Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2008
Advanced Subsidiary Examination

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

Thursday 22 May 2008 1.30 pm to 2.30 pm

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

Time allowed: 1 hour

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in the margins or on blank pages will not be marked.
- 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 two marks for the Quality of Written Communication.
- The marks for questions are shown in brackets.
- A *Data Sheet* is provided as a loose insert to this question paper.
- You are expected to use a calculator where appropriate.
- Questions 2(a), 2(b) and 2(c) and 4 should be answered in continuous prose. In these questions you will 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			
6			
Total (Column 1) →			
Total (Column 2) →			
Quality of Written Communication			
TOTAL			
Examiner's Initials			

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

1 The equation represents an event in which, following a neutron impact, a $^{233}_{92}U$ nucleus is split into two nuclei and two neutrons.

$$^{233}_{92}U + ^{1}_{0}n \longrightarrow X + ^{95}_{37}Rb + ^{1}_{0}n + ^{1}_{0}n$$

1 (a) How many protons, neutrons and electrons are there in an atom of $^{95}_{37}Rb$?

.... protons

.... neutrons

.... electrons

(2 marks)

1 (b) Determine for a nucleus of X

1 (b) (i) the mass number, *A*,

....

1 (b) (ii) the atomic number, *Z*.

....

(1 mark)

1 (c) Calculate the $\frac{\text{charge}}{\text{mass}}$ ratio of a $^{95}_{37}Rb$ nucleus, in $C\,kg^{-1}$.

....

....

....

....

(2 marks)

5

2 Monoenergetic α particles, directed normally in a parallel beam at a thin metal foil in a vacuum, are scattered at various angles.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer to parts a, b and c of this question.

2 (a) (i) Explain why the incident α particles should be in a narrow beam.

....

....

....

....

2 (a) (ii) The metal foil should be very thin to prevent too many α particles from being absorbed.
State another reason for using a very thin metal foil.

....

....

(2 marks)

2 (b) Describe the angular distribution of the scattered α particles coming from the foil.

State the scattering angles at which the number of α particles will be a maximum and a minimum.

....

....

....

....

....

....

(2 marks)

Question 2 continues on the next page

Turn over ▸

2 (c) State and explain **two** deductions made from the scattering distribution about the structure of the atoms in the foil.

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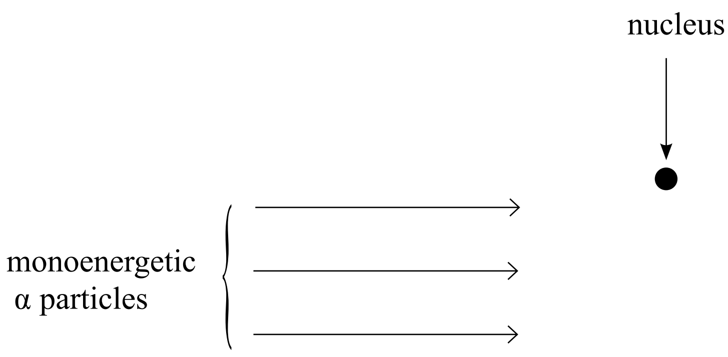
....

....

(4 marks)

2 (d) On **Figure 1** complete the paths taken by the parallel monoenergetic α particles which all come close enough to the nucleus to be deflected.

Figure 1



(3 marks)

11

Areas outside the box will not be scanned for marking

3 A $\overline{K^\circ}$ meson decays into two π mesons in the following event.

$$\overline{K^\circ} \longrightarrow \pi^- + \pi^+$$

The $\overline{K^\circ}$ has strangeness –1.

3 (a) Determine the quark structure of these three mesons.

$\overline{K^\circ}$ ....

π^- ....

π^+ ....

(3 marks)

3 (b) Complete the following table with ticks and crosses.

	baryon	**lepton**	**hadron**	**charged**
$\overline{K^\circ}$				×
π^-				✓

(2 marks)

3 (c) (i) By which fundamental interaction does the $\overline{K^\circ}$ decay?

....

3 (c) (ii) Give a reason for your answer.

....

....

(2 marks)

7

Turn over for the next question

4 The tube in a fluorescent lamp contains mercury vapour at low pressure. When connected to a suitable power supply the lamp emits light.

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

4 (i) Describe what happens in the fluorescent tube to excite the mercury atoms.

....

....

....

....

....

....

4 (ii) What is emitted from the mercury atoms when they de-excite?

....

....

4 (iii) Describe the purpose of the coating on the inside surface of the fluorescent tube.

....

....

....

....

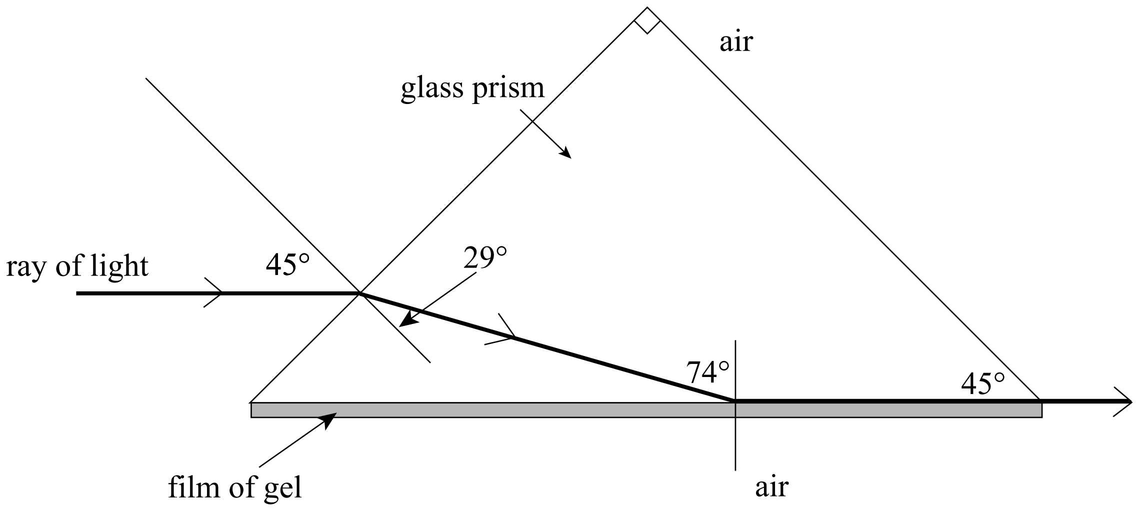
....

(7 marks)

7

5 **Figure 2** shows a 45° right angled glass prism in air, coated on one side with a film of transparent gel. A ray of light strikes the prism, at an angle of incidence of 45°, and continues through the glass to strike the glass-gel interface at the critical angle.

Figure 2



5 (a) Calculate the refractive index of

5 (a) (i) the glass,

....

....

....

....

5 (a) (ii) the gel.

....

....

....

....

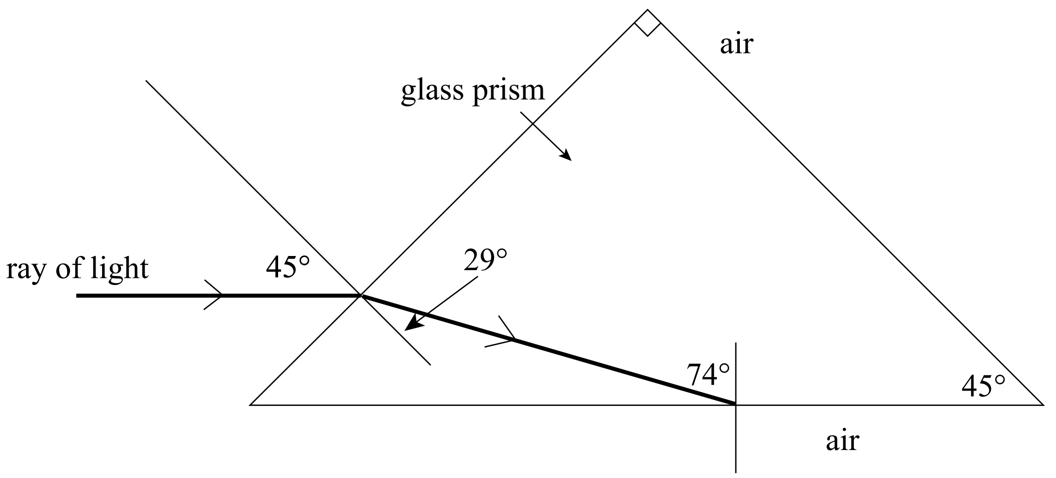
(5 marks)

Question 5 continues on the next page

Areas outside the box will not be scanned for marking

5 (b) On **Figure 3** draw, using a ruler, the path of the ray of light with the gel removed. Mark the values of all relevant angles.

Figure 3



(4 marks)

5 (c) A ray of light passes through a straight, 5.00 m long, optical fibre of refractive index 1.59. Calculate the time taken for a ray of light to travel along the axis of the fibre.

....

....

....

....

(2 marks)

11

6 (a) (i) State what is meant by the dual nature of electrons.

....

....

6 (a) (ii) Give **one** example of **each** type of behaviour of electrons.

....

....

....

....

(3 marks)

6 (b) (i) Calculate the speed of an electron whose de Broglie wavelength is 1.50×10^{-6} m.

....

....

....

6 (b) (ii) Calculate the momentum of a proton that would have the same de Broglie wavelength as the electron in part (b)(i).

....

....

....

Question 6 continues on the next page

Areas outside the box will not be scanned for marking

6 (b) (iii) Explain why electrons in part (b)(i) cannot be diffracted significantly by a crystal in which the atomic spacing is 1.0×10^{-10} m.

....

....

....

....

(4 marks)

7

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

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General Certificate of Education
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ASSESSMENT and QUALIFICATIONS ALLIANCE

PHYSICS (SPECIFICATION A) **PA01**

Unit 1 Particles, Radiation and Quantum Phenomena

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 (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}	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}	C kg^{-1}
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	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

$v = u + at$

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

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

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

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

$P = Fv$

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

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

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^{γ} = 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

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

maximum possible

$\text{efficiency} = \frac{T_H - T_C}{T_H}$

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

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

$\in = I(R + r)$

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

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

$P = I^2R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

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