Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2007
Advanced Subsidiary Examination

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

Friday 8 June 2007 9.00 am to 10.00 am

For this paper you must have:
- 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.
- 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.
- Two of these marks will be awarded for using good English, organising information clearly and using specialist vocabulary where appropriate.
- 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 3(a) and 5(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			
6			
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.

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 $= Tt$

$\Delta Q = \Delta U + \Delta W$

$\Delta W = p\Delta V$

$pV^{\gamma} =$ 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 ▶

magnitude of induced emf $= N \dfrac{\Delta\Phi}{\Delta t}$

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

force $= Bev$

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

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

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 = 1.50×10^{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 $= \dfrac{1}{f}$

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

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

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

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

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

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

Turn over for the first question

Turn over ▶

LEAVE MARGIN BLANK

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

1 (a) Give the number of protons, neutrons and electrons in an atom of the isotope ${}^{55}_{26}\mathrm{Fe}$.

protons ....

neutrons ....

electrons ....

(2 marks)

(b) Calculate the ratio $\frac{\text{charge}}{\text{mass}}$ for the nucleus of a ${}^{55}_{26}\mathrm{Fe}$ atom.

....

....

....

....

(3 marks)

(c) Determine the values of *a* and *b* in the decay represented by the equation

$$ {}^{a}_{b}\mathbf{X} \longrightarrow {}^{55}_{26}\mathrm{Fe} + e^{+} + \nu_{e}. $$

....

....

a = ...

b = ...

(2 marks)

7

LEAVE MARGIN BLANK

2 The Ω^- particle is a baryon with strangeness –3. It rapidly decays in stages to a baryon and several pions.

(a) State the general quark structure of a baryon.

....

(1 mark)

(b) State what class of particle a pion is. Give its general quark structure.

class ....

structure ....

(2 marks)

(c) State what pion is identical to its antiparticle.

....

(1 mark)

(d) State what baryon the Ω^- particle finally decays into.

....

(1 mark)

(e) State why the weak interaction must be involved at some stage in the decay of the Ω^- particle.

....

....

(1 mark)

6

Turn over for the next question

LEAVE MARGIN BLANK

3 (a) Describe and explain the principal features of the spectrum from excited gas atoms.

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)

(b) The energy levels of atomic hydrogen, in J, are given by the equation

$$E_n = -\frac{22 \times 10^{-19}}{n^2},$$

where n is a whole number corresponding to the energy level. Therefore the ground state, level 1, has energy $E_1 = -22 \times 10^{-19}$ J and level 2 has energy

$$E_2 = -\frac{22 \times 10^{-19}}{2^2} = -5.5 \times 10^{-19}\ \text{J}.$$

A photon is emitted from atomic hydrogen as the atom undergoes a transition from level 4 to level 2.

Calculate

(i) the energy of the emitted photon,

....

....

....

....

....

LEAVE MARGIN BLANK

(ii) the frequency of the photon.

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(4 marks)

(c) How many different wavelengths of electromagnetic radiation can be emitted after atomic hydrogen is excited to level 4?

....

....

(1 mark)

8

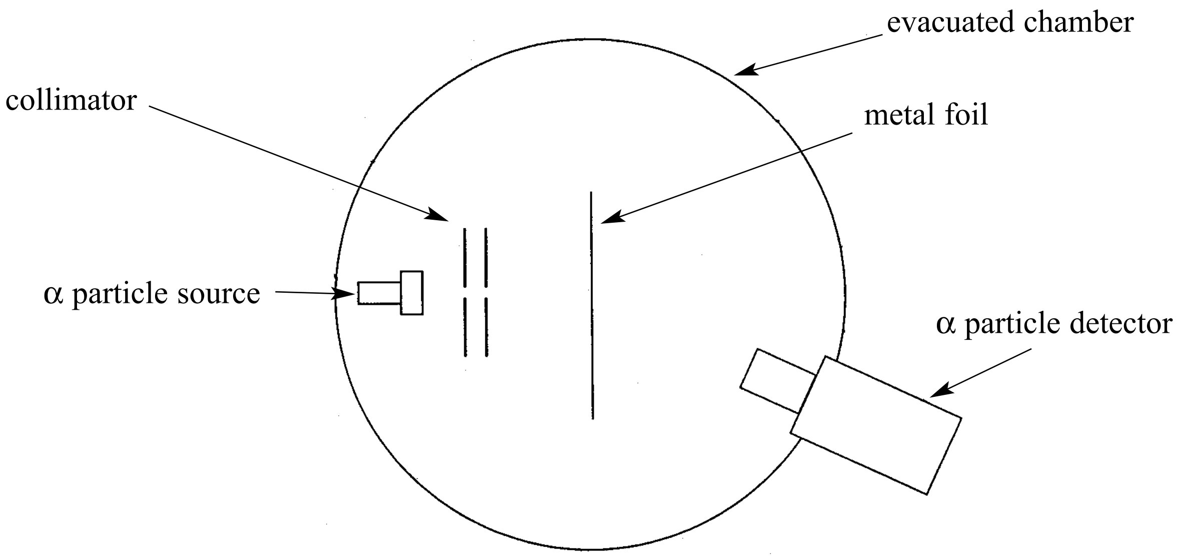
Turn over for the next question

Turn over

LEAVE MARGIN BLANK

4 **Figure 1** shows the apparatus in which α particles are directed at a metal foil in order to investigate the structure of the atom.

Figure 1



(a) (i) Give **two** reasons why the metal foil should be thin.

1 ....

....

2 ....

....

(ii) Explain why the incident beam of α particles should be narrow.

....

....

....

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....

(3 marks)

LEAVE MARGIN BLANK

(b) Describe and explain **one** feature of the distribution of the scattered α particles that suggests the nucleus contains most of the mass of an atom.

....

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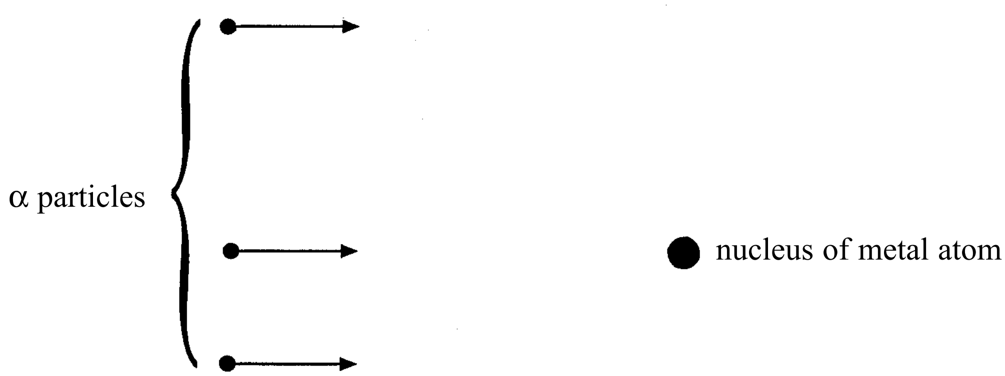
....

....

(2 marks)

(c) **Figure 2** shows three α particles with the same constant velocity incident on an atom in the metal foil. They all approach the nucleus close enough to be deflected by **at least** 10°.

Figure 2



Draw on **Figure 2** the paths followed by the three α particles whose initial directions are shown by the arrows. *(3 marks)*

8

Turn over for the next question

5 (a) Explain the term *work function*.

....

....

....

(2 marks)

(b) When a clean lithium surface is illuminated with ultraviolet radiation of photon energy 7.9×10^{-19} J, photoelectrons of energies up to 4.2×10^{-19} J are emitted.

Calculate

(i) the wavelength of the ultraviolet radiation,

....

....

....

....

(ii) the work function of lithium, in J,

....

....

....

....

(iii) the work function of lithium, in eV.

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(6 marks)

(c) Describe and explain the effect of increasing the intensity of the incident ultraviolet radiation on the emitted photoelectrons.

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)

11

Turn over for the next question

6 (a) Explain the term *critical angle* when applied to a transparent material in air.

....

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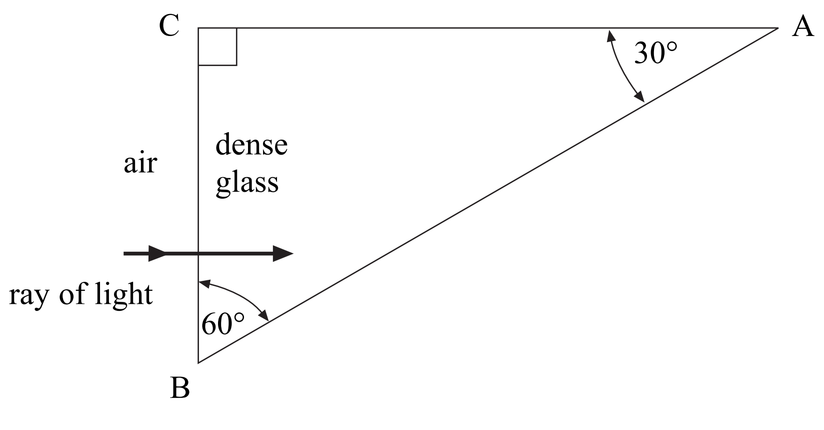
....

(2 marks)

(b) Dense glass in the shape of a prism, ABC, is surrounded by air as shown in **Figure 3**.
A ray of light enters one side normally.
refractive index of the glass = 1.60

Figure 3



(i) Calculate the critical angle for this dense glass–air boundary.

....

....

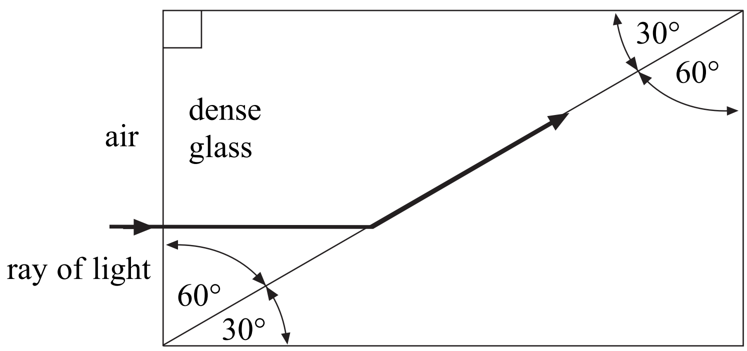
....

(ii) Complete the path of the ray on **Figure 3** showing it emerging into the air. Mark all relevant angles at the point of incidence on side AB.
No calculations are expected.

LEAVE MARGIN BLANK

(iii) A second prism made from a different type of glass is fixed to the original as shown in **Figure 4**. The ray of light now passes parallel to the boundary with the second prism.

Figure 4



Calculate the refractive index of the glass from which the second prism is made.

....

....

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....

(6 marks)

8

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

There are no questions printed on this page