Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
January 2009
Advanced Subsidiary Examination

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

Tuesday 13 January 2009 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 3(a), and 6(a) 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			

Areas outside the box will not be scanned for marking

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

1 Potassium ${}^{40}_{19}K$, may undergo β^+ decay producing an *isotope* of argon as represented in the following equation,

$${}^{40}_{19}K \rightarrow {}^{x}_{y}Ar + \beta^+ + \nu_e$$

1 (a) What is meant by the word isotope?

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(2 marks)

1 (b) How many hadrons are there in an atom of ${}^{40}_{19}K$?

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(1 mark)

1 (c) Calculate the $\frac{\text{charge}}{\text{mass}}$ ratio for a nucleus of an atom of ${}^{40}_{19}K$.

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(3 marks)

1 (d) Write down the numbers represented by x and y in the equation.

x ....

y ....

(1 mark)

7

2 A fluorescent light tube contains mercury vapour at low pressure. The tube is coated on the inside surface and contains two electrodes.

2 (a) Describe and explain the processes which occur involving some of the atoms of mercury in the vapour when the fluorescent tube is in operation.

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(4 marks)

2 (b) Explain the purpose of the coating on the inside surface of the glass tube.

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(3 marks)

7

Turn over for the next question

3 (a) When electromagnetic radiation is incident on a particular metal plate, photoelectrons are emitted only when the wavelength of the electromagnetic radiation is below a specific value.

Explain, in terms of energy, why no photoelectron emission occurs above this specific wavelength.

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

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(3 marks)

3 (b) A sodium metal plate is illuminated with electromagnetic radiation of wavelength 4.90×10^{-7} m.

The work function of sodium is 3.94×10^{-19} J

3 (b) (i) Calculate the frequency of the incident radiation.

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3 (b) (ii) Show that the energy of a single photon of the incident radiation is about 4×10^{-19} J.

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3 (b) (iii) Calculate the maximum kinetic energy, in J, of the emitted photoelectrons.

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3 (b) (iv) Convert this maximum kinetic energy into eV.

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(5 marks)

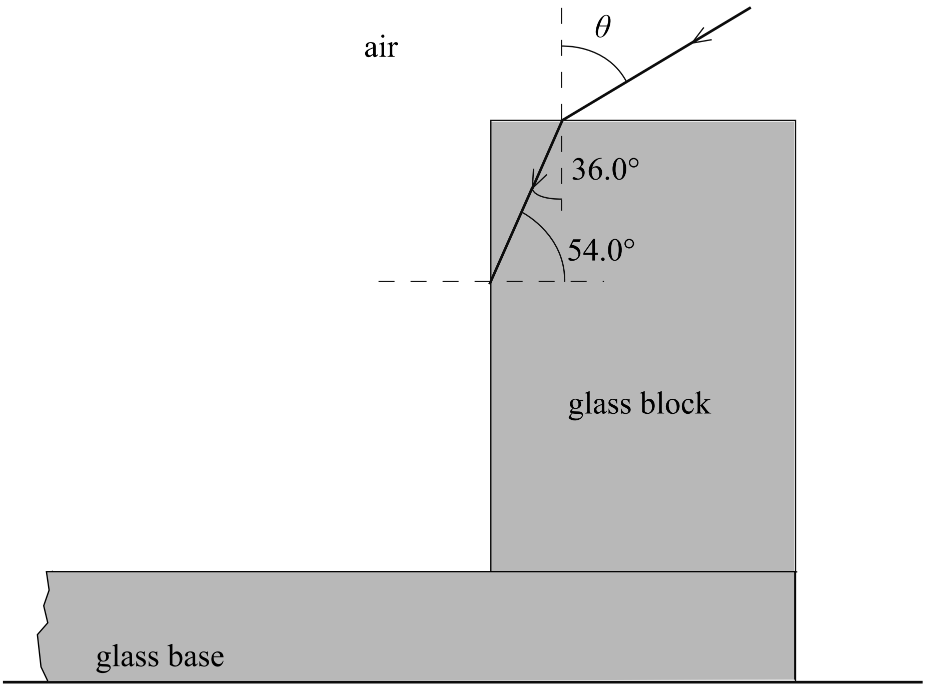
8

Turn over for the next question

4 **Figure 1** shows a vertical rectangular glass block standing on a glass base with a ray of monochromatic light incident on the top surface at an angle θ. The ray refracts to an angle of 36.0° in the glass.

refractive index of the glass block and glass base = 1.60

Figure 1



4 (a) (i) Calculate the angle of incidence θ.

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4 (a) (ii) Calculate the critical angle at the glass-air boundary.

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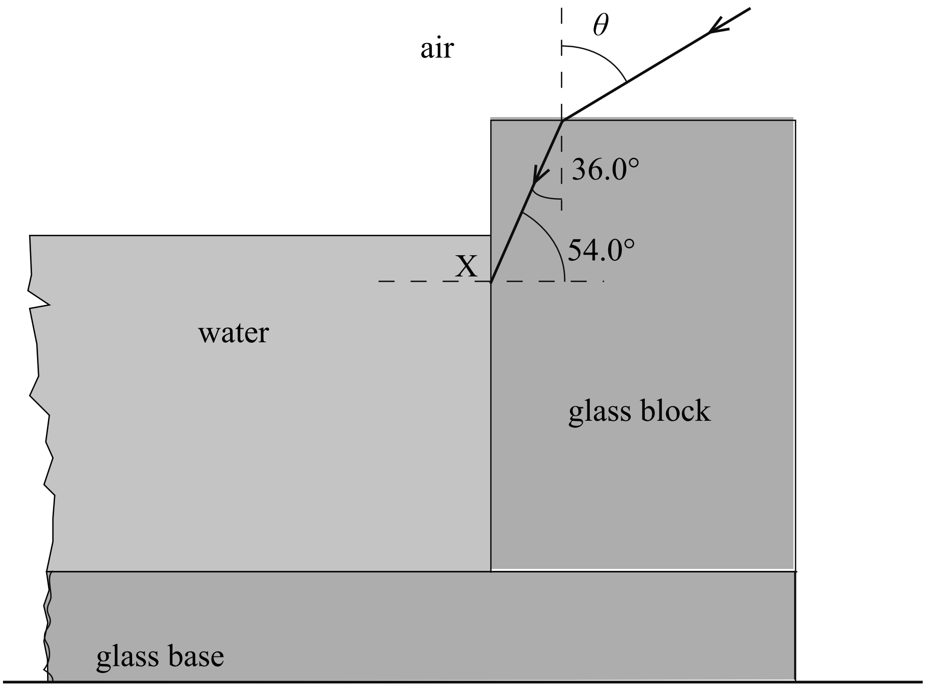
4 (a) (iii) On **Figure 1** continue the path of the ray, show it entering the glass base. Ignore partially reflected rays.

(5 marks)

4 (b) The rectangular glass block now acts as a barrier to a pool of water as in **Figure 2.**
refractive index of water = 1.33

Figure 2



4 (b) (i) Show, with a suitable calculation, that the ray does not undergo total internal reflection at the glass-water boundary at X.

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4 (b) (ii) On **Figure 2** continue the path of the ray showing it entering the glass base. Ignore partially reflected rays.

(6 marks)

11

5 (a) β^- decay is represented by the equation

$$n \longrightarrow p + \beta^- + \overline{\nu}_e$$

Draw a Feynman diagram that shows the change in quark composition in a β^- decay.

(3 marks)

5 (b) In electron capture as represented by the equation

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

energy, momentum and strangeness are all conserved.

Identify **three** other conserved properties and show how each is conserved in electron capture.

Property 1 ....

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Property 2 ....

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Property 3 ....

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(4 marks)

7

6 (a) Electrons behave in two distinct ways; this behaviour is referred to as the duality of electrons.

Identify, and give **one** example of each type of behaviour of electrons.

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

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(3 marks)

6 (b) (i) Calculate the speed of an electron that has a de Broglie wavelength of 2.30×10^{-10} m.

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Question 6 continues on the next page

6 (b) (ii) A different lepton particle, travelling at a speed of 911 m s^{-1}, has the same de Broglie wavelength as the electron in part (b)(i).
Calculate the mass of this lepton particle.

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(5 marks)

8

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

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General Certificate of Education
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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}	$\mathrm{m\ s^{-1}}$
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

$v = u + at$

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

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

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

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

$P = Fv$

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

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

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

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

This insert should **not** be sent to the examiner magnitude of induced emf $= N \dfrac{\Delta\Phi}{\Delta t}$

$I_{rms} = \dfrac{I_0}{\sqrt{2}}$

$V_{rms} = \dfrac{V_0}{\sqrt{2}}$

Mechanical and Thermal Properties

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

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

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

$\Delta Q = ml$

$pV = \frac{1}{3} N m\overline{c^2}$

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

Nuclear Physics and Turning Points in Physics

force $= \dfrac{eV_p}{d}$

force $= Bev$

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

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

work done $= eV$

$F = 6\pi\eta rv$

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

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

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

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

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

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

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

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

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

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 $= 1.50 \times 10^{11}$ 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}

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

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

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

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

$v = Hd$

$P = \sigma A T^4$

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

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

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

Medical Physics

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

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

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

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

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

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

$Z = \dfrac{V_{rms}}{I_{rms}}$

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

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

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

Alternating Currents

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

Operational amplifier

$G = \dfrac{V_{out}}{V_{in}}$ voltage gain

$G = -\dfrac{R_f}{R_1}$ inverting

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

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