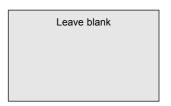
Surname			Othe	er Names			
Centre Number	er			Candid	ate Number		
Candidate Sig	nature						



General Certificate of Education June 2005 Advanced Level Examination



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

Thursday 16 June June 2005 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)	<b>→</b>				
TOTAL						
Examine	r'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 a	and valu	ies	
Quantity	Symbol	Value	Units
speed of light in vacuo	c	$3.00 \times 10^{8}$	m s <sup>-1</sup>
permeability of free space	$\mu_0$	$4\pi \times 10^{-7}$	H m <sup>-1</sup>
permittivity of free space	$\epsilon_0$	$8.85 \times 10^{-12}$	F m <sup>-1</sup>
charge of electron	e	$1.60 \times 10^{-19}$	C
the Planck constant	h	$6.63 \times 10^{-34}$	Js
gravitational constant	G	$6.67 \times 10^{-11}$	$N m^2 kg^{-2}$
the Avogadro constant	$N_{\rm A}$	$6.02 \times 10^{23}$	mol <sup>-1</sup>
molar gas constant	R	8.31	J K <sup>-1</sup> mol
the Boltzmann constant	k	$1.38 \times 10^{-23}$	J K <sup>-1</sup>
the Stefan constant	$\sigma$	$5.67 \times 10^{-8}$	W m <sup>-2</sup> K <sup>-4</sup>
the Wien constant	$\alpha$	$2.90 \times 10^{-3}$	m K
electron rest mass	$m_{ m e}$	$9.11 \times 10^{-31}$	kg
(equivalent to $5.5 \times 10^{-4}$ u)			
electron charge/mass ratio	$e/m_{\rm e}$	$1.76 \times 10^{11}$	C kg <sup>-1</sup>
proton rest mass	$m_{ m p}$	$1.67 \times 10^{-27}$	kg
(equivalent to 1.00728u)		_	_
proton charge/mass ratio	$e/m_{\rm p}$	$9.58 \times 10^{7}$	C kg <sup>-1</sup>
neutron rest mass	$m_{\rm n}$	$1.67 \times 10^{-27}$	kg
(equivalent to 1.00867u)			
gravitational field strength	g	9.81	N kg <sup>-1</sup>
acceleration due to gravity	g	9.81	m s <sup>-2</sup>
atomic mass unit	u	$1.661 \times 10^{-27}$	kg
(1u is equivalent to			•
931.3 MeV)			

#### **Fundamental particles**

Class	Name	Symbol	Rest energy
			/MeV
photon	photon	γ	0
lepton	neutrino	$ u_{\rm e}$	0
		$ u_{\mu}$	0
	electron	$e^{\pm}$	0.510999
	muon	$\mu^{\pm}$	105.659
mesons	pion	$\pi^{\pm}$	139.576
		$\pi^0$	134.972
	kaon	$K^{\pm}$	493.821
		$K^0$	497.762
baryons	proton	p	938.257
	neutron	n	939.551

#### Properties of quarks

Туре	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

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

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

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

$$I = \sum mr^2$$

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

$$\omega_2 = \omega_1 + at$$

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

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

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

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

$$T = I\alpha$$
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 $loop) \times (no.\ of\ cycles/s) \times$ (no. of cylinders)

 $friction\ power = indicated$ power – brake power

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

maximum possible

$$efficiency = \frac{T_{\rm H} - T_{\rm C}}{T_{\rm H}}$$

### Fields, Waves, Quantum Phenomena

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

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

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

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

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

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

$$x = A \cos 2\pi f t$$

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

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

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

$$d \sin \theta = n\lambda$$

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

$$_1 n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$$

$$_1 n_2 = \frac{n_2}{n_1}$$

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

$$E = hf$$

$$hf = \phi + E_k$$

$$hf = E_1 - E_2$$

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

### **Electricity**

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

$$\epsilon = I(R+r)$$

$$\frac{1}{R_{T}} = \frac{1}{R_{1}} + \frac{1}{R_{2}} + \frac{1}{R_{3}} + \cdots$$

$$R_{T} = R_{1} + R_{2} + R_{3} + \cdots$$

$$P = I^{2}R$$

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

$$E = \frac{1}{4\pi\epsilon_{0}} \frac{Q}{r^{2}}$$

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

$$F = BII$$

$$F = BOv$$

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

 $\Phi = BA$ 

Turn over

## **Data Sheet**

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

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

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

# Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

# Nuclear Physics and Turning Points in Physics

$$force = \frac{eV_{p}}{d}$$

$$force = Bev$$

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

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

 $work\ done = eV$ 

$$F = 6\pi \eta r v$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

v = Hd

 $P = \sigma A T^4$ 

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

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

$$R_{\rm s} \approx \frac{2GM}{c^2}$$

## **Medical Physics**

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

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

intensity level =  $10 \log \frac{I}{I_0}$ 

 $I = I_0 e^{-\mu x}$ 

$$\mu_{\rm m} = \frac{\mu}{\alpha}$$

### **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

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

$$\frac{1}{C_{\rm T}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$$

$$C_{\mathrm{T}} = C_1 + C_2 + C_3 + \cdots$$

$$X_{\rm C} = \frac{1}{2\pi fC}$$

## **Alternating Currents**

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

### **Operational amplifier**

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

$$G = -\frac{R_{\rm f}}{R_{\rm 1}}$$
 inverting

$$G = 1 + \frac{R_{\rm f}}{R_1}$$
 non-inverting

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

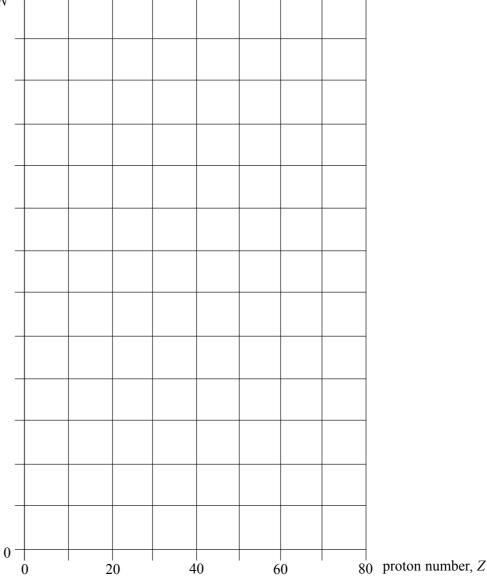
TURN OVER FOR THE FIRST QUESTION

#### SECTION A: NUCLEAR INSTABILITY

Answer all parts of the question.

1 (a) Sketch, using the axes provided, a graph of neutron number, N, against proton number, Z, for stable nuclei over the range Z = 0 to Z = 80. Show suitable numerical values on the N axis.

neutron number, N



(2 marks)

- (b) On the graph indicate, for each of the following, a possible position of a nuclide that may decay by
  - (i)  $\alpha$  emission, labelling the position with **W**,
  - (ii)  $\beta^-$  emission, labelling the position with **X**,
  - (iii)  $\beta^+$  emission, labelling the position with **Y**.

(3 marks)

(c)	The isotope $^{222}_{86}$ Rn decays sequentially by emitting $\alpha$ particles and $\beta$ -particles, eventually forming the isotope $^{206}_{82}$ Pb. Four $\alpha$ particles are emitted in the sequence.
	Calculate the number of $\beta^-$ particles in the sequence.
	(2 marks)
(d)	A particular nuclide is described as proton-rich. Discuss <b>two</b> ways in which the nuclide may decay.
	You may be awarded marks for the quality of written communication in your answer.
	(3 marks)



### TURN OVER FOR SECTION B

#### SECTION B: TURNING POINTS IN PHYSICS

Answer all questions.

2 In a transmission electron microscope, electrons from a heated filament are accelerated through a certain potential difference and then directed in a beam through a thin sample. The electrons scattered by the sample are focused by magnetic lenses onto a fluorescent screen where an image of the sample is formed, as shown in **Figure 1**.

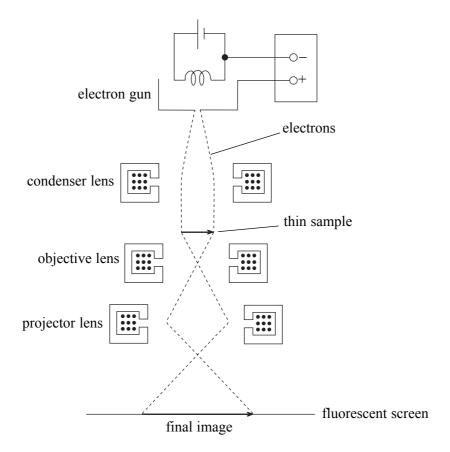


Figure 1

(a)	state and explain <b>one</b> reaspeed.	son wny it is importan	t that the electrons	in the beam	nave the same
					(2 marks)

b)	When the potential difference is increased, a more detailed image is seen. Explain why this change happens.
	(3 marks)

## TURN OVER FOR THE NEXT QUESTION

	pelectric emission occurs from a certain metal plate when the plate is illuminated by blue light but y red light.
(a)	Explain why photoelectric emission occurs from this plate using blue light but not using red light.
	(4 marks)
(b)	Outline why Huygens' wave theory of light fails to explain the fact that blue light causes photoelectric emission from this plate but red light does not.
	(2 marks)

3

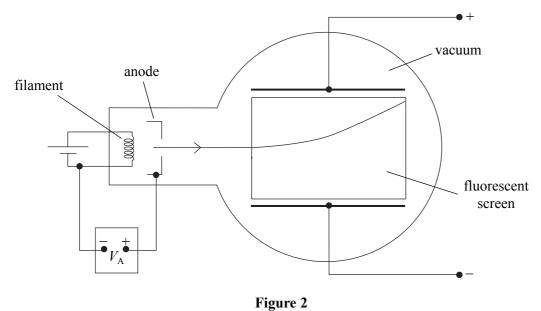
Calculate the speed at which a matter particle has a mass equal to 10 times its rest mass.
(3 m
kinetic energy can be increased without limit.

 $\frac{1}{6}$ 

# TURN OVER FOR THE NEXT QUESTION

(4 marks)

5 A narrow beam of electrons is directed into a uniform electric field created by two oppositely charged parallel horizontal plates, as shown in Figure 2. The initial direction of the beam is perpendicular to the direction of the electric field. The beam makes a visible trace on a vertical fluorescent screen.



(a)	Explain why the beam curves upwards at an increasing angle to the horizontal.
	You may be awarded marks for the quality of written communication in your answer.

		77
(i)	Show that the beam is undeflected when the ma	agnetic flux density $B = \frac{E}{V}$ , where
	E is the electric field strength between the plate	
(ii)	Hence show that the specific charge, $e/m$ , of the	e electron can be calculated using
	$\frac{e}{m} = \frac{E^2}{2B^2 V_{\rm A}}$	
	where $V_{\rm A}$ is the anode voltage and $B$ is the deflection.	magnetic flux density needed for ze
	Determine the specific charge of the electron us	sing the following data:
(iii)		
(iii)	anode voltage	$= 4500 \mathrm{V}$
(iii)	potential difference between the plates	= 3800 V
(iii)		
(iii)	potential difference between the plates plate separation	= 3800 V $= 50 mm$
(iii)	potential difference between the plates plate separation	= 3800 V $= 50 mm$
(iii)	potential difference between the plates plate separation	= 3800 V $= 50 mm$

(7 marks)

**QUALITY OF WRITTEN COMMUNICATION** (2 marks)

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