SERANGOON JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME

CIVICS GROUP

INDEX NUMBER

1234567S

PHYSICS **9646/03**

Paper 3 Longer Structured Questions **22 August 2011**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, Civics Group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

You are advised to spend about one hour on each section.

At the end of the examination, fasten all your work securely together.
The number of marks is given in bracket [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total	

This document consist of **24** printed pages and **no** blank page.

SERANGOON JUNIOR COLLEGE
Science Department Physics Unit

DATA AND FORMULAE

Data

speed of light in free space,	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}
			$(1 / (36\pi)) \times 10^{-9}$ 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	=	$-\dfrac{Gm}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos\omega t$
	v	=	$\pm \omega\sqrt{\left(x_0^2 - x^2\right)}$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_0 \sin\omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
			where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{0.693}{t_{\frac{1}{2}}}$

For Examiner's Use

Section A

Answer **all** the questions in this section

1 **(a)** Define *gravitational potential at a point*.

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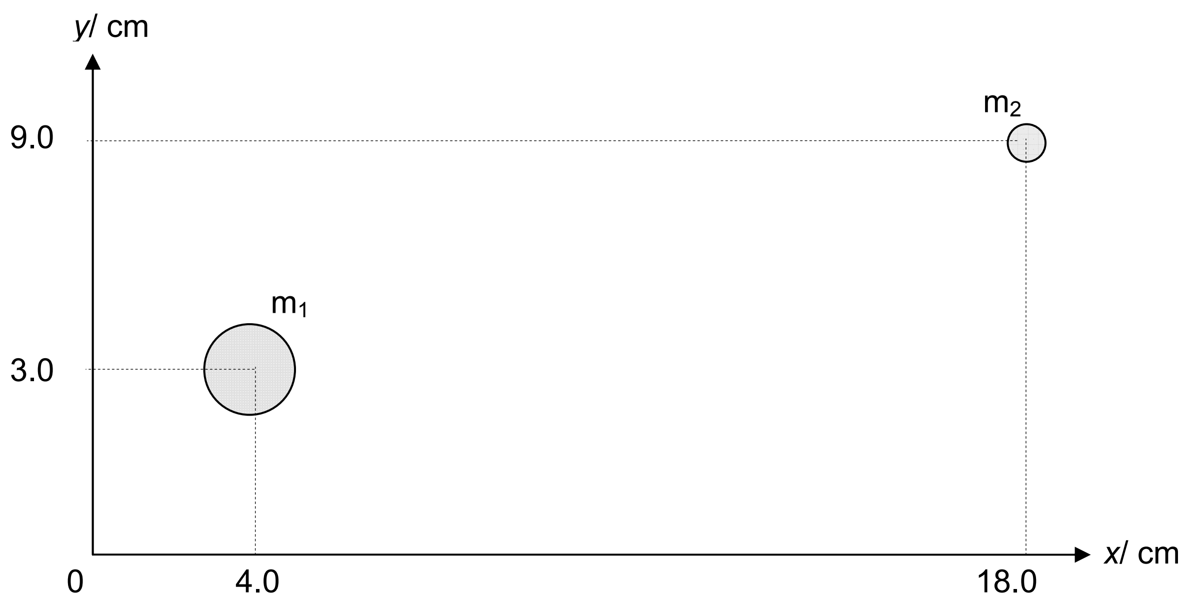
....[1]

(b) Two masses m_1 and m_2 are placed at positions as shown in the diagram, where m_1 = 25 000 kg and m_2 = 15 000 kg.



(i) Determine the gravitational potential at the origin due to m_1 and m_2 respectively.

gravitational potential due to m_1 = ... J kg^{-1}

gravitational potential due to m_2 = ... J kg^{-1} [3]

(ii) Hence, or otherwise, determine the total gravitational potential energy of a 1000 kg mass placed at the origin.

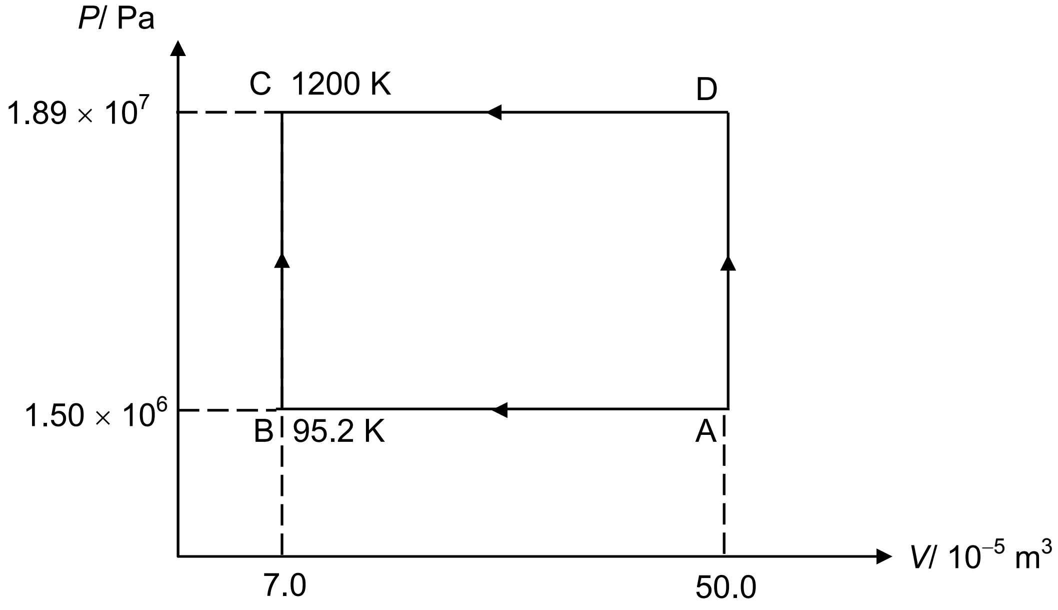
total gravitational potential energy = ... J [2]

(iii) State the work required to move the 1000 kg mass from the origin to infinity.

work done = ... J [1]

For Examiner's Use

2 The figure below shows the variation of pressure with volume for a fixed mass of ideal gas. The gas is taken from state A to state C through two different paths ABC and path ADC.



(a) Calculate the number of moles in the gas.

number of moles of gas = …………………… [1]

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(b) **(i)** During process BC, the temperature of the gas rises from 95.2 K to 1200 K at constant volume. The molar heat capacity of the gas at constant volume is 12.5 J K^{-1} mol^{-1}. During process AB, 1613 J of thermal energy is lost.

By showing your working clearly, calculate the change in internal energy from A to C.

[Note: Molar heat capacity is the amount of thermal energy required to raise the temperature of one mole of gas by one degree Celcius]

change in internal energy = …………………….. J [3]

(ii) Hence, calculate the thermal energy lost during process ADC.

thermal energy lost = …………………….. J [2]

(c) To bring the gas from state A to state C, less heat is needed for process ADC compared to process ABC. Explain why.

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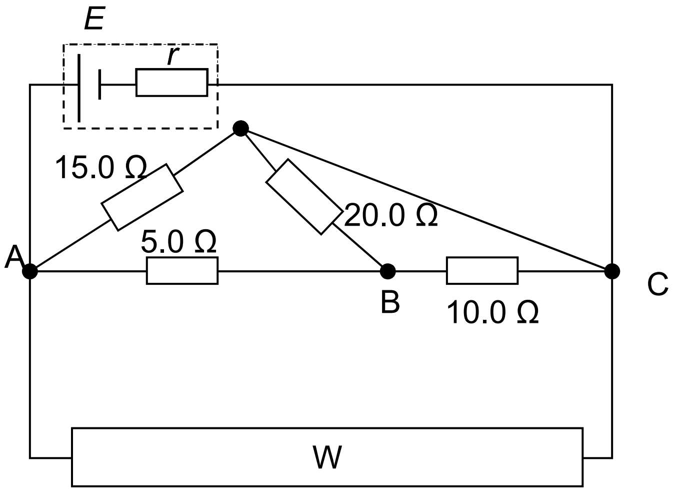
…………………………………………………………………………………… [2]

3 A cell of e.m.f. *E* with an internal resistance *r* is connected in an electrical circuit consisting four resistors and a resistance wire W as shown below.



When the current flowing through the cell is 12.0 A, the potential difference across AC is 6.0 V.

(a) 1.875×10^{19} electrons pass through the cell in *t* seconds.

(i) Show that $t = 0.25$ s. [1]

(ii) Calculate the amount of electrical energy converted by the cell between the points A and C during this time period.

energy = ………………….. J [1]

(b) The resistivity of W is 1.36×10^{-5} Ω m, its length is 0.5 m, and its diameter is 4.0×10^{-3} m. Show that the effective resistance across AC due to the four resistors and W is 0.5 Ω. [3]

(c) Calculate,

(i) the potential difference across BC.

potential difference = ………………….. V [2]

(ii) the ratio of the currents passing through the 20 Ω and 5 Ω resistors respectively, $\frac{I_{20\Omega}}{I_{5\Omega}}$.

ratio = ………………….. [1]

(d) The 5 Ω resistor is replaced by a light-dependent resistor. Explain how the potential difference across BC would change when the room in which the circuit is placed becomes brighter.

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…………..

…………..[2]

For Examiner's Use

4 Fig. 4.1 shows a high voltage supply set up to produce energetic electrons to bombard the cool sodium gas in the discharge tube, giving rise to a line spectrum through a diffraction grating. Fig. 4.2 shows some energy levels of sodium.

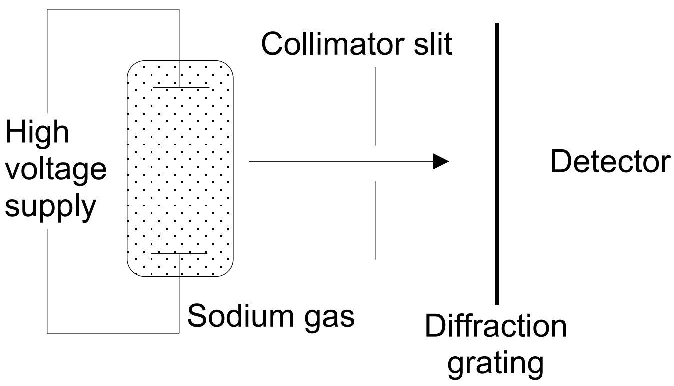

Fig. 4.1

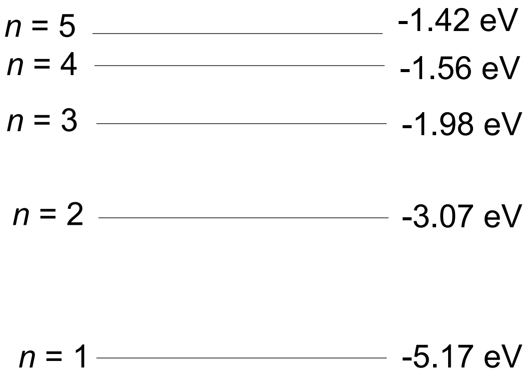

Fig. 4.2

Each bombarding electron has a kinetic energy of 3.20 eV.

(a) On Fig. 4.2 draw all the possible transitions that lead to emission of radiation. [2]

(b) Determine the range of kinetic energies of the recoiling electrons (in joules) after they have excited the sodium atoms.

range of KE = ……………………… to …………………….. J [2]

For Examiner's Use

(c) A sample of a cool gas X is placed between the discharge tube and the collimator as shown in Fig. 4.3.

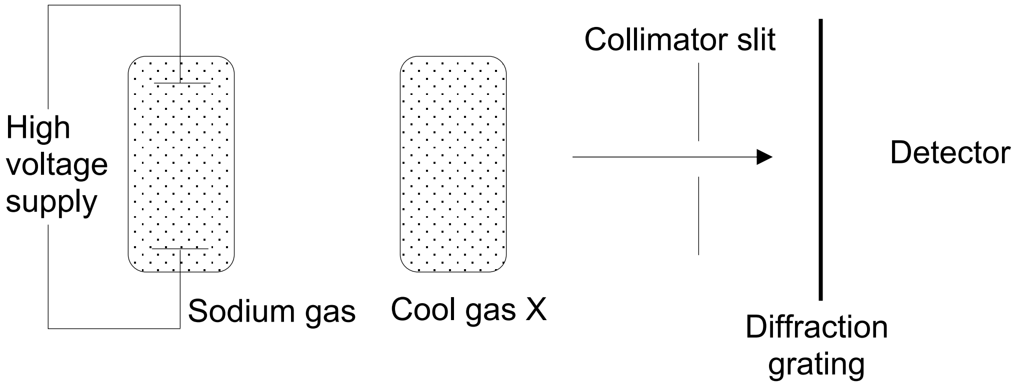

Fig. 4.3

Fig. 4.4 shows the energy levels in cool gas X.

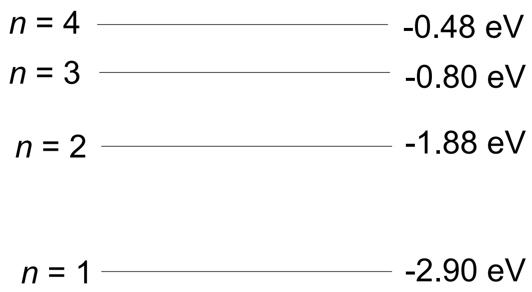

Fig. 4.4

Two extra spectral lines are detected as compared to **(a)**. Explain the process that results in this. Assume that the detector is very sensitive and is able to detect a single photon.

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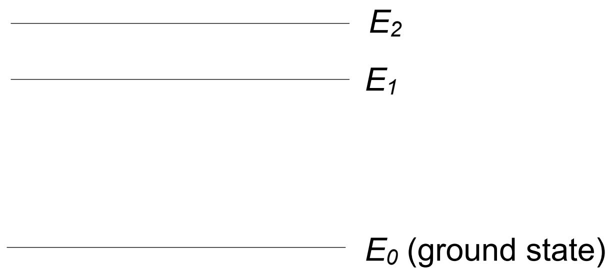
For Examiner's Use

5 **(a)** The energy level diagram shows a three-level laser system.



Explain how the laser is produced.

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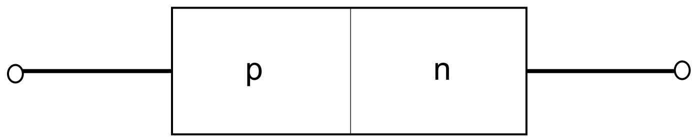
(b) The diagram below shows a p-type semiconductor placed in contact with an n-type semiconductor.



(i) Explain how a depletion layer is formed between the p-type and n-type semiconductors.

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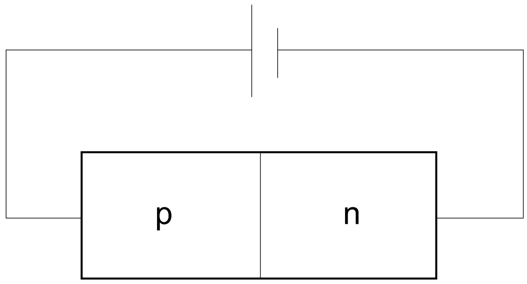
………………………………………………………………………………………[3]

(ii) State and explain how the width of the depletion layer changes when an e.m.f. is connected as shown in the diagram.



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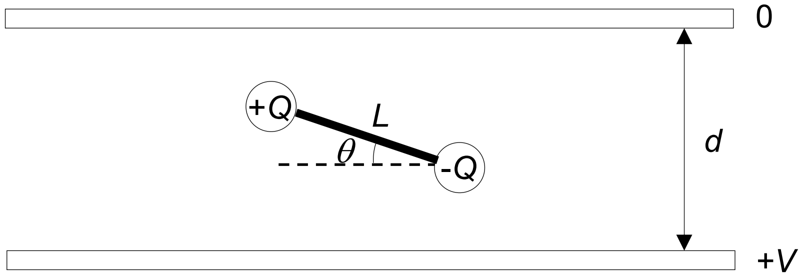
....[2]

Section B

Answer **two** questions from this section

6 **(a)** An electric dipole consists a positive charge $+Q$ and a negative charge $-Q$ which are a distance L apart. The electric dipole of negligible mass is placed in a region between a pair of charged plates as shown in the figure below. The plates are at potentials of 0 V and $+V$ respectively, and are a distance d apart.



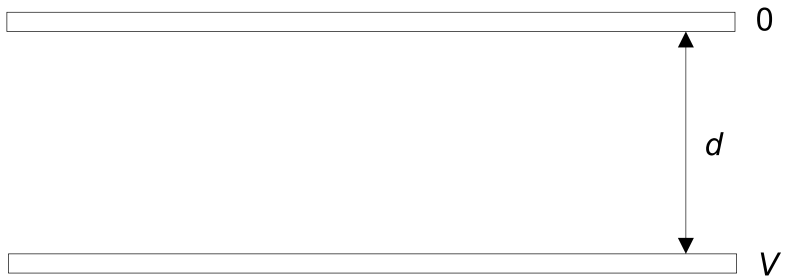
(i) Describe the initial motion of the electric dipole.

………………………………………………………………………………………..……..

……………………………………………………………………………..……….[1]

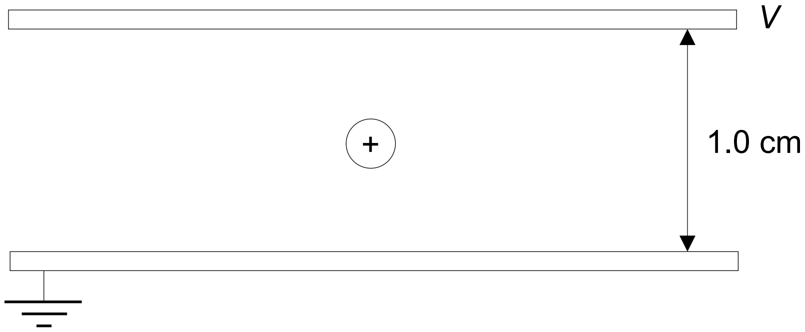
(ii) Derive, in terms of Q, L, V, d and θ, the net torque on the dipole at this instant. [2]

(ii) Hence sketch the orientation of the electric dipole within the region when it experiences zero torque. [1]



For Examiner's Use

(b) An isolated proton is now placed in the middle of another pair of parallel plates separated by a distance of 1.0 cm. One of the plates is earthed, while the potential of the other is maintained at V, where $V = 8.0 \times 10^{-12} \cos(7.8t)$.



(i) State the angular frequency of the oscillation.

angular frequency = ………………………. rad s^{-1} [1]

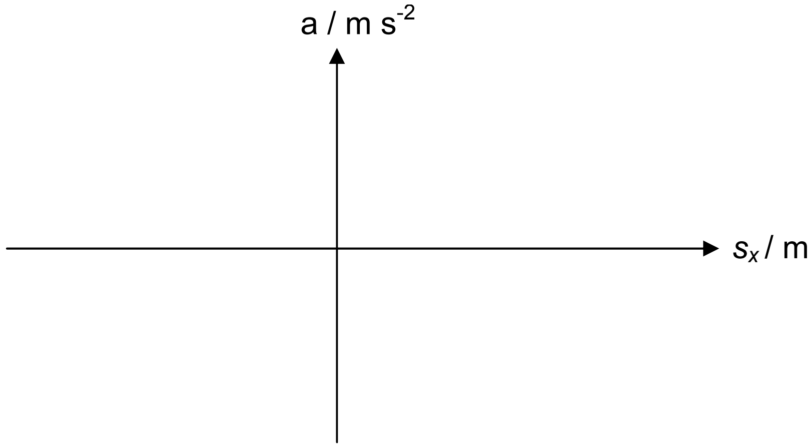
(ii) Calculate the maximum force acting on the charge, assuming that the weight of the proton is negligible.

force = ………………………. N [2]

(iii) If the proton is performing simple harmonic motion, calculate the amplitude of its oscillation.

amplitude = ………………………. m [2]

(iv) Sketch, on the axes below, the acceleration – displacement graph of the motion of the proton, indicating all critical values. [2]



(v) Write down the equation which describes the displacement of the proton. [1]

(vi) Sketch, on the axes below:

1. the displacement – time graph of the proton for 2 oscillations, and [2]

2. the velocity – time graph of the proton for 2 oscillations. [2]

(vii) Describe the changes in energy throughout one cycle.

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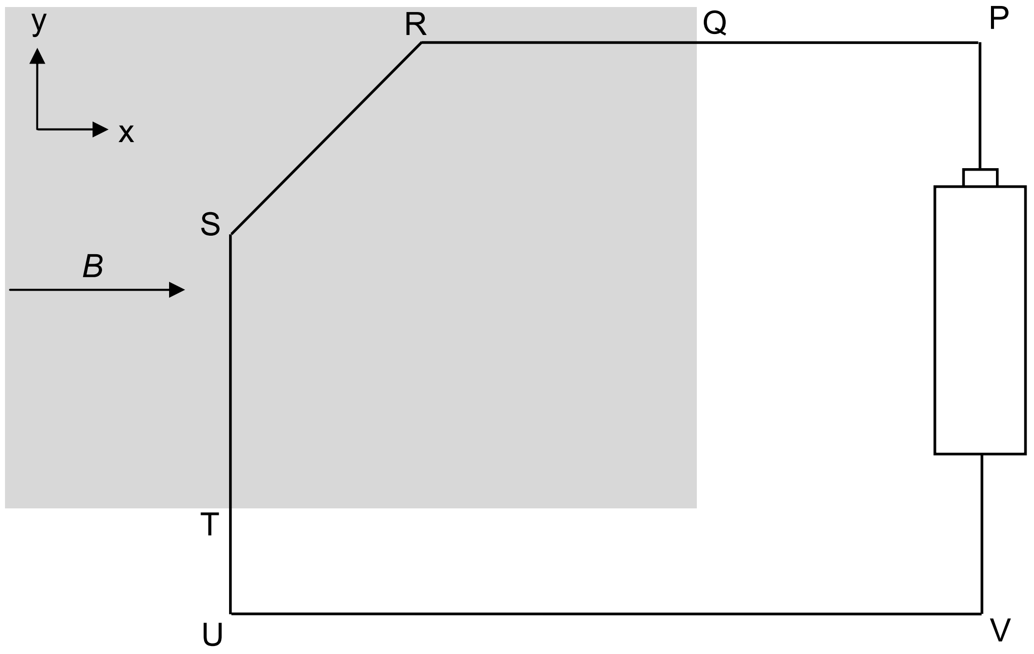
....[4]

For Examiner's Use

7 **(a)** The diagram below shows the full scale diagram of a circuit. Part of the circuit QRST is placed in a region of uniform field *B* of 0.530 T that is directed in the positive x-direction. The battery supplies a current I of 2.50 A. The wire experiences a force as a result.

The region of the magnetic field is represented by the shaded region.



(i) Define *tesla.*

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....[1]

(ii) State and explain the direction of the resultant force acting on the wire.

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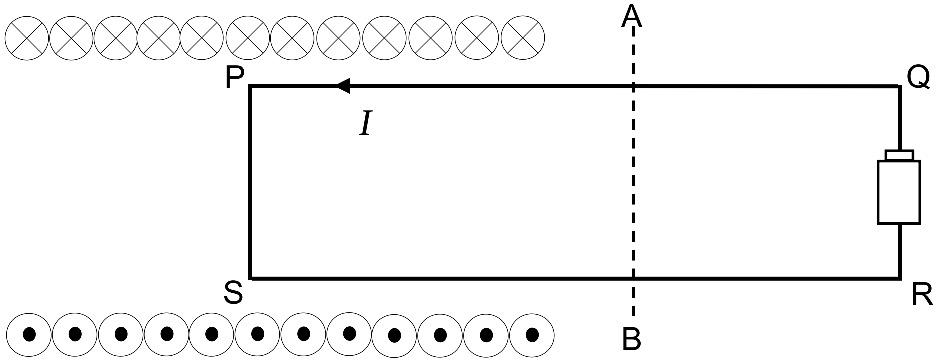
....[3]

(iii) Calculate the resultant force acting on the wire.

resultant force = ... N [2]

(iv) It is possible that there is no resultant force acting on the wire if the field points in one particular direction. Draw the field in this direction in the figure above and label it P. [1]

(b) The figure below shows the top view of a current balance where the rectangular wire loop PQRS pivoted at AB is in equilibrium. It is connected in series with a battery of 300 g and an e.m.f. of 2.0 V. Part of the wire loop is placed inside a solenoid. The mass of the loop can be taken to be negligible.



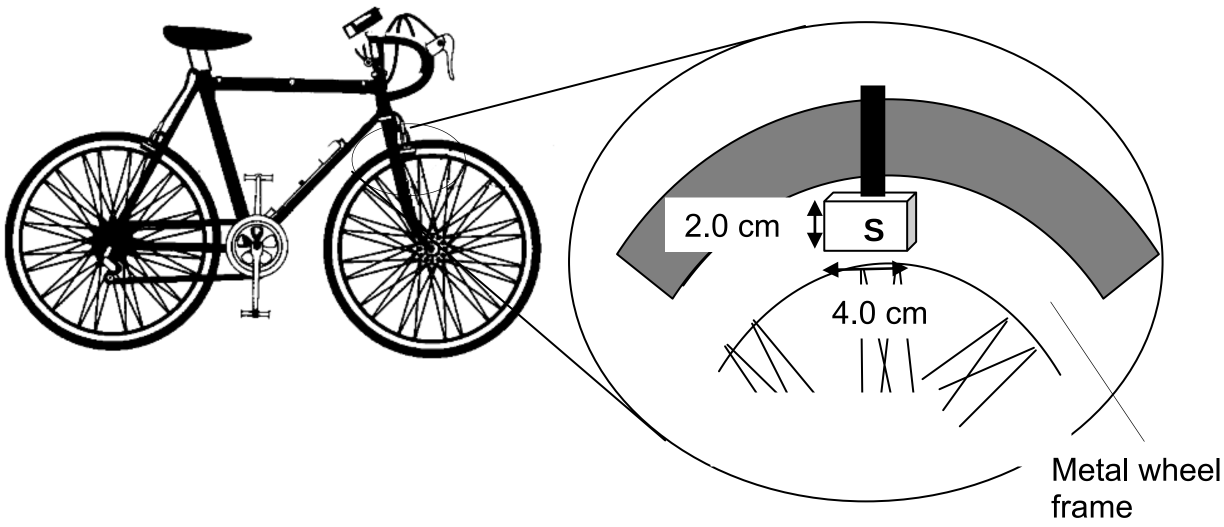
(i) Draw the magnetic field lines in the solenoid. [2]

(ii) The length of the side PS is 6.0 cm and SB = 0.6SR. Given that the magnetic flux density in the solenoid is 0.40 T and the wire has no resistance, calculate the internal resistance of the battery.

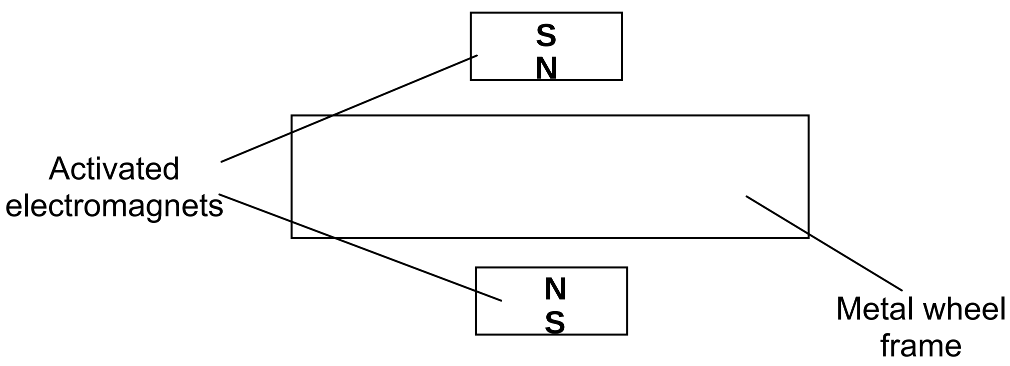
internal resistance = ... Ω [3]

For Examiner's Use

(c) A student designs a bicycle that uses electromagnetic braking instead of braking by friction. Two pairs of electromagnets are attached to the brakes of front and back wheels of the bicycle. When the brakes are activated, magnetic north poles face the wheels.



(i) The diagram below shows the top view of the cross section of the braking system. Sketch the magnetic field lines in the metal wheel frame. [2]



(ii) Using energy consideration, explain how the above setup acts as a braking system.

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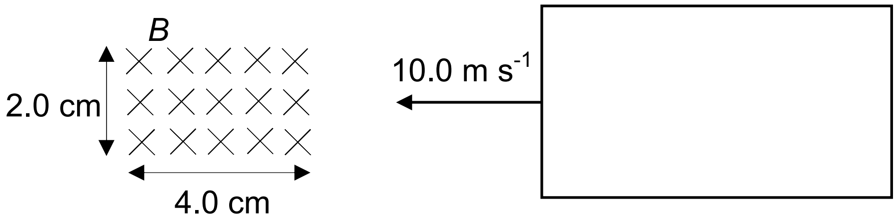
....[3]

(iii) An experiment is conducted before fitting the electromagnet to the bicycle. To test the effectiveness of the braking system, the student places the electromagnet at a fixed position, with the field produced pointing into the plane of the paper. The surface of the magnet facing the wheel has a dimension of 4.0 cm by 2.0 cm. A wire loop is moved at a speed of 10.0 m s^{-1} towards the magnet.



Assuming that the uniform magnetic flux density *B* is 0.70 T, calculate the e.m.f induced in the wire as it cuts the field.

e.m.f = ... V [2]

(iv) Suggest, using your answer from **(b)(iii),** why the braking system is an effective one.

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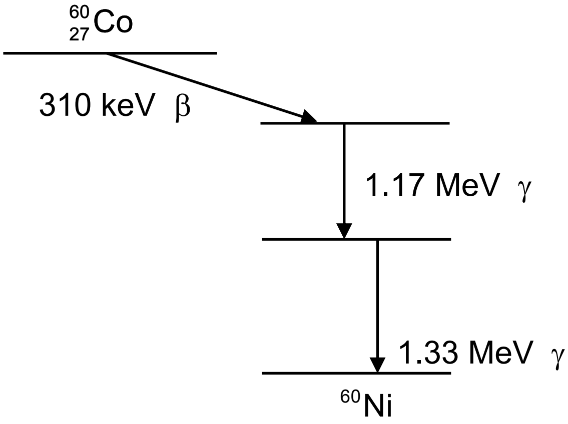
....[1]

8 **(a)** Cobalt-60 undergoes nuclear decay to form the stable isotope Nickel-60. In the process of decay, Cobalt-60 emits one electron with an energy of 310 keV and then two gamma rays with energies of 1.17 MeV and 1.33 MeV, respectively.



Some rest mass information relating to the above reaction is as shown.

Rest mass of a neutron	=	1.008665 *u*
Rest mass of a proton	=	1.007825 *u*
Rest mass of an electron	=	0.000549 *u*

(i) Write down the number of protons and neutrons in the Nickel nuclide produced when the Cobalt-60 nuclide decays.

number of protons = ……………………

number of neutrons = ……………………. [1]

(ii) The binding energy per nucleon of a Cobalt-60 nuclide is 8.74 MeV. Calculate, to 5 decimal places, the rest mass of Cobalt-60 in terms of *u.*

rest mass = …………………… *u* [2]

(iii) Calculate, to 5 decimal places, the rest mass of the stable nickel nuclide in terms of *u*.

rest mass = …………………… *u* [3]

(iv) In practice, the above radioactive decay of Cobalt-60 could be used for the treatment of cancer.

Suggest and explain which of the products of decay is used for the purpose of tumour treatment.

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……………………………………………………………………………………...[1]

(v) **1.** Sketch a graph to show the variation of binding energy per nucleon with nucleon number, and mark the binding energy per nucleon of a Cobalt-60 nuclide on the graph. [2]

2. Hence explain why fusion of nuclei having small nucleon numbers is associated with a release of energy.

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(b) A Carbon-14 $\left({}^{14}_{6}C\right)$ nuclide undergoes spontaneous and random beta decay to transform into a stable Nitrogen-14 $\left({}^{14}_{7}N\right)$ nuclide.

$$ {}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta $$

(i) Explain the terms *spontaneous* and *random*.

………………………………………………………………………………………

……………………………………………………………………………………...

……………………………………………………………………………………...[2]

(ii) The nuclide of Carbon-14 has a half-life of 5730 years. If a Carbon-14 source emits *n* β-particles in one second today, calculate the time taken for the source to emit the same number of β-particles 10,000 years later.

time taken = ………………. s [2]

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(iii) Calculate the number of years that must lapse so that the source will take one year to emit *n* β-particles.

number of years = ………………. [2]

(iv) In a sample initially containing only radioactive Carbon-14, the number of remaining carbon-14 and number of stable Nitrogen-14 produced are recorded over time. The recording ends when there is negligible number of Carbon-14 nuclides left in the sample.

Sketch and label, in the same axes below, the graphs of

1. the number of remaining Carbon-14 nuclides (Graph C)
2. the number of Nitrogen-14 nuclides produced (Graph N)

Label the position of the half-life, *T*, in the graph. [2]