

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
 January 2007
 Advanced Subsidiary Examination



ASSESSMENT and
 QUALIFICATIONS
 ALLIANCE

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

Friday 12 January 2007 1.30 pm to 2.30 pm

<p>For this paper you must have:</p> <ul style="list-style-type: none"> • 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.
- Four 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 2(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.

Data Sheet

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	$F = \frac{\Delta(mv)}{\Delta t}$	$a = -(2\pi f)^2 x$		
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$	$P = Fv$	$v = \pm 2\pi f \sqrt{A^2 - x^2}$		
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}	$\text{efficiency} = \frac{\text{power output}}{\text{power input}}$	$x = A \cos 2\pi ft$		
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$	$\omega = \frac{v}{r} = 2\pi f$	$T = 2\pi \sqrt{\frac{m}{k}}$		
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}	$a = \frac{v^2}{r} = r\omega^2$	$T = 2\pi \sqrt{\frac{L}{g}}$		
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$	$I = \sum mr^2$	$\lambda = \frac{\omega s}{D}$		
the Wien constant	α	2.90×10^{-3}	m K	$E_k = \frac{1}{2} I\omega^2$	$d \sin \theta = n\lambda$		
electron rest mass	m_e	9.11×10^{-31}	kg	$\omega_2 = \omega_1 + at$	$\theta = \frac{\lambda}{D}$		
(equivalent to $5.5 \times 10^{-4}u$)				$\theta = \omega_1 t + \frac{1}{2} at^2$	$1/n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$		
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}	$\omega_2^2 = \omega_1^2 + 2a\theta$	$1/n_2 = \frac{n_2}{n_1}$		
proton rest mass	m_p	1.67×10^{-27}	kg	$\theta = \frac{1}{2} (\omega_1 + \omega_2)t$	$\sin \theta_c = \frac{1}{n}$		
(equivalent to 1.00728u)				$T = I\alpha$	$E = hf$		
proton charge/mass ratio	e/m_p	9.58×10^7	C kg^{-1}	$\text{angular momentum} = I\omega$	$hf = \phi + E_k$		
neutron rest mass	m_n	1.67×10^{-27}	kg	$W = T\theta$	$hf = E_1 - E_2$		
(equivalent to 1.00867u)				$P = T\omega$	$\lambda = \frac{h}{p} = \frac{h}{mv}$		
gravitational field strength	g	9.81	N kg^{-1}	$\text{angular impulse} = \text{change of angular momentum} = Tt$	$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$		
acceleration due to gravity	g	9.81	m s^{-2}	$\Delta Q = \Delta U + \Delta W$			
atomic mass unit	u	1.661×10^{-27}	kg	$\Delta W = p\Delta V$			
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$			
Fundamental particles				Electricity			
Class	Name	Symbol	Rest energy /MeV	$\epsilon = \frac{E}{Q}$			
photon	photon	γ	0	$\epsilon = I(R + r)$			
lepton	neutrino	ν_e	0	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$			
		ν_μ	0	$R_T = R_1 + R_2 + R_3 + \dots$			
	electron	e^\pm	0.510999	$P = I^2 R$			
	muon	μ^\pm	105.659	$E = \frac{F}{Q} = \frac{V}{d}$			
mesons	pion	π^\pm	139.576	$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$			
		π^0	134.972	$E = \frac{1}{2} QV$			
	kaon	K^\pm	493.821	$F = BIl$			
		K^0	497.762	$F = BQv$			
baryons	proton	p	938.257	$Q = Q_0 e^{-l/RC}$			
	neutron	n	939.551	$\Phi = BA$			
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 = $\frac{4}{3}\pi r^3$							

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

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

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

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

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

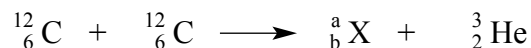
$$G = -\frac{R_f}{R_1} \quad \text{inverting}$$

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

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

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

- 1 The equation shows a carbon-carbon fusion reaction.



- (a) Determine the number of protons and the number of neutrons in the nuclide X.

.....

.....

number of protons

number of neutrons

(2 marks)

- (b) Two ${}^{12}_6\text{C}$ nuclei may also undergo a fusion reaction that produces other *isotopes* of X and He.

State what is meant by the term isotopes.

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(2 marks)

- (c) Calculate the ratio $\frac{\text{charge}}{\text{mass}}$ for the helium nucleus ${}^3_2\text{He}$.

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(3 marks)

Turn over for the next question

7

- 2 (a) State what is meant by the duality of electrons. Give **one** example of each type of behaviour.

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) (i) Calculate the speed of an electron which has a de Broglie wavelength of 1.3×10^{-10} m.

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- (ii) A particle when travelling at the speed calculated in (b)(i) has a de Broglie wavelength of 8.6×10^{-14} m.
Calculate the mass of the particle.

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(4 marks)

7

- 3 (a) The decay shown in the equation



cannot occur because it violates two conservation laws.

- (i) State the **two** conservation laws that are violated.

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- (ii) Give the correct equation for positron emission.

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(3 marks)

- (b) Draw a Feynman diagram in terms of quarks, to represent positron emission.

(3 marks)

6

Turn over for the next question

- 4 (a) (i) In relation to the photoelectric effect explain the meaning of the term *threshold frequency*.

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- (ii) Sketch on the axes a graph of the maximum kinetic energy of photoelectrons against the frequency of the incident electromagnetic radiation. Label the position of the threshold frequency, f_0 . Values are not required on the axes.



(4 marks)

- (b) The table gives the work function of some metals.

metal	work function/ 10^{-19} J
caesium	3.0
lithium	3.7
beryllium	6.2
mercury	7.2
tungsten	7.4

- (i) Calculate the threshold frequency for caesium.

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- (ii) A caesium surface is illuminated with electromagnetic radiation of wavelength 3.0×10^{-7} m. Determine the maximum kinetic energy of the ejected photoelectrons.

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- (iii) State which metals listed in the table will not emit photoelectrons when illuminated with electromagnetic radiation of wavelength 3.0×10^{-7} m.

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(7 marks)

Turn over for the next question

5 The diagram represents energy levels of the hydrogen atom.

energy level	energy / eV
6	-0.37
5	-0.54
4	-0.85
3	-1.5
2	-3.4
(ground state) 1	-13.6

(a) (i) State a similarity in the physical processes of excitation and ionisation.

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(ii) State how these two processes differ from each other.

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(2 marks)

(b) (i) One of the emitted spectral lines of hydrogen has a frequency of 4.6×10^{14} Hz. Calculate the energy, in eV, of a photon of this frequency.

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(ii) On the diagram draw an arrow to indicate the transition responsible for this spectral line.

(3 marks)

- (c) An electron in the ground state of a hydrogen atom is struck by a photon. State and explain what happens to the electron, and what happens to the photon, when the energy of the photon is (i) 10 eV and (ii) 20 eV.

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

- (i) Photon energy is 10 eV.

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- (ii) Photon energy is 20 eV.

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(4 marks)

9

Turn over for the next question

- 6 **Figure 1** shows a pool of water of depth 1.0 m which has a lamp set into the bottom corner as shown. The angle θ_c marked on the diagram is the critical angle for a water-air boundary. refractive index of water = 1.33

Figure 1



- (a) Calculate

- (i) the speed of light in water,

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- (ii) the critical angle θ_c .

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(3 marks)

- (b) On **Figure 1** draw the continuation of the paths taken by the three rays shown. No further calculations are required. (3 marks)

- (c) A layer of oil is poured over the surface of the water. Without calculation explain how the critical angle for the water-oil boundary differs from the critical angle, θ_c , for the water-air boundary.

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(2 marks)

8

Quality of Written Communication (2 marks)

2

END OF QUESTIONS

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