MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

H2 Physics 9749/03

Paper 3 Longer Structured Questions **17 September 2018**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

Candidate Name: ______________________

Class	Reg No

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend about one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.

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

For Examiner's Use	
Section A	
1	**/ 10**
2	**/ 7**
3	**/ 9**
4	**/ 4**
5	**/ 5**
6	**/ 10**
7	**/ 15**
Section B	
8	**/ 20**
9	**/ 20**
Deductions	
Total	**/ 80**

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$\left(1/\left(36\pi\right)\right) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translation kinetic energy an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm\, \omega\sqrt{x_o^{\,2} - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** **(i)** State Newton's first law of motion.

....

.... [1]

(ii) State the conditions for equilibrium.

....

....

....

.... [2]

(b) Fig. 1.1 shows a uniform ladder of weight 80 N resting on a smooth wall and a rough floor. The ladder makes an angle of 60° with the floor.

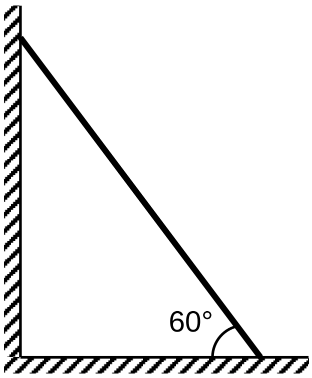

Fig. 1.1

(i) Show that the force exerted by the wall on the ladder is 23 N.

[2]

(ii) Calculate the force exerted by the floor on the ladder.

magnitude of force = ... N

direction of force : .... [3]

(iii) A person now stands on the ladder. The ladder remains stationary.

State and explain the effects, if any, on

1. the vertical force exerted by the floor on the ladder.

....

....

.... [1]

2. the horizontal force exerted by the wall on the ladder.

....

....

.... [1]

2 In an experiment to determine the specific heat capacity of a liquid, a student heated a fixed mass of the liquid for a fixed duration of time, using an electric heater. The student repeated the experiment three times to find the rise in temperature of the liquid. The following measurements were obtained:

Mass of liquid, *m*	309 ± 3 g
Voltage applied across heater, *V*	11.8 ± 0.3 V
Current flow in the heater, *I*	4.125 ± 0.002 A
Time taken, *t*	200.0 ± 0.5 s

The rise in temperature θ was recorded for each attempt:

Attempt:	1st	2nd	3rd
θ / K	10.2	9.7	10.5

(a) Estimate the uncertainty in θ.

uncertainty in θ = ... K [1]

(b) Calculate the specific heat capacity *c* of the liquid.

c = ... J kg^{-1} K^{-1} [2]

(c) Calculate the uncertainty in specific heat capacity *c* of the liquid and express the specific heat capacity *c* together with its uncertainty.

c = ... ± .... J kg^{-1} K^{-1} [3]

(d) State an assumption made in your calculation of the specific heat capacity *c* of the liquid.

....

.... [1]

3 **(a)** State Newton's second law of motion.

....

....

.... [1]

(b) A car of mass 800 kg was travelling on a horizontal road at a constant speed of 20 m s^{-1} before a net horizontal constant forward force of 4800 N acts on the car for 12 s.

Calculate

(i) the distance travelled by the car over the 12 s,

distance = ... m [2]

(ii) the speed of the car at the end of the 12 s,

speed = ... m s^{-1} [2]

(iii) the work done on the car during the 12 s

1. using the answer to **(b)(i)**;

work done = ...J [1]

2. using the answer to **(b)(ii)**.

work done = ...J [1]

(iv) the impulse exerted on the car over the 12 s.

impulse = ... N s [2]

4 A person threw a ball vertically upwards.

(a) Fig. 4.1 shows the variation with time of the velocity when air resistance is absent.

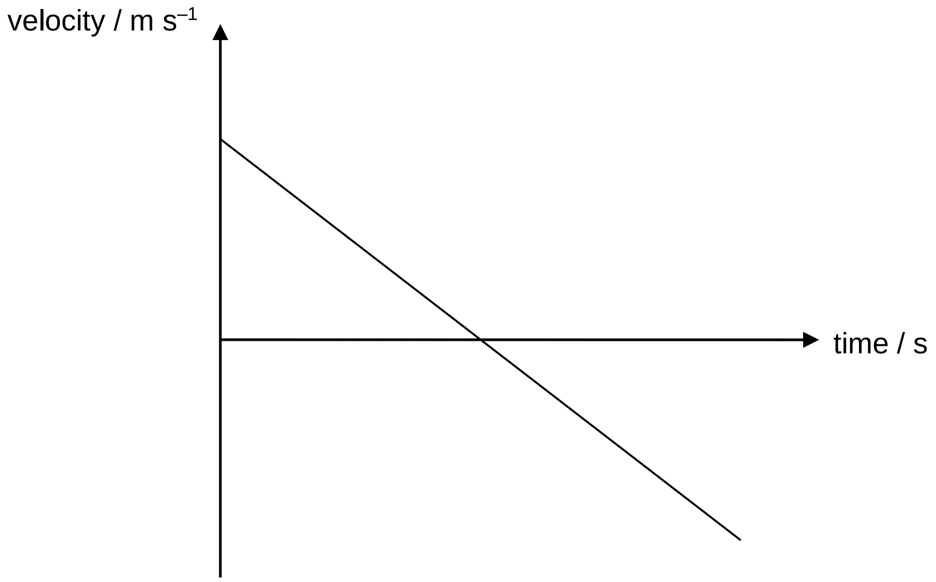

Fig. 4.1

Draw on Fig. 4.1 a second graph for the case where air resistance is present. [3]

(b) Explain how the presence of air resistance would affect the maximum height reached by the ball.

....

....

.... [1]

5 Ball A, of mass 800 g and travelling with a speed of 9.2 m s^{-1}, collided head-on with a stationary ball B of mass 2400 g. The collision is completely inelastic.

(a) Explain whether the total momentum is conserved during the collision.

....

....

.... [1]

(b) Calculate the percentage loss in total kinetic energy.

percentage loss = ... % [2]

(c) Shortly after the collision, Ball B comes into contact with a spring of spring constant 2500 N m^{-1}. Calculate the maximum compression of the spring.

maximum compression = ... m [2]

6 Fig. 6.1 shows an isolated conducting sphere which has been charged. Dashed lines (−−−−) join points of equal potential V. The potential difference between successive lines of equal potential is equal.

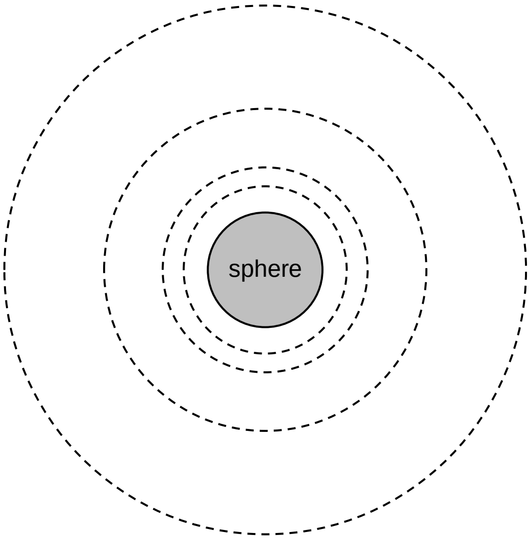

Fig. 6.1

For points on the surface or outside the sphere, the charge on the sphere behaves as if it were concentrated at the centre.

Measurements of the distance x from the centre of the sphere and the corresponding values of the potential V are given in Fig. 6.2. The values in Fig. 6.2 do not correspond to the dashed lines in Fig. 6.1.

x / m	V / V
0.19	-1.50×10^5
0.25	-1.14×10^5
0.32	-0.89×10^5
0.39	-0.73×10^5

Fig. 6.2

(a) On Fig. 6.1, draw the electric field lines. Label these lines E. [2]

(b) Explain how your drawing in **(a)** shows the relationship between electric potential *V* and the electric field *E*.

....

....

.... [2]

(c) **(i)** Use the data in Fig. 6.2 to show that the potential *V* is inversely proportional to the distance *x*. Explain your reasoning.

[2]

(ii) The potential at the surface of the sphere is -1.9×10^5 V. Calculate the radius of the sphere.

radius of sphere = ... m [2]

(iii) Determine the charge on the sphere.

charge = ...C [2]

7 **(a)** A power bank (which is basically a battery) can be used to power many devices at the same time. A power bank of e.m.f. 12.0 V and internal resistance 3.0 Ω is connected to multiple devices in the circuit shown in Fig. 7.1.

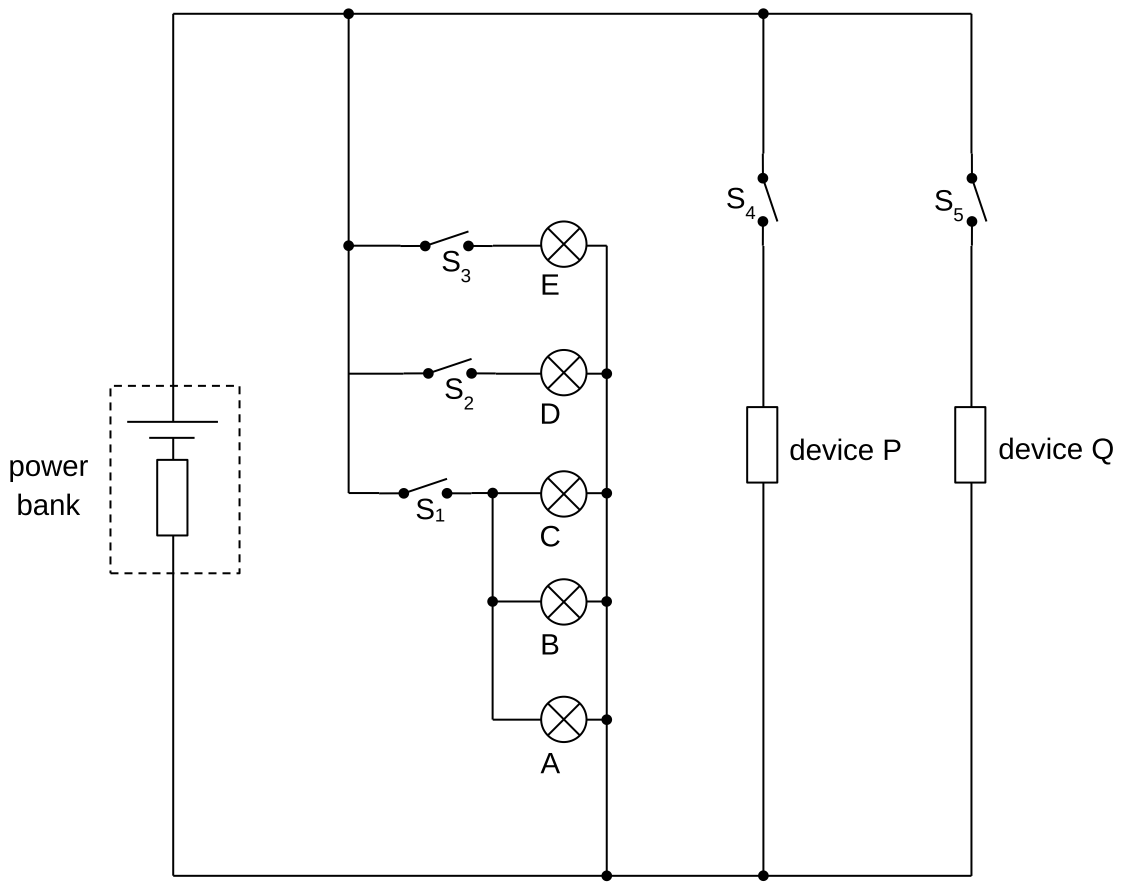

Fig. 7.1

The power bank is connected to 5 identical lamps (A, B, C, D and E) and 2 devices (P and Q). The lamps and devices can be turned on and off using the various switches (S_1, S_2, S_3, S_4 and S_5).

(i) Explain what is meant by "*e.m.f. of 12.0 V*" with reference to the power bank.

....

.... [2]

(ii) State the effect of closing switch S_1.

....

.... [1]

(iii) All the switches are now closed. Given the data below, calculate the current supplied by the power bank.

Resistance of each lamp = 25.0 Ω

Resistance of device P = 38.0 Ω

Resistance of device Q = 42.0 Ω

current = ... A [2]

(iv) Calculate the terminal potential difference of the power bank when all the switches are closed.

terminal potential difference = ... V [2]

(v) State and explain the effect, if any, on the brightness of the lamps if switches S_4 and S_5 are now opened while the rest remain closed.

....

....

....

.... [2]

(b) The same power bank from **(a)** is now connected in a potentiometer circuit as shown in Fig. 7.2.

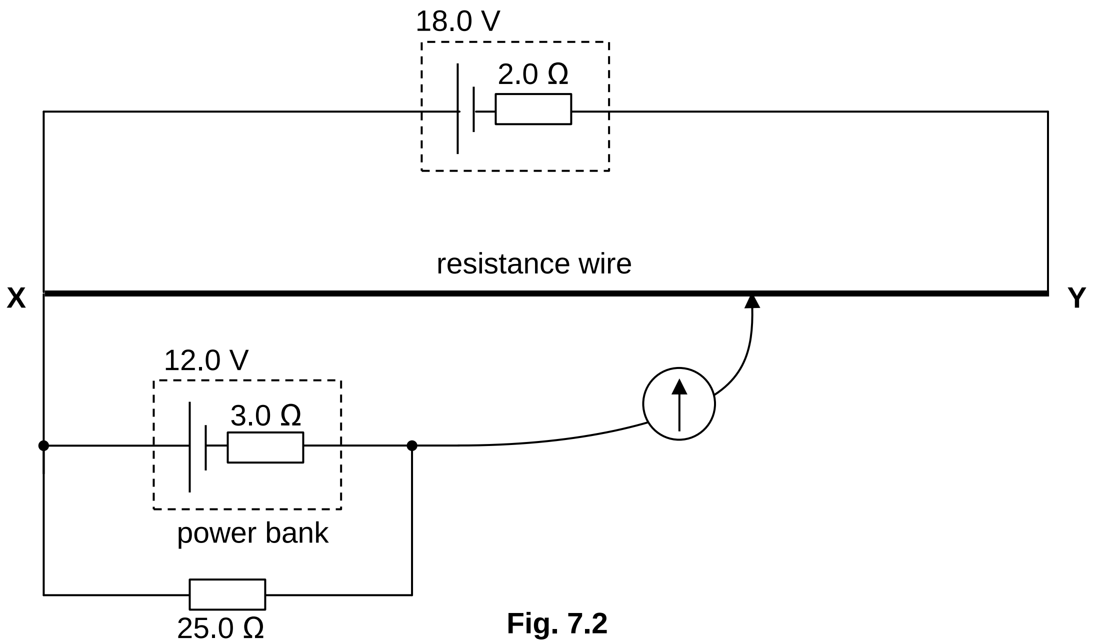

Fig. 7.2

A 18.0 V battery with internal resistance of 2.0 Ω is connected to a resistance wire XY. XY is 1.00 m long and has resistance of 7.2 Ω. A resistor of 25.0 Ω is connected in parallel to the power bank.

(i) Calculate the balance length when the galvanometer shows a reading of zero.

balance length = ... m [3]

(ii) Explain why it is desirable to obtain a balance point which is closer to end Y.

....

.... [1]

(iii) State and explain the effect, if any, on the balance length if resistance wire XY is now made of a material with higher resistivity.

....

.... [2]

Section B

Answer **one** question from this Section in the spaces provided.

8 **(a)** A binary star consists of two stars that orbit about a fixed point C, as shown in Fig. 8.1.

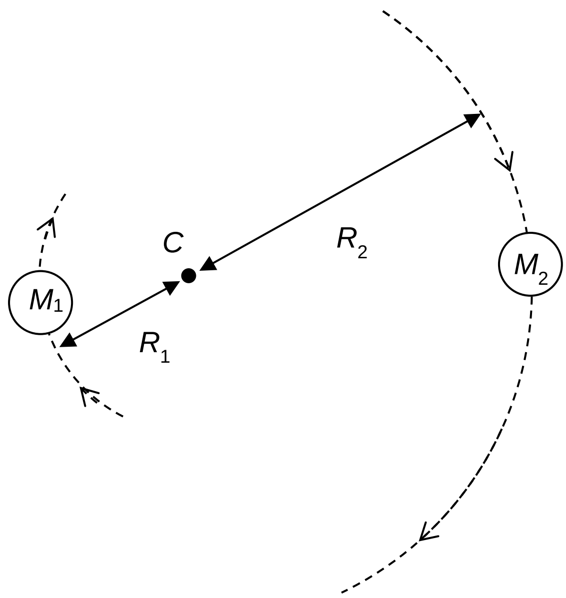

Fig. 8.1

The star of mass M_1 has a circular orbit of radius R_1 and the star of mass M_2 has a circular orbit of radius R_2. Both stars have the same angular speed ω about C.

(i) State the formula, in terms of G, M_1, M_2, R_1, R_2 and ω for

1. The gravitational force between the two stars

.... [1]

2. The centripetal force on the star of mass M_1.

.... [1]

(ii) The stars orbit each other in a time of 1.26×10^8 s. Calculate the angular speed ω for each star.

ω = ... rad s^{-1} [1]

(iii) Show that the ratio of the masses of the stars is given by the expression $\dfrac{M_1}{M_2} = \dfrac{R_2}{R_1}$.

[1]

(iv) The ratio $\dfrac{M_1}{M_2} = \dfrac{R_2}{R_1}$ is equal to 3.0 and the separation of the stars is 3.2×10^{11} m.

Determine the radii R_1 and R_2.

R_1 = ... m

R_2 = ... m [1]

(v) By considering the expressions in **(i)** and using the data calculated in **(ii)** and **(iv)**, determine M_2.

M_2 = ...kg [3]

(b) Fig. 8.2 shows an electron entering a region between two oppositely-charged parallel metal plates. The plates have length 5.1 cm.

The electric field in the region between the plates is uniform and is zero outside this region.

The original direction of motion of the electron is normal to the electric field.

The original speed of the electron is $v = 1.7 \times 10^{7}$ m s^{-1}.

The electric field strength between the plates E is 4000 V m^{-1}.

The electron exits the plates at an angle θ to the horizontal.

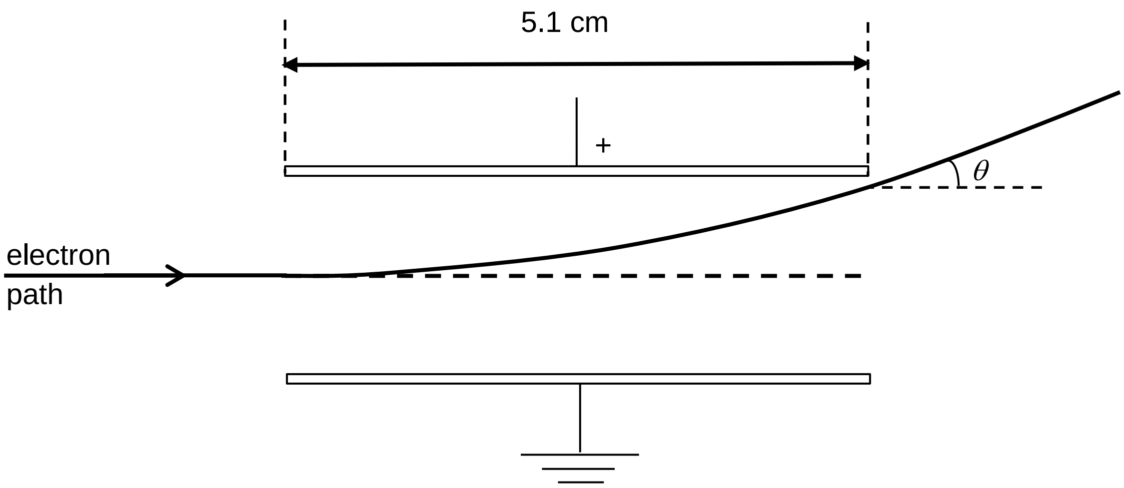

Fig. 8.2

(i) Show that the acceleration of the electron inside the electric field is 7.0×10^{14} m s^{-2}.

[1]

(ii) Calculate the magnitude of the final velocity of the electron, and the angle θ.

final velocity = ... m s^{-1}

θ = ... ° [4]

(iii) A proton is projected with the same initial velocity along the same line. Without detailed calculation, draw the path that the proton takes on Fig. 8.2. Explain your answer.

....

....

.... [2]

(c) Fig. 8.3 shows a uniform magnetic field *B* denoted by the shaded area. An electron moves into the field at the same speed *v* as in **(b)**, and is also deflected from its original path. The original direction of motion of the electron is normal to the magnetic field.

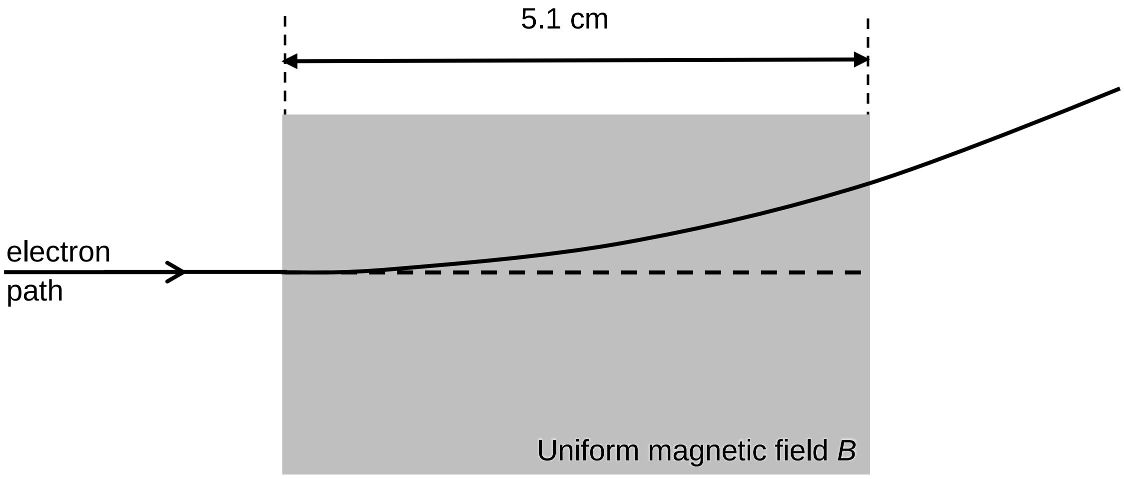

Fig. 8.3

(i) State the difference between the shape of the path taken by the electron in the magnetic field, and the shape of the path taken by the electron in the electric field described in **(b)**. Explain this difference.

....

....

....

....

....

....

.... [3]

(ii) State and explain how the final speed of the electron after passing through the magnetic field compares with the final speed of the electron after passing through the electric field in **(b)**.

....

....

.... [2]

9 A radon-222 ($^{222}_{86}\text{Rn}$) nucleus, originally at rest, spontaneously decays to form a polonium-218 ($^{218}_{84}\text{Po}$) nucleus and an alpha particle. It may be assumed that no gamma ray is emitted.

(a) Explain what is meant by *spontaneous*.

....

.... [1]

The rest masses of the nuclei are shown in Fig. 9.1.

$^{222}_{86}\text{Rn}$	222.0176 u
$^{218}_{84}\text{Po}$	218.0090 u
alpha particle	4.0026 u
proton	1.00727 u
neutron	1.00866 u

Fig. 9.1

(b) (i) Calculate the total kinetic energy of the decay products.

total kinetic energy = ...J [3]

(ii) Describe the subsequent motion of the decay products. Explain your answer with reference to the principle of conservation of momentum.

....

....

....

....

.... [2]

(iii) Show that the ratio $\dfrac{\text{kinetic energy of alpha particle}}{\text{kinetic energy of Po-218 nucleus}} \approx 54.5$.

[1]

(c) **(i)** Calculate the value of mass defect per nucleon $\left(\text{i.e. } \dfrac{\text{mass defect}}{\text{number of nucleons}}\right)$ for Radon-222. Leave your answer in terms of atomic mass units (u).

mass defect per nucleon for Radon-222 = ... u [3]

(ii) The mass defect per nucleon for Polonium-218 has a value of 8.08312×10^{-3} u. With reference to your answer in **(c)(i)**, explain whether Polonium-218 or Radon-222 is more stable.

....

....

....

....

....

.... [3]

(d) Radon-222 has a half-life of 3.8 days.

(i) State what is meant by *half-life*.

....

.... [1]

(ii) Calculate the probability of a given radon-222 nucleus decaying per second.

probability = ... s^{-1} [2]

(iii) A student stated that "radioactive materials with a short half-life always have a high activity". Discuss whether the student's statement is valid.

....

....

.... [1]

(e) A sample of Radon-222 was carefully measured out and sealed in a container. The rate of radioactive decay was measured using an accurate instrument, taking into account background radiation. The number of alpha particles detected was significantly higher than expected. State what this suggests about the stability of Polonium-218. Explain your answer.

....

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....

....

.... [3]