2005-2

SECTION A – Core

Instructions for Section A

Answer **all** questions **for both** Areas of study in this section of the paper.

Area of study 1 – Electric power

A vertical wire carrying a current I is placed opposite the centre of a permanent bar magnet as shown in Figure 1.

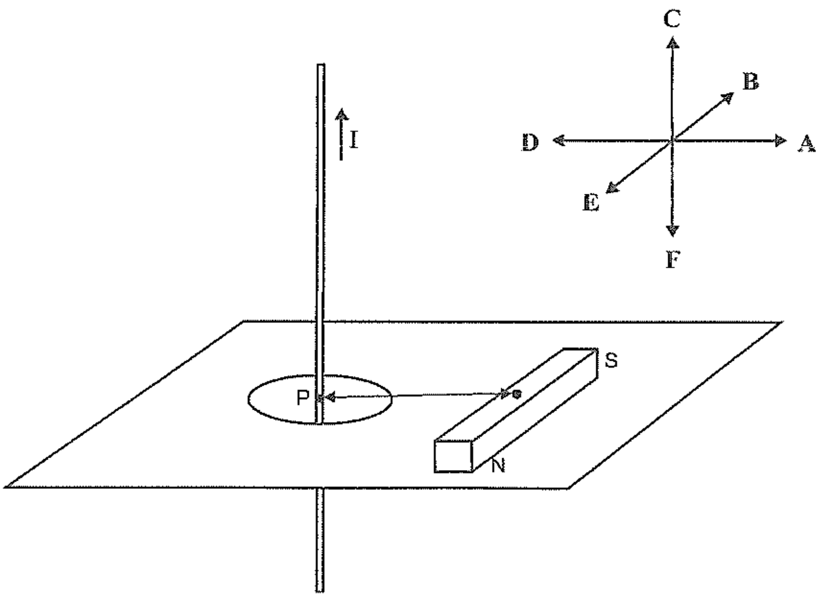

Figure 1

Question 1

Which of the arrows **(A–F)** best shows the direction of the magnetic force on the wire at the point P?

2 marks

Some students are studying the emf induced by a magnetic field in a coil of wire. Their experimental apparatus consists of a coil of 100 turns of wire in a magnetic field of 2.0×10^{-2} T as shown in Figure 2 below.

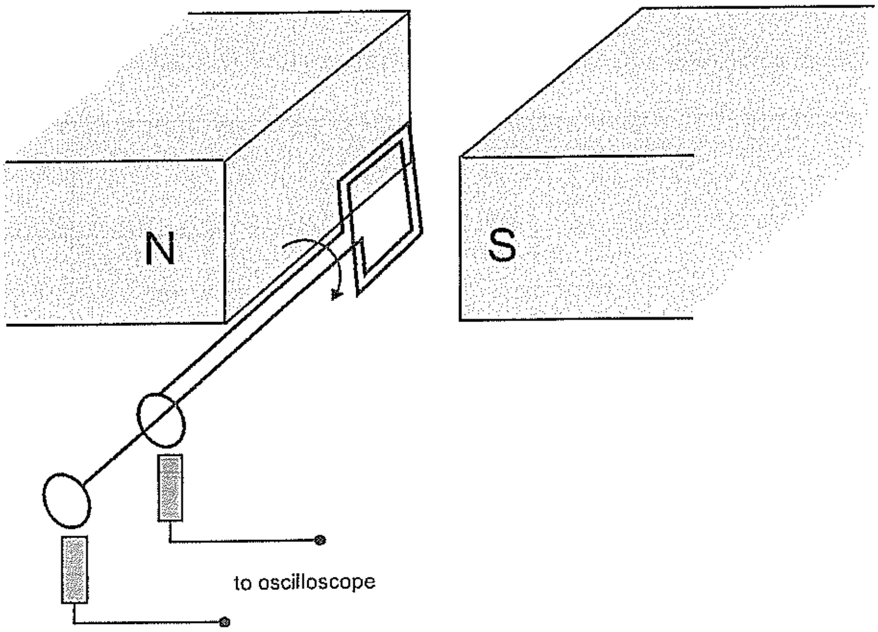

Figure 2

Question 2

With the coil vertical as shown in Figure 2, the flux through the coil is 8×10^{-6} Wb. What is the area of the coil?

m^2

2 marks

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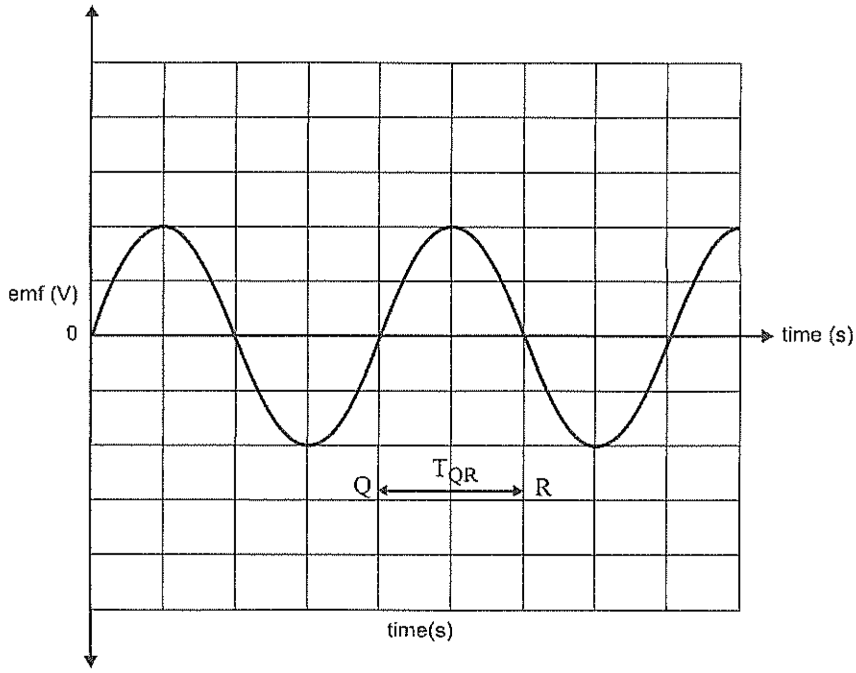

Figure 3

The coil (in Figure 2) is rotated at a rate of 10 revolutions per second, and the output is observed on an oscilloscope (CRO), as shown in Figure 3 above.

Question 3

What is the time interval, T_{QR}, between Q and R?

s

2 marks

Question 4

Calculate the **average** emf observed over the time interval T_{QR}.

V

3 marks

The rotation speed of the coil is increased to 20 revolutions per second.

Question 5

On Figure 3, sketch the output from the oscilloscope that would be observed now.

3 marks

An electrician is planning a new power supply to a farm house. The house is 1.0 km from the existing supply. At this supply point there is a choice of either a high voltage 11 000 V_{RMS} AC or a lower voltage 240 V_{RMS} AC supply. All of the appliances in the house require 240 V_{RMS} AC and the expected maximum power demand (load) is 12 000 W. The owner is keen to avoid the cost of a transformer, and so initially plans to use a 1.0 km supply line to the house from the 240 V_{RMS} supply.

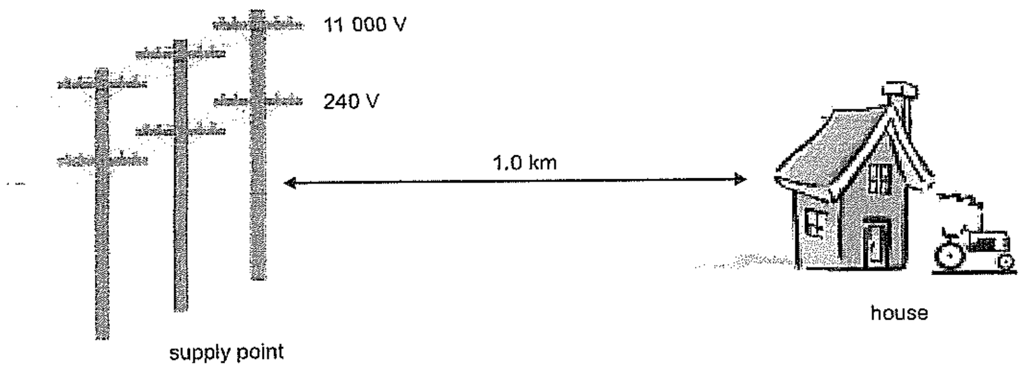

Figure 4

Question 9

A heater in the house is rated at 1200 W.

Calculate the current flowing through the heater when it is connected to a 240 V_{RMS} supply.

A

2 marks

The electrician connects the house to the 240 V_{RMS} supply using lines with a **total** resistance of 2.0 Ω. Some of the appliances in the house are turned on to test the new supply. Measurements reveal that, under these test conditions, the current flowing is 30 A.

Question 10

Calculate the power loss in the supply lines from the road to the house when the current flowing is 30 A.

W

2 marks

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Question 11

What would be the voltage measured at the house when the current is 30 A?

V

4 marks

The electrician suggests that using the 11 000 V_{RMS} supply with a step-down transformer at the house could deliver the same amount of power to the house, with a significant reduction in the power loss in the supply lines.

Question 12

Explain why using an 11 000 V_{RMS} rather than the 240 V_{RMS} supply would reduce the power loss in the lines.

3 marks

Question 13

What is $V_{peak\text{-}peak}$ at the 11 000 V_{RMS} supply point?

V

2 marks

Joan found an old transformer in her grandfather's shed and performed some simple tests to see if it was still working using the circuit shown in Figure 5. These tests included voltage and current measurements, and the data obtained is summarised below in Table 1. Joan's conclusion was that the transformer still worked, but for safety reasons she chose not to measure the current in the primary coil and assumed the voltage to be 240 V_{RMS}.

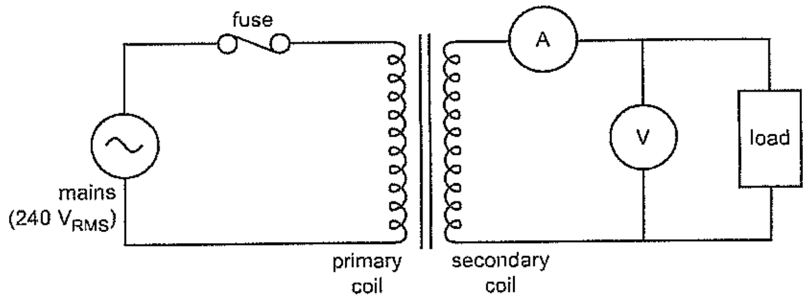

Figure 5

Table 1

Primary coil		**Secondary coil**	
$I_{p\ RMS}$	$V_{p\ RMS}$	$I_{s\ RMS}$	$V_{s\ RMS}$
	240 V_{RMS}	2.2 A_{RMS}	11.3 V_{RMS}

Question 14

Assuming the transformer is ideal, calculate the RMS current in the primary coil.

A

2 marks

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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.

3 marks

As a final test of the transformer, Joan increases the load on the secondary side of the transformer. Suddenly, it stops working. She suspects that the fuse in the primary circuit has blown and intends to replace it.

Question 16

In order to replace the fuse as safely as possible, which of the following is the **best** precaution for Joan to take?

A. stand on a rubber mat

B. switch off the mains supply

C. disconnect the transformer from the mains supply

D. remove the load from the transformer

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 11–13.

A class of physics students builds a model of an electricity distribution system. The circuit diagram of the model is shown in Figure 8. Ignore the resistance of wires connecting the power supply, transformer and globe to the transmission lines.

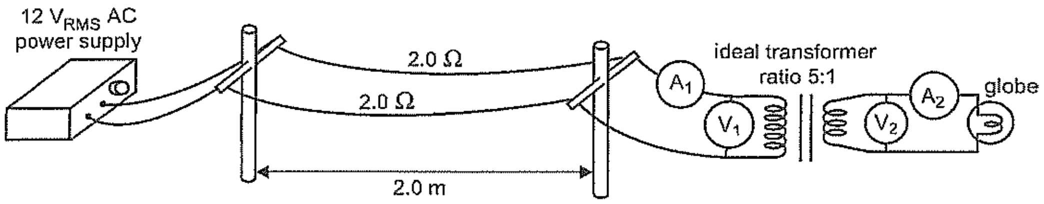

Figure 8

Assume that the transformer acts as an ideal transformer (no energy losses in transformer) of ratio primary to secondary windings of 5:1.

The current through ammeter A_1 is 0.50 A.

Question 11

What would be the reading on each of the meters A_2, V_1 and V_2?

i. A_2 ______ A

ii. V_1 ______ V

iii. V_2 ______ V

3 marks

Question 12

What would be the power delivered at each of the points listed below?

i. At the output of the 12 V_{RMS} power supply ______ W

ii. At the input to the primary coil of the transformer ______ W

iii. At the globe ______ W

3 marks

Question 13

The 12 V_{RMS} AC power supply is replaced by a 12 V battery.

What will be observed at the globe shown in Figure 8?

Explain this observation in terms of the operation of a transformer.

3 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.

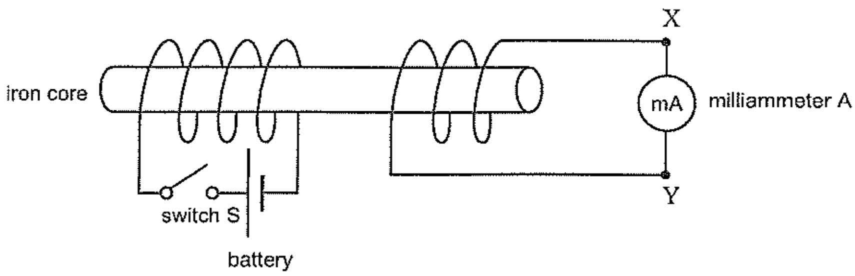

Figure 9

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

END OF AREA OF STUDY 1

Use the following information to answer Questions 8–10.

A group of students is studying electromagnetic induction. The apparatus the students use is shown in Figure 4a.

The apparatus consists of a square magnet and a square loop that can move. The magnet, of sides 8.0 cm, has a uniform magnetic field strength of 4.0×10^{-3} T between the poles. The field can be considered zero outside the poles. The loop is square of side 2.0 cm. The loop moves through the magnet at a constant speed of 2.0 cm s^{-1}. Figure 4b shows the situation as seen from above.

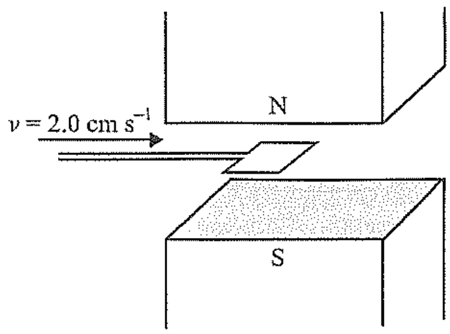

Figure 4a

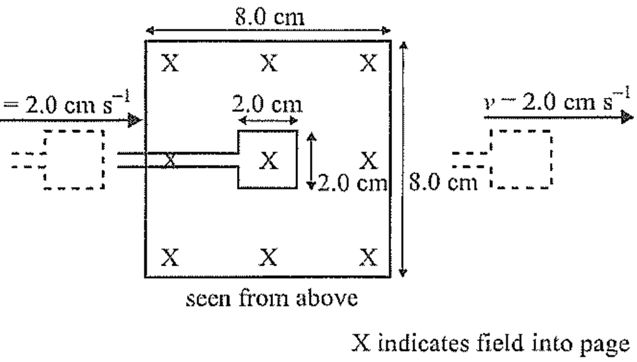

Figure 4b

Question 8

Which of the following diagrams (A.–F. in Figure 4c) best shows the shape of the output emf (voltage) induced in the loop as a function of time as the loop moves from outside the field at left to outside the field at right as shown in Figure 4b?

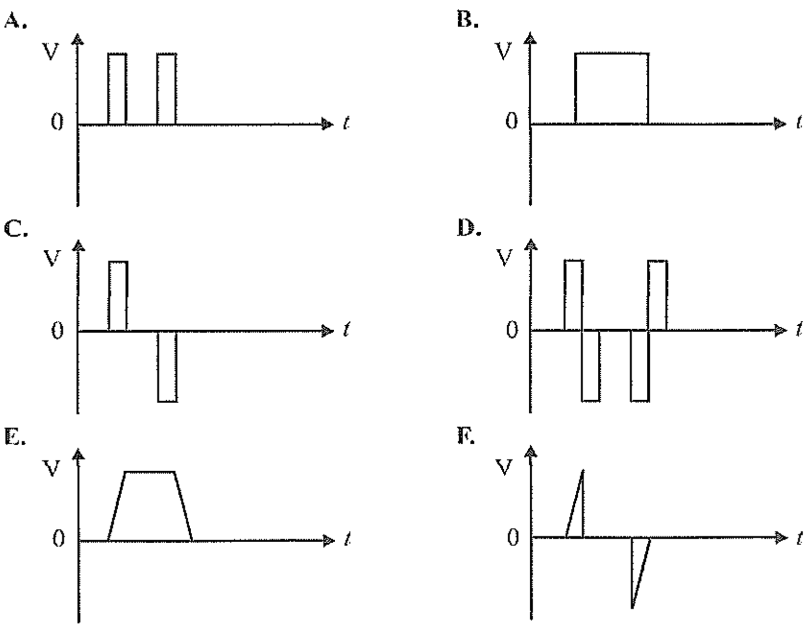

Figure 4c

2 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.

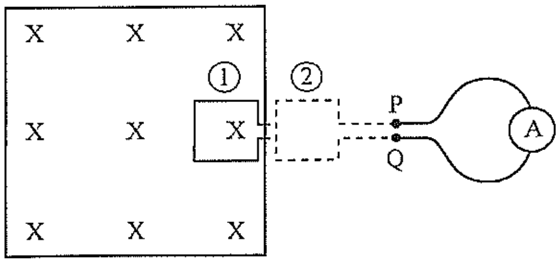

Figure 4d

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 11–13.

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Figure 5a

Bruce's garden has a pond with a fountain in it (as shown in Figure 5a). Bruce buys a floodlight to illuminate the fountain. The resistance of the floodlight filament is 3.0 Ω when operating.

Question 11

First Bruce tests the floodlight before he installs it. He tests it by applying 12 V_{RMS} across the floodlight.

What is the power used in the floodlight when supplied with a voltage of 12 V_{RMS}?

Show working.

W

3 marks

Bruce now installs the floodlight.

The electricity supply for the floodlight is supplied from the house using two wires (as shown in Figure 5b). Each of the two wires that connect the supply has a resistance of 0.50 Ω.

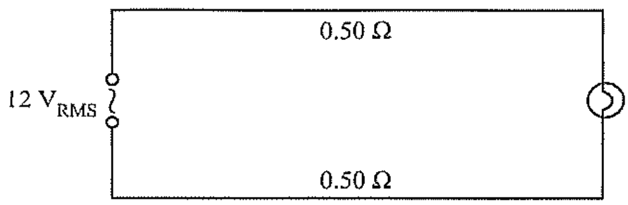


Figure 5b

Question 12
When operating, what is the voltage across the floodlight?
Show working.

V$_{RMS}$

3 marks

Bruce decides that the light is not bright enough and installs a second identical floodlight (as shown in the circuit below in Figure 5c).

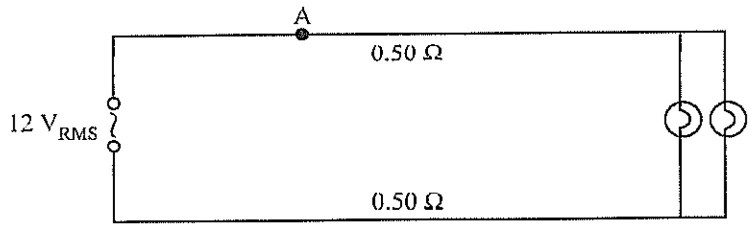


Figure 5c

Question 13
What is the current now flowing through the wire at point A?
Show working.

A

3 marks

The players find the lights too dim. They call in an electrician.

She suggests the following.

- retain the diesel motor
- replace the DC generator with an AC alternator producing 500 V_{RMS}
- insert a 1:10 step-up transformer between the alternator and the power lines, and a 10:1 step-down transformer between the power lines and the light tower

The transformers can be considered ideal.

The arrangement is shown in Figure 5.

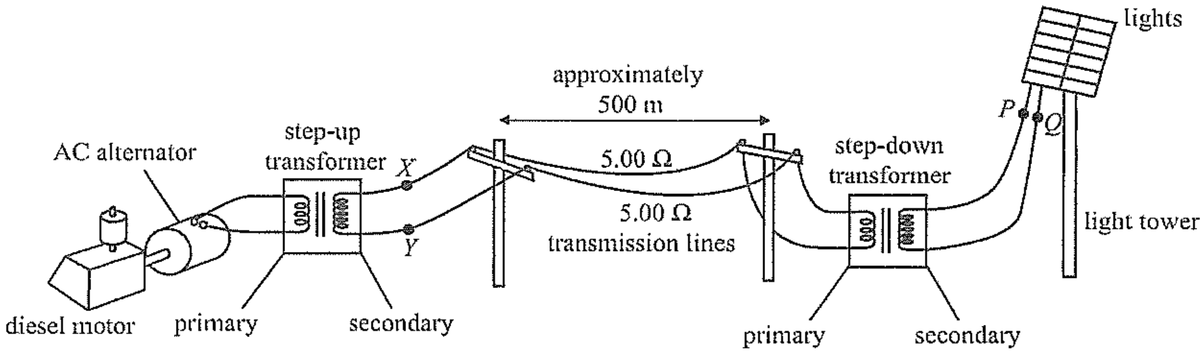


Figure 5

The lights are on.

The resistance of each wire in the transmission lines is still 5.00 Ω. Ignore the resistance of the other connecting wires.

The output of the alternator is 20.0 A_{RMS}.

(The generator output was 20.0 A DC.)

Question 12

What will the RMS voltage (potential difference) now be at the input to the transmission lines (at point *XY*) at the alternator end?

V

2 marks

Question 13

The primary of the step-down transformer has 4800 turns. How many turns are in the secondary winding?

1 mark

Question 14

What will be the power loss in the transmission lines now?

W

2 marks

Question 15

What will be the voltage at the output of the step-down transformer? Give your answer correct to three significant figures.

V

3 marks

Area of study 1 – Electric power

The following information relates to Questions 1–5.

Figure 1 shows a solenoid and a battery.

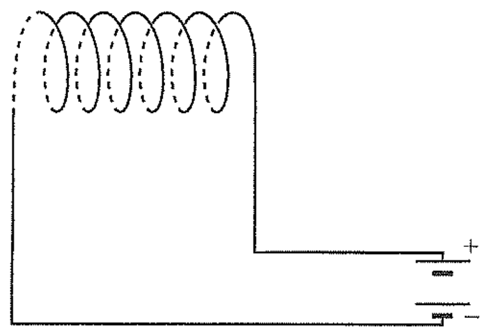


Figure 1

Question 1

Draw **three** magnetic field lines, with arrows to show direction, to indicate the magnetic field produced both inside and outside the solenoid.

2 marks

The following information relates to Questions 2–5.

A rectangular loop of wire, PQRS, of sides PQ = 4.0 cm and QR = 8.0 cm, is placed inside the solenoid as shown in Figure 2.

The loop has 3 turns of wire. A current of 4.0 amps flows in the loop, in the direction indicated by the arrow.

The uniform magnetic field strength inside the solenoid is 5.0×10^{-2} T.

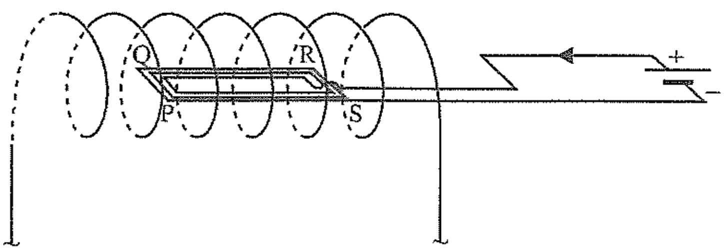


Figure 2

Question 2

What is the magnetic flux threading the loop? Explain your answer.

[ ] Wb

2 marks

Question 3

Draw an arrow on Figure 2 to indicate the direction of the force on the side PQ.

1 mark

Question 4

What is the magnitude of the force on the side PQ? Show your working.

[ ] N

2 marks

Question 5

What is the force (magnitude and direction) on the side QR? Explain your answer.

2 marks

The following information relates to Questions 8–11.

Figure 5 shows an experiment where the voltage induced in a coil by a time-dependent magnetic field is measured.

The voltmeter measures the voltage induced in the coil as a function of time.

The coil has 120 turns.

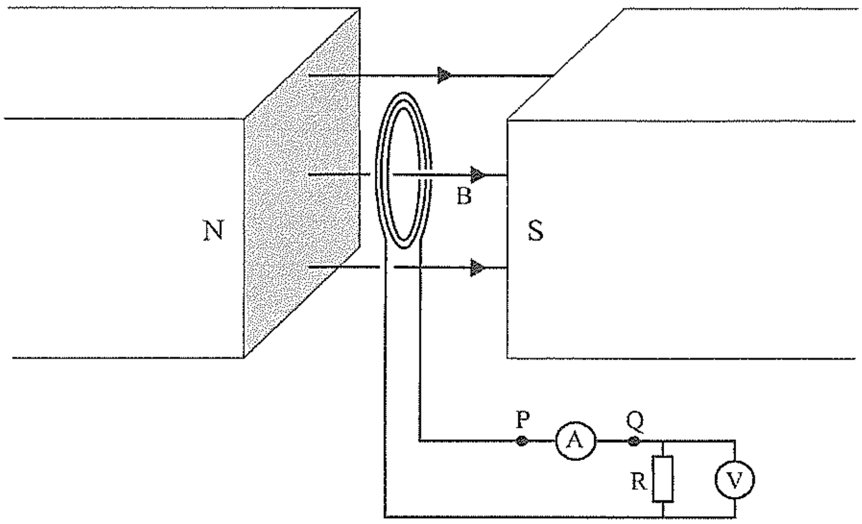


Figure 5

The magnetic field varies with time as shown in Figure 6.

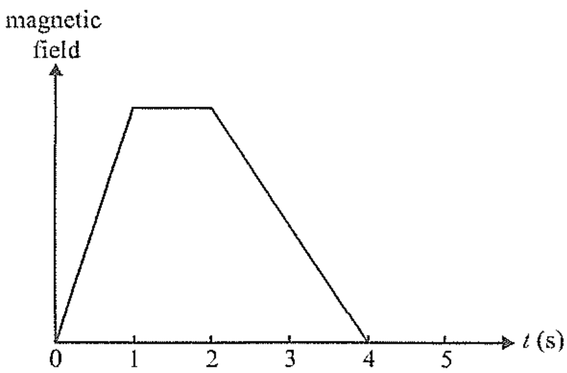
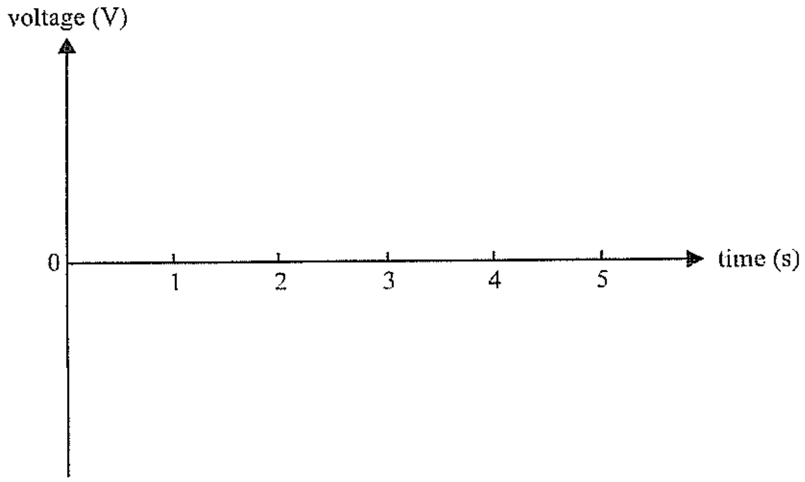


Figure 6

Question 8

Sketch a graph of voltage against time as measured by the voltmeter.



2 marks

Question 9

Identify the physical law you used for constructing your graph.

____

1 mark

At another time, the magnetic flux through the 120 turns coil is a constant 3.0×10^{-4} Wb.

Question 10

The magnetic field is now reduced to zero over a period of 0.012 s.

What is the average EMF induced in the coil during that 0.012 s interval? Show your working.

V

2 marks

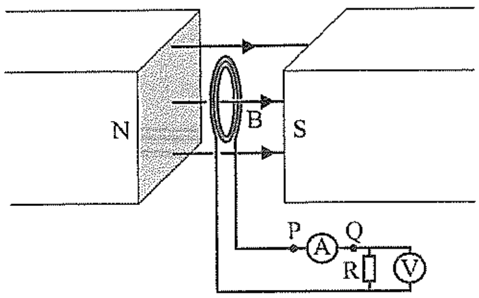


Figure 5 (repeated)

Question 11

As the field is being reduced, in what direction (P→Q or Q→P) will the current flow through the ammeter A in Figure 5 above? Explain your answer.

Direction

2 marks

The following information relates to Questions 12 and 13.

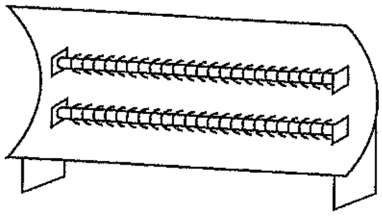


Figure 7

Hilary has bought a new electric heater, as shown in Figure 7, that operates on an AC voltage of 240 V_{RMS}. It has two identical heating elements, each with a constant resistance of 48 Ω. The elements can be connected in three different ways to provide three heating power settings of

600 W
1200 W
2400 W.

Question 12

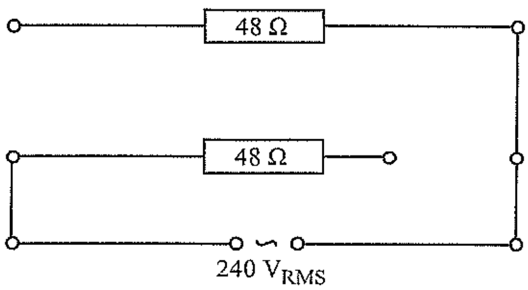
When the heater is used with **only one element connected**, what is the power output? Show your working.

W

2 marks

Question 13

Complete the circuit below to show the connections when the heater is set to provide a heating power of 600 W.



2 marks

The following information relates to Questions 14–20.

Students are using a model of a transmission line to study power and voltage loss in transmission lines.

The students' 'transmission lines' consist of two wires, **each** of constant resistance **2.0 Ω**. As a load they use a 4.0 W globe which operates at 4.0 W when there are 2.0 V across it.

The experimental arrangement is shown in Figure 8.

The connecting wires from the power supply to the transmission lines and from the transmission lines to the globe have negligible resistance.

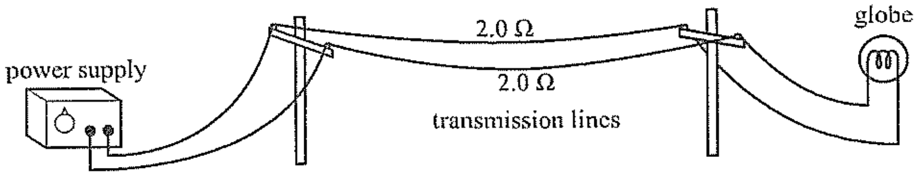


Figure 8

Question 14

Initially the students use the power supply set on a voltage of 2.0 V DC.

They find that the globe does not glow as brightly as they expected. Explain why.

____

____

____

____

____

2 marks

Question 15

The voltage setting of the power supply is then set so that the globe operates at 4.0 W as designed.

Calculate the required voltage setting of the power supply. Show your working.

V

3 marks

Question 16

When the globe is operating at 4.0 W as designed, what is the power loss in the transmission lines? Show your working.

W

2 marks

One of the students, Catherine, says that in the real situation which they are attempting to model, this fractional power loss would be unacceptable. She observes that AC rather than DC is often used for long-distance electric power transmission systems.

Question 17

Explain why AC is often used for long-distance electric power transmission.

2 marks

To model this AC transmission system, the students modify their experiment as shown in Figure 9 below.

They set the output of the power supply to 20.8 V_{RMS} AC. They use a 10:1 step-down transformer at the other end. The output of the transformer is connected to the globe.

The globe is operating at 2.0 V and 4.0 W.

This is shown in Figure 9. Consider the transformer as ideal.

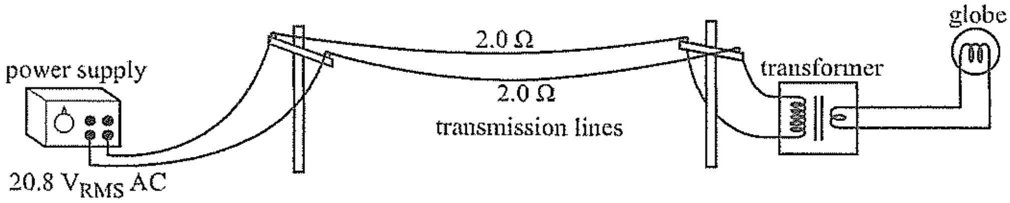


Figure 9

Question 18

Before connecting the circuit, the students test the power supply by connecting it to an oscilloscope as shown in Figure 10.

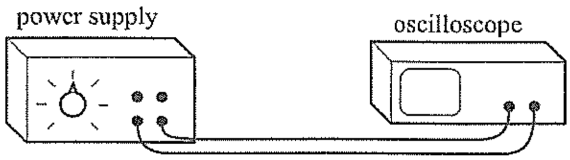


Figure 10

What signal will they observe on the oscilloscope?

A. 20.8 V peak

B. 20.8 V peak to peak

C. 29.4 V peak to peak

D. 58.8 V peak to peak

2 marks

Question 19

The input coil of the 10:1 step-down transformer has 1460 turns.

How many turns does the secondary coil have?

turns

1 mark

Question 20

With the experiment set up as in Figure 9, what is the power loss in the transmission lines? Show your working.

W

3 marks

Area of study 1 – Electric power

Use the following information to answer Questions 1 and 2.

Two identical bar magnets of the same strength are arranged at right angles and are equidistant from point P, as shown in Figure 1.

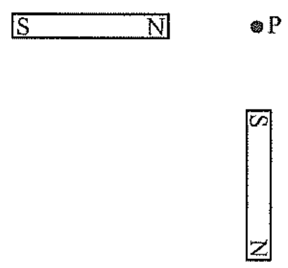


Figure 1

For Question 1 only, ignore Earth's magnetic field.

Question 1

At point P on the diagram, draw an arrow indicating the direction of the combined magnetic field of the bar magnets.

1 mark

Question 2

The bar magnets are replaced by two weaker magnets. The two new magnets are identical to each other. They are arranged at right angles and are equidistant from point P.

The magnitude of the magnetic field of a **single** bar magnet at point P is the same as the magnitude of magnetic field of Earth at point P. The direction of Earth's magnetic field is shown in Figure 2.

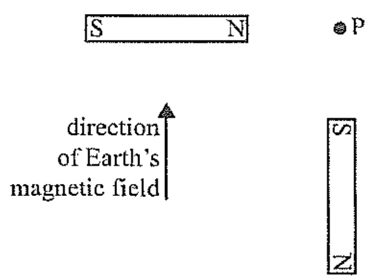


Figure 2

At point P on the diagram, draw an arrow indicating the direction of the combined magnetic field of the bar magnets and Earth.

2 marks

Use the following information to answer Questions 3–7.

Figure 3 shows a schematic diagram of a DC electric motor. The motor has a rectangular coil, JKLM, of 50 turns. The permanent magnets provide a uniform magnetic field of 0.30 T in the region of coil JKLM. The commutator with contacts X and Y is connected to a source of constant DC current.

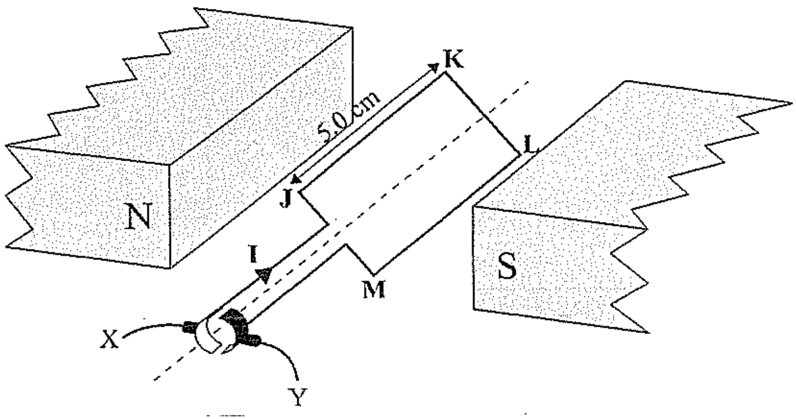


Figure 3

Question 3

Explain the role of the commutator in the operation of the motor.

3 marks

Question 4

A current, I, is flowing through the rectangular coil in the direction shown.

When the coil is in the position shown in the diagram, draw an arrow on side JK to show the direction of the magnetic force on side JK.

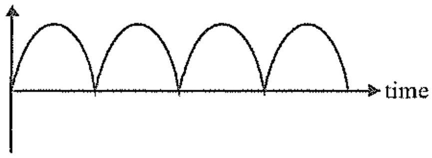
1 mark

Coil JKLM is now disconnected from the source of steady current, and the coil is turned by hand at a constant speed. Points X and Y are now connected to an oscilloscope.

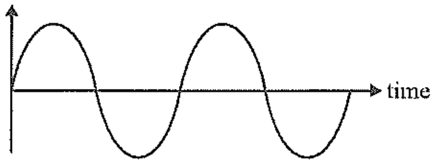
Question 6

Which of the following graphs best shows the shape of the voltage-time display on the oscilloscope?

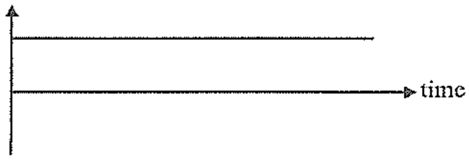
A.



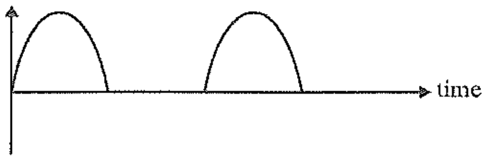
B.



C.



D.



1 mark

Question 7

Explain your answer to Question 6.

___

___

___

___

2 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.

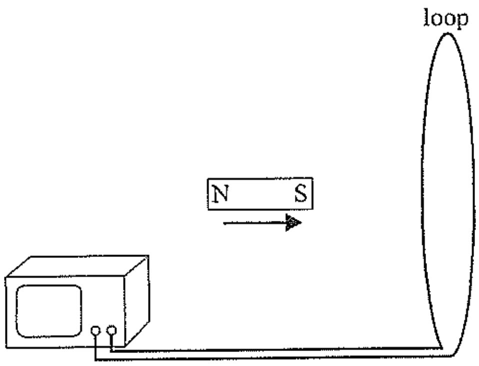


Figure 5

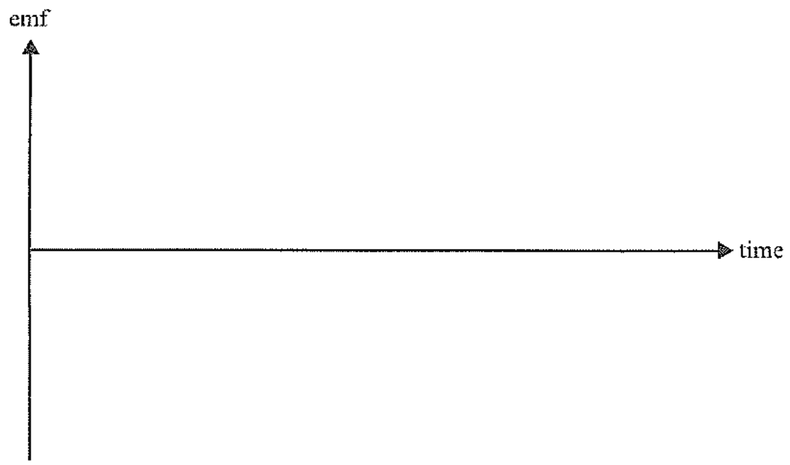
Question 10

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

Use the following information to answer Questions 13–16.

A small town is supplied with electricity from a small hydroelectric generation plant about 20 km from the town. Electricity is transmitted to the town through a two-wire high-voltage transmission line.

The input voltage to the transmission lines at the generator end is 50 000 V_{RMS} AC.

The current in the lines is 15 A_{RMS}. At the edge of town, a transformer converts this into 250 V_{RMS} AC for use in the town.

The system is shown in Figure 6.

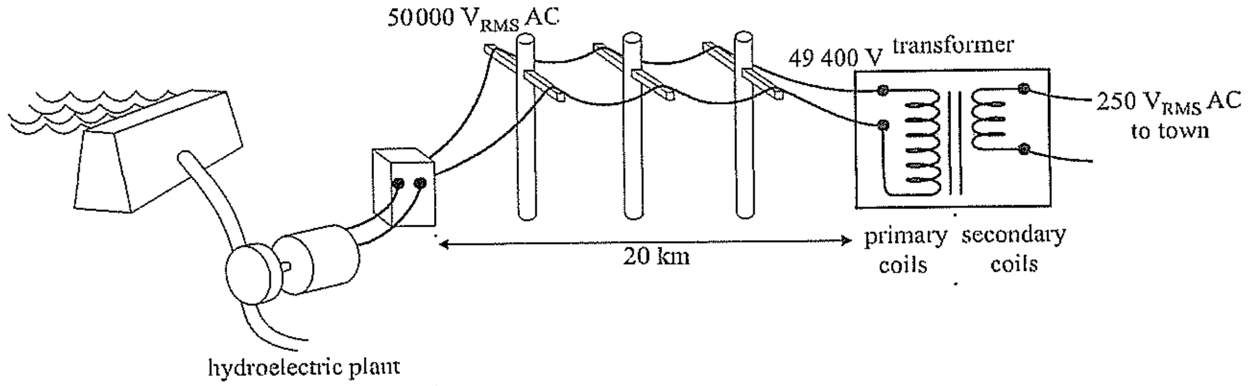


Figure 6

Question 13

Calculate the power supplied to the transmission lines. Show your working.

W

2 marks

Question 14

Some townspeople are concerned about the high voltages, and propose that the same power could be transmitted more safely at a lower transmission voltage.

Explain clearly why this proposal would increase power losses in the transmission process.

3 marks

The proposal is not accepted, and the transmission lines operate as originally designed.

With a current in the transmission lines of 15 A_{RMS} the total power loss in the transmission lines is 9000 W.

Question 15

Calculate the total resistance of the transmission lines.

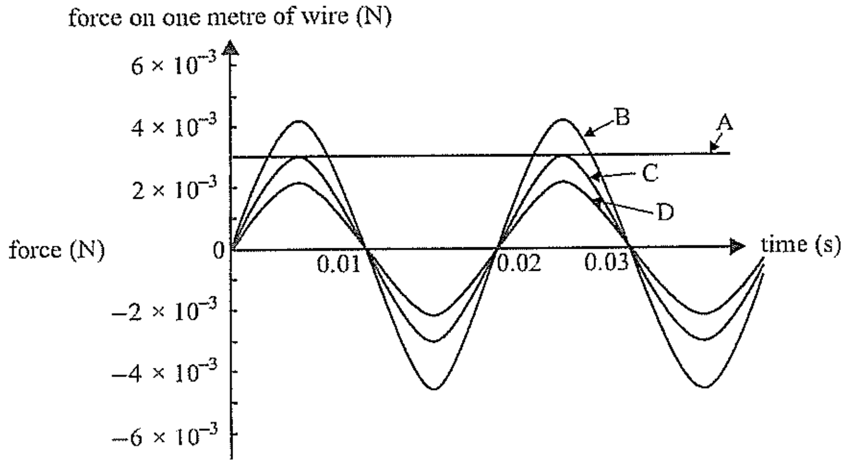
Ω

2 marks

In a part of Victoria, a section of one wire of a transmission line is running horizontally from east to west. The current in the transmission line is 30 A_{RMS}.
Earth's magnetic field there is pointing directly north, parallel to the ground, of strength 1.0×10^{-4} T.

Question 17

Which of the graphs (A–D) below best illustrates how the electromagnetic force acting on each metre of wire varies as a function of time? Show a numerical calculation to justify your answer.



2 marks