

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
 June 2005
 Advanced Subsidiary Examination



PA01

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

Friday 10 June 2005 Morning Session

<p>In addition to this paper you will require:</p> <ul style="list-style-type: none"> • a calculator; • a pencil and a ruler.
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For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1)	→		
Total (Column 2)	→		
TOTAL			
Examiner's Initials			

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.

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				Mechanics and Applied Physics		Fields, Waves, Quantum Phenomena	
Quantity	Symbol	Value	Units				
speed of light in vacuo	c	3.00×10^8	m s^{-1}	$v = u + at$			$g = \frac{F}{m}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}	$s = \left(\frac{u+v}{2}\right)t$			$g = -\frac{GM}{r^2}$
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}	$s = ut + \frac{at^2}{2}$			$g = -\frac{\Delta V}{\Delta x}$
charge of electron	e	1.60×10^{-19}	C	$v^2 = u^2 + 2as$			$V = -\frac{GM}{r}$
the Planck constant	h	6.63×10^{-34}	J s	$P = Fv$			$a = -(2\pi f)^2 x$
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$	$\text{efficiency} = \frac{\text{power output}}{\text{power input}}$			$v = \pm 2\pi f \sqrt{A^2 - x^2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}	$\omega = \frac{v}{r} = 2\pi f$			$x = A \cos 2\pi ft$
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$	$a = \frac{v^2}{r} = r\omega^2$			$T = 2\pi\sqrt{\frac{m}{k}}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}	$I = \sum mr^2$			$T = 2\pi\sqrt{\frac{l}{g}}$
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$	$E_k = \frac{1}{2} I\omega^2$			$\lambda = \frac{\omega s}{D}$
the Wien constant	a	2.90×10^{-3}	m K	$\omega_2 = \omega_1 + at$			$d \sin \theta = n\lambda$
electron rest mass	m_e	9.11×10^{-31}	kg	$\theta = \omega_1 t + \frac{1}{2} at^2$			$\theta \approx \frac{\lambda}{D}$
(equivalent to $5.5 \times 10^{-4}u$)				$\omega_2^2 = \omega_1^2 + 2a\theta$			$n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}	$\theta = \frac{1}{2} (\omega_1 + \omega_2)t$			$n_2 = \frac{n_2}{n_1}$
proton rest mass	m_p	1.67×10^{-27}	kg	$T = I\alpha$			$\sin \theta_c = \frac{1}{n}$
(equivalent to 1.00728u)				<i>angular momentum</i> = $I\omega$			$E = hf$
proton charge/mass ratio	e/m_p	9.58×10^7	C kg^{-1}	$W = T\theta$			$hf = \phi + E_k$
neutron rest mass	m_n	1.67×10^{-27}	kg	$P = T\omega$			$hf = E_1 - E_2$
(equivalent to 1.00867u)				<i>angular impulse</i> = change of angular momentum = Tt			$\lambda = \frac{h}{p} = \frac{h}{mv}$
gravitational field strength	g	9.81	N kg^{-1}	$\Delta Q = \Delta U + \Delta W$			$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$
acceleration due to gravity	g	9.81	m s^{-2}	$\Delta W = p\Delta V$			Electricity
atomic mass unit	u	1.661×10^{-27}	kg	$pV^\gamma = \text{constant}$			$\epsilon = \frac{E}{Q}$
(1u is equivalent to 931.3 MeV)				<i>work done per cycle</i> = area of loop			$\epsilon = I(R+r)$
Fundamental particles				<i>input power</i> = calorific value \times fuel flow rate			$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
<i>Class</i>	<i>Name</i>	<i>Symbol</i>	<i>Rest energy</i>	<i>indicated power</i> as (area of $p-V$ loop) \times (no. of cycles/s) \times (no. of cylinders)			$R_T = R_1 + R_2 + R_3 + \dots$
			/MeV	<i>friction power</i> = indicated power - brake power			$P = I^2 R$
photon	photon	γ	0	<i>efficiency</i> = $\frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$			$E = \frac{F}{Q} = \frac{V}{d}$
lepton	neutrino	ν_e	0	<i>maximum possible efficiency</i> = $\frac{T_H - T_C}{T_H}$			$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$
		ν_μ	0				$E = \frac{1}{2} QV$
	electron	e^\pm	0.510999				$F = BIl$
	muon	μ^\pm	105.659				$F = BQv$
mesons	pion	π^\pm	139.576				$Q = Q_0 e^{-t/RC}$
		π^0	134.972				$\Phi = BA$
	kaon	K^\pm	493.821				
		K^0	497.762				
baryons	proton	p	938.257				
	neutron	n	939.551				
Properties of quarks							
<i>Type</i>	<i>Charge</i>	<i>Baryon number</i>	<i>Strangeness</i>				
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							
<i>arc length</i> = $r\theta$							
<i>circumference of circle</i> = $2\pi r$							
<i>area of circle</i> = πr^2							
<i>area of cylinder</i> = $2\pi rh$							
<i>volume of cylinder</i> = $\pi r^2 h$							
<i>area of sphere</i> = $4\pi r^2$							
<i>volume of sphere</i> = $\frac{4}{3}\pi r^3$							

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

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

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

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

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

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

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

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.

1 (a) What are isotopes?

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(2 marks)

(b) One of the isotopes of nitrogen may be represented by ${}^{15}_7\text{N}$.

(i) State the number of each type of particle in its nucleus.

.....
.....

(ii) Determine the ratio $\frac{\text{charge}}{\text{mass}}$, in C kg^{-1} , of its nucleus.

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

(4 marks)

(c) (i) What is the charge, in C, of an atom of ${}^{15}_7\text{N}$ from which a single electron has been removed?

.....

(ii) What name is used to describe an atom from which an electron has been removed?

.....

(2 marks)

8

Turn over ►

2 Some energy levels of an atom of a gas are shown in **Figure 1**.

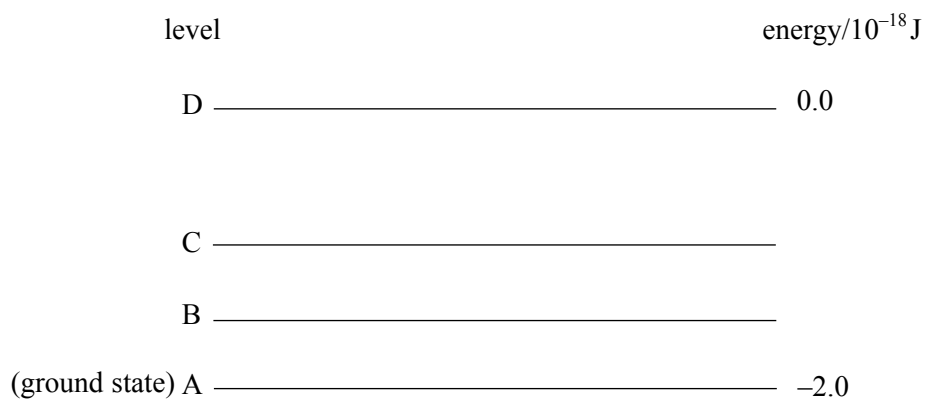


Figure 1

When a current is passed through the gas at low pressure, a line spectrum is produced. Two of these lines, which correspond to transitions from levels B and C respectively to the ground state, are shown in **Figure 2**.

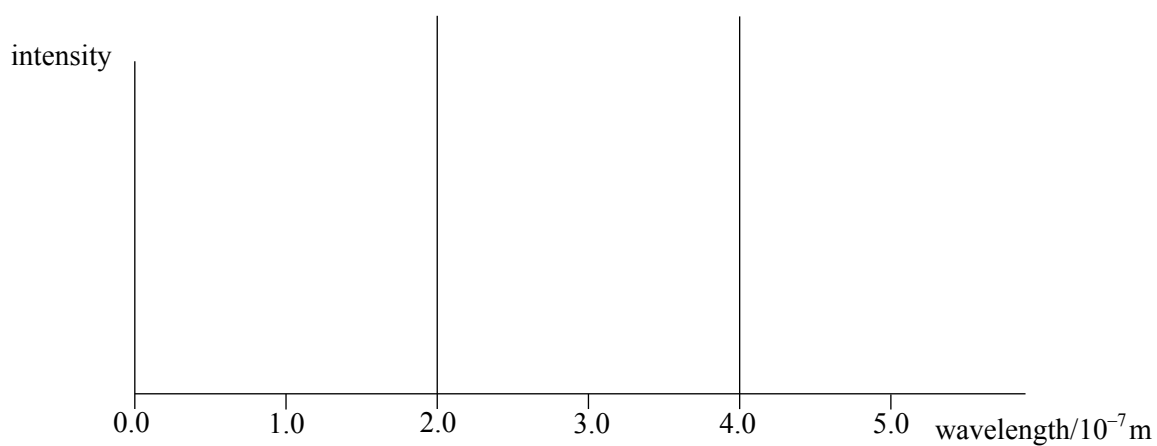


Figure 2

- (a) Describe what happens to an electron in an atom in the ground state in order for the atom to emit light of wavelength 4.0×10^{-7} m.

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

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(3 marks)

- (b) Determine the energy, in J, of

- (i) the photons responsible for each of the two lines shown in **Figure 2**,

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- (ii) levels B and C in **Figure 1**.

.....

.....

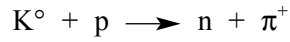
.....

energy of level B =

energy of level C =

(5 marks)

3 The equation represents the collision of a neutral kaon with a proton, resulting in the production of a neutron and a positive pion.



(a) Show that this collision obeys **three** conservation laws in addition to energy and momentum.

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

(3 marks)

(b) The neutral kaon has a strangeness of +1.
Write down the quark structure of the following particles.

K^0

π^+

p

(4 marks)



- 4 The diagram shows a cube of glass. A ray of light, incident at the centre of a face of the cube, at an angle of incidence θ , goes on to meet another face at an angle of incidence of 50° , as shown in **Figure 3**.

critical angle at the glass-air boundary = 45°

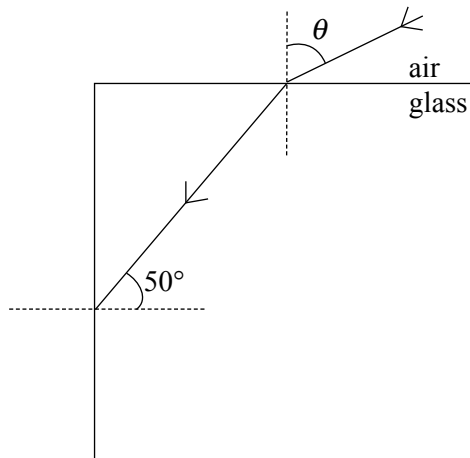


Figure 3

- (a) Draw on the diagram the continuation of the path of the ray, showing it passing through the glass and out into the air. (3 marks)

- (b) Show that the refractive index of the glass is 1.41.

.....

(2 marks)

- (c) Calculate the angle of incidence, θ .

.....

(3 marks)

- 5 (a) Explain what is meant by the term *work function* of a metal.

.....

.....

(2 marks)

- (b) In an experiment on the photoelectric effect, the maximum kinetic energy of the emitted photoelectrons is measured over a range of incident light frequencies. The results obtained are shown in **Figure 4**.

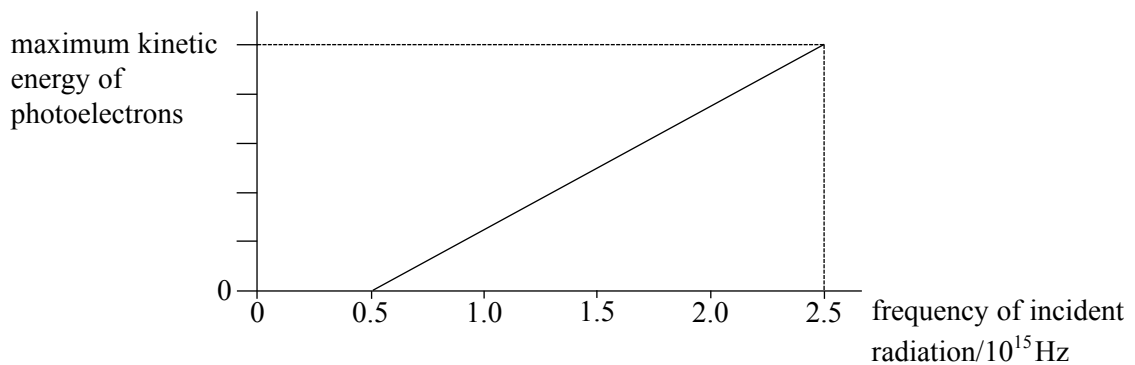


Figure 4

- (i) A metal of work function ϕ is illuminated with light of frequency f . Write down the equation giving the maximum kinetic energy, E_K , of the photoelectrons emitted in terms of ϕ and f .

$$E_K =$$

- (ii) Use the data in **Figure 4** to determine the work function of the metal.

.....

.....

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- (iii) Determine the maximum kinetic energy of the photoelectrons when the frequency of the incident radiation is 2.5×10^{15} Hz.

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(6 marks)

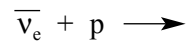
- (c) The experiment is repeated but with the light incident on a metal of lower work function. Draw a new line on **Figure 4** that results from this change. (2 marks)

10

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

- 6 (a) (i) Complete the equation that represents the collision between a proton and an antineutrino.



- (ii) What fundamental force is responsible for the interaction shown in part (i)?

.....

- (iii) Name an exchange particle that could be involved in this interaction.

.....

(4 marks)

- (b) Describe what happens in pair production and give **one** example of this process.

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

.....

(3 marks)

QUALITY OF WRITTEN COMMUNICATION (2 marks)

END OF QUESTIONS

$\frac{7}{7}$

$\frac{2}{2}$