Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2006
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Friday 9 June 2006 9.00 am to 10.00 am

For this paper you must have:
- a calculator
- a pencil and 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 marked.

Information
- The maximum mark for this paper is 50. This includes up to 2 marks for the Quality of Written Communication.
- 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.
- You are reminded of the need for good English and clear presentation in your answers. Questions 4(a), 4(b) and 5(c) on the paper should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1) →			
Total (Column 2) →			
Quality of Written Communication			
TOTAL			
Examiner's Initials			

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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 them examination.
- You may wish to detach this sheet before you begin work.

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Data Sheet

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	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}	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}	C kg^{-1}
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	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 $= Tt$

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

$\Delta W = p\Delta V$

$pV^{\gamma} = \text{constant}$

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

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

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

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

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

Mechanical and Thermal Properties

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

$$\textit{energy stored} = \tfrac{1}{2}Fe$$

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

$$\textit{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

$$E = mc^2 = \frac{m_0c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

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

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

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}

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

Medical Physics

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

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

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

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

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

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

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

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

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Turn over for the first question

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

1 (a) An ion of plutonium $^{239}_{94}Pu$ has an overall charge of $+1.6 \times 10^{-19}$ C.
For this ion state the number of

(i) protons ....

(ii) neutrons ....

(iii) electrons ....

(3 marks)

(b) Plutonium has several *isotopes*. Explain the meaning of the word isotopes.

....

....

....

(2 marks)

5

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2 Under certain conditions a γ photon may be converted into an electron and a positron.

(a) What is this process called?

....

(1 mark)

(b) (i) Explain why there is a minimum energy of the γ photon for this conversion to take place and what happens when a γ photon has slightly more energy than this value.

....

....

....

....

....

(ii) Using values from the data sheet calculate this minimum energy in MeV.

....

....

(3 marks)

(c) Under suitable conditions, a γ photon may be converted into two other particles rather than an electron and positron.
Give an example of the two other particles it could create.

....

(1 mark)

5

Turn over for the next question

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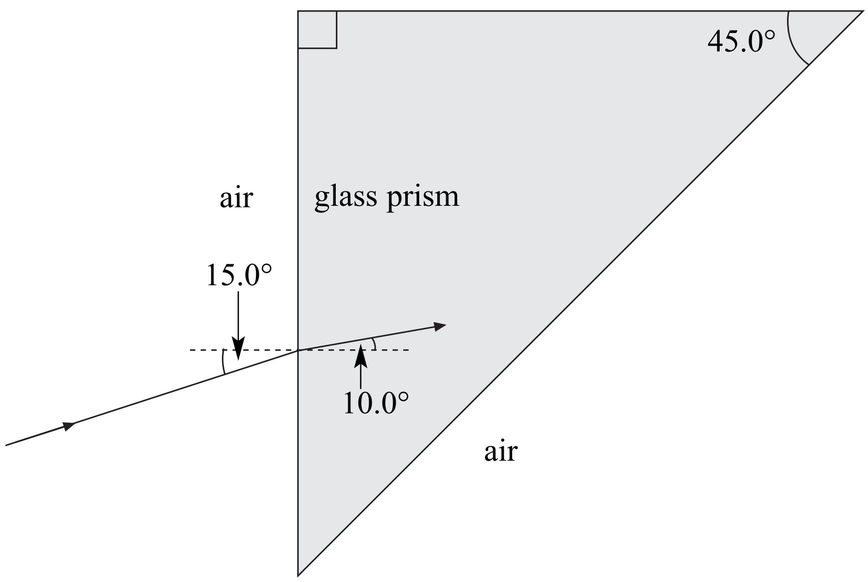
3 A ray of light passes from air into a glass prism as shown in **Figure 1**.

Figure 1



(a) Confirm, by calculation, that the refractive index of the glass from which the prism was made is 1.49.

....

....

....

....

(1 mark)

(b) On **Figure 1**, draw the continuation of the path of the ray of light until it emerges back into the air. Write on **Figure 1** the values of the angles between the ray and any normals you have drawn.

the critical angle from glass to air is less than 45°

(2 marks)

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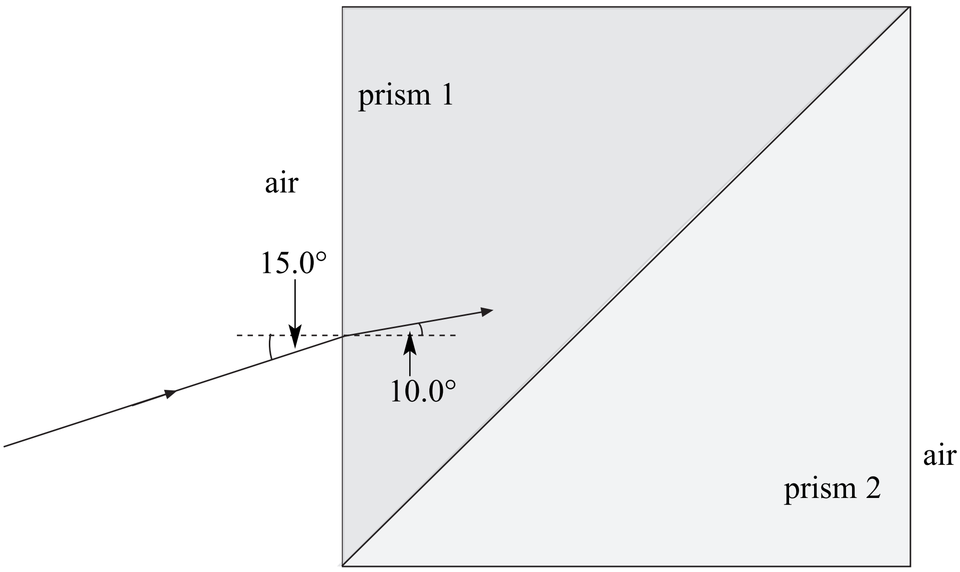
(c) A second prism, prism 2, made from transparent material of refractive index 1.37 is placed firmly against the original prism, prism 1, to form a cube as shown in **Figure 2**.

Figure 2



(i) The ray strikes the boundary between the prisms. Calculate the angle of refraction of the ray in prism 2.

....

....

....

....

....

....

....

(ii) Calculate the speed of light in prism 2.

....

....

....

(iii) Draw a path the ray could follow to emerge from prism 2 into the air.

(7 marks)

10

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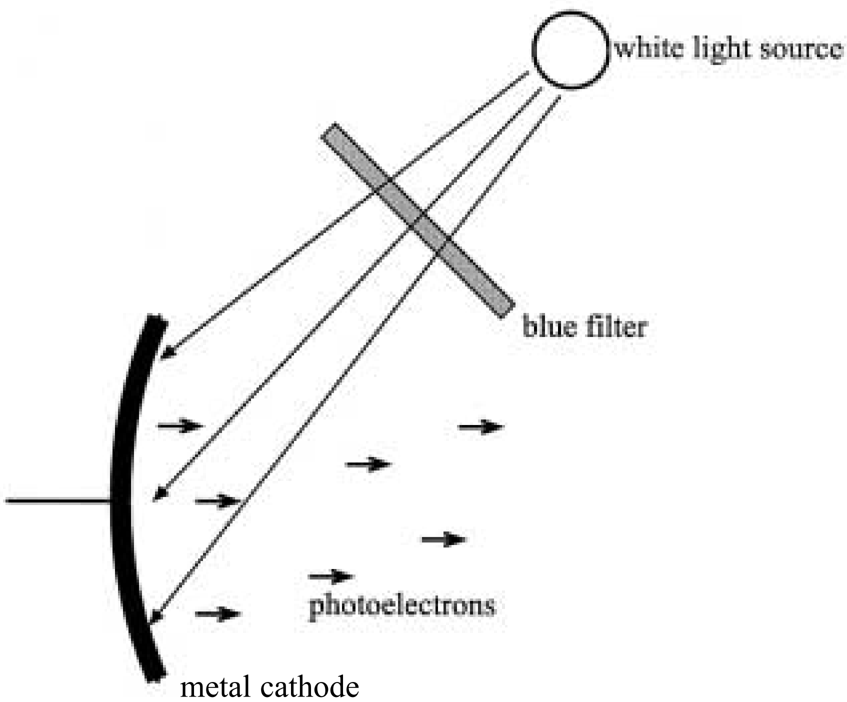
4 The apparatus shown in **Figure 3** can be used to demonstrate the photoelectric effect. Photoelectrons are emitted from the metal cathode when it is illuminated with white light which has passed through a blue filter.

Figure 3



You may be awarded additional marks to those shown in brackets for the quality of written communication in your answers to parts (a) and (b).

(a) The intensity of the light source is reduced. State and explain the effect of this on the emitted photoelectrons.

....

....

....

....

(3 marks)

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(b) Explain why no photoelectrons are emitted when the blue filter is replaced by a red filter.

....

....

....

....

(3 marks)

(c) When a metal of work function 2.30×10^{-19} J is illuminated with ultraviolet radiation of wavelength 200 nm, photoelectrons are emitted.

Calculate

(i) the frequency of the ultraviolet radiation,

....

....

(ii) the threshold frequency of the metal,

....

....

....

(iii) the maximum kinetic energy of the photoelectrons, in J.

....

....

....

....

(5 marks)

11

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5 **Figure 4** shows the energy level diagram of a hydrogen atom. Its associated spectrum is shown in **Figure 5**.

The transition labelled **A** in **Figure 4** gives the spectral line labelled **B** in **Figure 5**.

Figure 4

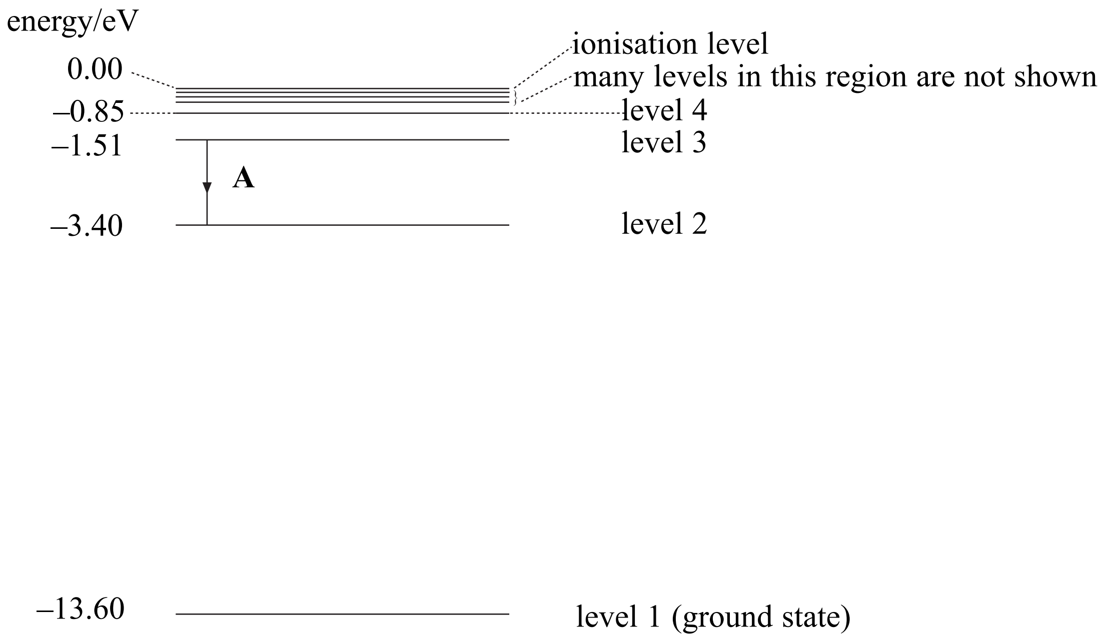
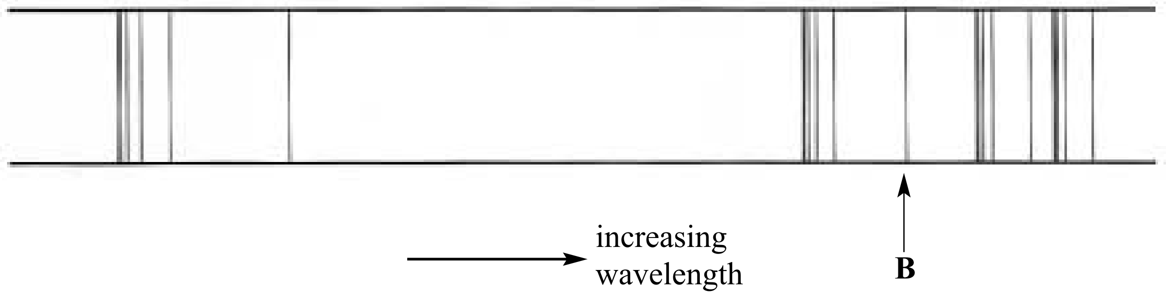


Figure 5

hydrogen spectrum showing some of the main spectral lines



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(a) (i) Show that the frequency of spectral line B is about 4.6×10^{14} Hz.

....

....

....

(ii) Calculate the wavelength represented by line B.

....

....

(3 marks)

(b) The hydrogen atom is excited and its electron moves to level 4.

(i) How many different wavelengths of electromagnetic radiation may be emitted as the atom returns to its ground state?

....

(ii) Calculate the energy, in eV, of the longest wavelength of electromagnetic radiation emitted during this process.

....

....

(2 marks)

(c) In a fluorescent tube, explain how the mercury vapour and the coating of its inner surface contribute to the production of visible light.

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)

8

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6 (a) Complete the following equations

$$p + e^{-} \longrightarrow \_\_\_ + \_\_\_$$

$$n + \nu_{\mu} \longrightarrow p + \_\_\_$$

$$p + p \longrightarrow p + p + K^{-} + \_\_\_$$

(4 marks)

(b) Give an equation that represents β^{-} decay, using quarks in the equation rather than nucleons.

....

....

(2 marks)

(c) (i) Which fundamental force is responsible for electron capture?

....

(ii) What type of particle is an electron?

....

(iii) State the other fundamental forces that electrons may experience.

....

(3 marks)

9

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

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