NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	
CLASS	
TUTOR'S NAME	
CENTRE NUMBER	S
INDEX NUMBER	

PHYSICS 9749/02

Paper 2 Structured Questions

15 September 2025

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number 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 HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

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	
1	/ 7
2	/ 7
3	/ 11
4	/ 11
5	/ 8
6	/ 7
7	/ 9
8	/ 20
Total	/ 80

This document consists of **24** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$p = \rho g h$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} \langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
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	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 The rate of heat flow through a rod due to conduction is given by Fourier's Law:

$$\frac{Q}{t} = \frac{CA(\Delta T)}{L}$$

where A is the cross-sectional area of the material,

L is the length of the material,

ΔT is the temperature difference across the length of the material, and

C is a constant.

(a) Determine the SI base units of C.

SI base units = ... [2]

(b) An experiment is conducted to determine the value of C. Using copper rod of diameter 0.80 cm but different length, and two ends of the rod are maintained at pure ice point and steam point, the rate of flow of thermal energy was measured using a heat flux sensor. A graph of how $\frac{Q}{t}$ varies with $\frac{1}{L}$ is plotted, as shown in Fig. 1.1.

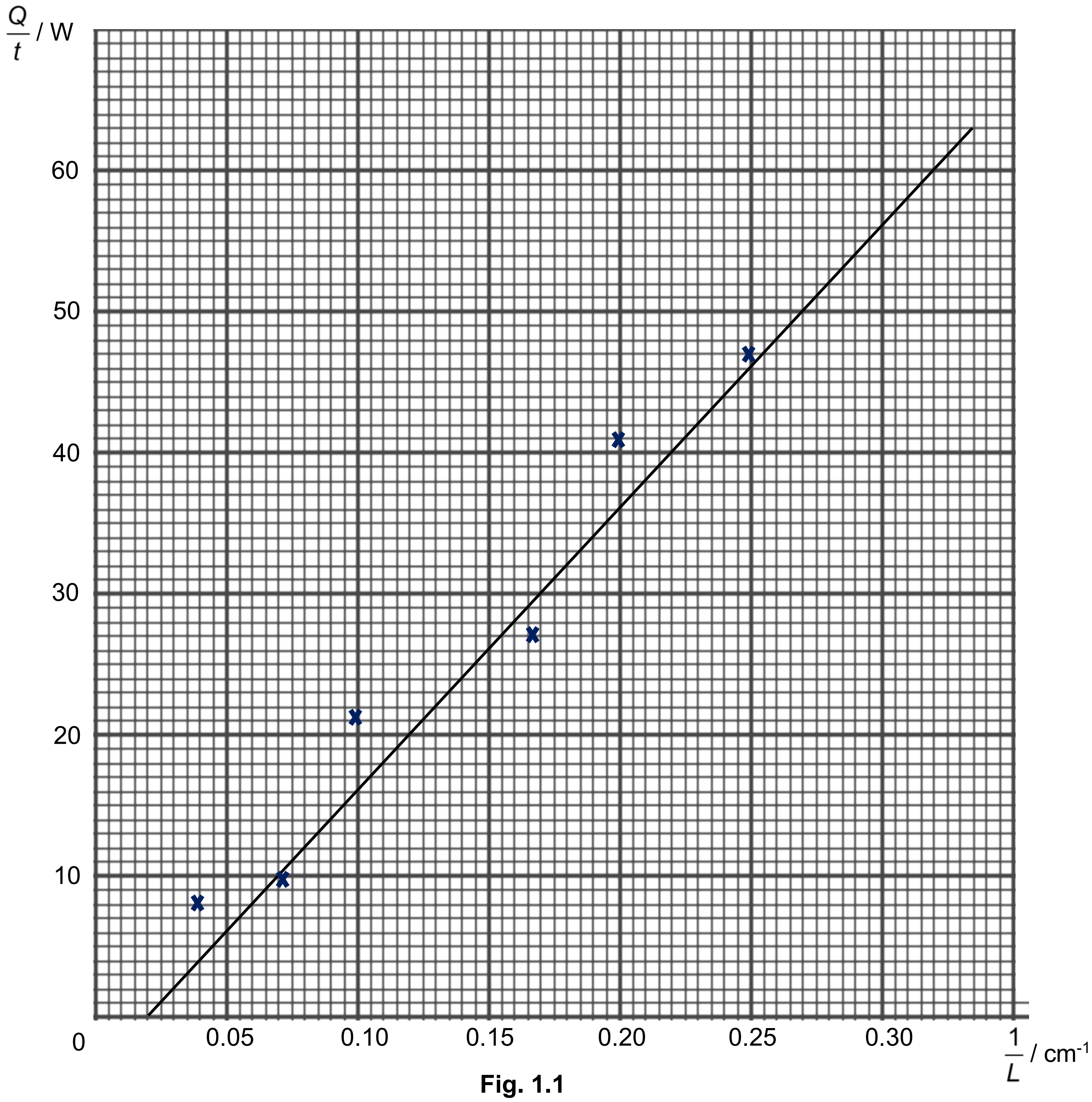


Fig. 1.1

(i) State the feature of the graph that indicates the presence of systematic error in the experiment.

....

....[1]

(ii) Calculate the value of *C*, in SI units, from Fig. 1.1.

value of *C* = ………..…………. SI base units [3]

(iii) With reference to Fig. 1.1 and **(b)(i)**, state and explain whether the accuracy of *C* is affected by the presence of systematic error in the experiment.

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

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

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

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

[Total: 7]

2 (a) State the principle of conservation of momentum.

………

………

………

………[1]

(b) Fig. 2.1 shows a metal bullet of mass 2.0 g fired horizontally into a block of wood of mass 600 g. The block is suspended from strings so that it is free to move in the vertical plane. The bullet hits and becomes embedded in the block. The block and bullet rise together through a vertical distance of 8.6 cm.

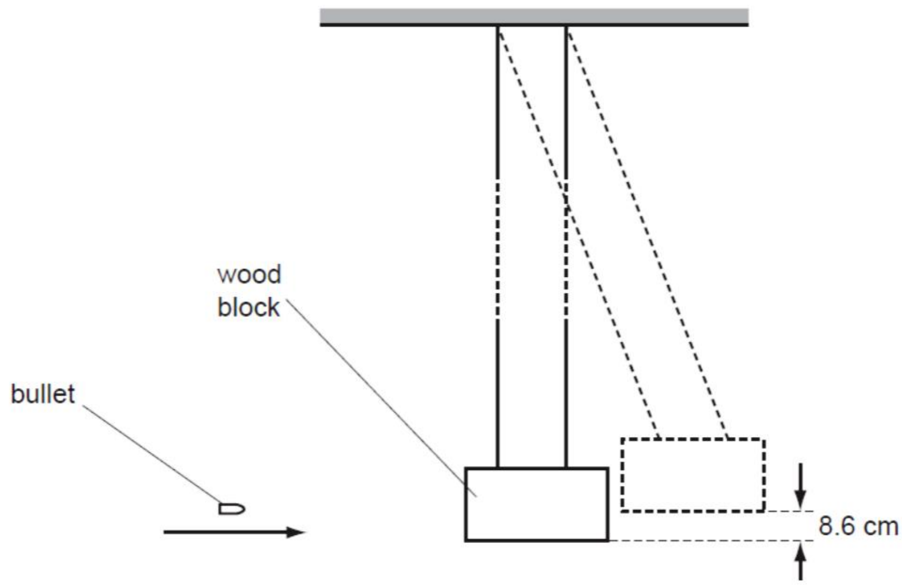


Fig. 2.1

(i) Show that the speed of the block and bullet as they just move off together is 1.3 m s^{-1}.

[2]

(ii) Using **(a)** and **(b)(i)**, determine the speed of the bullet before the impact with the block.

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

(iii) A rubber bullet of the same mass hits the block with the same speed calculated in **(ii)** and rebounds in the opposite direction. State and explain whether the block will reach a maximum height of greater or less than 8.6 cm.

....

....

....

....[2]

[Total : 7]

3 A steel sphere of mass 0.30 kg is suspended in equilibrium from a vertical spring. The centre of the sphere is 8.5 cm from the top of the spring, as shown in Fig. 3.1.

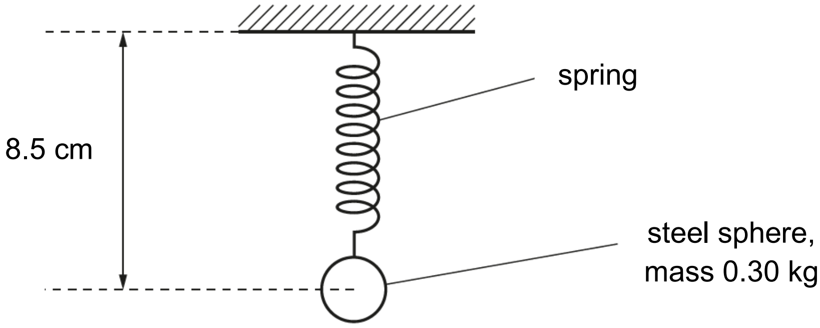


Fig. 3.1

The sphere is now set in motion so that it is moving in a horizontal circle at constant speed, as shown in Fig. 3.2.

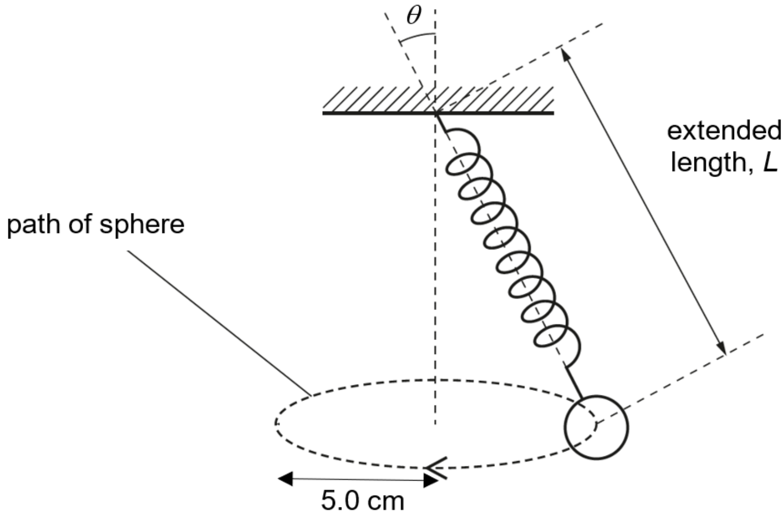


Fig. 3.2

The spring stretches to a new extended length L, and the radius of the circular motion is 5.0 cm. The angle between the linear axis of the spring and the vertical is θ. The period of the circular motion is 0.60 s.

(a) Explain, with reference to the forces acting on the sphere, why the length of the spring in Fig. 3.2 is greater than in Fig. 3.1.

....

....

....

....

....[3]

(b) **(i)** Calculate the centripetal acceleration of the sphere.

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

(ii) Show that the angle θ is 29°.

[2]

(iii) Calculate the tension in the spring in Fig. 3.2.

tension in spring = ... N [2]

(iv) Calculate the spring constant of the spring.

spring constant = ... N m^{-1} [3]

[Total: 11]

4 Fig. 4.1 shows a fixed mass of ideal gas in a cylinder of pressure 2.1×10^5 Pa, volume 4.0×10^{-4} m^3 and temperature 27 °C.

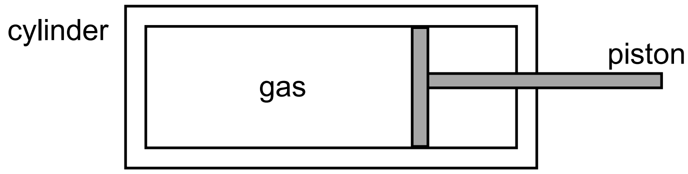


Fig. 4.1

The gas is compressed at constant temperature along process I. Fig. 4.2 shows the variation with volume V of the pressure P of the gas.

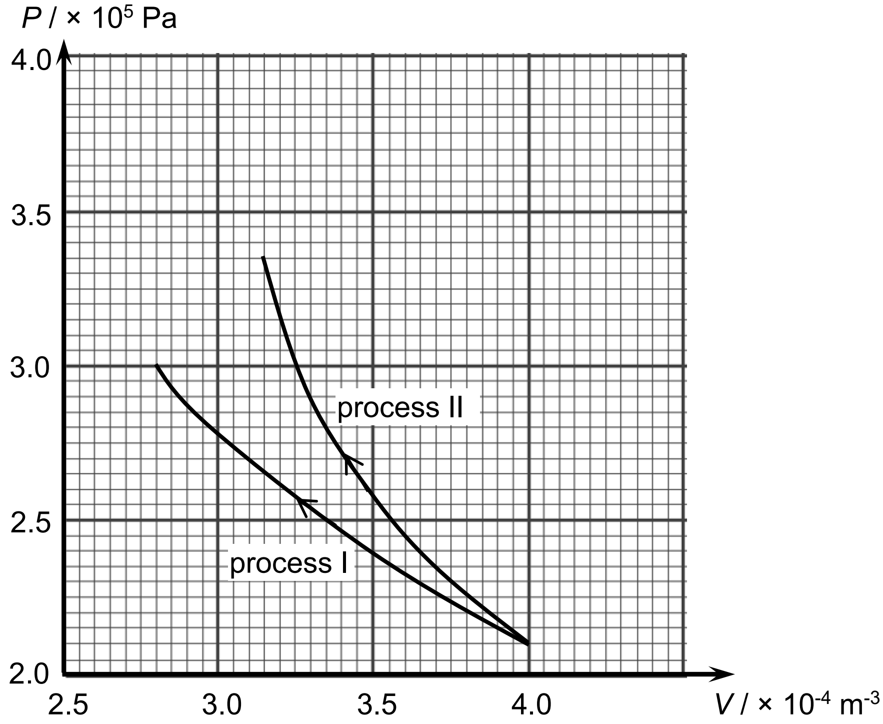


Fig. 4.2

(a) (i) With reference to Fig. 4.2, estimate the work done on the gas through process I.

work done = ... J [3]

(ii) State the *first law of thermodynamics*.

....

....[1]

(ii) Determine the heat loss from the gas through process I.

....

....[1]

(b) A second identical cylinder containing the same ideal gas is thermally insulated. The gas is compressed to a new pressure and volume, as shown in process II. The work done on the gas in process I equals to the work done on the gas in process II.

(i) Using the kinetic theory of gases, explain why the pressure in process II increases.

....

....

....

....

....[4]

(ii) Calculate the final temperature of process II.

temperature = ... °C [2]

[Total: 11]

5 **(a)** State one differences between *progressive* waves and *stationary* waves.

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

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

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

(b) Define *transverse* waves and *longitudinal* waves.

1. Transverse wave: ………………………………………………………………………………...

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

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

2. Longitudinal wave: ………………………………………………………………………………...

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

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

(c) **(i)** Explain why it would not be possible to polarise sound waves.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………

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

(ii) Unpolarised light of intensity I_0 is incident on two polarising filters P and Q, as shown in Fig. 5.1 below. The transmission axis of filter P is aligned vertically. The intensity of the unpolarised light is halved after passing P.

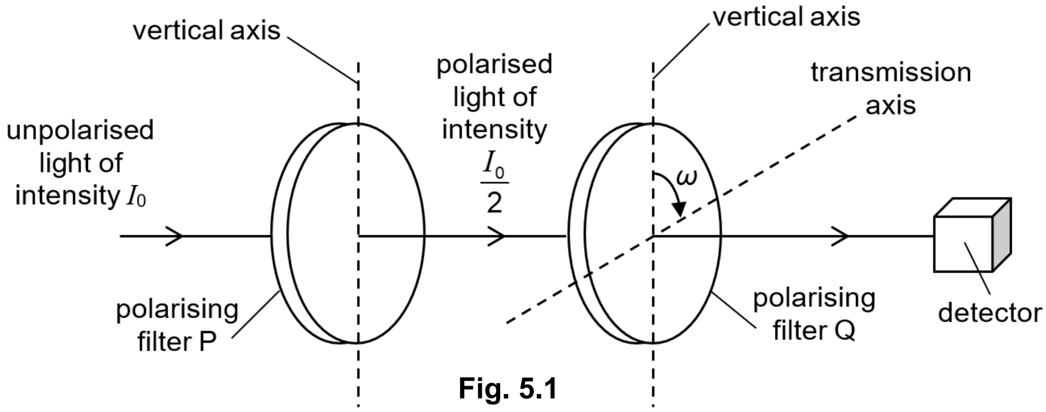


Fig. 5.1

The light is then passed through filter Q, which has the transmission axis initially aligned vertically and spun at a constant angular velocity of 2.0 rad s^{-1}.

Determine the ratio $\dfrac{\text{intensity reaching detector}}{\text{initial intensity } I_0}$ after 9.0 s.

ratio = ... [3]

[Total: 8]

6 (a) A uniform magnetic field has a constant flux density B. A straight wire of fixed length carries a current I at angle θ to the magnetic field, as shown in Fig. 6.1.

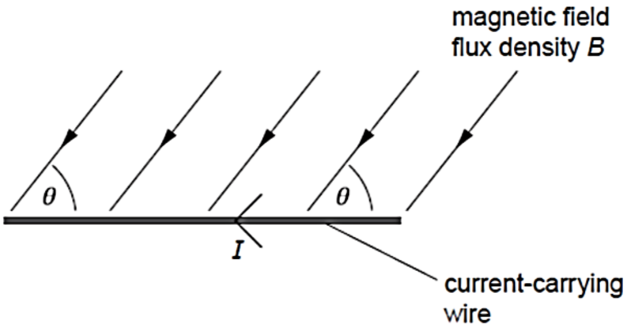


Fig. 6.1

(i) The current in the wire is changed, keeping the angle θ constant.

On Fig. 6.2, sketch the graph to show the variation with the current I of the force F on the wire.

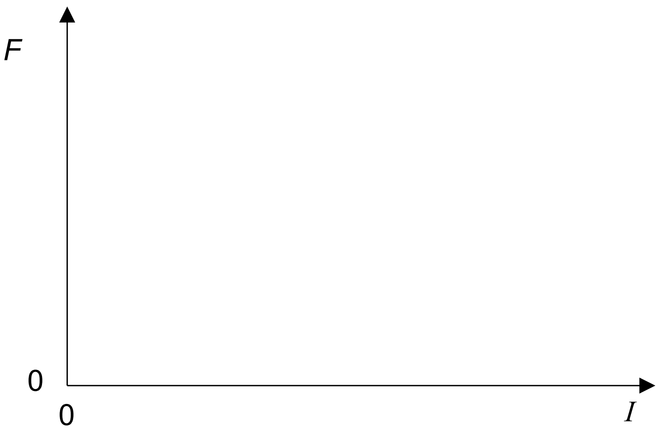
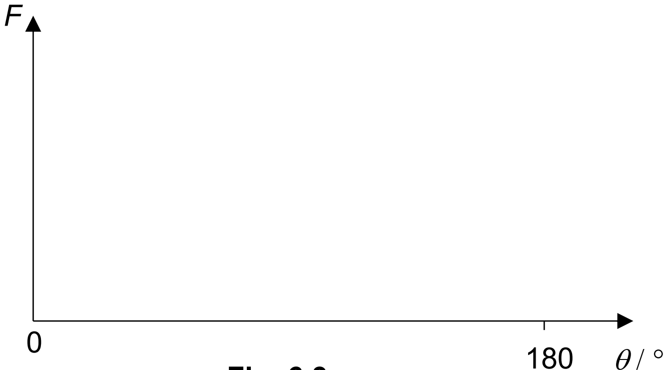


Fig. 6.2

[2]

(ii) The angle θ between the wire and the magnetic field is now varied and the current I is kept constant.

On Fig. 6.3, sketch a graph to show the variation with angle θ of the force F on the wire from θ = 0° to 180°.



[2]

Fig. 6.3

(b) A uniform magnetic field is directed at right angle to the rectangular surface PQRS of a slice of conducting material, as shown in Fig. 6.4.

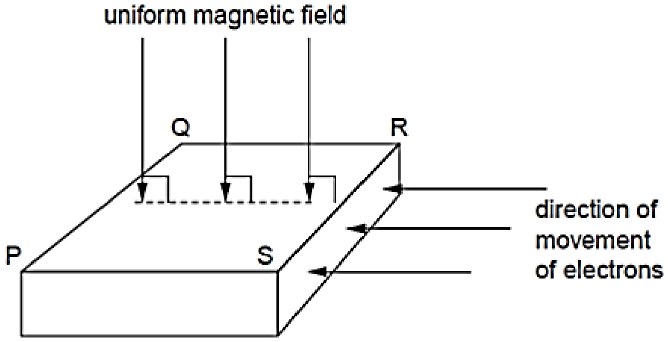


Fig. 6.4

Electrons, moving towards side SR, enters the slice of conducting material. The electrons enter the slice at right angle to side SR.

(i) Explain why the electrons do not travel in straight lines across the slice from side SR to side PQ.

....

....

....[2]

(ii) State the direction of the electric field applied to the slice of conducting material for the electrons to pass through the slice undeviated.

....[1]

[Total: 7]

7 In a nuclear reaction, a stationary fluorine-19 is bombarded with a proton having a kinetic energy of 5.00 MeV. The following reaction may occur.

$$^{1}_{1}H + ^{19}_{9}F \rightarrow ^{16}_{8}O + ^{4}_{2}He$$

The following data may be used for the calculation.

Rest mass of $^{19}_{9}F$	18.998403 *u*
Rest mass of $^{1}_{0}n$	1.008665 *u*
Rest mass of $^{1}_{1}H$	1.007825 *u*
Rest mass of $^{4}_{2}He$	4.003860 *u*

(a) Explain what is meant by

(i) binding energy of a nucleus,

....

....[1]

(ii) mass defect of a nucleus.

....

....[1]

(b) Calculate the binding energy per nucleon, in MeV, for fluorine-19.

binding energy per nucleon = ……………. MeV [3]

(c) Use the answer in **(b)** and the following data to determine the total kinetic energy of the products. Assume no photon is emitted in this reaction.

	Binding energy per nucleon/MeV
Oxygen-16	7.72
Helium-4	6.82

total kinetic energy = ……………………..………. J [2]

(d) Determine the rest mass of ${}^{16}_{8}O$.

rest mass of ${}^{16}_{8}O$ = ………………….………. kg [2]

[Total: 9]

8 Read the passage below and answer the questions that follow.

DPM Heng Swee Kiat announced in Budget 2020 that Singapore will be phasing out internal combustion engine vehicles (i.e. vehicles that use petrol or diesel as fuel) in favour of fully electric vehicles (EV) by 2040. The move is part of Singapore's commitment to tackle climate change and build an eco-friendlier city.

To increase the adoption rate of EVs, all HDB car parks in at least eight "EV-Ready Towns" across Singapore will be fitted with EV charging stations, according to Minister for Transport Ong Ye Kung during his Committee of Supply debate for the Singapore Green Plan on March 4, 2021.

The battery of an EV can be charged through either conductive or inductive methods. Conductive charging involves wired connection to the electricity supply grid. Inductive charging refers to wireless charging systems (WCS). WCS can function in both stationary and dynamic modes. This means that they can be utilized when the car is parked or stopped, such as in car parks, garages, or at traffic signals, or they can be utilized while the vehicle is in motion.

Battery chargers can be implemented inside (on-board) or outside (off-board) the vehicle. Fig 8.1 shows the typical architecture of an EV charging system, where both the on-board charger and the off-board charger are represented.

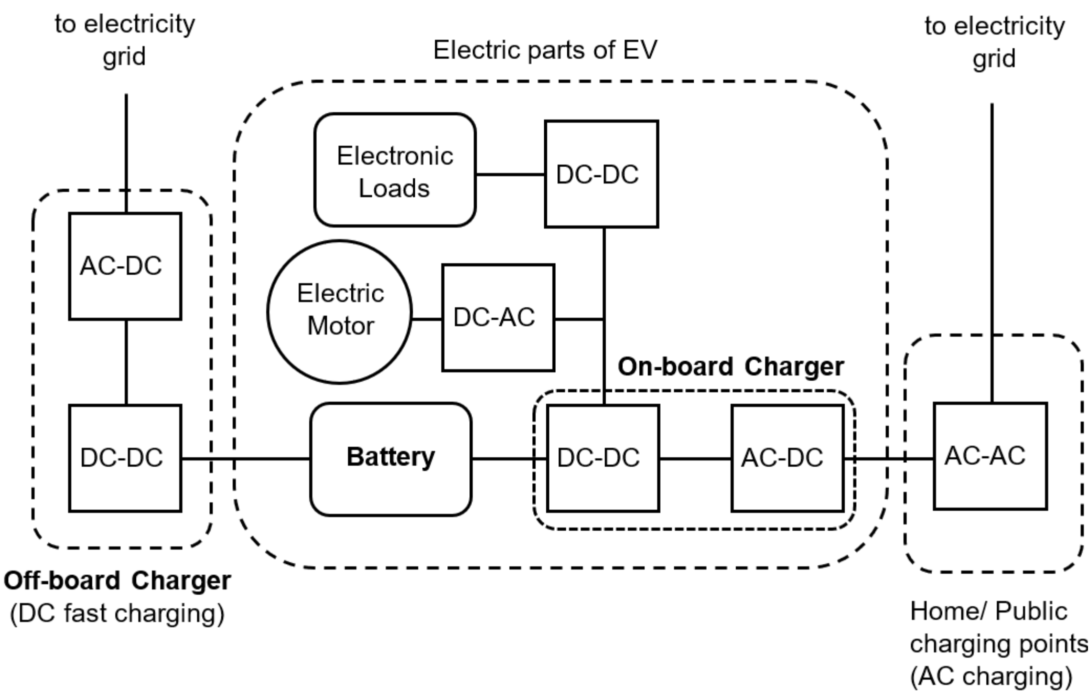


Fig. 8.1

On-board battery chargers are limited by size, weight and volume. On-board chargers are typically composed of two stages: a front-end AC-DC (a.c. to d.c.) stage and a back-end DC-DC (d.c. to d.c.) stage. The front-end conversion can be performed by a full-bridge diode rectifier circuit.

Off-board charging systems, with higher power ratings, are installed outside the vehicle. It is usually made up of two stages: a grid-facing AC-DC converter followed by a DC-DC converter providing an interface to the EV battery.

The batteries installed on EVs are not all the same. The battery capacity is the quantity that measures how much electricity can be stored. Charging power is the quantity that measures the amount of effective energy per unit time that is transferred from the charging station to the battery of the car. Ideally it could be equal to the power of the charging station but in reality, it is almost always limited by a series of factors including charging station power, maximum charging power of the machine, maximum current of the charging cable and grid energy availability.

(a) The alternating voltage from the power sub-station has to be stepped down from 21 kV to 250 V with a transformer before connecting to a domestic EV charger with a rated output of 8.0 kW.

(i) Calculate the current in the secondary coil of the transformer.

current in the secondary coil = ... A [2]

(ii) Assuming the transformer is ideal, calculate the current in the primary coil of the transformer.

current in the primary coil = ... A [2]

(iii) Determine the ratio of the number of turns in the primary coil to the number of turns in the secondary coil in the transformer.

ratio = ... [2]

(iv) If the output voltage from the charger is half-wave rectified to give a d.c. voltage, determine the peak value of this rectified voltage. Explain your working clearly.

peak rectified voltage = ... V [2]

(v) The charger is used to charge an EV installed with a 27 kWh battery. Calculate the duration, in hours, required for the battery to be 80% charged.

time = ... hr [2]

(b) The current from the battery must first be converted from a d.c. to an a.c before it can power the electric motor. This is achieved using a circuit known as an *Inverter*. Fig. 8.2 shows a schematic of a simple inverter.

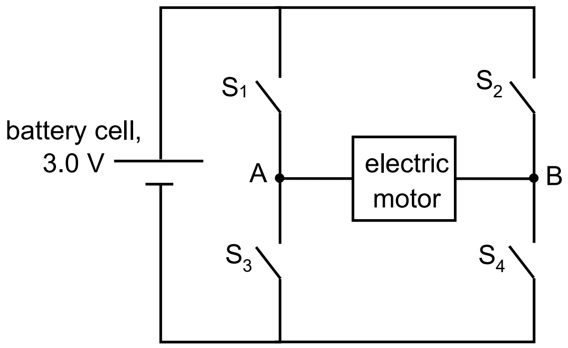


Fig. 8.2

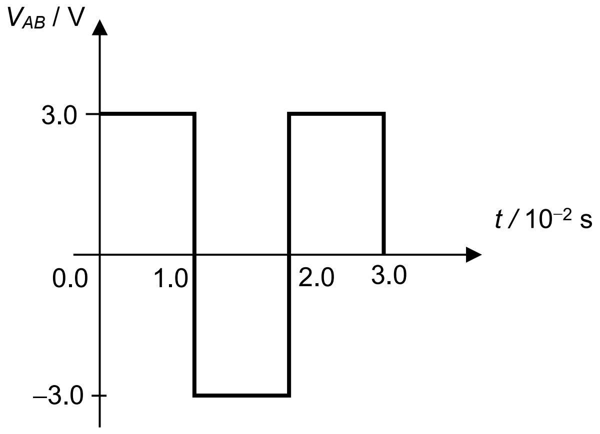


Fig. 8.3

Fig. 8.3 shows the output voltage V_{AB} across points A and B, connected to the motor in the circuit.

(i) The 4 switches S_1, S_2, S_3 and S_4 in Fig. 8.2 are electronically controlled to operate in pairs, so that at any one instant, 2 of switches will be closed while the other 2 will be open.

State and explain how the switches can be paired and operated to produce the output voltage V_{AB} in Fig. 8.3.

....

....

....

....

....

....

....[3]

(ii)

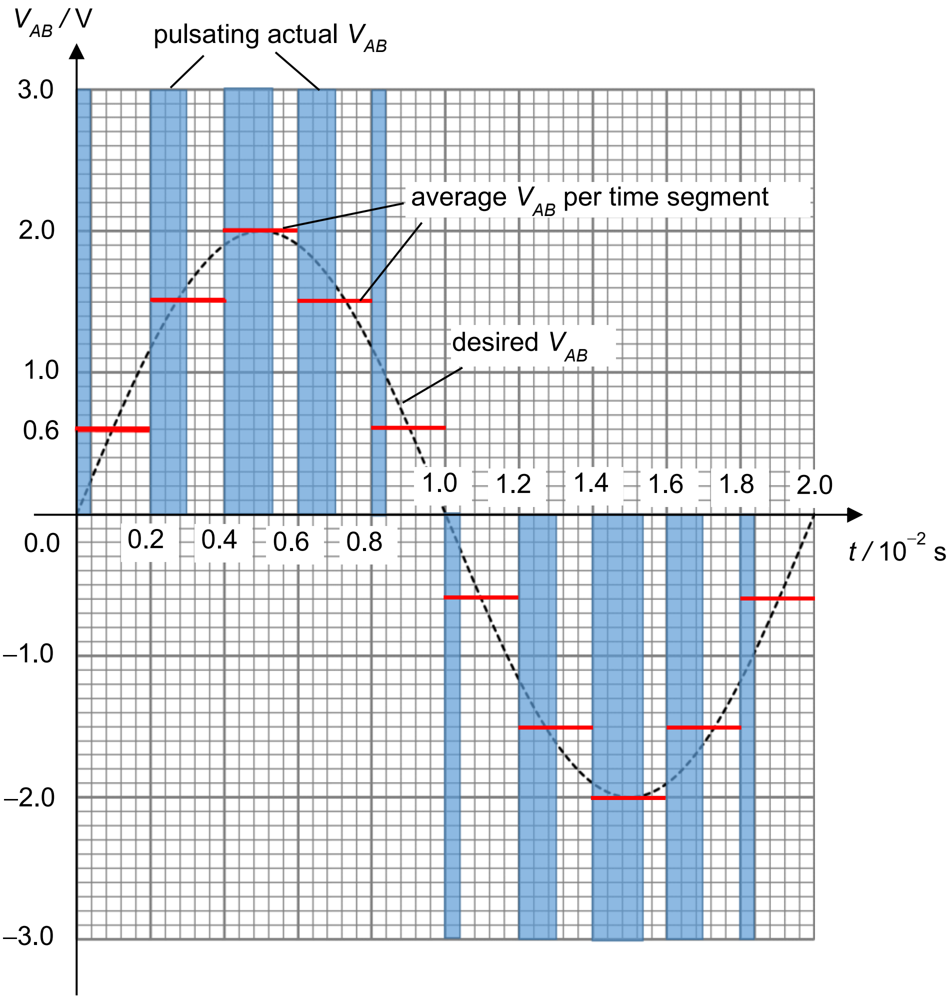


Fig. 8.4

To produce an output waveform that resembles a sinusoidal waveform, the opening and closing of the switches are specially programmed. While one pair of switches is open, the other pair of switches does not just stay closed for the duration of the half-cycle. Instead, they are made to rapidly open and close multiple times in a pulsating pattern. Each pulse varies in width, as shown in Fig. 8.4. This is known as *Pulse Width Modulation*.

The cycle is broken up into multiple smaller segments. By rapidly pulsating the switches the average voltage per segment can be controlled to increase or decrease from one time segment to the next.

The resultant output experienced by the motor can thus be made to approximate a sine wave. The more segments there are, the closer the output mimics a smooth wave.

1. Using information from Fig. 8.4, show that the average output voltage V_{AB} for the time segment $0.00 \leq t \leq 0.20 \times 10^{-2}$ s is 0.60 V.

[1]

2. Explain how the magnitude and the frequency of the average output voltage V_{AB} can be changed.

....

....

....

....

....[2]

(c) Inductive charging, or wireless charging, consists of a transfer of energy from the charging station to the vehicle without using a cable.

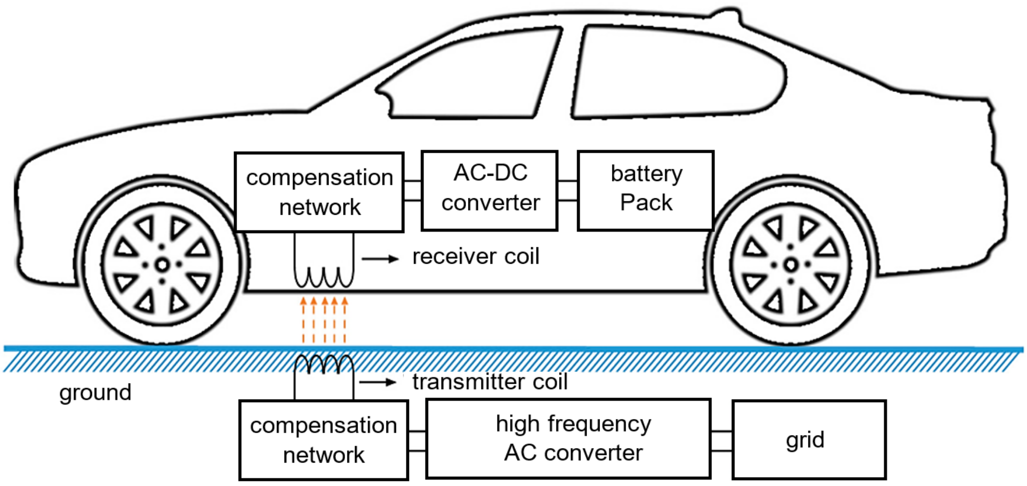


Fig. 8.5

Fig. 8.5 shows two conductive coils, one placed under the car body and the other installed at the ground level of the charging station.

(i) Use Faraday's law to explain how the battery in the EV is charged.

....

....

....

....

....[2]

(ii) Wireless charging is rarely used due to the high inefficiencies involved. Charging cables allow for a near 100% energy transfer from the source to the battery, but a wireless charger can have efficiencies as low as 60%.

Suggest two reasons why the energy transfer process might be inefficient.

1. ....

....

.... [1]

2. ....

....

.... [1]

[Total: 20]

End of Paper