

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

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

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

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

### 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   | $2.00 \times 10^{30}$ | $7.00 \times 10^8$ |
| Earth | $6.00 \times 10^{24}$ | $6.40 \times 10^6$ |

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

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

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

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

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

### 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

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

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

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

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

---

**Turn over for the first question**

**Turn over ►**

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

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

protons .....

neutrons .....

electrons .....

(2 marks)

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

.....

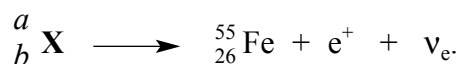
.....

.....

.....

(3 marks)

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



.....

.....

$a =$  .....

$b =$  .....

(2 marks)

|   |
|---|
| 7 |
|---|

- 2 The  $\Omega^-$  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  $\Omega^-$  particle finally decays into.

.....  
(1 mark)

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

.....  
.....  
(1 mark)

**Turn over for the next question**

- 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.

.....

.....

.....

.....

.....

.....

(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,

.....

.....

.....

.....

.....



(ii) the frequency of the photon.

.....

.....

.....

(4 marks)

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

.....

.....

(1 mark)

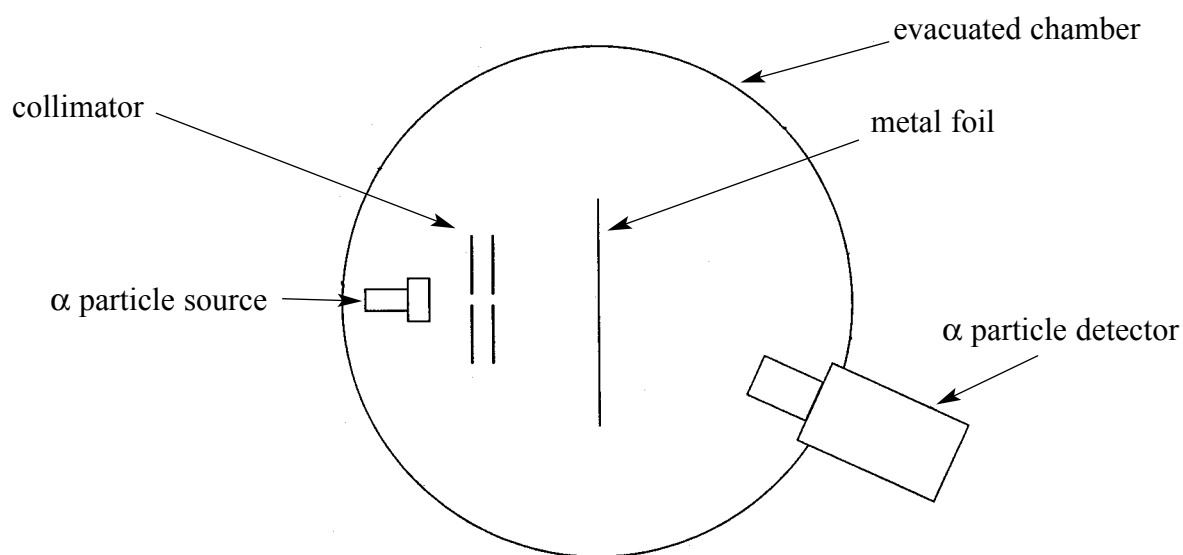
|   |
|---|
| 8 |
|---|

**Turn over for the next question**

**Turn over ►**

- 4 **Figure 1** shows the apparatus in which  $\alpha$  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  $\alpha$  particles should be narrow.

.....

.....

.....

.....

.....

(3 marks)

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

.....

.....

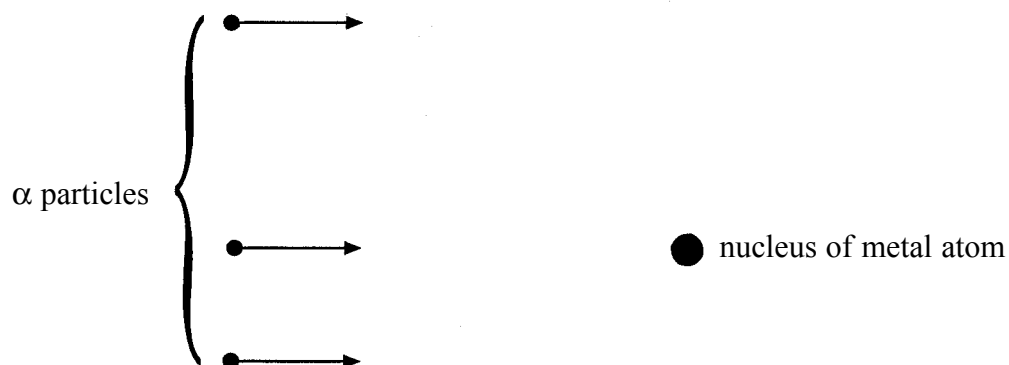
.....

.....

(2 marks)

- (c) **Figure 2** shows three  $\alpha$  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**  $10^\circ$ .

**Figure 2**



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

|   |
|---|
| 8 |
|---|

**Turn over for the next question**

**Turn over ►**

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

.....

.....

.....

(2 marks)

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

.....

.....

.....

.....

(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.

.....

.....

.....

.....

.....

.....

(3 marks)

**Turn over for the next question**

|    |
|----|
| 11 |
|----|

**Turn over ►**

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

.....

.....

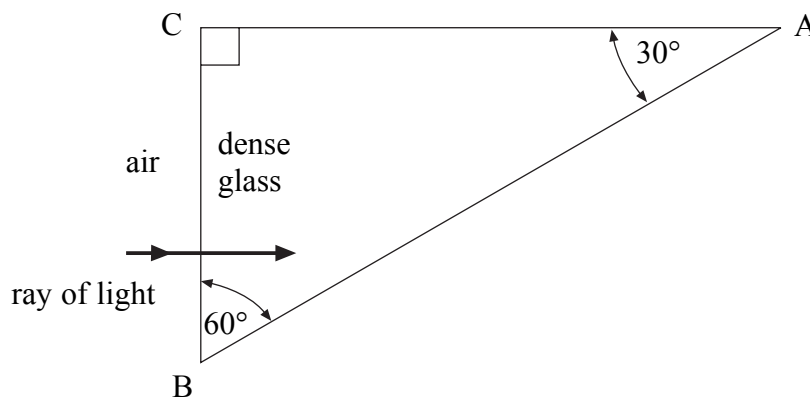
.....

.....

(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.

.....

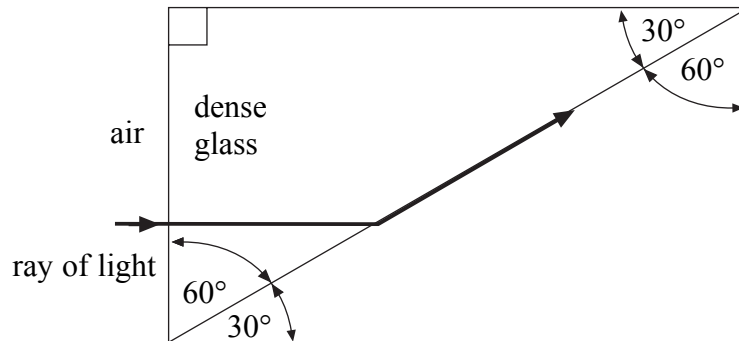
.....

.....

- (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.

- (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.

.....

.....

.....

.....

(6 marks)

8

**Quality of Written Communication** (2 marks)

2

**END OF QUESTIONS**

---

**There are no questions printed on this page**