Surname				Other Names			

Centre Number					Candidate Number				

Candidate Signature	

PHYSICS (SPECIFICATION A)   **PA01**
Unit 1 Particles, Radiation and Quantum Phenomena

Monday 14 June 2004   Afternoon Session

In addition to this paper you will require:
- 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 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 50.
- Mark allocations are shown in brackets.
- The paper carries 30% of the total marks for Physics Advanced Subsidiary and carries 15% 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.

Leave blank

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1)			
Total (Column 2)			
TOTAL			
Examiner's Initials			

PA01

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

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

$v = u + at$

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

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

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

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

$P = Fv$

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

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

$angular\ momentum = I\omega$
$W = T\theta$
$P = T\omega$

$angular\ impulse = change\ of$
$\quad angular\ momentum = Tt$
$\Delta Q = \Delta U + \Delta W$
$\Delta W = p\Delta V$
$pV^\gamma = constant$

$work\ done\ per\ cycle = area\ of\ loop$

$input\ power = calorific\ value \times fuel\ flow\ rate$

$indicated\ power\ as\ (area\ of\ p-V\ loop) \times (no.\ of\ cycles/s) \times (no.\ of\ cylinders)$

$friction\ power = indicated\ power - brake\ power$

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

$maximum\ possible$
$\quad efficiency = \dfrac{T_H - T_C}{T_H}$

Fields, Waves, Quantum Phenomena

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

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

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

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

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

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

$x = A\cos 2\pi ft$

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

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

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

$d\sin\theta = n\lambda$

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

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

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

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

$E = hf$
$hf = \phi + E_k$
$hf = E_1 - E_2$

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

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

Electricity

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

$\epsilon = I(R + r)$

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

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

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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 = 1.50×10^{11} m

1 parsec = 206265 AU = 3.08×10^{16} m = 3.26 ly

1 light year = 9.45×10^{15} m

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

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

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

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

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

$$v = Hd$$

$$P = \sigma A T^4$$

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

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

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

Medical Physics

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

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

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

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

$$\mu_m = \frac{\mu}{\rho}$$

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

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

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

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

$$X_C = \frac{1}{2\pi f C}$$

Alternating Currents

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

Operational amplifier

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

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

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

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

Answer **all** questions

1 (a) (i) Determine the charge, in C, of a $^{239}_{92}$U nucleus.

....

....

(ii) A positive ion with a $^{239}_{92}$U nucleus has a charge of 4.80×10^{-19} C.
Determine how many electrons are in this ion.

....

....

....

(4 marks)

(b) A $^{239}_{92}$U nucleus may decay by emitting **two** β⁻ particles to form a plutonium nucleus ^X_YPu.
State what X and Y represent and give the numerical value of each.

X ....

....

Y ....

....

(4 marks)

$\overline{8}$

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

0204/PA01

2 In a radioactive decay of a nucleus, a β⁺ particle is emitted followed by a γ photon of wavelength 8.30×10^{-13} m.

(a) (i) State the rest mass, in kg, of the β⁺ particle.

....

(ii) Calculate the energy of the γ photon.

....

....

....

....

(iii) Determine the energy of the γ photon in MeV.

....

....

(6 marks)

(b) Name the fundamental interaction or force responsible for β⁺ decay.

....

(1 mark)

(c) β⁺ decay may be represented by the Feynman diagram.
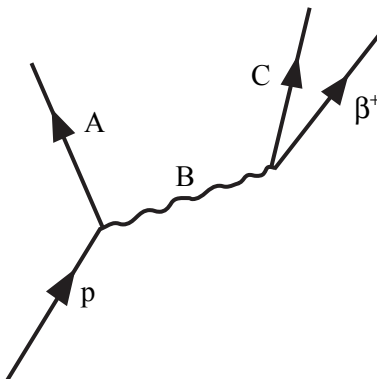
Name the particles represented by A, B and C.

A ....

B ....

C ....

(3 marks)

3 Some subatomic particles are classified as *hadrons*.

(a) What distinguishes a hadron from other subatomic particles?

....

....

(1 mark)

(b) Hadrons fall into two subgroups.
Name each subgroup and describe the general structure of each.

subgroup 1 ....

....

subgroup 2 ....

....

(3 marks)

(c) The following equation represents an event in which a positive muon collides with a neutron to produce a proton and an antineutrino.

$$n \; + \; \mu^{+} \; \Rightarrow \; p \; + \; \bar{\nu}_{\mu}.$$
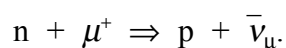
Show that this equation obeys the conservation laws of charge, lepton number and baryon number.

....

....

....

(3 marks)

TURN OVER FOR THE NEXT QUESTION

4 The diagram shows a cross-sectional view of the base of a glass tank containing water. A point monochromatic light source is in contact with the base and ray, R_1, from the source has been drawn up to the point where it emerges along the surface of the water.

air

R_1

water

E

F

water

D

C

A

B

glass

R_1

R_2

point monochromatic
light source
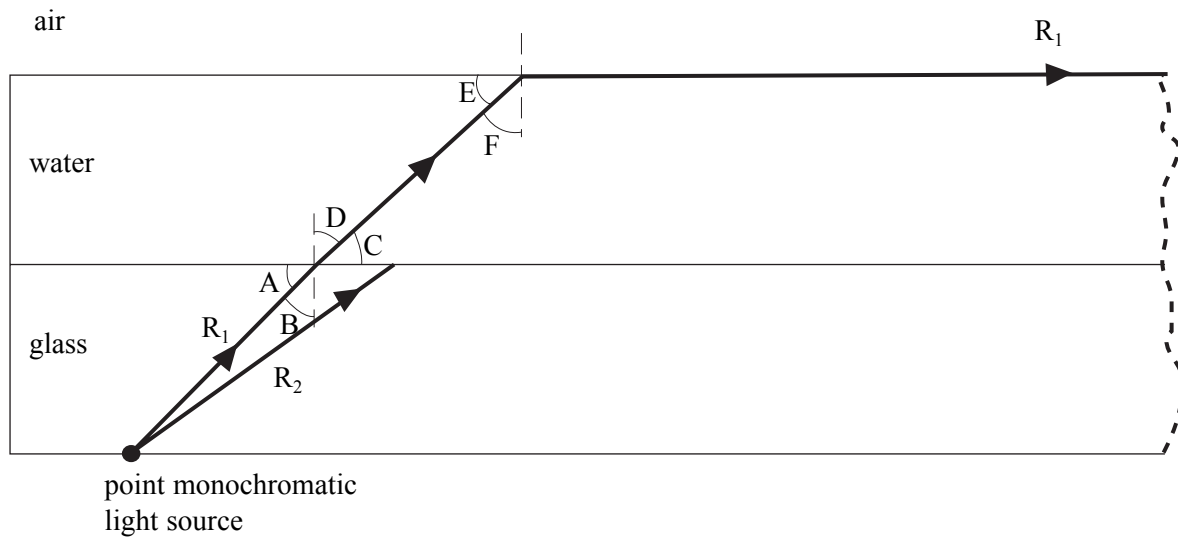
(a)   (i)   Which angle, A to F, is a critical angle?

....

      (ii)   Explain how the path of R_1 demonstrates that the refractive index of glass is greater than the refractive index of water.

....

....

(2 marks)

(b) Using the following information

A = 47.1°
B = 42.9°
C = E = 41.2°
D = F = 48.8°

calculate

  (i) the refractive index of water,

....

....

....

  (ii) the ratio, $\dfrac{\text{speed of light in water}}{\text{speed of light in glass}}$.

....

....

....

(5 marks)

(c) Ray R_2 emerges from the source a few degrees away from ray R_1 as shown.
Draw on the diagram opposite the continuation of ray R_2.
Where possible show the ray being refracted.   *(2 marks)*

TURN OVER FOR THE NEXT QUESTION

5 (a) Explain what happens to electrons in hydrogen atoms when a spectrum, such as that represented below, is produced.

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

intensity of
electromagnetic
radiation

wavelength

....

....

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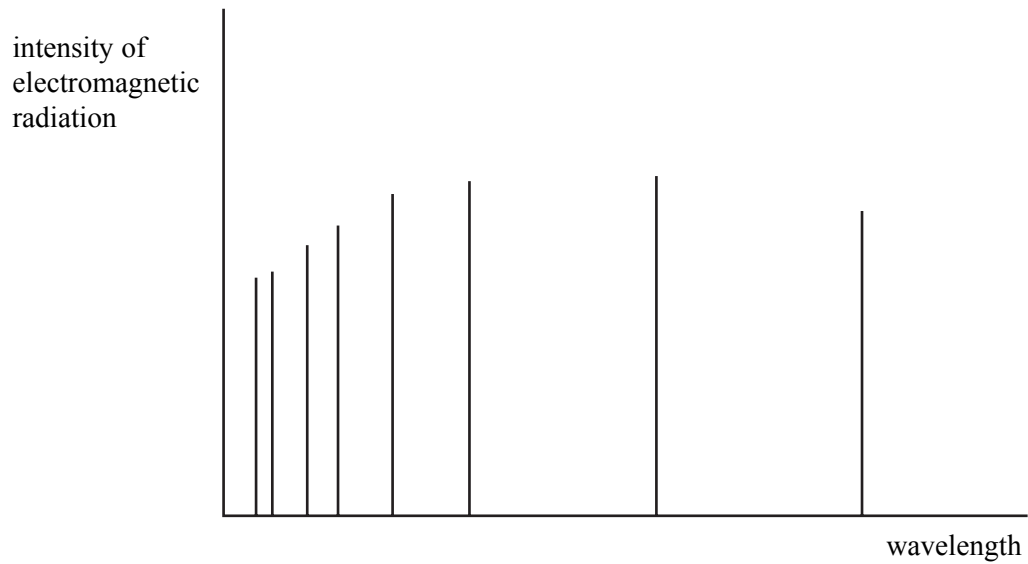
(4 marks)

(b)   A fluorescent tube is normally coated on the inside with a powder. The tube is then filled with mercury vapour at low pressure. When the tube is switched on, the mercury vapour emits ultraviolet electromagnetic radiation.

Explain how this ultraviolet radiation causes the powder to emit electromagnetic radiation as well. State the difference between the radiations emitted by the mercury vapour and the powder.

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

....

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....

....

(4 marks)

$\overline{8}$

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

6 A proton and an electron have the same velocity. The de Boglie wavelength of the electron is 3.2×10^{-8} m.

(a) Calculate,

(i) the velocity of the electron,

....

....

....

....

(ii) the de Broglie wavelength of the proton.

....

....

....

(4 marks)

(b) (i) State what kind of experiment would confirm that electrons have a wave-like nature. Experimental details are not required.

....

....

(ii) State why it is easier to demonstrate the wave properties of electrons than to demonstrate wave properties of protons.

....

....

....

(2 marks)

QUALITY OF WRITTEN COMMUNICATION *(2 marks)*

$\frac{}{6}$

$\frac{}{2}$

END OF QUESTIONS