Candidate Name	Centre Number	Candidate Number
		2

GCE A level

545/01

PHYSICS

ASSESSMENT UNIT PH5:
FIELDS, FORCES AND NUCLEI

A.M. WEDNESDAY, 11 June 2008

1½ hours

ADDITIONAL MATERIALS

In addition to this paper, you may require a calculator.

INSTRUCTIONS TO CANDIDATES

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.

You are advised to spend not more than 45 minutes on questions 1 to 5.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 90.

The number of marks is given in brackets at the end of each question or part question.

You are reminded of the necessity for good English and orderly presentation in your answers.

You are reminded to show all working. Credit is given for correct working even when the final answer given is incorrect.

Your attention is drawn to the information "Mathematical Data and Relationships" on the back page of this paper.

For Examiner's use only.	
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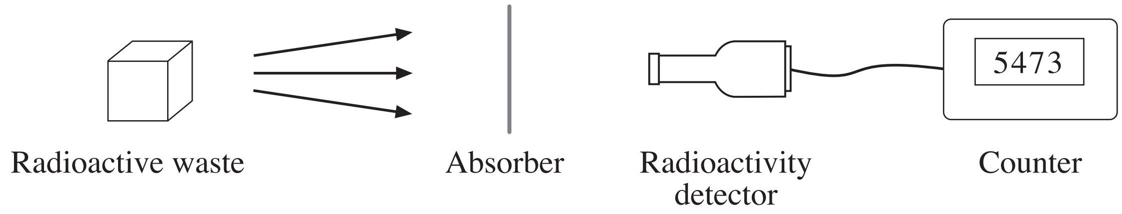
Total	

Fundamental Constants

Avogadro constant	N_A	=	$6{\cdot}0 \times 10^{23}$ mol^{-1}
Fundamental electronic charge	e	=	$1{\cdot}6 \times 10^{-19}$ C
Mass of an electron	m_e	=	$9{\cdot}1 \times 10^{-31}$ kg
Mass of a proton	m_p	=	$1{\cdot}67 \times 10^{-27}$ kg
Molar gas constant	R	=	$8{\cdot}3$ J mol^{-1} K^{-1}
Acceleration due to gravity at sea level	g	=	$9{\cdot}8$ m s^{-2}
[Gravitational field strength at sea level	g	=	$9{\cdot}8$ N kg^{-1}]
Universal constant of gravitation	G	=	$6{\cdot}7 \times 10^{-11}$ N m^{2} kg^{-2}
Planck constant	h	=	$6{\cdot}6 \times 10^{-34}$ J s
Unified mass unit	1 u	=	$1{\cdot}66 \times 10^{-27}$ kg
Boltzmann constant	k	=	$1{\cdot}38 \times 10^{-23}$ J K^{-1}
Speed of light *in vacuo*	c	=	$3{\cdot}0 \times 10^{8}$ m s^{-1}
Permittivity of free space	ε_o	=	$8{\cdot}9 \times 10^{-12}$ F m^{-1}
Permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}

1. A student devises an experiment to determine which of the radiations α, β and γ are emitted by a sample of radioactive waste. The student measures and records the detected count rate using the set-up below.



The results obtained are summarised in the table.

Absorber	Count rate / s^{-1}
None	8894
3 sheets of paper	5473
None	8921
0·5 mm of Aluminium foil	5455
None	8860
10 cm of Lead	439
None	8888

(a) (i) Explain which types of radiation are present in the radioactive waste. [4]

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(ii) Suggest a reason why the student measured the activity without an absorber several times. [2]

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(b) The activity of a radioactive nuclide drops to 78·5% of its initial value in 2 000 years. Calculate the half life of the radioactive nuclide. [4]

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2. A possible reaction for future fusion power stations on Earth is the fusion of deuterium ($^{2}_{1}H$) and tritium ($^{3}_{1}H$).

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + X$$

(a) Determine the mass number and atomic number of X and state its name. [2]

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The nuclear masses involved in the above reaction are

Mass of $^{2}_{1}H$ = 2·0136 u, mass of $^{3}_{1}H$ = 3·0155 u, mass of $^{4}_{2}He$ = 4·0015 u,

mass of X = 1·0087 u. Also, 1 u = 931 MeV.

(b) Calculate the energy released (in eV) in the above reaction. [3]

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(c) Calculate the energy released (in joules) when 1 mole of $^{2}_{1}H$ fuses with 1 mole of $^{3}_{1}H$. [2]

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(d) Explain briefly how you know that the nuclear binding energy of $^{4}_{2}He$ is greater than that of $^{2}_{1}H$ and $^{3}_{1}H$ combined. [3]

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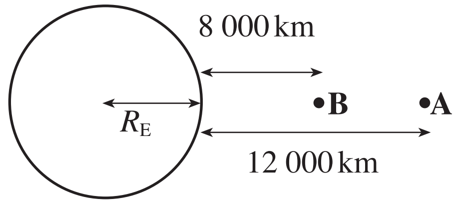
3. An object of mass 4·6 kg falls towards the Earth from rest at point **A**. Point **A** is 12 000 km above the Earth's surface and point **B** 8 000 km above the Earth's surface.



Earth radius $R_E = 6400$ km, Mass of the Earth $M_E = 6·0 \times 10^{24}$ kg

(a) Calculate the gravitational force acting on the object at **A**. [2]

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(b) Calculate the gravitational potential

(i) at **A**, [2]

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(ii) at **B**. [1]

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(c) (i) Calculate the change in potential energy as the object falls from **A** to **B**. [2]

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(ii) Hence calculate the velocity of the object when it reaches **B**. [3]

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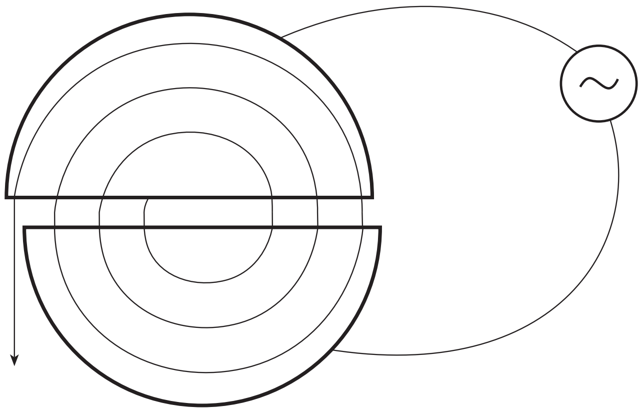
4. The diagram shows the spiral path of an accelerated **proton** in a cyclotron.



(a) Indicate the direction of the magnetic field B, and state how you obtained your answer. [2]

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(b) Explain why the proton moves in a spiral. [4]

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(c) By equating the centripetal force to the force experienced by a moving charge in a magnetic field, show that the frequency, f, is given by [3]

$$f = \frac{Be}{2\pi m}$$

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(d) The magnetic flux density, B = 3·0 T. Calculate the frequency of the accelerating voltage. [1]

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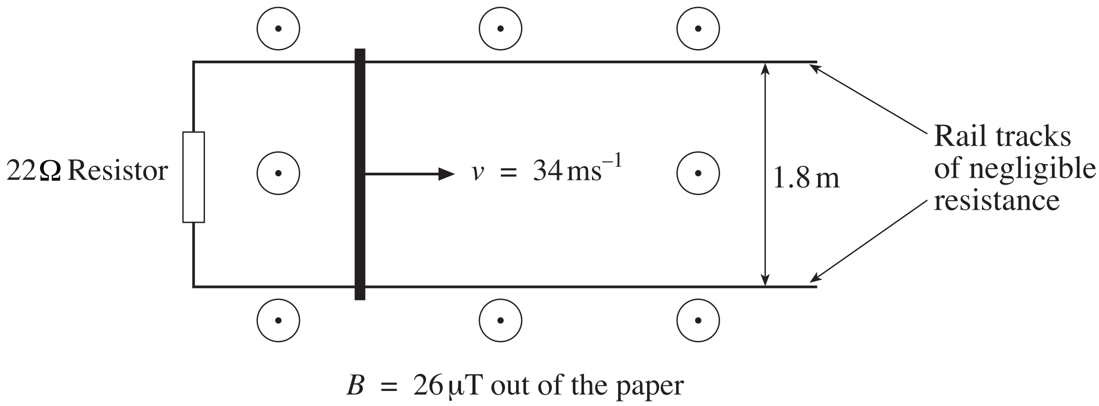
5. A thick metal conductor slides horizontally along conducting rail tracks at a speed of $34\,\text{ms}^{-1}$ in a region of uniform magnetic field (see below).



(a) Explain briefly why an induced current flows through the resistor. [3]

(b) Calculate the current flowing through the resistor. [4]

(c) A student suggests that this current will provide a force on the metal conductor that increases the speed of the conductor. Explain whether or not the student is correct. [3]

6. *(a)* (i) Describe briefly the **results** of the Rutherford α-particle scattering experiment. [3]

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(ii) Explain how these results led to the current model of the atom. [3]

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(b) The Rutherford experiment was also used to estimate the size of the nucleus. The experiment was attempted using α-particles of kinetic energy 7·7 MeV fired at gold foil.

(i) Write down the formula for the electrical potential energy when two charges (Q and q) are a distance r apart in a vacuum. [1]

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(ii) Write down the charges of the alpha particle and a gold nucleus.

Charge on alpha particle .... [1]

Charge on $^{197}_{79}$Au nucleus .... [1]

(iii) Calculate the K.E. of the 7·7 MeV α-particles in joules. [1]

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(iv) Calculate the distance of nearest approach of the 7·7 MeV α-particles to the gold nucleus. [3]

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(v) Calculate the electrical force between the α-particle and the gold nucleus when they are separated by a distance of $3{\cdot}0 \times 10^{-14}$ m. [2]

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(vi) Calculate the magnitude of the electric field strength a distance of $3{\cdot}0 \times 10^{-14}$ m from a gold nucleus. [1]

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(vii) The α-particle undergoes a head-on elastic collision with a **far heavier** stationary gold nucleus. Its initial speed is $1{\cdot}9 \times 10^{7}\,\mathrm{ms^{-1}}$ towards the gold nucleus. Write down an approximate value of the speed of the α-particle after the collision (no equations or calculations required). [1]

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(viii) Use conservation of momentum to estimate the speed of the gold nucleus after the α-particle has collided with it head-on.
(mass of α-particle = 4u, mass of gold nucleus = 197u) [3]

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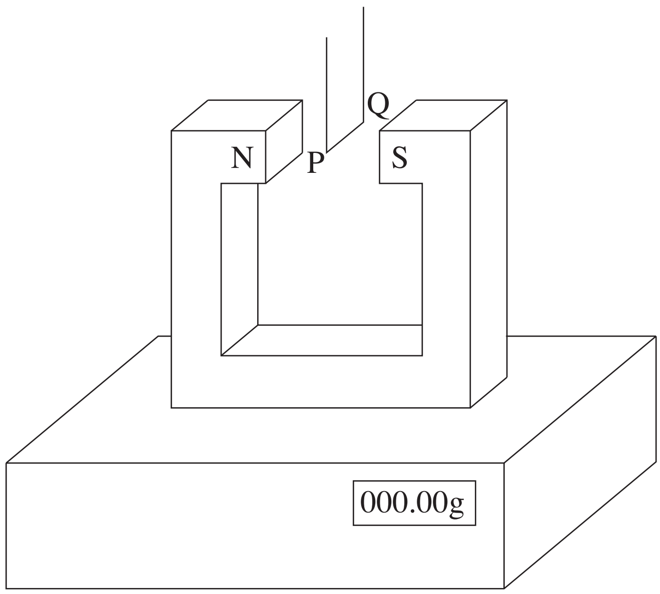
7. *(a)* A magnet is placed on an accurate digital balance and a current-carrying wire is placed in the region of uniform magnetic field between the poles of the magnet (see below).



(i) Sketch magnetic field lines (due to the magnet) between its poles. [1]

(ii) When no current flows through the wire the digital balance is adjusted to read zero. As the current is increased the reading on the digital balance becomes negative. Explain briefly why the negative readings indicate that there is a downward force on the wire. [2]

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(iii) On the diagram, indicate the direction of the current flow. [1]

(iv) The length of the horizontal portion (PQ) of the current carrying wire is 2·7 cm. When a current of 1·86 A flows through the wire the digital balance reads –1·49 gram. Calculate the magnetic field strength *B* between the poles of the magnet. [3]

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(b) A Hall probe is used to check the value of the magnetic field strength.

(i) Where would you place the probe and how would you orientate it? [2]

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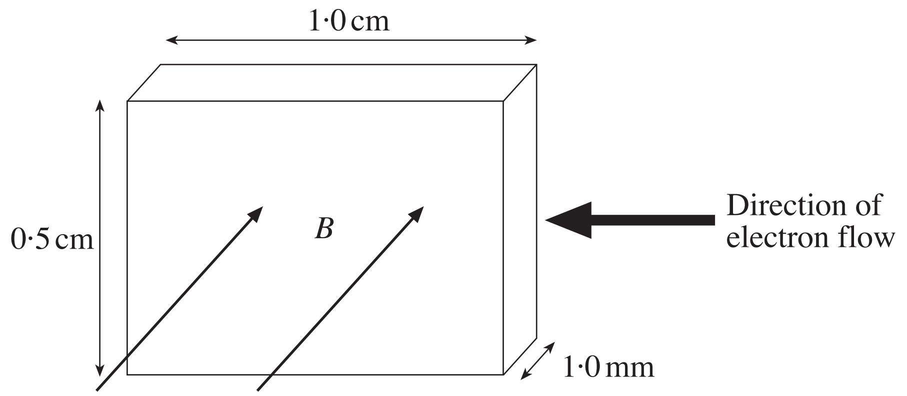
Hall probe



(ii) Explain how you would measure the Hall voltage (you may like to add to the above diagram). [2]

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(iii) The Hall voltage is 75 μV and the drift velocity of the electrons in the probe is 0·048 ms^{-1}. Calculate the magnetic field strength, *B*, measured by the Hall probe. [5]

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(iv) The current flow in the Hall probe is 0·16 A. Use the equation $I = nAve$ to find the number of free electrons per m^3. [2]

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(v) Two perpendicular electric fields are present in the Hall probe. **Draw arrows** on the diagram representing these vectors and label them E_H (due to the Hall effect) and E_C (from the external power supply). [2]

Turn over.

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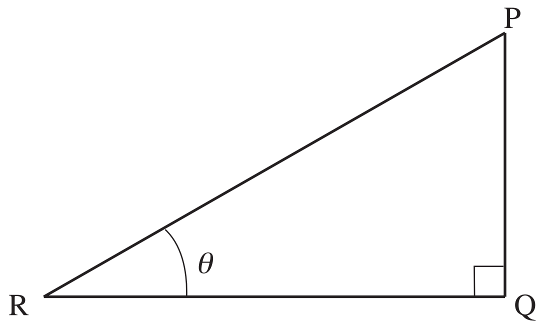
Mathematical Data and Relationships

SI multipliers

Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

Multiple	Prefix	Symbol
10^{-2}	centi	c
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P

Geometry and trigonometry



$$\sin\theta = \frac{PQ}{PR}, \quad \cos\theta = \frac{QR}{PR}, \quad \tan\theta = \frac{PQ}{QR}, \quad \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$PR^2 = PQ^2 + RQ^2$$

Areas and Volumes

Area of a circle = $\pi r^2 = \dfrac{\pi d^2}{4}$

Area of a triangle = ½ base × height

Solid	Surface area	Volume
rectangular block	$2(lh + hb + lb)$	lbh
cylinder	$2\pi r(r + h)$	$\pi r^2 h$
sphere	$4\pi r^2$	$\frac{4}{3}\pi r^3$

Logarithms

[Unless otherwise specified 'log' can be $\log_e$ (i.e. ln) or $\log_{10}$.]

$\log(ab) = \log a + \log b$

$\log\left(\dfrac{a}{b}\right) = \log a - \log b$

$\log(x^n) = n\log x$

$\log(kx^n) = \log k + n\log x$

$\log_e(e^{kx}) = \ln(e^{kx}) = kx$

$\log_e 2 = \ln 2 = 0{\cdot}693$