Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
January 2008
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Friday 11 January 2008 1.30 pm to 2.30 pm

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

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.
- Answer the questions in the spaces provided.
- 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 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.
- Questions 2(c) and 4(c) 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			
Total (Column 1) →			
Total (Column 2) →			
Quality of Written Communication			
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

Quantity	*Symbol*	*Value*	*Units*
speed of light in vacuo	c	3.00×10^{8}	$\mathrm{m\,s^{-1}}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$\mathrm{H\,m^{-1}}$
permittivity of free space	ε_0	8.85×10^{-12}	$\mathrm{F\,m^{-1}}$
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}	$\mathrm{N\,m^{2}\,kg^{-2}}$
the Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\,K^{-1}\,mol^{-1}}$
the Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\,K^{-1}}$
the Stefan constant	σ	5.67×10^{-8}	$\mathrm{W\,m^{-2}\,K^{-4}}$
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}	$\mathrm{C\,kg^{-1}}$
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}	$\mathrm{C\,kg^{-1}}$
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	$\mathrm{N\,kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\,s^{-2}}$
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

$v = u + at$

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

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

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

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

$P = Fv$

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

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

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

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

maximum possible 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

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

$\epsilon = I(R + r)$

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

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

$P = I^2R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

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 $= \frac{\textit{tensile stress}}{\textit{tensile strain}} = \frac{F}{A}\frac{l}{e}$

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 $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

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

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

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

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 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}

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

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

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

$\lambda_{max} T$ = constant = 0.0029 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

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

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

1 The fluorine isotope ${}^{18}_{9}F$ can be produced in the process represented by

$$X + {}^{1}_{1}p \longrightarrow {}^{18}_{9}F + {}^{1}_{0}n$$

in which nucleus X combines with a fast moving proton to form the nucleus ${}^{18}_{9}F$ with the ejection of a neutron.

(a) (i) Determine the number of protons and neutrons in nucleus X.

.... protons

.... neutrons

(ii) Only one isotope of X produces this reaction.
Explain what is meant by *isotope*.

....

....

(3 marks)

(b) (i) Determine the $\frac{\text{charge}}{\text{mass}}$ ratio for the ${}^{18}_{9}F$ nucleus, in $C\,kg^{-1}$.

....

....

....

(ii) Show that the $\frac{\text{charge}}{\text{mass}}$ ratio for the ${}^{18}_{9}F$ nucleus is larger than that of nucleus X.

....

....

....

....

(3 marks)

6

Turn over

2 When a metal plate is illuminated with electromagnetic radiation of wavelength 1.5×10^{-7} m, the maximum kinetic energy of the emitted photoelectrons is 1.2×10^{-19} J.

(a) State what is meant by the *work function* of the metal.

....

....

....

(2 marks)

(b) (i) Show that the work function of the metal is 1.2×10^{-18} J.

....

....

....

....

(ii) Calculate the threshold frequency for the metal.

....

....

....

(4 marks)

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(c) The wavelength of the incident electromagnetic radiation remains at 1.50×10^{-7} m but its intensity is doubled.
State and explain what changes occur, if any, to the maximum kinetic energy of each photoelectron and to the number emitted per second.

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

....

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(4 marks)

10

Turn over for the next question

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3 (a) A muon can decay via the weak interaction

$$\mu^- \rightarrow e^- + X + \nu_\mu$$

(i) Name a mediating particle of the weak interaction.

....

(ii) Identify particle X.

....

....

....

....

(3 marks)

(b) An electron-neutrino may interact with a neutron as represented in the following equation.

$$\nu_e + n \rightarrow e^- + p$$

Draw a Feynman diagram to represent this interaction.

(3 marks)

(c) In a head-on collision between a proton and an antiproton the following reaction was observed.

$$p + \overline{p} \rightarrow 4\pi^{+} + 4\pi^{-}$$

(i) What name is given to the type of process in which a particle and its antiparticle interact?

....

(ii) Immediately following the process named in part (c)(i), what was formed before the $4\pi^{+}$ and $4\pi^{-}$ were created?

....

....

(3 marks)

(d) Determine the quark structure of an antiproton, $\overline{p}$.

....

....

(1 mark)

10

Turn over for the next question

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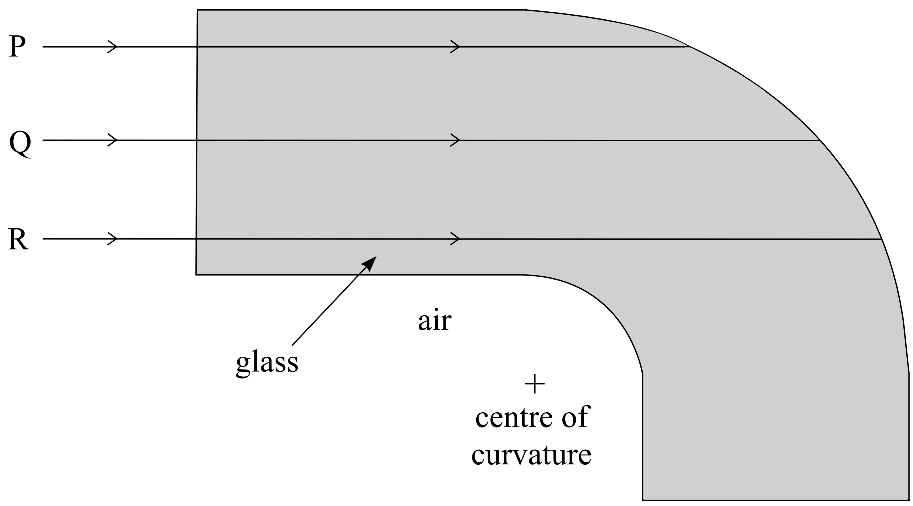
MARGIN
BLANK

4 **Figure 1** shows a glass optical fibre bent through 90° and surrounded by air. Three light rays PQR, initially travelling parallel to the axis of the fibre, are incident normally on the flat end of the fibre. They then strike the internal surface of the fibre at the glass-air boundary. Ray Q is incident at the critical angle.

Figure 1



(a) (i) Explain what is meant by *critical angle*.

....

....

(ii) Calculate the critical angle for a boundary between the glass and air.
refractive index of the glass = 1.54

....

....

....

(4 marks)

(b) Draw, using a ruler, on **Figure 1** the path taken by rays P, Q and R on striking the internal surface.

(3 marks)

LEAVE MARGIN BLANK

(c) (i) Describe what would happen to ray Q if the glass shown in **Figure 1** had been surrounded during manufacture with a glass cladding of lower refractive index.

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

....

....

....

....

....

(ii) State **one** reason why a glass cladding is normally used.

....

....

....

(iii) Calculate the critical angle for a boundary between the glass core and the glass cladding.

refractive index of the glass used for the cladding = 1.46

....

....

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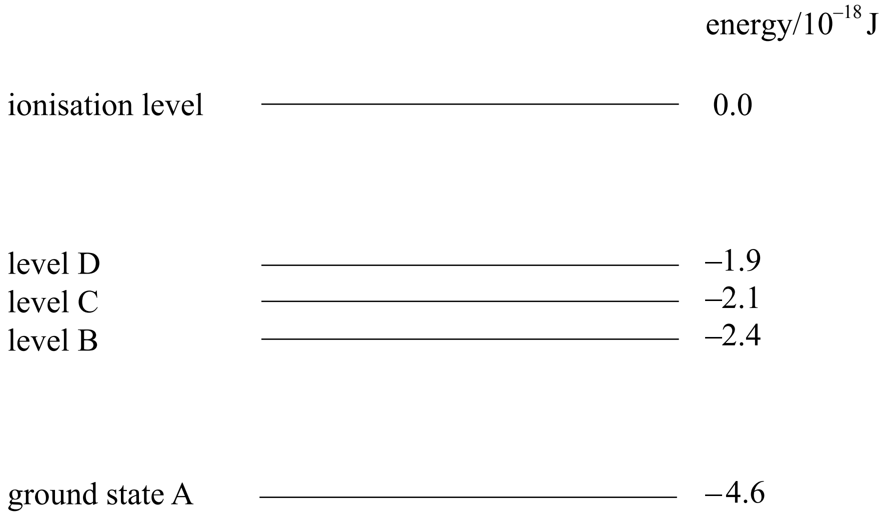
....

(6 marks)

13

Turn over for the next question

5 The diagram shows five electron energy levels of an isolated atom.
The ground state and the ionisation level are included.



(a) (i) Explain what is meant by *ionisation*.

....

....

(ii) Ionisation may be caused by electron impact.
Explain how else might an atom be ionised.

....

....

(iii) Calculate the ground state energy in eV.

....

....

....

(3 marks)

LEAVE MARGIN BLANK

(b) (i) An electron with kinetic energy 2.6×10^{-18} J collides inelastically with an electron in the ground state.
State which energy levels may be occupied following this collision.

....

(ii) A photon of energy 2.6×10^{-18} J is incident on an electron in the ground state.
State and explain what would happen.

....

....

....

....

(3 marks)

(c) After a separate excitation process, level D is occupied.
Calculate the longest possible wavelength of electromagnetic radiation emitted as the atom de-excites.

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(3 marks)

9

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

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