T_C}{T_H}$		$E = \frac{1}{2} QV$	
	electron	e^\pm	0.510999			$F = BI$	
	muon	μ^\pm	105.659			$F = BQv$	
mesons	pion	π^\pm	139.576			$Q = Q_0 e^{-t/RC}$	
		π^0	134.972			$\Phi = BA$	
	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							
<i>arc length</i> = $r\theta$							
<i>circumference of circle</i> = $2\pi r$							
<i>area of circle</i> = πr^2							
<i>area of cylinder</i> = $2\pi rh$							
<i>volume of cylinder</i> = $\pi r^2 h$							
<i>area of sphere</i> = $4\pi r^2$							
<i>volume of sphere</i> = $\frac{4}{3}\pi r^3$							

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

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

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

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	2.00×10^{30}	7.00×10^8
Earth	6.00×10^{24}	6.40×10^6

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

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

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

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

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

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

TURN OVER FOR THE FIRST QUESTION

SECTION A: NUCLEAR INSTABILITYAnswer **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} .

.....

.....

.....

.....

.....

.....

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

.....

.....

.....

.....

(7 marks)

- (b) Discuss the dangers of exposing the human body to a source of α radiation. In particular compare the dangers when the α 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.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(3 marks)

10

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

SECTION B: TURNING POINTS IN PHYSICS

Answer **all** questions.

- 2 Hertz discovered how to produce and detect radio waves. He measured the wavelength of radio waves produced at a constant frequency using the arrangement shown in **Figure 1**.

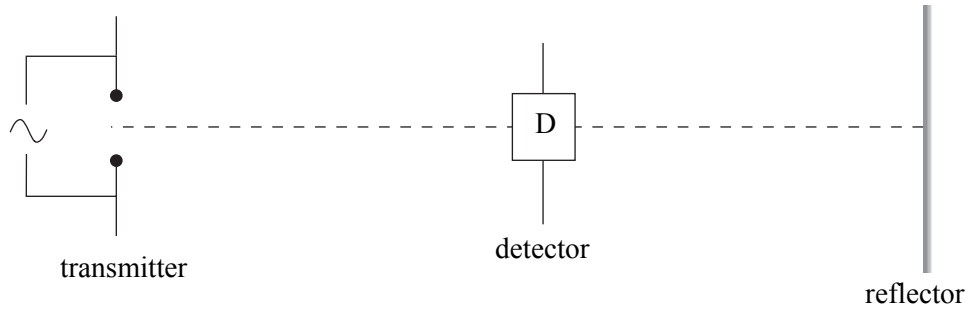


Figure 1

- (i) Explain why the strength of the detector signal varied repeatedly between a minimum and a maximum as the detector was moved slowly away from the transmitter along the dotted line.

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

.....

.....

.....

.....

.....

.....

.....

- (ii) Hertz found that a minimum was detected each time the detector was moved a further 1.5 m away from the transmitter.
Calculate the frequency of the radio waves.

.....

.....

.....

.....

(5 marks)

3 (i) Calculate the kinetic energy, in J, of a proton accelerated in a straight line from rest through a potential difference of 1.1×10^9 V.

.....
.....

(ii) Show that the mass of a proton at this energy is $2.2 m_0$, where m_0 is the proton rest mass.

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

(iii) Hence calculate the speed of a proton of mass $2.2 m_0$.

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

(7 marks)

7

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

- 4 A potential difference was applied between two electrodes in a glass tube containing air, as shown in **Figure 2**. The pressure of the air in the tube was gradually reduced until a glow of light was observed between the electrodes.

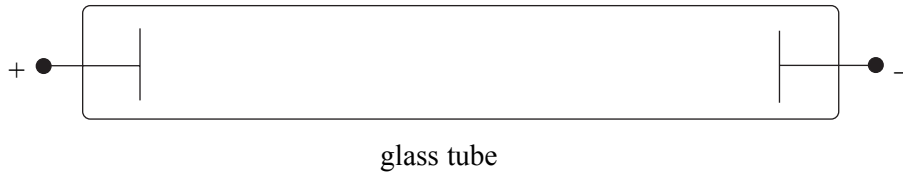


Figure 2

- (i) Explain why light was emitted.

.....

.....

.....

.....

.....

.....

.....

- (ii) State why the glow was not observed until the pressure of the air in the tube was low enough.

.....

.....

.....

(4 marks)

—
4

- 5 In an experiment to measure the charge on a charged oil droplet, a droplet was observed between two horizontal metal plates, as shown in **Figure 3**, spaced 6.0 mm apart.

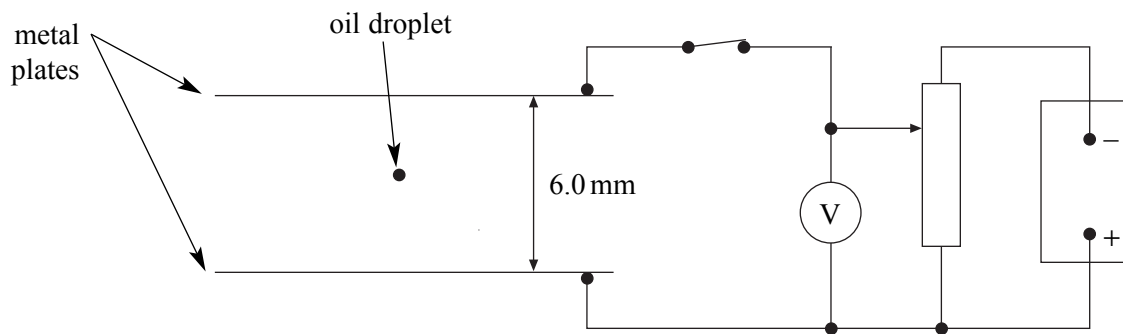


Figure 3

- (a) The oil droplet was held stationary when a negative potential of 320 V was applied to the top plate, keeping the lower plate at zero potential.

- (i) State the sign of the charge on the droplet.

.....

- (ii) With reference to the forces acting on the droplet explain why it was stationary.

.....

.....

.....

.....

(2 marks)

- (b) The potential difference between the plates was then switched off and the droplet fell at constant speed through a vertical distance of 1.20 mm in 13.8 s.

- (i) Calculate its speed of descent.

.....

.....

Turn over ►

- (ii) By considering the forces on the spherical droplet of radius r as it falls at constant speed v , show that

$$v = \frac{2\rho gr^2}{9\eta},$$

where η is the viscosity of the air between the plates and ρ is the density of the oil. Ignore buoyancy effects.

.....

.....

.....

.....

.....

.....

- (iii) Calculate the radius of the droplet and hence show that its mass is 2.6×10^{-15} kg.

viscosity of the air = $1.8 \times 10^{-5} \text{ N s m}^{-2}$
density of the oil = 960 kg m^{-3}

.....

.....

.....

.....

.....

.....

.....

.....

.....

(iv) Calculate the charge carried by this droplet.

.....

.....

.....

.....

.....

.....

.....

(10 marks)

$\frac{12}{12}$

$\frac{2}{2}$

QUALITY OF WRITTEN COMMUNICATION

END OF QUESTIONS

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE