Jackie and Jim are studying electromagnetic induction. They have a small permanent magnet and a coil of wire wound around a hollow cylinder as shown in Figure 4.

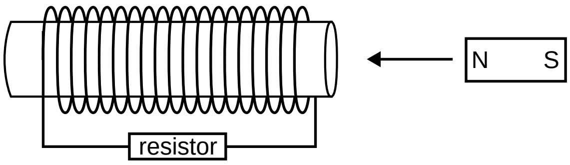


Figure 4

Jackie moves the magnet through the coil in the direction shown at constant speed.

Question 9

Indicate on the diagram the direction of the induced current that flows in the resistor. Explain the physics reason for your choice.

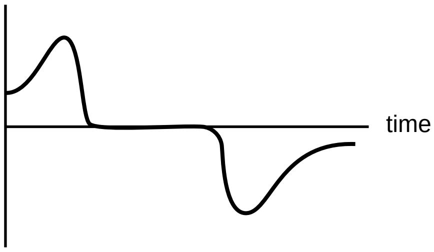
2 marks

They next decide to move the magnet, at a constant speed, all the way through the coil and out the other side.

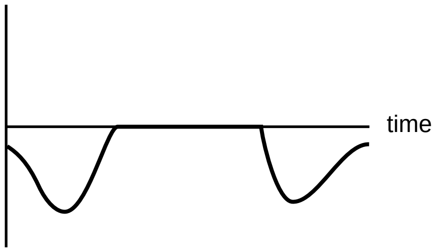
Question 10

Which **one** of the diagrams (**A–D**) below best shows how the current through the coil varies with time?

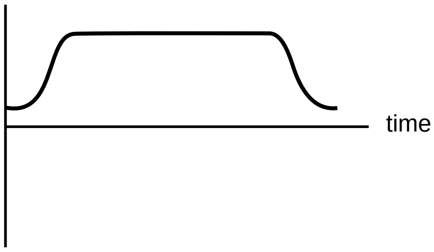
A.



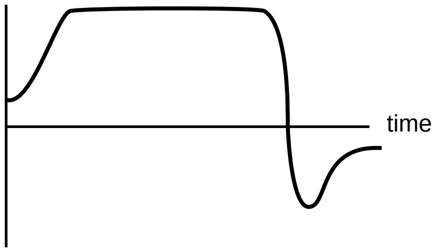
B.



C.



D.



2 marks

A transformer as shown in Figure 2 below is being tested. The primary coil is connected to a battery and switch. The switch is initially open and no current is flowing in the primary coil. An ammeter is connected to the secondary coil and initially shows no deflection. When the switch is **first** closed, the ammeter needle is deflected to the right and then returns to its initial position of no deflection.

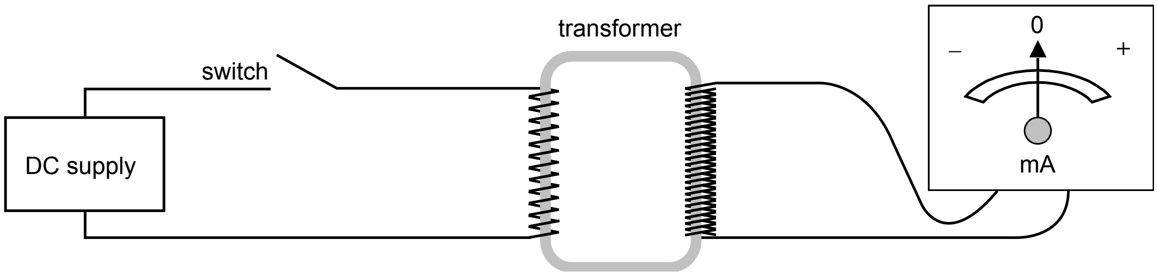


Figure 2

Question 5

Explain why the meter deflects when the switch is closed and then returns to the undeflected position.

2 marks

The switch, which has been closed for a short time, is now returned to the open position and remains open.

Question 6

Which one of the following best describes what happens to the reading of the ammeter?

A. it deflects to the left and stays at this position
B. it deflects to the right and stays at this position
C. it deflects to the left and returns to the middle position
D. it deflects to the right and returns to the middle position
E. it does not change

2 marks

Kris is investigating a generator. The magnets are attached to a shaft and are free to rotate around the fixed coil as shown in Figure 3. In this test, the shaft is connected to an electric motor and rotated at a constant speed. Figure 4 below shows the magnetic flux inside the coil. At a speed of 10 revolutions (rotations) per second (rps), the 40-turn coil produces an emf of 2.0 V_{RMS}, and the light globe glows dimly.

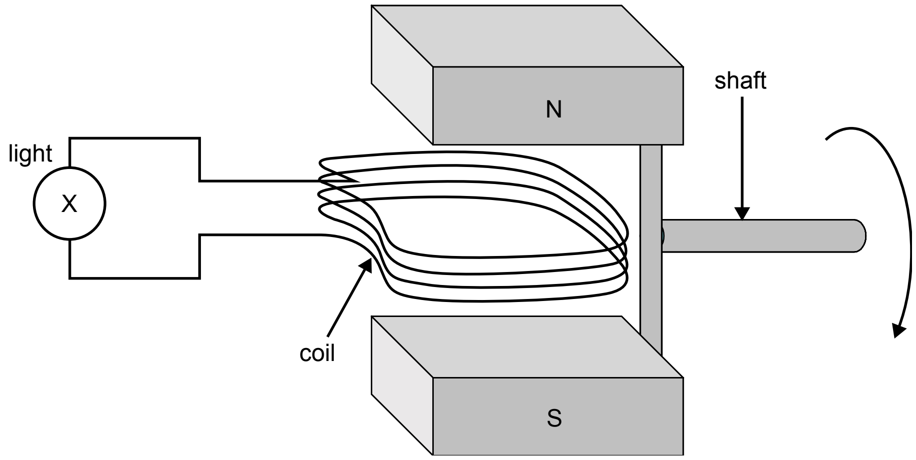


Figure 3

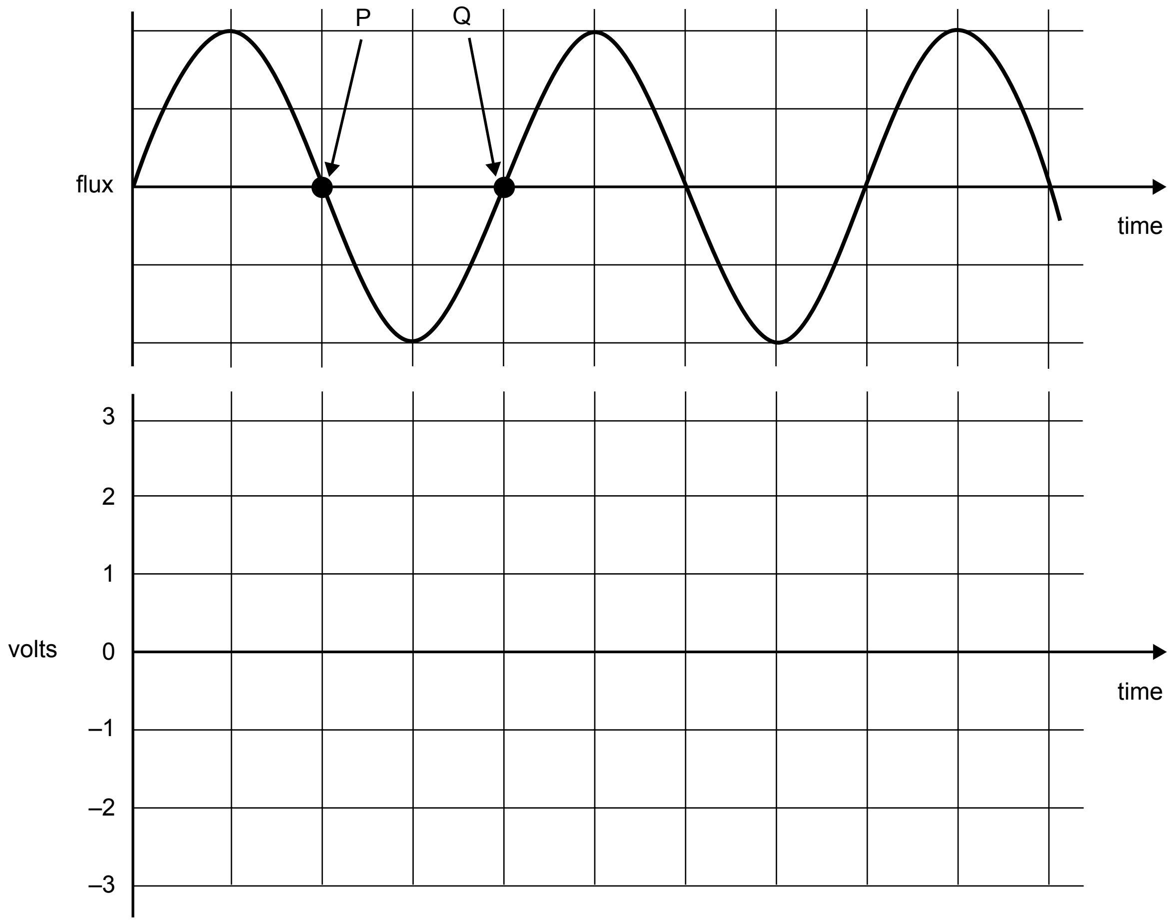


Figure 4

Question 7

What is the time difference between points P and Q in Figure 4?

s

2 marks

Question 8

Complete Figure 4 by sketching the voltage output of the coil. Label your sketch to indicate the maximum and minimum voltages.

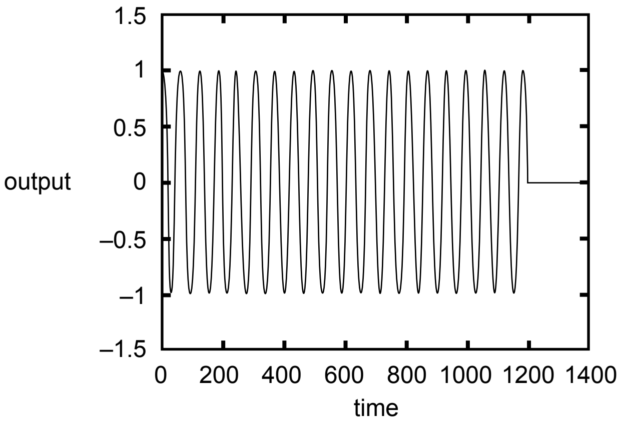
4 marks

Question 9

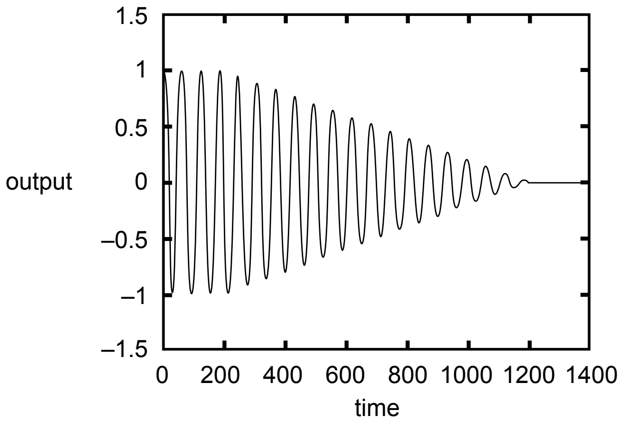
The electric motor is now turned off, and the shaft gradually slows to a halt.

Which one of the following diagrams best describes the voltage output of the generator as it comes to rest?

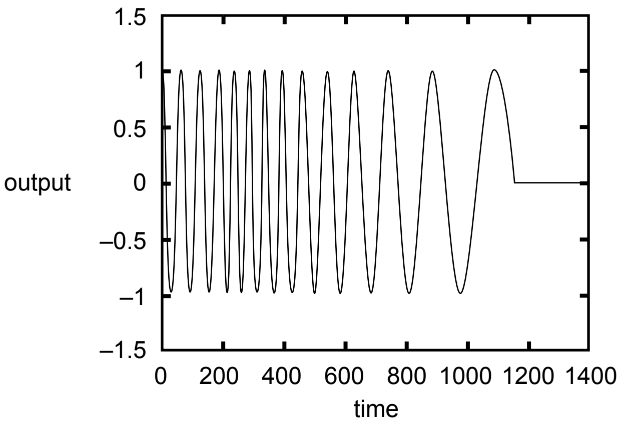
A.



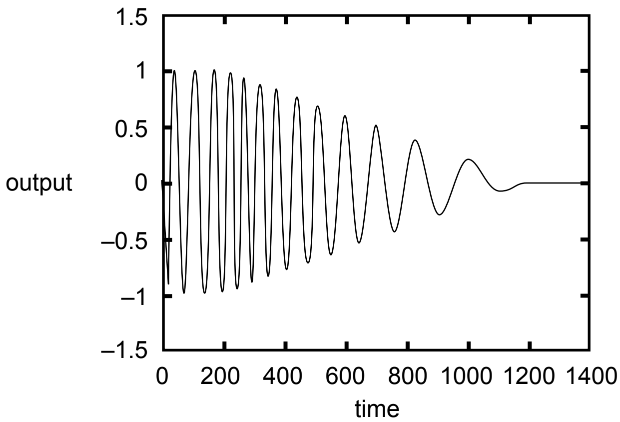
B.



C.



D.



2 marks

2005

Question 15

Joan and her grandfather were discussing how a transformer works and this led to a discussion about Faraday's and Lenz's laws. Joan's grandfather stated that the two laws were essentially the same, but Joan disagreed.

Compare and contrast Faraday's law and Lenz's law.

A village has a maximum electrical power requirement of 100 kW. The power is supplied by an alternator, approximately 20.0 km from the village, which generates electricity at 250 V_{RMS} at a frequency of 50 Hz. This is converted by a step-up transformer (T_1) to 22 000 V_{RMS}, transmitted to the edge of the village by power lines with a total resistance of 2.0 Ω, and converted back to 250 V_{RMS} by a step-down transformer (T_2) near the village. A diagram of the system is shown in Figure 5 below.

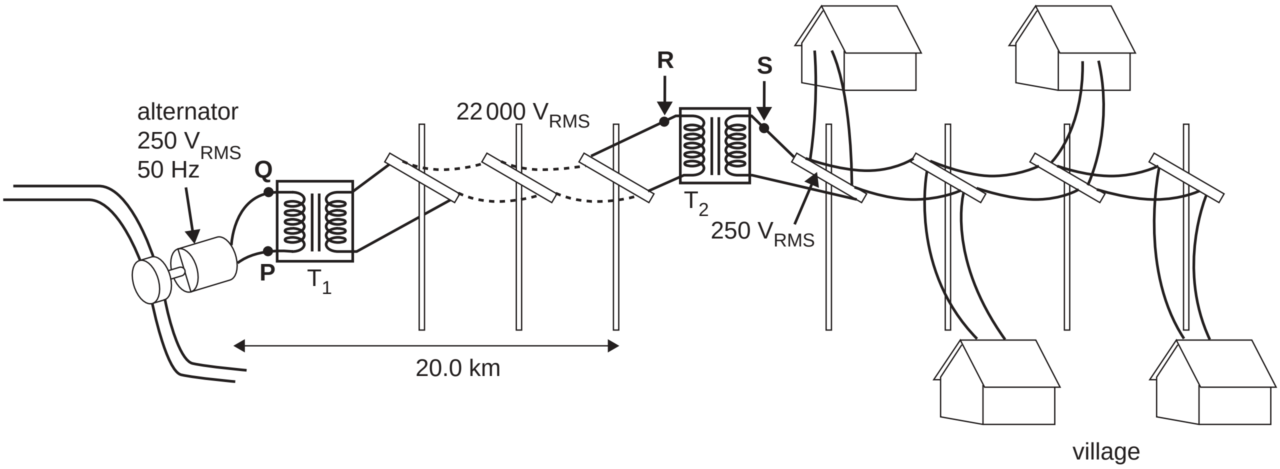


Figure 5

Question 9

What would be the current in the wires at the point marked S when 100 kW of power is being used?

A

2 marks

Question 10

Show that the current at point R is approximately 4.55 A when 100 kW of power is being used.

2 marks

Question 11

Estimate the power loss in the high voltage transmission lines supplying transformer T_2 when 100 kW of power is being used in the village. Show your working. Include the unit.

3 marks

Question 12

Briefly explain how high-voltage transmission leads to lower power losses in the system.

2 marks

A number of different transformers, A–D, are available for use as transformer T_1 in the system. Their characteristics are shown below.

Transformer	Number of turns in primary (input)	Number of turns in secondary (output)
A	62 200	500
B	44 000	500
C	500	44 000
D	500	62 200

Question 13

Which one of the transformers, A–D, would be suitable for use as transformer T_1?

2 marks

Question 14

Explain the operation of a transformer in terms of electromagnetic induction.

3 marks

The alternator fails and the village is without power. One possibility is to replace the alternator with a DC generator but an electrician says this should not be used.

Question 15

Explain why an alternator rather than a DC generator should be used in this system.

2 marks

Normally, the power being used in the village is 40 kW. However, as people come home, the power use increases to 80 kW. The alternator continues to provide 250 V_{RMS} at point P.

Question 16

Which one of the following (A–D below) is the most likely effect on the voltage at point S in Figure 5?

A. The voltage would increase slightly.

B. The voltage would decrease slightly.

C. The voltage would remain the same.

D. The voltage would halve.

2 marks

Use the following information to answer Questions 14 and 15.

To study Lenz's law, students set up the following experiment using the circuit shown in Figure 9.

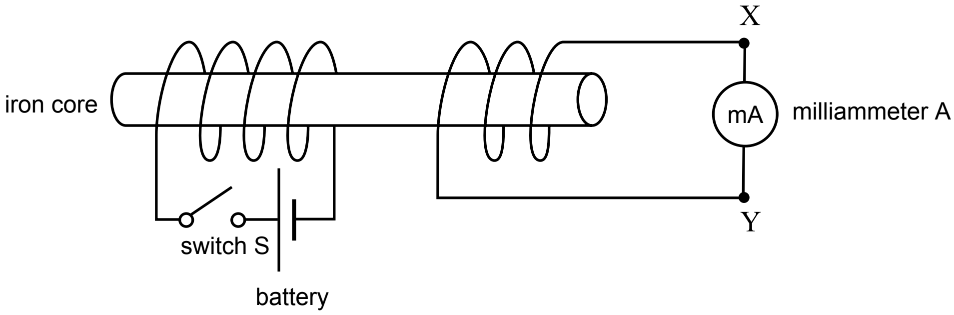


Figure 9

Question 14

Initially switch S is open.

Which one of the following **(A–D)** will best describe the current through the milliammeter A, when the switch S is closed?

A. current flows momentarily in the direction X to Y

B. current flows momentarily in the direction Y to X

C. current flows continuously in the direction X to Y

D. current flows continuously in the direction Y to X

2 marks

Question 15

Explain how Lenz's law enables you to determine the direction of the current flow in this experiment.

3 marks

Question 9

The square loop moves from position 1 (just inside the magnetic field) to position 2 (just outside the magnetic field) as shown in Figure 4d (seen from above). What is the average emf (voltage) induced?

Show working.

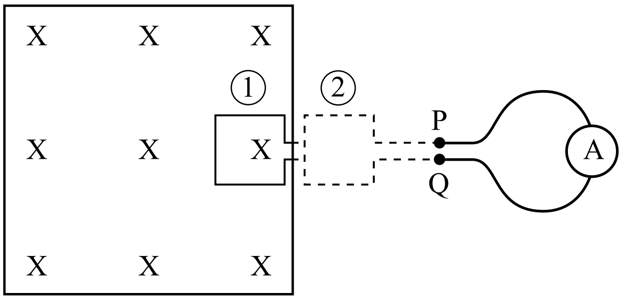


Figure 4d

V

3 marks

Question 10

Will the current due to the induced voltage flow from P to Q **or** Q to P **through the square loop** as it moves from position 1 to position 2?

Explain your answer in terms of Lenz's law.

4 marks

Use the following information to answer Questions 10–12.

A small bar magnet is moved through a circular wire loop, as shown in Figure 5. The magnet moves with **constant** speed through the centre of the loop, in the direction shown by the arrow. An emf is generated in the wire loop. The wire loop is connected to an oscilloscope, as shown in Figure 5.

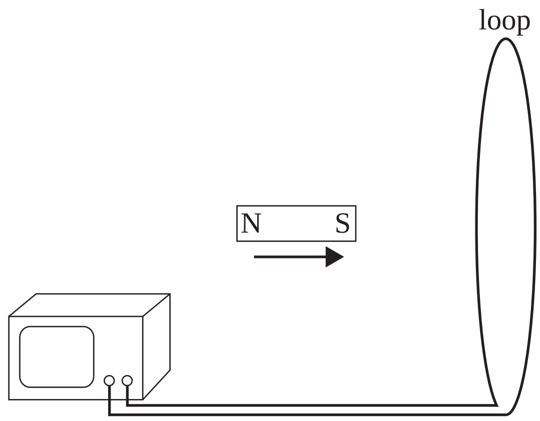


Figure 5

Question 10

Explain why an emf is generated in the wire loop.

2 marks

Question 11

On the graph axes below, sketch the variation of the emf with time, from when the magnet is a long way to the left of the loop, through the loop, to when it is a long way to the right of the loop. Note that you can take either upwards or downwards as positive.

2 marks

Question 12

After the magnet has passed through the wire loop, and is moving away from the loop, current flows around the loop in an **anticlockwise** direction, as viewed from the left in Figure 5.

Use Lenz's law to explain why the current flows in an **anticlockwise** direction.

3 marks

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided. Write using blue or black pen.
Where an answer box is provided, write your final answer in the box.
If an answer box has a unit printed in it, give your answer in that unit.
In questions where more than one mark is available, appropriate working **must** be shown.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1 (3 marks)

A particle of mass m and charge q travelling at velocity v enters a uniform magnetic field B, as shown in Figure 1.

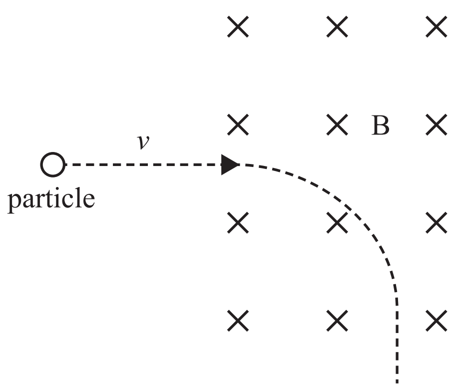


Figure 1

a. Is the charge q positive or negative? Give a reason for your answer. 1 mark

b. Explain why the path of the particle is an arc of a circle while the particle is in the magnetic field. 2 marks

Question 7 (11 marks)

Students in a Physics practical class investigate the piece of electrical equipment shown in Figure 5. It consists of a single rectangular loop of wire that can be rotated within a uniform magnetic field. The loop has dimensions 0.50 m × 0.25 m and is connected to the output terminals with slip rings. The loop is in a uniform magnetic field of strength 0.40 T.

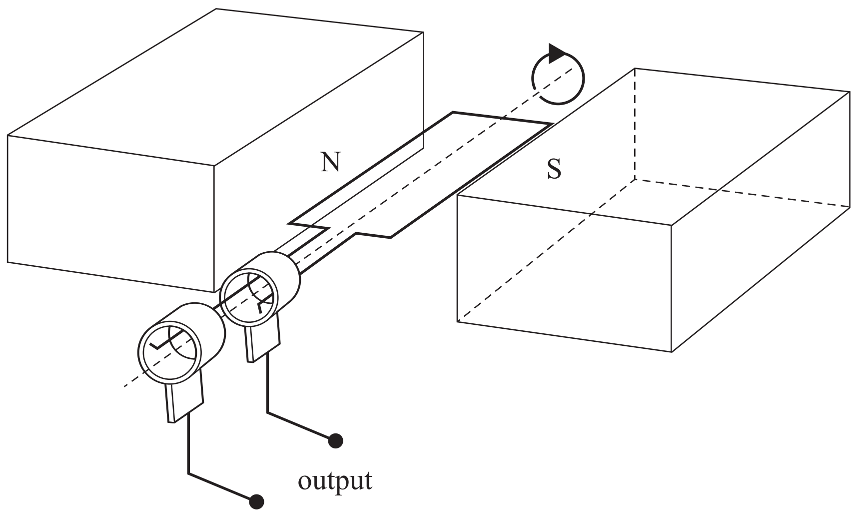


Figure 5

a. Circle the name that best describes the piece of electrical equipment shown in Figure 5. 1 mark

alternator DC generator DC motor AC motor

b. i. What is the magnitude of the flux through the loop when it is in the position shown in Figure 5? 1 mark

Wb

ii. Explain your answer to **part b.i.** 1 mark

Question 3 (6 marks)

Electron microscopes use a high-precision electron velocity selector consisting of an electric field, E, perpendicular to a magnetic field, B.

Electrons travelling at the required velocity, v_0, exit the aperture at point Y, while electrons travelling slower or faster than the required velocity, v_0, hit the aperture plate, as shown in Figure 2.

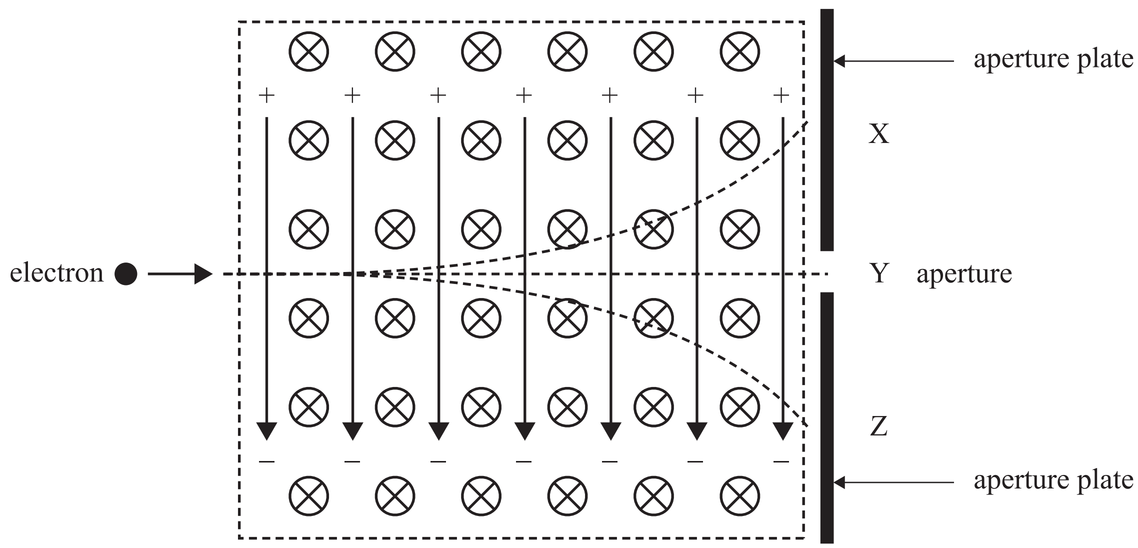


Figure 2

a. Show that the velocity of an electron that travels straight through the aperture to point Y is given by $v_0 = \frac{E}{B}$. 1 mark

c. **i.** At which of the points – X, Y or Z – in Figure 2 could electrons travelling faster than v_0 arrive? 1 mark

ii. Explain your answer to **part c.i.** 2 marks

Question 6 (6 marks)

Two Physics students hold a coil of wire in a constant uniform magnetic field, as shown in Figure 5a. The ends of the wire are connected to a sensitive ammeter. The students then change the shape of the coil by pulling each side of the coil in the horizontal direction, as shown in Figure 5b. They notice a current register on the ammeter.

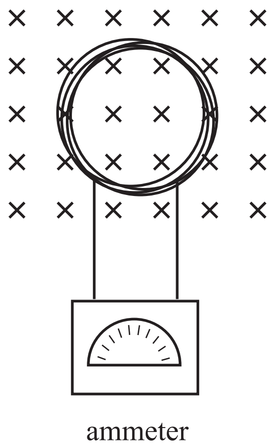


Figure 5a

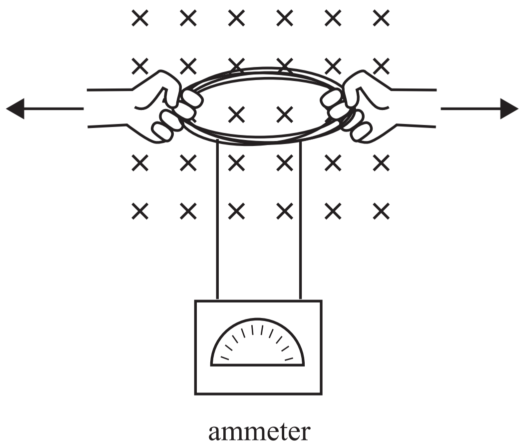


Figure 5b

a. Will the magnetic flux through the coil increase, decrease or stay the same as the students change the shape of the coil? 1 mark

b. Explain, using physics principles, why the ammeter registered a current in the coil and determine the direction of the induced current. 3 marks

c. The students then push each side of the coil together, as shown in Figure 6a, so that the coil returns to its original circular shape, as shown in Figure 6b, and then changes to the shape shown in Figure 6c.

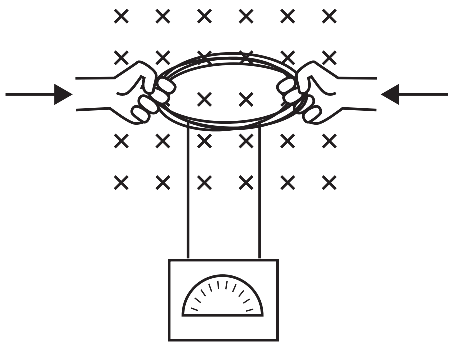


Figure 6a

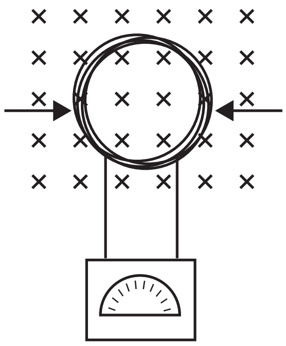


Figure 6b

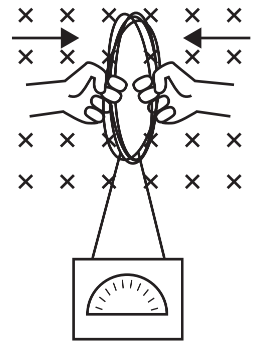
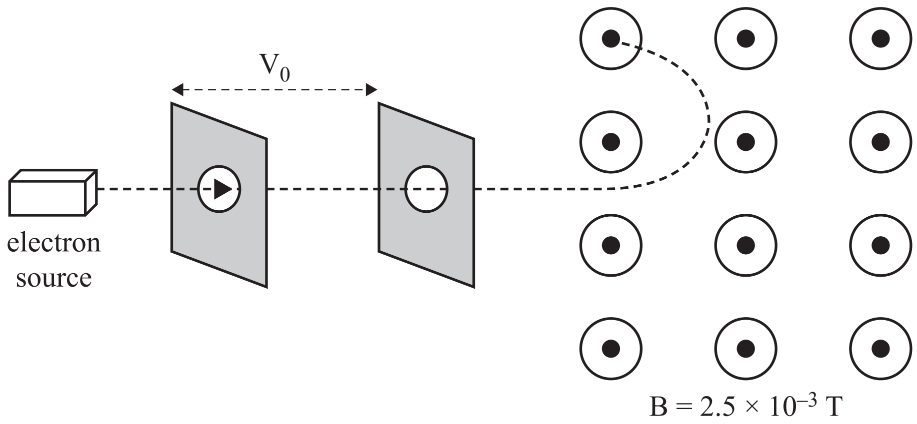


Figure 6c

Describe the direction of any induced currents in the coil during these changes. Give your reasoning. 2 marks

Question 2 (8 marks)

An electron is accelerated from rest by a potential difference of V_0. It emerges at a speed of 2.0×10^7 m s^{-1} into a magnetic field, B, of strength 2.5×10^{-3} T and follows a circular arc, as shown in Figure 2.



b. Explain why the path of the electron in the magnetic field follows a circular arc. 2 marks

Question 5 (9 marks)

Figure 5 shows a stationary electron (e^-) in a uniform magnetic field between two parallel plates. The plates are separated by a distance of 6.0×10^{-3} m, and they are connected to a 200 V power supply and a switch. Initially, the plates are uncharged. Assume that gravitational effects on the electron are negligible.

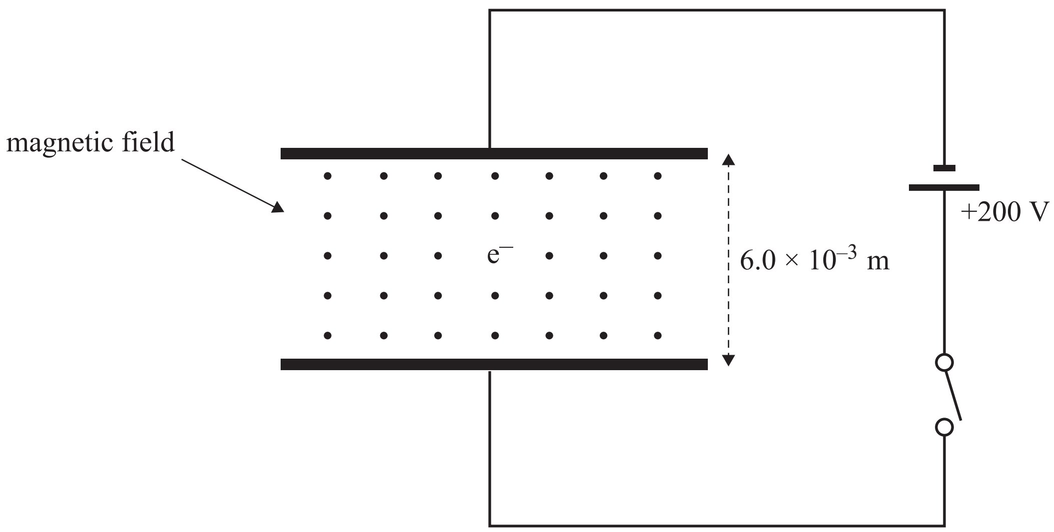


Figure 5

a. Explain why the magnetic field does not exert a force on the electron. Justify your answer with an appropriate formula. 2 marks

The switch is now closed.

b. Determine the magnitude and the direction of any electric force now acting on the electron. Show your working. 3 marks

N	Direction

c. Ravi and Mia discuss what they think will happen regarding the size and the direction of the magnetic force on the electron after the switch is closed.

Ravi says that there will be a magnetic force of constant magnitude, but it will be continually changing direction.

Mia says that there will be a constantly increasing magnetic force, but it will always be acting in the same direction.

Evaluate these two statements, giving clear reasons for your answer. 4 marks

Question 5 (2 marks)
A bar magnet is moved towards a single closed loop of conducting wire with the bar magnet's south pole closest to the loop, as shown in Figure 3. The loop is stationary.

Figure 3

The area and the shape of the loop remain constant and the magnet is not changed.

Explain, in terms of magnetic flux, how a current is induced in the loop.

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.
Where an answer box is provided, write your final answer in the box.
If an answer box has a unit printed in it, give your answer in that unit.
In questions where more than one mark is available, appropriate working **must** be shown.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1 (5 marks)

Figure 1 shows four positions (1, 2, 3 and 4) of the coil of a single-turn, simple DC motor. The coil is turning in a uniform magnetic field that is parallel to the plane of the coil when the coil is in Position 1, as shown.

When the motor is operating, the coil rotates about the axis through the middle of sides *LM* and *NK* in the direction indicated. The coil is attached to a commutator. Current for the motor is passed to the commutator by brushes that are not shown in Figure 1.

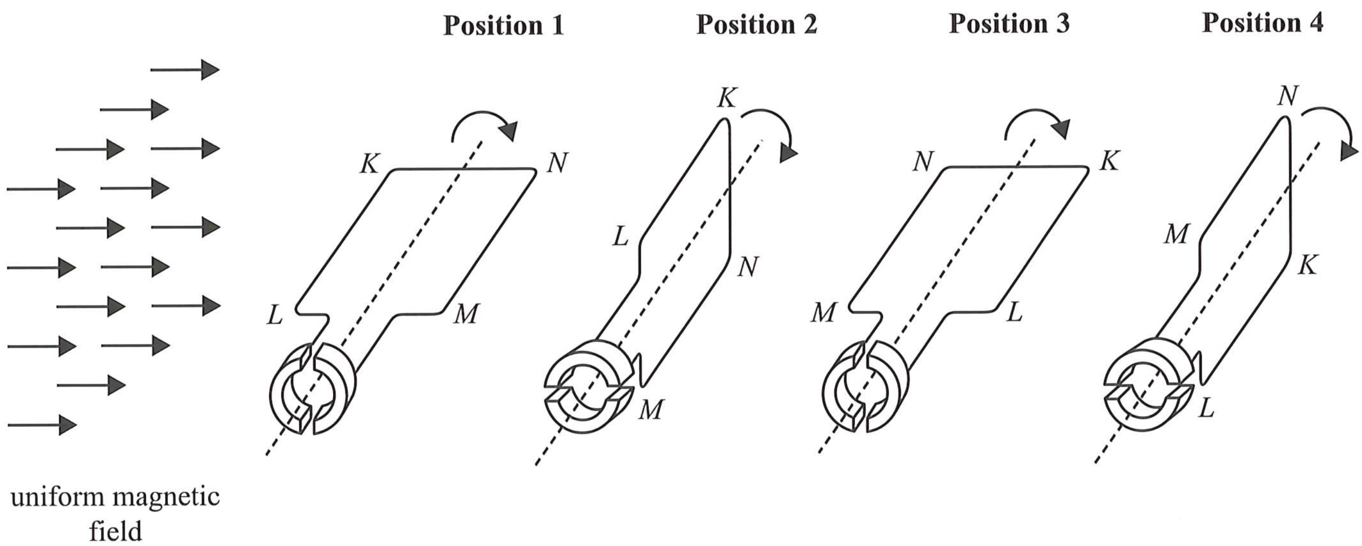


Figure 1

a. When the coil is in Position 1, in which direction is the current flowing in the side *KL* – from *K* to *L* or from *L* to *K*? Justify your answer. 2 marks

___

___

Question 4 (6 marks)

A square loop of wire connected to a resistor, R, is placed close to a long wire carrying a constant current, I, in the direction shown in Figure 4.

The square loop is moved three times in the following order:

- Movement A – Starting at Position 1 in Figure 4, the square loop rotates one full rotation at a steady speed about the x-axis. The rotation causes the resistor, R, to first move out of the page.
- Movement B – The square loop is then moved at a constant speed, parallel to the current carrying wire, from Position 1 to Position 2 in Figure 4.
- Movement C – The square loop is moved at a constant speed, perpendicular to the current carrying wire, from Position 2 to Position 3 in Figure 4.

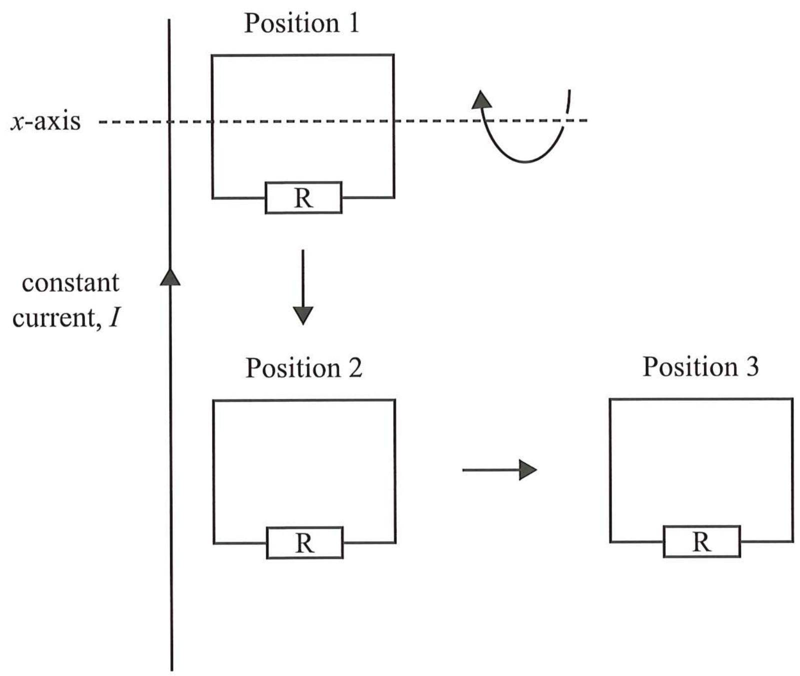
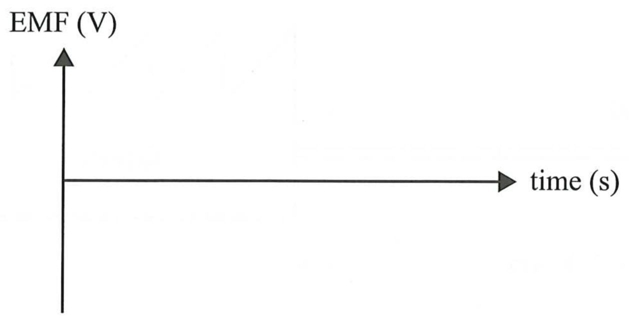
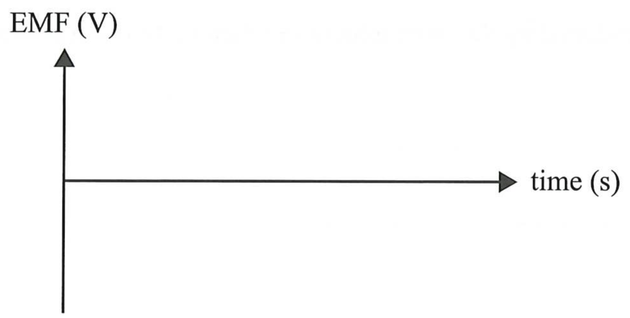
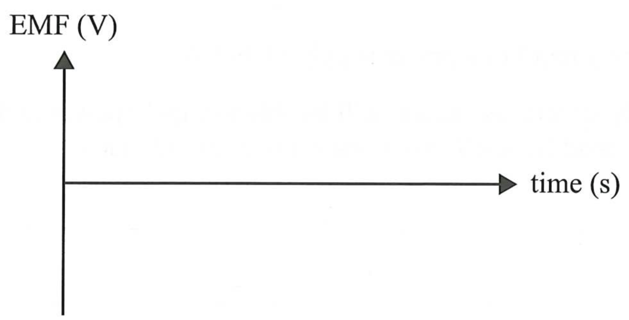


Figure 4

SECTION B – Question 4 – continued

Complete the table below to show the effects of each of the three movements by:

- sketching any EMF generated in the square loop during the motion on the axes provided (scales and values are not required)
- stating whether any induced current in the square loop is ‘alternating’, ‘clockwise’, ‘anticlockwise’ or has ‘no current’.

Movement	Possible induced EMF	Direction of any induced current (alternating/clockwise/ anticlockwise/no current)
A rotation about x-axis		
B moving from Position 1 to Position 2		
C moving from Position 2 to Position 3		

Question 2 (3 marks)

A positively charged particle carrying a charge of $+1.5 \times 10^{-8}$ C enters a region between two large, charged plates with opposite charges, as shown in Figure 2.

The potential difference between the plates is 2.0 kV, and the kinetic energy of the charged particle as it enters the hole is 2.8×10^{-5} J. Ignore gravitational effects and air resistance.

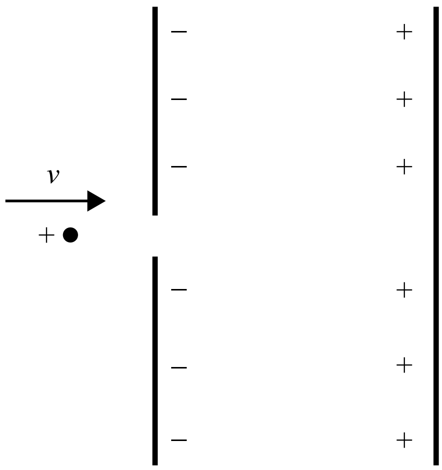


Figure 2

Ariel and Jamie discuss what they think will happen to the particle after it enters the region between the two equally but oppositely charged plates.

Ariel says that the particle has insufficient kinetic energy to reach the positively charged plate and will travel part of the way before returning towards the negatively charged plate.

Jamie says that the particle will collide with the positively charged plate and then head back towards the negatively charged plate.

Evaluate Ariel and Jamie's statements, giving clear reasons for your answer.

Question 3 (3 marks)

Two thin, light aluminium tubes, A and B, are supported in a vertical wooden rack, as shown in Figure 3. Both of the aluminium tubes rest horizontally on wooden pegs.

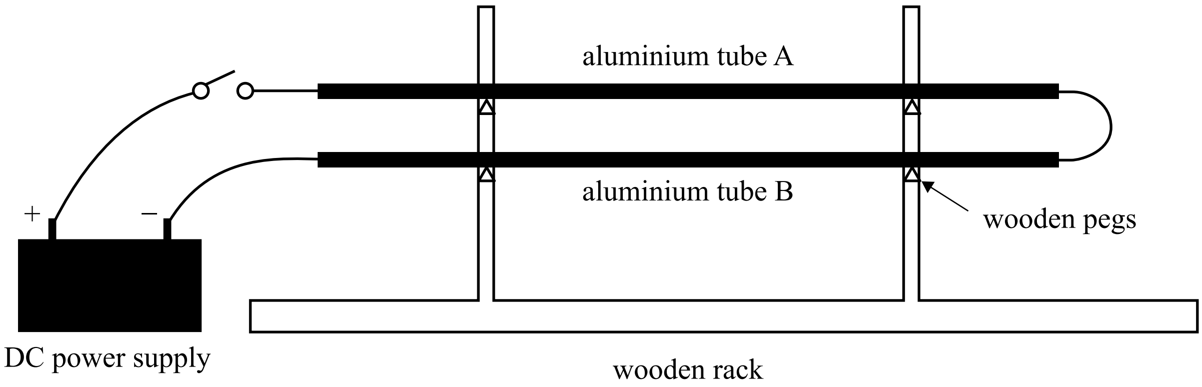


Figure 3

The two thin, light aluminium tubes form a series circuit with a DC power supply. It was observed that one of the tubes jumped upwards when the DC power supply was switched on.

Identify which tube jumped upwards and explain why this occurred.

Aluminium tube

Question 4 (4 marks)

Two electrons, e_1 and e_2, are emitted, one after the other, from point P in a uniform magnetic field, as shown in Figure 4.

Both electrons travel perpendicular to the magnetic field, but in opposite directions. Throughout their journey, both electrons remain within the magnetic field.

Electron e_1 travels at twice the speed of e_2. Relativistic effects can be ignored as both electrons are travelling at low speeds. Electrostatic effects at point P can be ignored as the two electrons are emitted at different times.

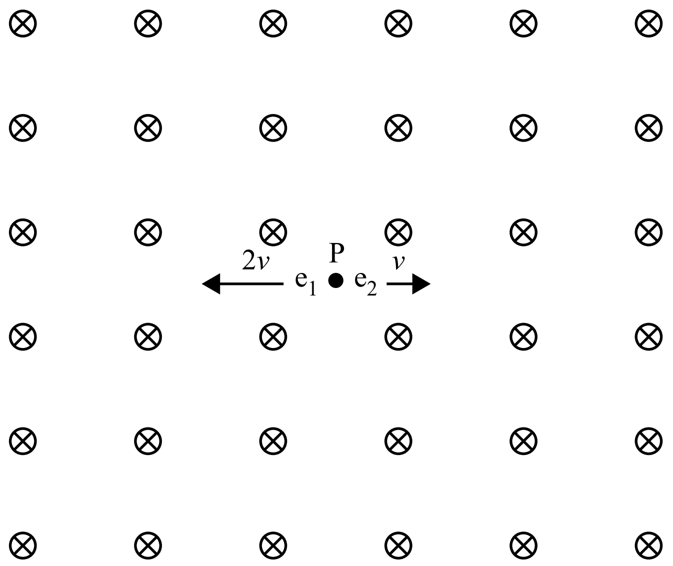


Figure 4

Which one of the following three outcomes occurs?

- Outcome 1 – Electron e_1 returns to point P in the shortest time.
- Outcome 2 – Electron e_2 returns to point P in the shortest time.
- Outcome 3 – Both electrons take the same time to return to point P.

Outcome

Explain your answer.

Question 8 (7 marks)

Sarah and Raminda construct a simple alternator, as shown in Figure 8.

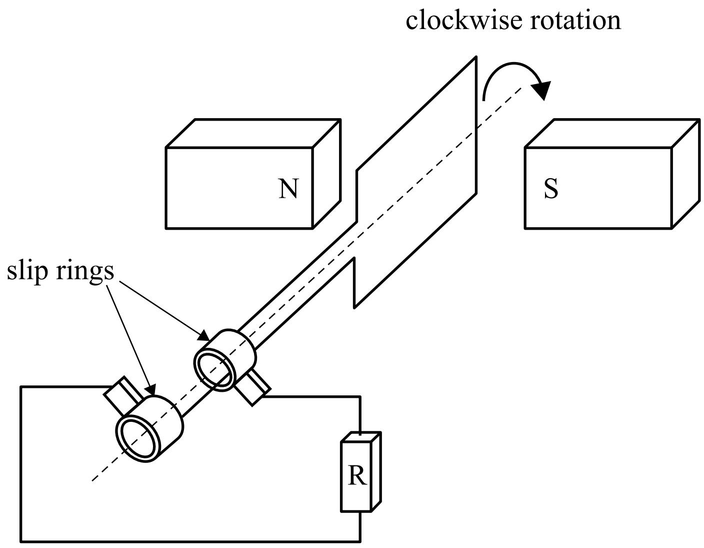


Figure 8

c. To increase the magnitude of the EMF produced by the alternator, Raminda suggests making a number of changes to the alternator.

Sarah insists that each change be investigated one at a time.

In the spaces provided, indicate whether each suggestion will increase, decrease or have no effect on the EMF produced by the alternator. 4 marks

Suggested change	**Effect on EMF (increases, decreases or has no effect)**
reduce the resistance of resistor R	
increase the strength of the permanent magnets	
reduce the period of rotation of the coil to 25 ms	
increase the number of turns of the rotating coil	

Question 10 (6 marks)

A single rectangular loop of wire containing a cut out section labelled EF moves to the right at a constant speed of 2.4 m s^{-1}, as shown in Figure 10a. At time t = 0, the right-hand edge of the loop enters a constant magnetic field into the page.

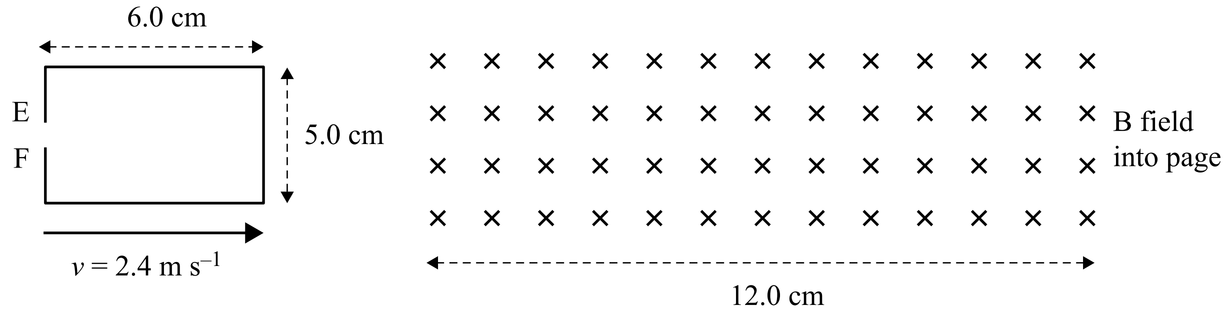


Figure 10a

The induced EMF produced as a function of time is shown in the graph in Figure 10b.

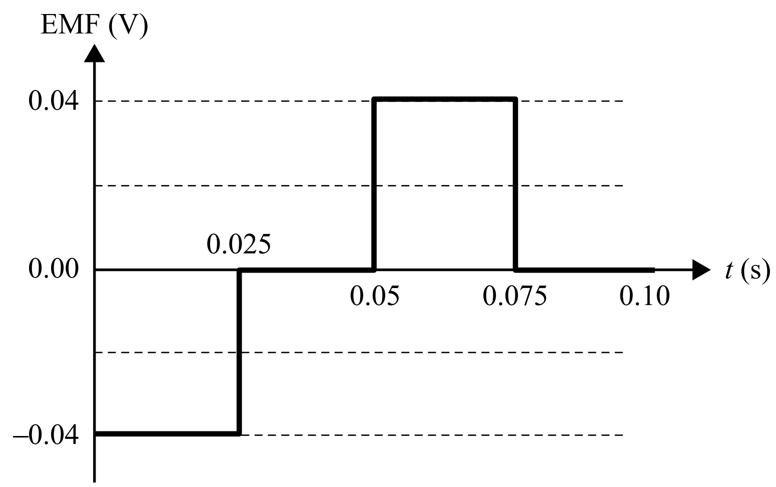


Figure 10b

While the loop enters, and is partially within, the field, an EMF is generated between points E and F.

a. Which point, E or F, is positive? 1 mark

b. Explain why the induced EMF is constant during the time period 0.00 s to 0.025 s. 2 marks

SECTION A – Multiple-choice questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

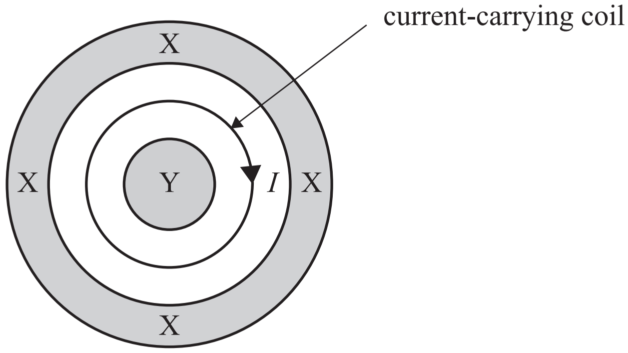
No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Take the value of g to be 9.8 m s^{-2}.

Question 1

One type of loudspeaker consists of a current-carrying coil within a radial magnetic field, as shown in the diagram below. X and Y are magnetic poles, and the direction of the current, I, in the coil is clockwise as shown.



The force, F, acting on the current-carrying coil is directed into the page.

Which one of the following statements correctly identifies the magnetic polarities of X and Y?

A. X is a north pole and Y is a south pole.

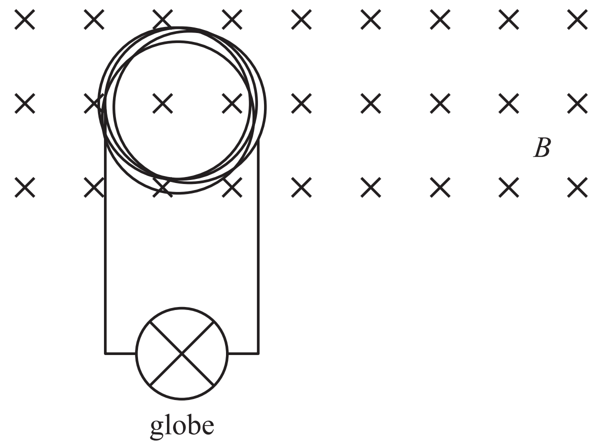
B. X is a south pole and Y is a north pole.

C. Both X and Y are north poles.

D. Both X and Y are south poles.

Use the following information to answer Questions 5 and 6.

The diagram below shows a stationary circular coil of conducting wire connected to a low-resistance globe in a uniform, constant magnetic field, *B*.



Question 5

The magnetic field is switched off.

Which one of the following best describes the globe in the circuit **before** the magnetic field is switched off, **during** the time the magnetic field is being switched off and **after** the magnetic field is switched off?

	Before	**During**	**After**
A.	Off	On	Off
B.	On	On	Off
C.	On	Off	Off
D.	Off	On	On

Question 3 (5 marks)

Two long, straight current-carrying wires, P and Q, are parallel, as shown in Figure 2a. The current in the wires is the same in magnitude and opposite in direction.

Figure 2b shows the wires as viewed from above.

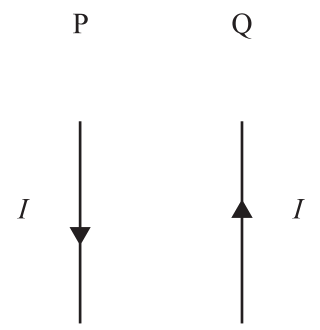


Figure 2a – Front view

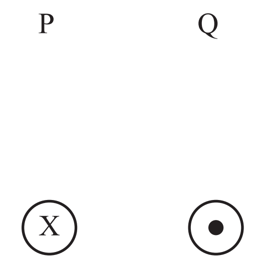


Figure 2b – Top view

a. On Figure 2b, sketch the magnetic field around the wires, showing the direction of the magnetic field. Use at least five field lines. 3 marks

b. Do the two wires, P and Q, attract or repel each other? Explain your reasoning. 2 marks

Question 5 (3 marks)

Figure 4a shows a single square loop of conducting wire placed just outside a constant uniform magnetic field, *B*. The length of each side of the loop is 0.040 m. The magnetic field has a magnitude of 0.30 T and is directed out of the page.

Over a time period of 0.50 s, the loop is moved at a constant speed, *v*, from completely outside the magnetic field, Figure 4a, to completely inside the magnetic field, Figure 4b.

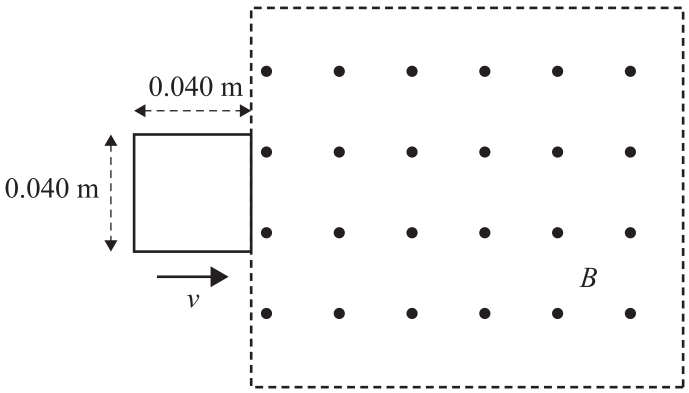


Figure 4a

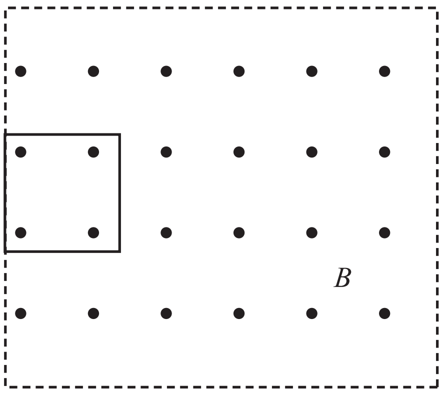


Figure 4b

b. On the small square loop in Figure 5, show the direction of the induced current as the loop moves into the area of the magnetic field. 1 mark

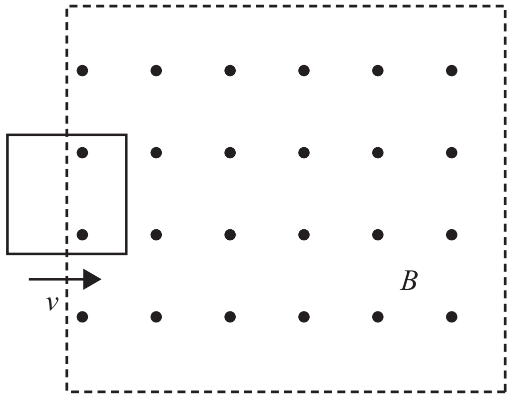


Figure 5

Question 6 (3 marks)

Kim and Charlie are attempting to create a DC generator and have arranged the magnets along the axis of rotation of the wire loop, J, K, L and M, as shown in Figure 6. They are having some trouble getting it to work. They rotate the loop in the direction of the arrow, as shown in Figure 6.

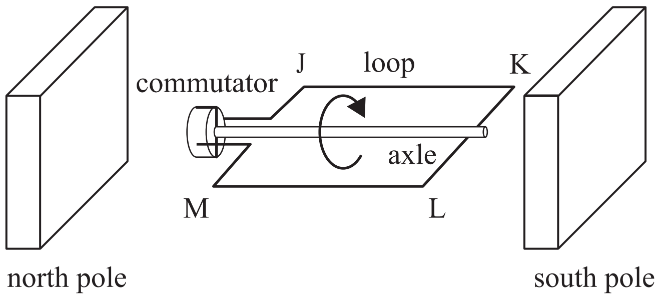


Figure 6

a. Using physics concepts, explain why this orientation of the magnets will not generate an EMF. 2 marks

b. Kim and Charlie decide to move the magnets so that an EMF is generated. On Figure 6, draw the positions of the magnets to ensure that an EMF is generated. 1 mark