General Certificate of Education
June 2003
Advanced Level Examination

PHYSICS (SPECIFICATION A) **PA04**
Unit 4 Waves, Fields and Nuclear Energy

Section A

Friday 20 June 2003 Afternoon Session

In addition to this paper you will require:
- an objective test answer sheet;
- a black ball-point pen;
- a calculator;
- a question paper/answer book for Section B (enclosed).

Time allowed: The total time for Section A and Section B of this paper is 1 hour 30 minutes

Instructions
- Use a black ball-point pen. Do **not** use pencil.
- Answer **all** questions in this section.
- For each question there are four responses. When you have selected the response which you think is the most appropriate answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book, **not** on the answer sheet.

Information
- The maximum mark for this section is 30.
- Section A and Section B of this paper together carry 15% of the total marks for Physics Advanced.
- All questions in Section A carry equal marks. No deductions will be made for incorrect answers.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- The question paper/answer book for Section B is enclosed within this question paper.

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	3.00×10^{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}	N m^2 kg^{-2}
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	J K^{-1} mol^{-1}
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	W m^{-2} 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 $= \frac{\text{power output}}{\text{power input}}$

$\omega = \frac{v}{r} = 2\pi f$

$a = \frac{v^2}{r} = r\omega^2$

$I = \sum mr^2$

$E_k = \frac{1}{2} I\omega^2$

$\omega_2 = \omega_1 + \alpha t$

$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$

$\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$

$T = I\alpha$

angular momentum $= I\omega$

$W = T\theta$

$P = T\omega$

angular impulse = change of angular momentum $= Tt$

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

$\Delta W = p\Delta V$

$pV^{\gamma} =$ 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

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

$\epsilon = I(R + r)$

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

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

$P = I^2 R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

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

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

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

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

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

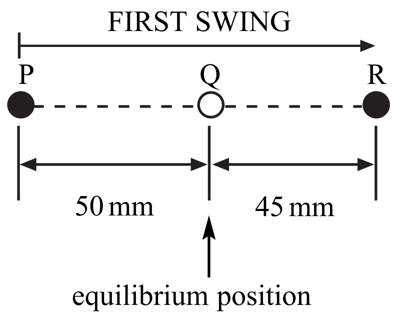
SECTION A

In this section each item consists of a question or an incomplete statement followed by four suggested answers or completions.

You are to select the most appropriate answer in each case.

You are advised to spend approximately **30 minutes** on this section.

1 A particle, whose equilibrium position is at Q, is set into oscillation by being displaced to P, 50 mm from Q, and then released from rest. Its subsequent motion is simple harmonic, but subject to damping. On the first swing, the particle comes to rest momentarily at R, 45 mm from Q.



During this first swing, the greatest value of the acceleration of the particle is when it is at

A P.
B Q.
C R.
D P and R.

2 A particle of mass 5.0×10^{-3} kg performing simple harmonic motion of amplitude 150 mm takes 47 s to make 50 oscillations. What is the maximum kinetic energy of the particle?

A 2.0×10^{-3} J
B 2.5×10^{-3} J
C 3.9×10^{-3} J
D 5.0×10^{-3} J

3 When the length of a simple pendulum is decreased by 600 mm, the period of oscillation is halved. What is the original length of the pendulum?

A 800 mm
B 1000 mm
C 1200 mm
D 1400 mm

Turn over

4 A wave of frequency 5 Hz travels at $8\,\text{km s}^{-1}$ through a medium. What is the phase difference, in radians, between two points 2 km apart?

A 0

B $\frac{\pi}{2}$

C π

D $\frac{3\pi}{2}$

5 A source emits light of wavelength 600 nm as a train of waves lasting 0.01 µs. How many complete waves are sent out?
speed of light = $3 \times 10^{8}\,\text{m s}^{-1}$

A 5×10^{6}
B 18×10^{7}
C 5×10^{9}
D 5×10^{22}

6 Interference fringes, produced by monochromatic light, are viewed on a screen placed a distance D from a double slit system with slit separation s. The distance between the centres of two adjacent fringes (the fringe separation) is w. If both s and D are doubled, what will be the new fringe separation?

A $\frac{w}{4}$
B w
C $2w$
D $4w$

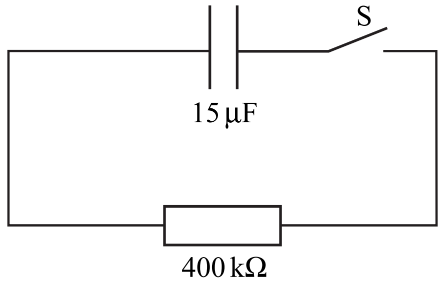
7 A narrow beam of monochromatic light falls on a diffraction grating at normal incidence. The second order diffracted beam makes an angle of 45° with the grating. What is the highest order visible with this grating at this wavelength?

A 2
B 3
C 4
D 5

8 A 10 mF capacitor is charged to 10 V and then discharged completely through a small motor. During this process, the motor lifts a weight of mass 0.10 kg. If 10 % of the energy stored in the capacitor is used to lift the weight, through what approximate height will the weight be lifted?

A 0.05 m
B 0.10 m
C 0.50 m
D 1.00 m

9 A capacitor of capacitance 15 μF is fully charged and the potential difference across its plates is 8.0 V. It is then connected into the circuit as shown.



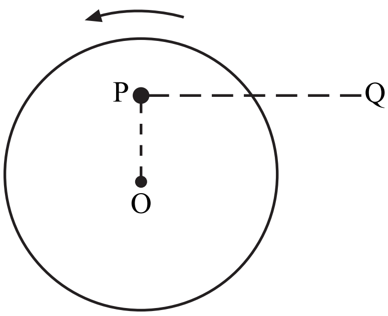
The switch S is closed at time $t = 0$. Which one of the following statements is correct?

A The time constant of the circuit is 6.0 ms.
B The initial charge on the capacitor is 12 μC.
C After a time equal to twice the time constant, the charge remaining on the capacitor is Q_0e^2, where Q_0 is the charge at time $t = 0$.
D After a time equal to the time constant, the potential difference across the capacitor is 2.9 V.

10 A fairground roundabout makes nine revolutions in one minute. What is the angular speed of the roundabout?

A 0.15 rad s^{-1}
B 0.34 rad s^{-1}
C 0.94 rad s^{-1}
D 2.1 rad s^{-1}

11



A small mass is placed at P on a horizontal disc which has centre O. The disc rotates anti-clockwise about a vertical axis through O with constant angular speed. Which one of the following describes the force which keeps the mass at rest relative to the disc?

A the weight of the mass
B a frictional force directed away from O
C a frictional force directed towards O
D a frictional force directed from P to Q

Turn over ▶

12 The force between two point charges is F when they are separated by a distance r. If the separation is increased to $3r$ what is the force between the charges?

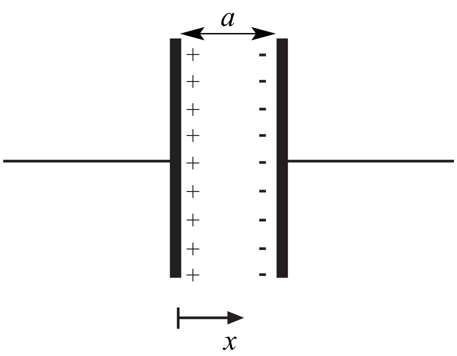
A $\frac{F}{3r}$

B $\frac{F}{9r}$

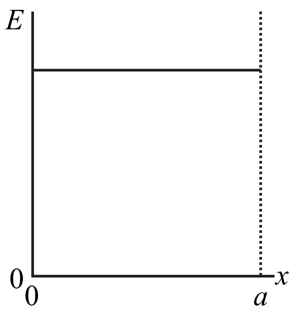
C $\frac{F}{3}$

D $\frac{F}{9}$

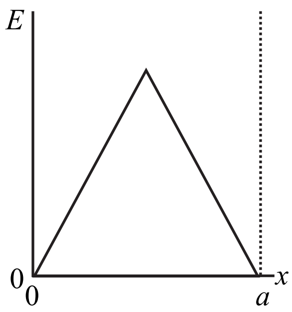
13



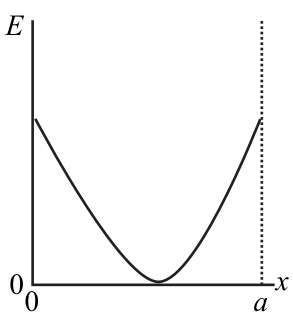
Two parallel metal plates of separation a carry equal and opposite charges. Which one of the following graphs, **A** to **D**, best represents how the electric field strength E varies with the distance x in the space between the plates?



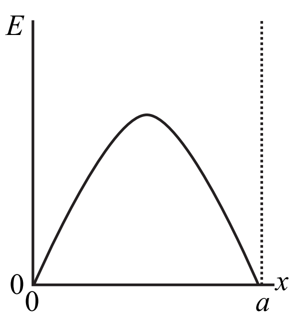
A



B



C



D

14 In a thermal reactor, induced fission is caused by the ${}^{235}_{92}U$ nucleus capturing a neutron, undergoing fission and producing more neutrons. Which one of the following statements is true?

A To sustain the reaction a large number of neutrons is required per fission.
B The purpose of the moderator is to absorb all the heat produced.
C The neutrons required for induced fission of ${}^{235}_{92}U$ should be slow neutrons.
D The purpose of the control rods is to slow down neutrons to thermal speeds.

15 Artificial radioactive nuclides are manufactured by placing naturally-occurring nuclides in a nuclear reactor. They are made radioactive in the reactor as a consequence of bombardment by

A α particles.
B β particles.
C protons.
D neutrons.

END OF SECTION A

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

Leave blank

General Certificate of Education
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Physics (SPECIFICATION A) **PA04**
Unit 4 Waves, Fields and Nuclear Energy

Section B

Friday 20 June 2003 Afternoon Session

In addition to this paper you will require:
- a calculator;
- a pencil and a ruler.

Time allowed: The total time for Section A and Section B of this paper is 1 hour 30 minutes

Instructions
- Use a blue or black 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 Section is 30.
- Mark allocations are shown in brackets.
- Section A and Section B of this paper together carry 15% of the total marks for Physics Advanced.
- A *Data sheet* is provided on pages 3 and 4 of Section A. 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.

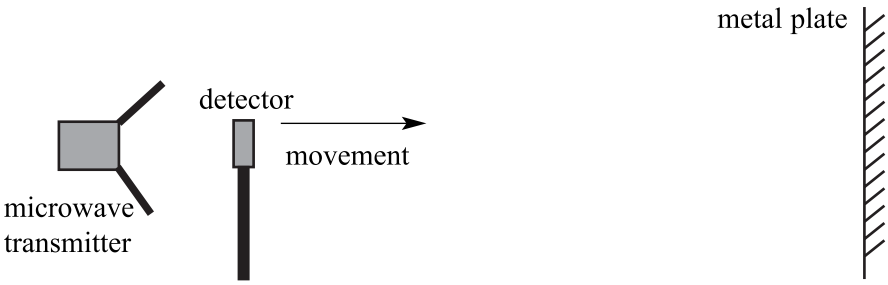
For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

LEAVE MARGIN BLANK

Answer **all** questions.

You are advised to spend approximately **one hour** on this section.

1



A microwave transmitter directs waves towards a metal plate. When a microwave detector is moved along a line normal to the transmitter and the plate, it passes through a sequence of equally spaced maxima and minima of intensity.

(a) Explain how these maxima and minima are formed.

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

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(4 marks)

LEAVE MARGIN BLANK

(b) The detector is placed at a position where the intensity is a minimum. When it is moved a distance of 144 mm it passes through nine maxima and reaches the ninth minimum from the starting point.

Calculate

(i) the wavelength of the microwaves,

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(ii) the frequency of the microwave transmitter.

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(3 marks)

7

TURN OVER FOR THE NEXT QUESTION

LEAVE MARGIN BLANK

2 Communications satellites are usually placed in a *geo-synchronous orbit*.

(a) State **two** features of a geo-synchronous orbit.

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(2 marks)

(b) Given that the mass of the Earth is 6.00×10^{24} kg and its mean radius is 6.40×10^{6} m,

(i) show that the radius of a geo-synchronous orbit must be 4.23×10^{7} m,

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(ii) calculate the increase in potential energy of a satellite of mass 750 kg when it is raised from the Earth's surface into a geo-synchronous orbit.

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(6 marks)

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8

LEAVE MARGIN BLANK

3 (a) The equation $F = BIl$, where the symbols have their usual meanings, gives the magnetic force that acts on a conductor in a magnetic field.

Give the unit of each of the quantities in the equation.

F .... B ....

I .... l ....

State the condition under which the equation applies.

....

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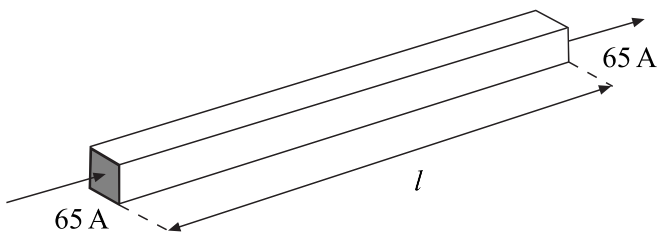
(2 marks)

(b) The diagram shows a horizontal copper bar of 25 mm × 25 mm square cross-section and length l carrying a current of 65 A.



(i) Calculate the minimum value of the flux density of the magnetic field in which it should be placed if its weight is to be supported by the magnetic force that acts on it.

density of copper = $8.9 \times 10^3\,\mathrm{kg\,m^{-3}}$

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(ii) Draw an arrow on the diagram above to show the direction in which the magnetic field should be applied if your calculation in part (i) is to be valid. Label this arrow M.

(5 marks)

7

Turn over ▶

4 (a) With reference to the process of nuclear fusion, explain why energy is released when two small nuclei join together, and why it is difficult to make two nuclei come together.

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

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(3 marks)

LEAVE MARGIN BLANK

(b) A fusion reaction takes place when two deuterium nuclei join, as represented by

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n$$

mass of ^{2}H nucleus = 2.01355 u
mass of ^{3}He nucleus = 3.01493 u
mass of neutron = 1.00867 u

Calculate

(i) the mass difference produced when two deuterium nuclei undergo fusion,

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(ii) the energy released, in J, when this reaction takes place.

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(3 marks)

— 6

QUALITY OF WRITTEN COMMUNICATION *(2 marks)*

— 2

END OF QUESTIONS