

Surname						Other Names					
Centre Number						Candidate Number					
Candidate Signature											

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General Certificate of Education
 January 2005
 Advanced Subsidiary Examination



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

PA01

Wednesday 12 January 2005 Morning 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.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1)	→		
Total (Column 2)	→		
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	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}	$\text{N m}^2 \text{kg}^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$
the Wien constant	a	2.90×10^{-3}	m K
electron rest mass	m_e	9.11×10^{-31}	kg
(equivalent to $5.5 \times 10^{-4} \text{u}$)			
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	μ^\pm	105.659
mesons	pion	π^\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 = πr^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 = $\frac{\text{power output}}{\text{power input}}$
- $\omega = \frac{v}{r} = 2\pi f$
- $a = \frac{v^2}{r} = r\omega^2$
- $I = \sum mr^2$
- $E_k = \frac{1}{2}I\omega^2$
- $\omega_2 = \omega_1 + at$
- $\theta = \omega_1 t + \frac{1}{2}at^2$
- $\omega_2^2 = \omega_1^2 + 2a\theta$
- $\theta = \frac{1}{2}(\omega_1 + \omega_2)t$
- $T = I\alpha$
- angular momentum = $I\omega$
- $W = T\theta$
- $P = T\omega$
- angular impulse = change of angular momentum = Tt
- $\Delta Q = \Delta U + \Delta W$
- $\Delta W = p\Delta V$
- $pV^\gamma = \text{constant}$
- 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 = $\frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$
- maximum possible efficiency = $\frac{T_H - T_C}{T_H}$

Fields, Waves, Quantum Phenomena

- $g = \frac{F}{m}$
- $g = -\frac{GM}{r^2}$
- $g = -\frac{\Delta V}{\Delta x}$
- $V = -\frac{GM}{r}$
- $a = -(2\pi f)^2 x$
- $v = \pm 2\pi f \sqrt{A^2 - x^2}$
- $x = A \cos 2\pi ft$
- $T = 2\pi \sqrt{\frac{m}{k}}$
- $T = 2\pi \sqrt{\frac{l}{g}}$
- $\lambda = \frac{\omega S}{D}$
- $d \sin \theta = n\lambda$
- $\theta \approx \frac{\lambda}{D}$
- $n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$
- $n_2 = \frac{n_2}{n_1}$
- $\sin \theta_c = \frac{1}{n}$
- $E = hf$
- $hf = \phi + E_k$
- $hf = E_1 - E_2$
- $\lambda = \frac{h}{p} = \frac{h}{mv}$
- $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

Electricity

- $\epsilon = \frac{E}{Q}$
- $\epsilon = I(R + r)$
- $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
- $R_T = R_1 + R_2 + R_3 + \dots$
- $P = I^2 R$
- $E = \frac{F}{Q} = \frac{V}{d}$
- $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$
- $E = \frac{1}{2} QV$
- $F = BIl$
- $F = BQv$
- $Q = Q_0 e^{-t/RC}$

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

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

$$pV = \frac{1}{3} Nmc^2$$

$$\frac{1}{2} mc^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$$

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$1 \text{ astronomical unit} = 1.50 \times 10^{11} \text{ m}$$

$$1 \text{ parsec} = 206265 \text{ AU} = 3.08 \times 10^{16} \text{ m} = 3.26 \text{ ly}$$

$$1 \text{ light year} = 9.45 \times 10^{15} \text{ m}$$

$$\text{Hubble constant } (H) = 65 \text{ kms}^{-1} \text{ Mpc}^{-1}$$

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

Medical Physics

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

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

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

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

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

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

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

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

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

$$X_C = \frac{1}{2\pi fC}$$

Alternating Currents

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

Operational amplifier

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

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

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

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

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

1 (a) Name the constituent of an atom which

(i) has zero charge,

.....

(ii) has the largest charge to mass ratio,

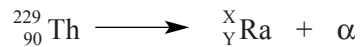
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(iii) when removed leaves a different isotope of the element.

.....

(3 marks)

(b) An α particle is the same as a nucleus of helium, ${}^4_2\text{He}$.
The equation



represents the decay of thorium by the emission of an α particle.

Determine

(i) the values of X and Y, shown in the equation,

X =

Y =

(ii) the ratio $\frac{\text{mass of } {}^X_Y\text{Ra nucleus}}{\text{mass of } \alpha \text{ particle}}$.

.....

.....

.....

(3 marks)

6

2 The diagram shows some of the electron energy levels of an atom.

level	energy/ 10^{-18} J
D	_____ -0.21
C	_____ -0.44
B	_____ -0.90
(ground state) A	_____ -1.94

An incident electron of kinetic energy 4.1×10^{-18} J and speed 3.0×10^6 m s⁻¹ collides with the atom represented in the diagram and excites an electron in the atom from level B to level D.

(a) For the incident electron, calculate

(i) the kinetic energy in eV,

.....

(ii) the de Broglie wavelength.

.....

(4 marks)

- (b) When the excited electron returns directly from level D to level B it emits a photon. Calculate the wavelength of this photon.

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(3 marks)

$\frac{7}{7}$

TURN OVER FOR THE NEXT QUESTION

- 3 (a) (i) Name a force which acts between an up quark, u, and an electron. Explain, with reference to an exchange particle, how this force operates.

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

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- (ii) With what particle must a proton collide to be annihilated?

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(4 marks)

- (b) A sigma plus particle, Σ^+ , is a baryon.

- (i) How many quarks does the Σ^+ contain?

.....

- (ii) If one of these quarks is an s quark, by what interaction will it decay?

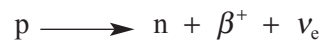
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- (iii) Which baryon will the Σ^+ eventually decay into?

.....
(3 marks)



4 The equation



represents the emission of a positron from a proton.

- (a) Energy and momentum are conserved in this emission.
What other quantities are conserved in this emission?

.....

.....

.....

.....

(3 marks)

- (b) Draw the Feynman diagram that corresponds to the positron emission represented in the equation.

(4 marks)

- (c) Complete the following table using ticks ✓ and crosses ×.

particle	fundamental particle	meson	baryon	lepton
p				
n				
β^+				
ν_e				

(4 marks)

- 5 (a) The photoelectric effect is represented by the equation

$$hf = \phi + E_k.$$

What does E_k represent?

.....
.....

(2 marks)

- (b) A metal plate is illuminated with electromagnetic radiation of wavelength 190 nm. The metal has a work function of 7.9×10^{-19} J.

- (i) Calculate the frequency of the incident electromagnetic radiation.

.....
.....
.....

- (ii) Show that the metal plate will emit photoelectrons when illuminated with radiation of this wavelength.

.....
.....
.....
.....

- (ii) The radiation incident on the metal plate remains at a constant wavelength of 190 nm but its intensity is now doubled.
State and explain the effect this has on the emitted photoelectrons.

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

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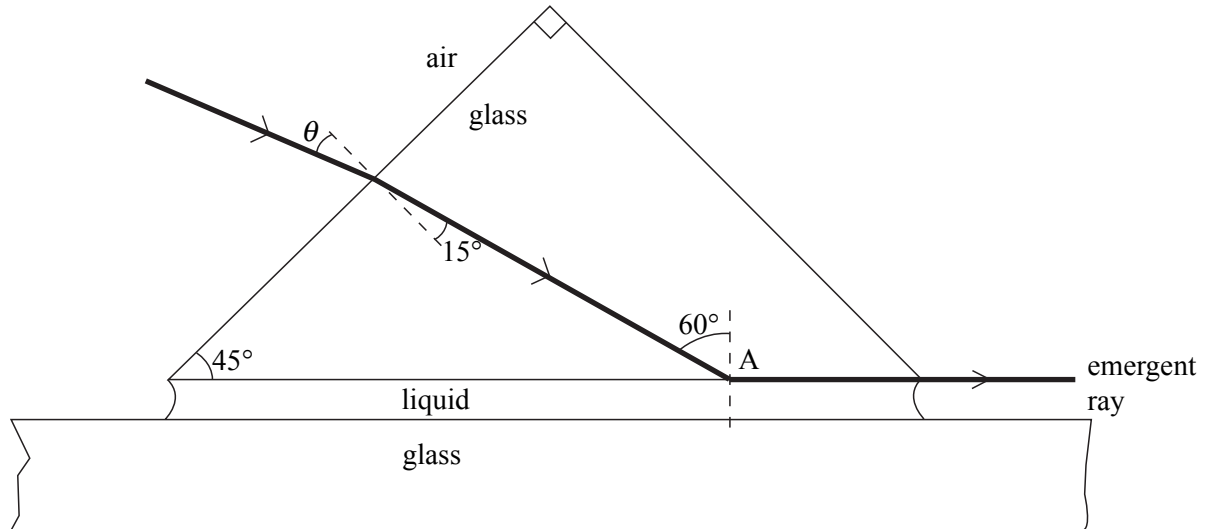
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(6 marks)

8

TURN OVER FOR THE NEXT QUESTION

- 6 The diagram, which is not to scale, shows the cross-section of a 45° right angled glass prism supported by a film of liquid on a glass table. A ray of monochromatic light is incident on the prism at an angle of incidence θ and emerges along the glass – liquid boundary as shown.
refractive index of glass = 1.5



- (a) Calculate the speed of light in the glass.

.....

(2 marks)

- (b) Determine

- (i) the angle of incidence, θ ,

.....

- (ii) the refractive index of the liquid.

.....

(5 marks)

- (c) The liquid is now changed to one with a lower refractive index. Draw a possible path for the ray beyond the point A and into the air. (2 marks)

$\frac{1}{9}$

QUALITY OF WRITTEN COMMUNICATION (2 marks)

$\frac{1}{2}$

END OF QUESTIONS