

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education  
 January 2003  
 Advanced Level Examination



**PHYSICS (SPECIFICATION A) PHA8/W**  
**Unit 8 Nuclear Instability: Turning Points in Physics Option**

Monday 27 January 2003 Morning Session

**In addition to this paper you will require:**

- a calculator;
- a pencil and a ruler.

Time allowed: 1 hour 15 minutes

**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 40.
- Mark allocations are shown in brackets.
- The paper carries 10% 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			
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	$c$	$3.00 \times 10^8$	$\text{m s}^{-1}$
permeability of free space	$\mu_0$	$4\pi \times 10^{-7}$	$\text{H m}^{-1}$
permittivity of free space	$\epsilon_0$	$8.85 \times 10^{-12}$	$\text{F m}^{-1}$
charge of electron	$e$	$1.60 \times 10^{-19}$	C
the Planck constant	$h$	$6.63 \times 10^{-34}$	J s
gravitational constant	$G$	$6.67 \times 10^{-11}$	$\text{N m}^2 \text{kg}^{-2}$
the Avogadro constant	$N_A$	$6.02 \times 10^{23}$	$\text{mol}^{-1}$
molar gas constant	$R$	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
the Boltzmann constant	$k$	$1.38 \times 10^{-23}$	$\text{J K}^{-1}$
the Stefan constant	$\sigma$	$5.67 \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$
the Wien constant	$\alpha$	$2.90 \times 10^{-3}$	m K
electron rest mass	$m_e$	$9.11 \times 10^{-31}$	kg
(equivalent to $5.5 \times 10^{-4}u$ )			
electron charge/mass ratio	$e/m_e$	$1.76 \times 10^{11}$	$\text{C kg}^{-1}$
proton rest mass	$m_p$	$1.67 \times 10^{-27}$	kg
(equivalent to 1.00728u)			
proton charge/mass ratio	$e/m_p$	$9.58 \times 10^7$	$\text{C kg}^{-1}$
neutron rest mass	$m_n$	$1.67 \times 10^{-27}$	kg
(equivalent to 1.00867u)			
gravitational field strength	$g$	9.81	$\text{N kg}^{-1}$
acceleration due to gravity	$g$	9.81	$\text{m s}^{-2}$
atomic mass unit	$u$	$1.661 \times 10^{-27}$	kg
(1u is equivalent to 931.3 MeV)			

**Fundamental particles**

Class	Name	Symbol	Rest energy
			/MeV
photon	photon	$\gamma$	0
lepton	neutrino	$\nu_e$	0
		$\nu_\mu$	0
	electron	$e^\pm$	0.510999
mesons	muon	$\mu^\pm$	105.659
	pion	$\pi^\pm$	139.576
		$\pi^0$	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 =  $\frac{\text{power output}}{\text{power input}}$
- $\omega = \frac{v}{r} = 2\pi f$
- $a = \frac{v^2}{r} = r\omega^2$
- $I = \sum mr^2$
- $E_k = \frac{1}{2}I\omega^2$
- $\omega_2 = \omega_1 + at$
- $\theta = \omega_1 t + \frac{1}{2}at^2$
- $\omega_2^2 = \omega_1^2 + 2a\theta$
- $\theta = \frac{1}{2}(\omega_1 + \omega_2)t$
- $T = I\alpha$
- 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**
- $\epsilon = \frac{E}{Q}$
- $\epsilon = I(R+r)$
- $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
- $R_T = R_1 + R_2 + R_3 + \dots$
- $P = I^2 R$
- $E = \frac{F}{Q} = \frac{V}{d}$
- $E = \frac{1}{4\pi \epsilon_0} \frac{Q}{r^2}$
- $E = \frac{1}{2} QV$
- $F = BI$
- $F = BQv$
- $Q = Q_0 e^{-t/RC}$
- $\Phi = BA$

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

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

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

### 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

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

### 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

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

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

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

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

### Alternating Currents

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

### Operational amplifier

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

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

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

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

**SECTION A NUCLEAR INSTABILITY**Answer **all** parts of the question.

- 1 The radioactive isotope of sodium  ${}_{11}^{22}\text{Na}$  has a half life of 2.6 years. A particular sample of this isotope has an initial activity of  $5.5 \times 10^5$  Bq (disintegrations per second).

- (a) Explain what is meant by the *random nature* of radioactive decay.

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

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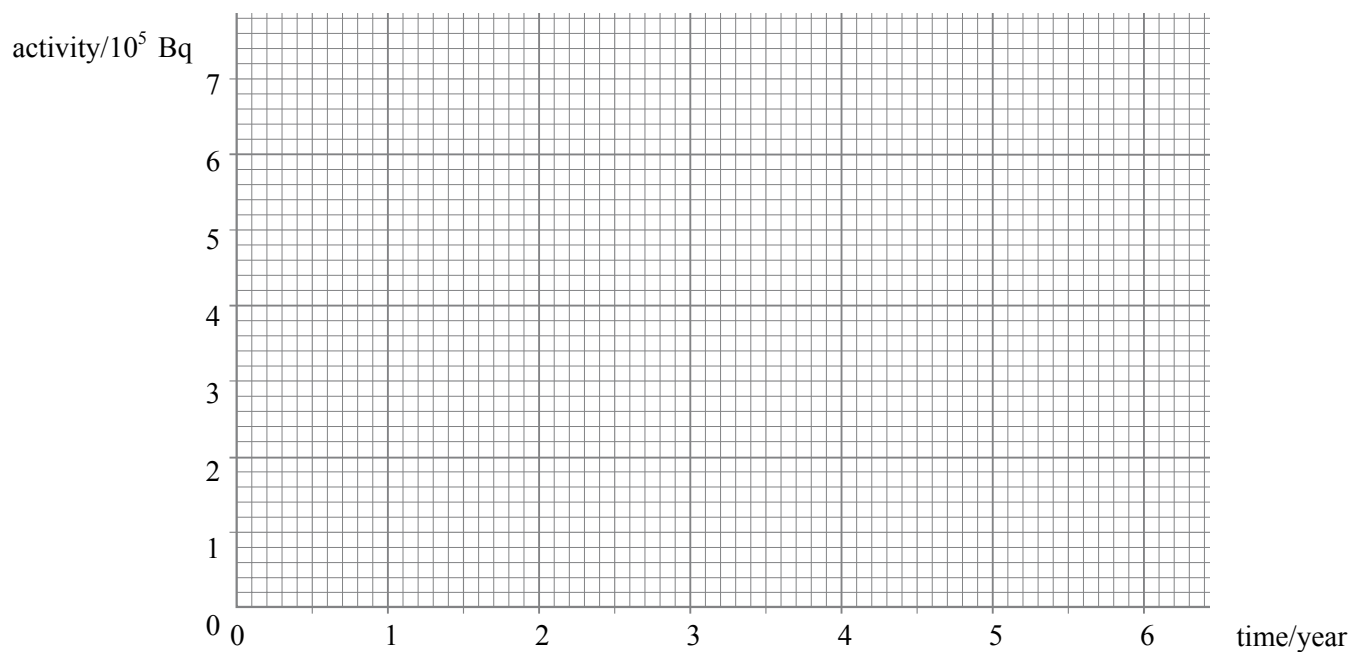
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(2 marks)

- (b) Use the axes to sketch a graph of the activity of the sample of sodium over a period of 6 years.



(2 marks)

(c) Calculate

- (i) the decay constant, in  $\text{s}^{-1}$ , of  ${}^{22}_{11}\text{Na}$ ,  
1 year =  $3.15 \times 10^7 \text{s}$

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- (ii) the number of atoms of  ${}^{22}_{11}\text{Na}$  in the sample initially,

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- (iii) the time taken, in s, for the activity of the sample to fall from  $1.0 \times 10^5 \text{ Bq}$  to  $0.75 \times 10^5 \text{ Bq}$ .

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(6 marks)

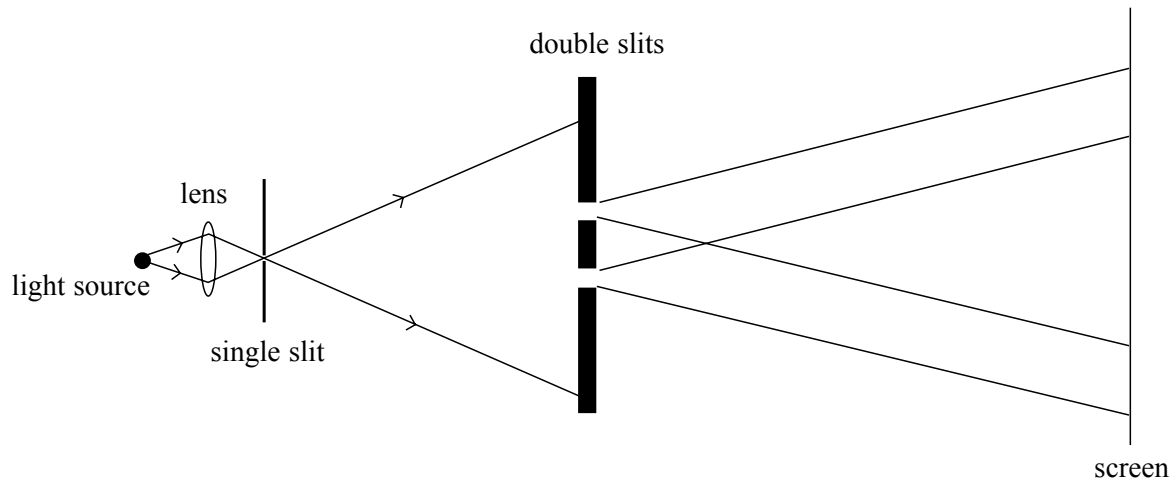
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**TURN OVER FOR THE NEXT QUESTION**

## SECTION B: TURNING POINTS

Answer **all** questions

- 2 Light from a point source was passed through two closely spaced parallel slits, as shown in the diagram. A pattern of alternate bright and dark fringes was observed on the screen.



- (a) Use Huygens' wave theory of light to explain the formation of these fringes by the double slits. You may be awarded marks for the quality of written communication provided in your answer.

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*(4 marks)*

- (b) (i) Explain what Newton's theory of light would predict for the same experimental arrangement.

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(ii) Give **one** reason why Huygens' wave theory of light did not replace Newton's theory of light when the fringe pattern due to the double slits was first observed.

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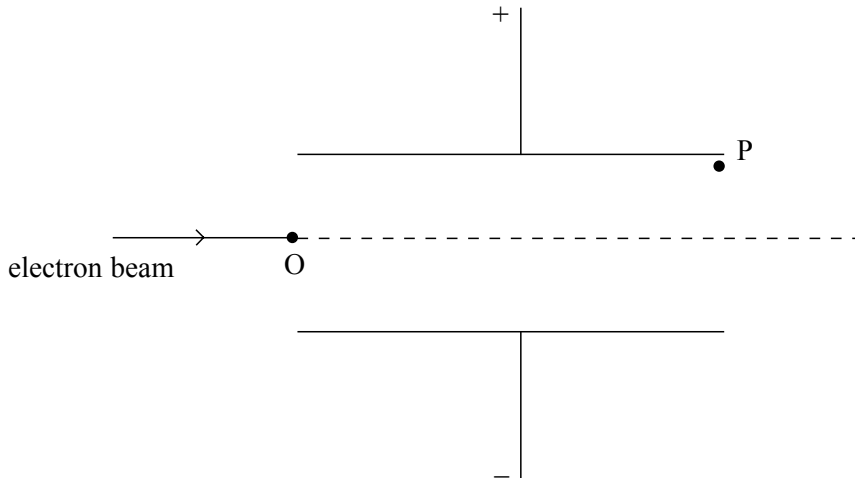
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(3 marks)



3 The diagram shows a narrow beam of electrons directed at right angles into a uniform electric field between two oppositely-charged parallel metal plates at a fixed potential difference.



(a) The electrons enter the field at O and leave it at P. Sketch the path of the beam from O to P and beyond P. (2 marks)

(b) A uniform magnetic field is applied to the beam perpendicular to the electric field and to the direction of the beam. The magnetic field reduces the deflection of the beam from its initial direction.

(i) Explain why the magnetic field has this effect on the beam.

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- (ii) The magnetic flux density is adjusted until the beam passes through the two fields without deflection. Show that the speed  $v$  of the electrons when this occurs is given by

$$v = \frac{E}{B}$$

where  $E$  is the electric field strength and  $B$  is the magnetic flux density.

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(5 marks)

- (c) In an experiment to measure the specific charge of the electron, electrons were accelerated from rest through a potential difference of 2900 V to a speed of  $3.2 \times 10^7 \text{ m s}^{-1}$ . Use this information to calculate the specific charge of the electron.

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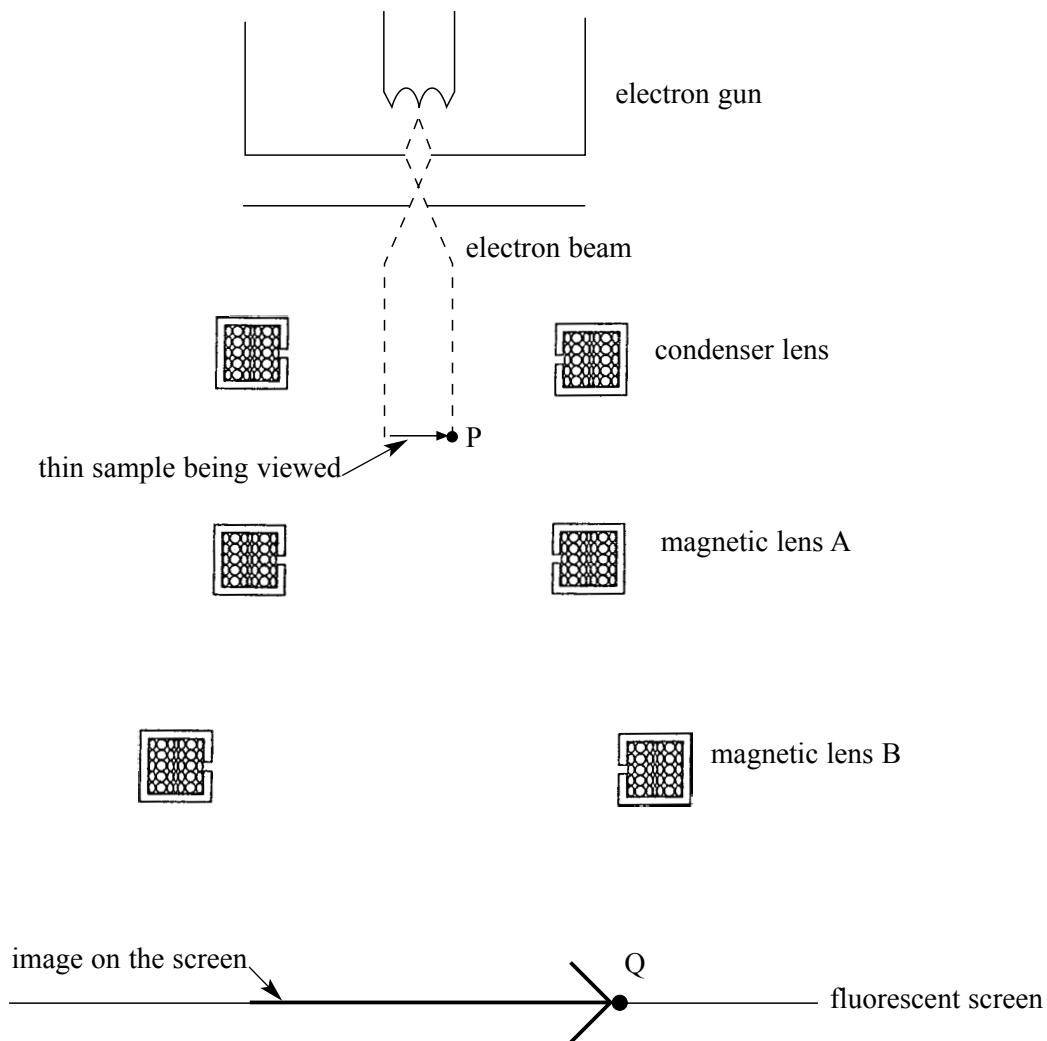
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(3 marks)

- 4 The diagram below shows a Transmission Electron Microscope. Electrons from the electron gun pass through a thin sample and then through two magnetic lenses A and B on to a fluorescent screen. An enlarged image of the sample is formed on the screen.



- (a) (i) Sketch the path of an electron that reaches point Q on the screen after passing through the sample at point P and through the two magnetic lenses A and B.
- (ii) State the function of magnetic lens A and the function of magnetic lens B.

magnetic lens A .....

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magnetic lens B .....

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(4 marks)

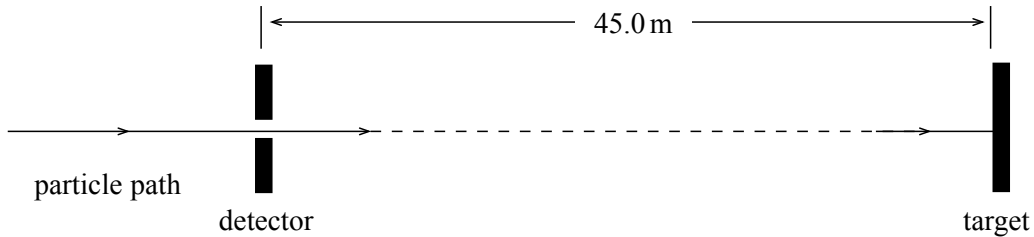
(b) Explain why greater image detail is seen when the anode voltage is increased.

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(3 marks)

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5 A particle passes through a detector and 152 ns later hits a target 45.0 m away from the detector.



(i) Calculate the speed of the particle between the detector and the target.

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(ii) Calculate the transit time of the particle from the detector to the target, in the frame of reference of the particle.

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(4 marks)

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QUALITY OF WRITTEN COMMUNICATION

(2 marks)

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