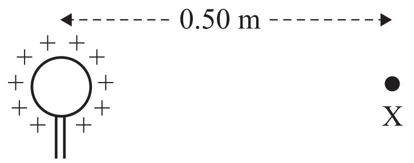
Question 3

A Van de Graaff generator, which is a piece of electric field demonstration equipment, consists of a small sphere that is electrically charged, as shown in the diagram below.



A particular Van de Graaff generator has a sphere that has a charge of 5.0×10^{-7} coulombs on it. Take the Coulomb's law constant to be $k = 9.0 \times 10^{9}$ N m^2 C^{-2}.

Which one of the following best gives the magnitude of the electric field at point X in the diagram above, 0.50 m from the sphere?

A. 1.8×10^{-2} V m^{-1}

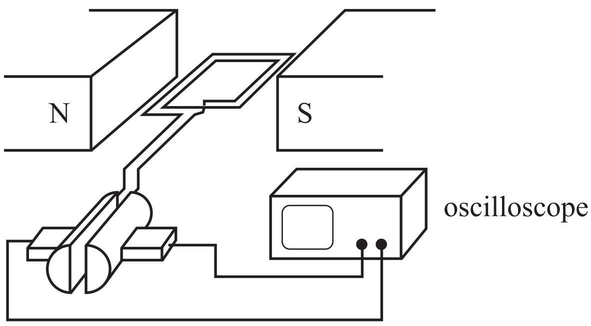
B. 3.6×10^{-2} V m^{-1}

C. 1.8×10^{4} V m^{-1}

D. 3.6×10^{4} V m^{-1}

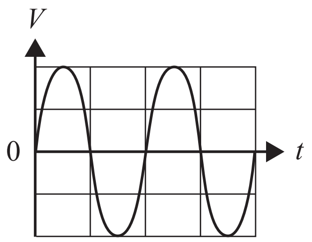
Question 4

A simple DC generator consists of two magnets that produce a uniform magnetic field, in which a square loop of wire of 100 turns rotates at constant speed, and a commutator, as shown in the diagram below.

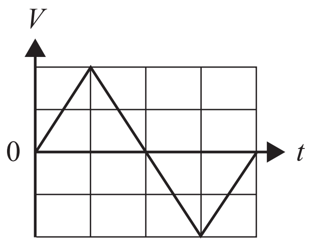


Which one of the following best shows the display observed on the oscilloscope?

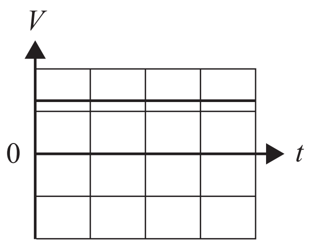
A.



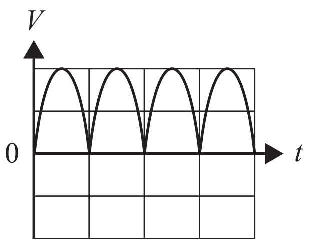
B.



C.



D.



Use the following information to answer Questions 5–7.

A step-down transformer is used to convert 240 V_{RMS} AC to 16 V_{RMS} AC.

Assume that the transformer is ideal.

✓ **Question 5**

Which one of the following best gives the peak voltage of the input to the transformer?

A. 171 V

B. 240 V

C. 339 V

D. 480 V

✓ **Question 6**

The ratio of turns in the primary (input) to turns in the secondary (output) is best given by

A. 15:1

B. 1:15

C. 24:1

D. 1:24

✓ **Question 7**

The power input to the primary of the transformer is 30 W.

Which one of the following best gives the RMS current in the secondary (output)?

A. 0.50 A

B. 1.9 A

C. 8.0 A

D. 15 A

Question 4 (9 marks)

Students move a square loop of wire of 100 turns and of cross-sectional area 4.0×10^{-4} m^2. The loop moves at constant speed from outside left, into, through and out of a magnetic field, as shown in Figure 1a. The area between the poles has a uniform magnetic field of magnitude 2.0×10^{-3} T. Figure 1b shows the view from above.

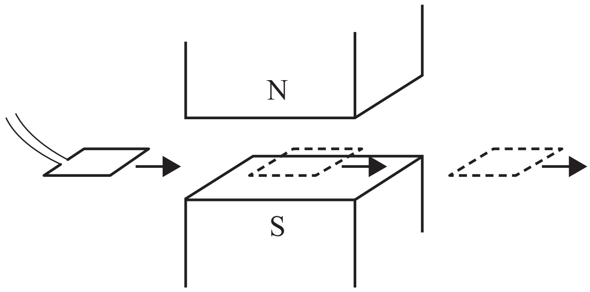


Figure 1a

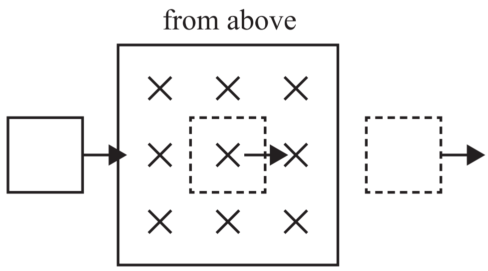


Figure 1b

a. On the axes provided below, sketch the magnetic flux, Φ_B, through the loop as it moves into, through and out of the magnetic field. 2 marks

b. On the axes provided below, sketch the EMF induced through the loop as it moves into, through and out of the magnetic field. 2 marks

c. The loop takes 2.0 s to move from completely outside to completely inside the magnetic field.

Calculate the magnitude of the induced EMF in the loop as it moves into the magnetic field. 2 marks

V

d. Determine the direction of the induced current in the loop as it moves into the magnetic field as viewed from above (clockwise or anti-clockwise). Justify your answer. 3 marks

✓ **Question 5** (8 marks)

Students construct a model to show the transmission of electricity in transmission lines.

The apparatus is shown in Figure 2.

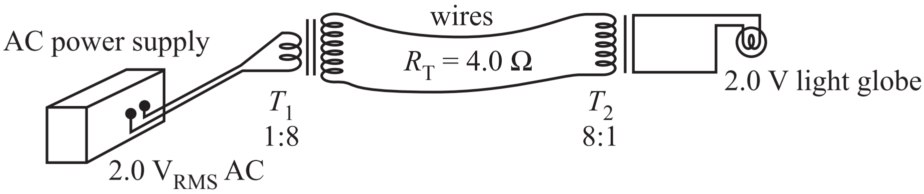


Figure 2

The students use two transformers, T_1 and T_2, with ratios of 1:8 and 8:1 respectively, and a $2.0\ V_{RMS}$ AC power supply. Assume that the transformers are ideal. The students use a light globe that operates correctly when there is a voltage of 2.0 V across it. The wires of the transmission lines have a total resistance of 4.0 Ω. The students measure the current in these wires to be 0.50 A.

a. Calculate the power loss in the wires. 2 marks

W

b. Calculate the voltage across the light globe. 4 marks

V

c. The light globe does not operate correctly, as it should with a voltage of 2.0 V across it.

Describe **one** change the students could make to the model to make the light globe operate correctly. 2 marks

Question 2 (6 marks)

A square loop of wire of 10 turns with a cross-sectional area of 1.6×10^{-3} m^2 passes at a constant speed into, through and out of a magnetic field of magnitude 2.0×10^{-2} T, as shown in Figure 2.

The loop takes 0.50 s to go from position X to position Y.

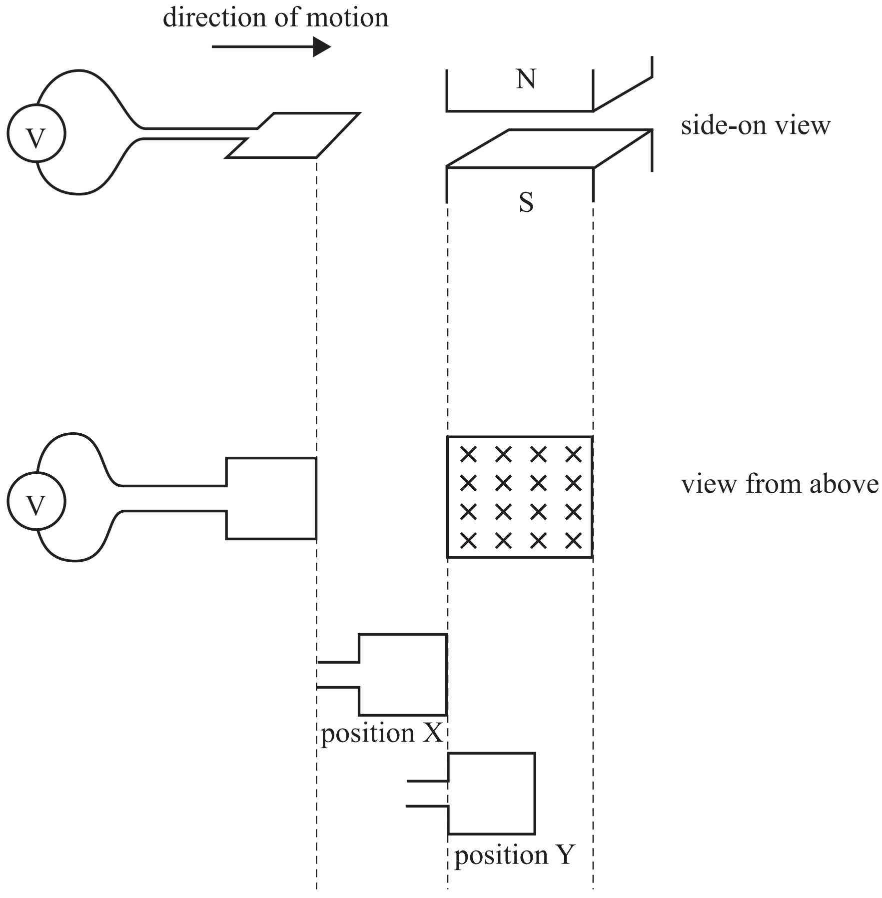
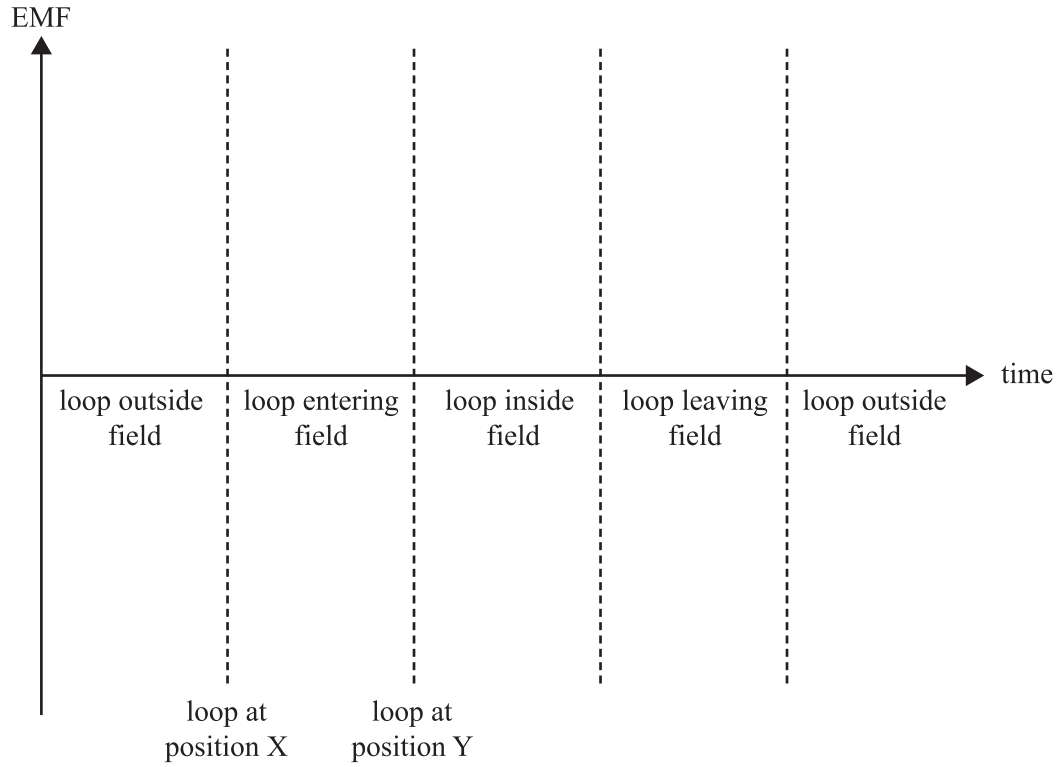


Figure 2

a. Calculate the average EMF induced in the loop as it passes from just outside the magnetic field at position X to just inside the magnetic field at position Y. Show your working. 3 marks

V

b. Sketch the EMF induced in the loop as it passes into, through and out of the magnetic field. You do not need to include values on the axes. 3 marks



✓**Question 3** (5 marks)

Students build a model of a simple DC motor, as shown in Figure 3.

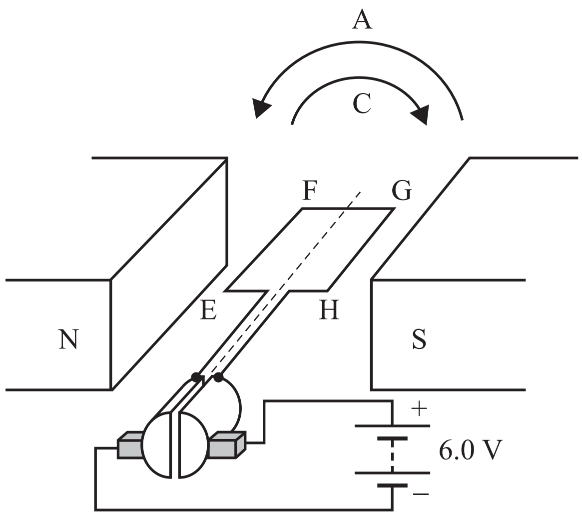


Figure 3

a. The motor is set with the coil horizontal, as shown, and the power source is applied.

Will the motor rotate in a clockwise (C) or anticlockwise (A) direction? Explain your answer. 3 marks

b. One student suggests that slip rings would be easier to make than a commutator and that they should use slip rings instead.

Explain the effect that replacing the commutator with slip rings would have on the operation of the motor, if no other change was made. 2 marks

✓**Question 4** (4 marks)

Figure 4 shows a simple AC alternator with the output connected to an oscilloscope and a light globe.

The oscilloscope can be considered as having a very large resistance. The coil is rotated, as shown in Figure 4.

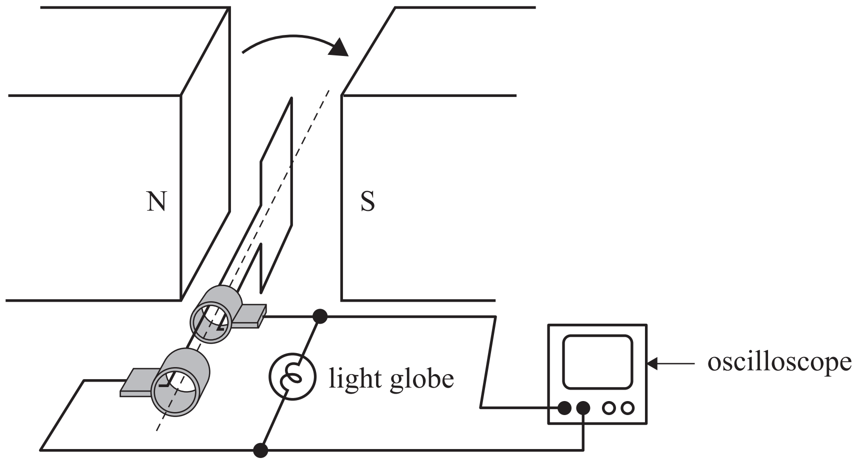


Figure 4

The output on the oscilloscope is shown in Figure 5.

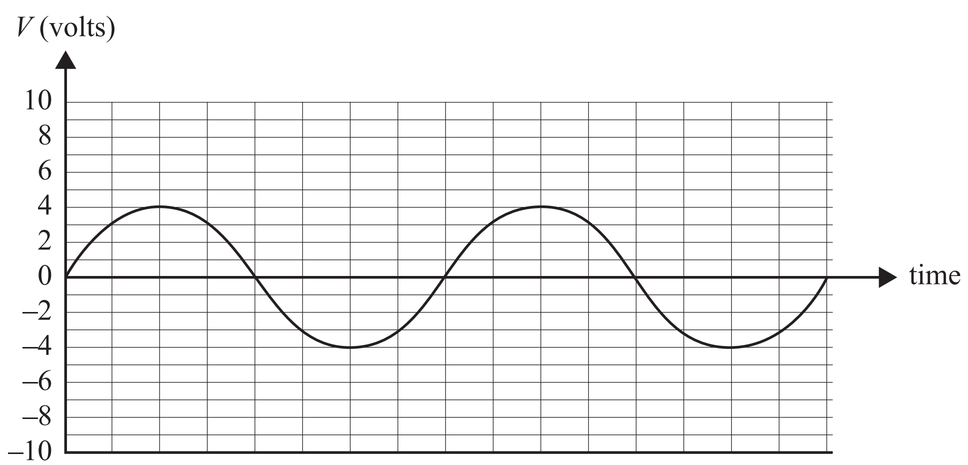


Figure 5

a. The AC alternator is to be replaced with a battery.

What voltage should the battery have for the light globe to light up with the same average brightness as it did with the alternator? Show your working. 2 marks

V

b. The rate of rotation of the loop is doubled.

On Figure 6 below, sketch the output that will now be seen on the oscilloscope. The original waveform is shown as a dashed line on Figure 6. 2 marks

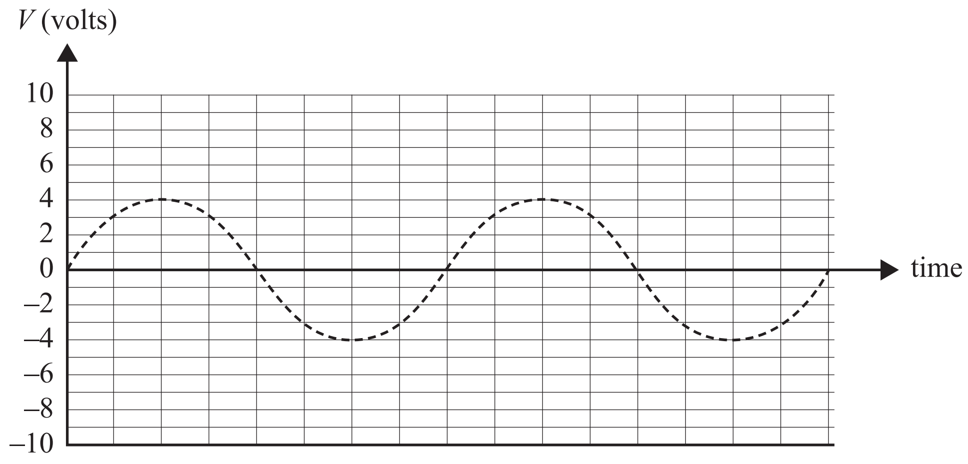


Figure 6

✓ **Question 5** (12 marks)

A Physics class is investigating power loss in transmission lines.

The students construct a model of a transmission system. They first set up the model as shown in Figure 7. The model consists of a variable voltage AC power supply, two transmission lines, each of 4.0 Ω (total resistance = 8.0 Ω), a variable ratio transformer, a light globe and meters as needed. The purpose of the model is to operate the 4.0 V light globe.

A variable ratio transformer is one in which the ratio of turns in primary windings to turns in secondary windings can be varied. The resistance of the connecting wires can be ignored.

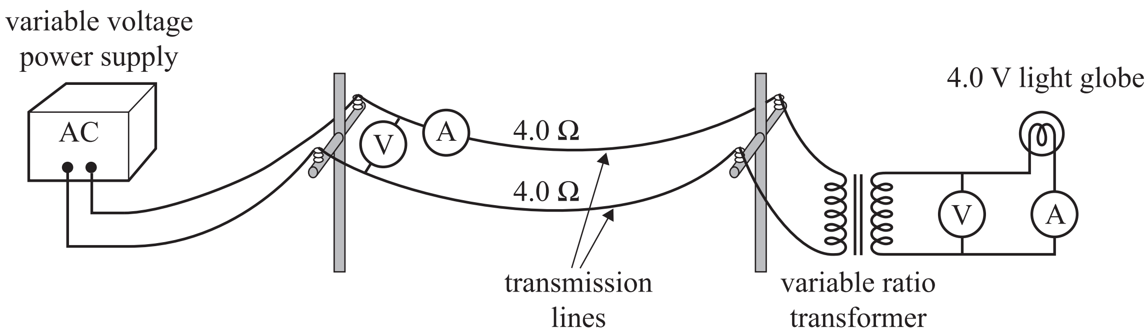


Figure 7

In their first experiment, the transformer is set on a ratio of 4:1 and the current in the transmission lines is measured to be 3.0 A. The light globe is operating correctly, with 4.0 V_{RMS} across it.

a. Calculate the power dissipated in the light globe. Show your working. 2 marks

W

b. Calculate the voltage output of the power supply. Show your working. 3 marks

V

c. Calculate the total power loss in the transmission lines. Show your working. 2 marks

W

d. In a second experiment, the students set the variable ratio of the transformer at 8:1 and adjust the variable voltage power supply so that the light globe operates correctly, with 4.0 V_{RMS} across it.

Calculate the total power loss in the transmission lines in this second experiment. Show your working. 3 marks

W

e. Suggest **two** reasons why high voltages are often used for the transmission of electric power over long distances. 2 marks

Use the following information to answer Questions 2 and 3.

A powerline carries a current of 1000 A DC in the direction east to west. At the point of measurement, Earth's magnetic field is horizontally north and its strength is 5.0×10^{-5} T.

Question 2

Which one of the following best gives the direction of the electromagnetic force on the powerline?

A. horizontally west

B. horizontally north

C. vertically upwards

D. vertically downwards

Question 3

The magnitude of the force on **each metre** of the powerline is best given by

A. 5.0×10^{3} N

B. 5.0×10^{2} N

C. 5.0×10^{-2} N

D. 5.0×10^{-5} N

Question 4

The gravitational field strength at the surface of Mars is 3.7 N kg^{-1}.

Which one of the following is closest to the change in gravitational potential energy when a 10 kg mass falls from 2.0 m above Mars's surface to Mars's surface?

A. 3.7 J

B. 7.4 J

C. 37 J

D. 74 J

Use the following information to answer Questions 5 and 6.

A light globe operates at 12 V_{RMS} AC that is supplied by a 240 V to 12 V transformer connected to a 240 V_{RMS} mains supply.

Question 5

In the transformer, the ratio of turns in the primary (input) to turns in the secondary (output) is

A. 20:1

B. 1:20

C. 28:1

D. 1:28

Question 6

If the light globe is to be operated using a battery instead of the mains supply, what voltage should the battery have for the light globe to operate correctly?

A. 12 V

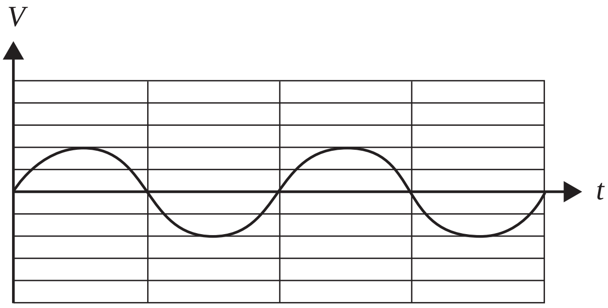
B. 17 V

C. 8.5 V

D. 6.0 V

Question 7

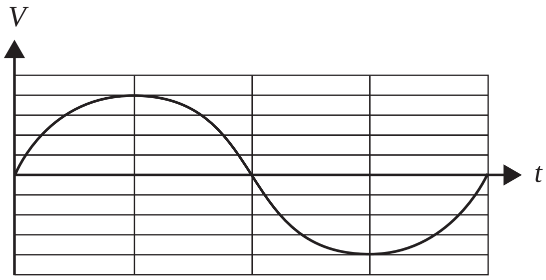
An alternator is rotating at 10 revolutions per second. Its output is measured by an oscilloscope. The signal produced is shown below.



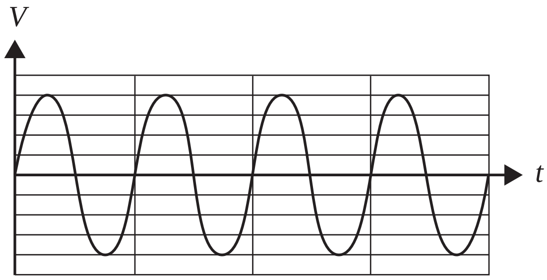
The alternator is then slowed so that it rotates at five revolutions per second.

Which one of the following best shows the display observed on the oscilloscope?

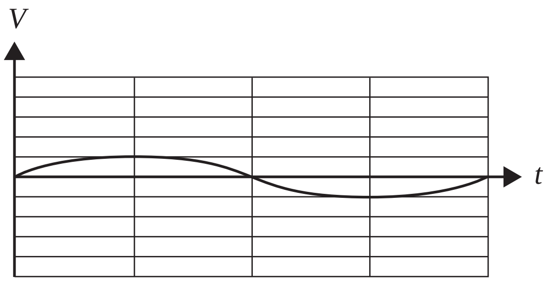
A.



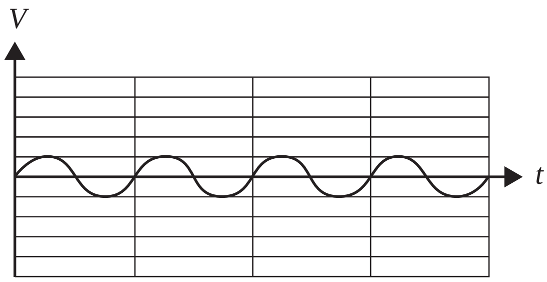
B.



C.



D.



✓ **Question 2** (5 marks)

A square loop of wire with a cross-sectional area of 0.010 m^2 and 20 turns rotates in a magnetic field of strength 4.0×10^{-2} T. The wires of the loop are connected to two slip rings and an oscilloscope, as shown in Figure 2.

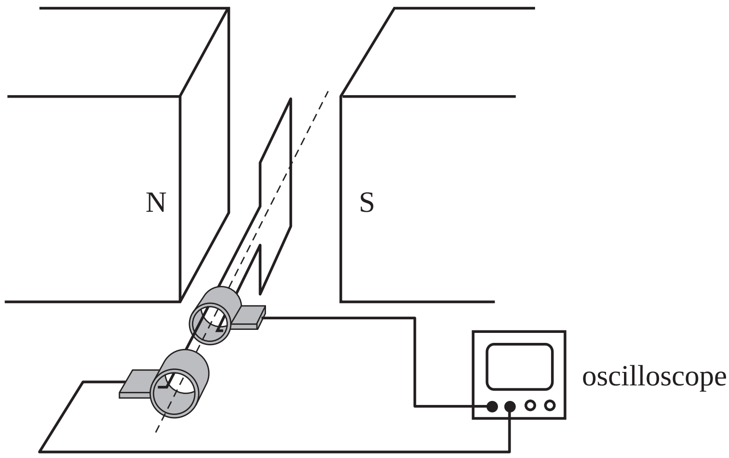


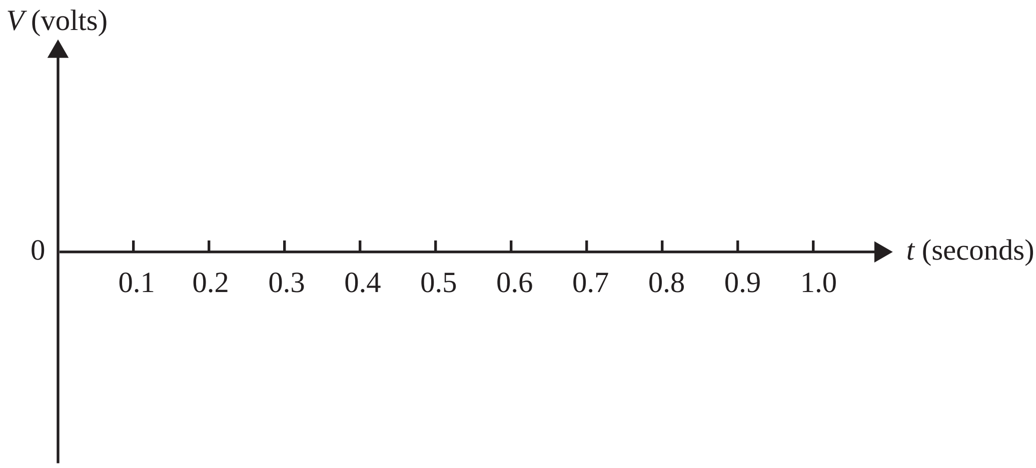
Figure 2

The loop takes 0.10 s to make a quarter rotation (from a position at right angles to the field to a position parallel to the field).

a. Calculate the average magnitude of the induced EMF in the loop as it makes this quarter rotation. Show your working. 3 marks

V

b. On the axes provided below, sketch the output signal that would be displayed on the oscilloscope over 1.0 s. A value or scale on the *y*-axis is not necessary. Take the position of the loop at $t = 0$ to be that shown in Figure 2. 2 marks



✓ **Question 3** (5 marks)

Figure 3 shows a simple DC motor consisting of a square loop of wire of side 10 cm and 10 turns, a magnetic field of strength 2.0×10^{-3} T, and a commutator connected to a 12 V battery. The current in the loop is 2.0 A.

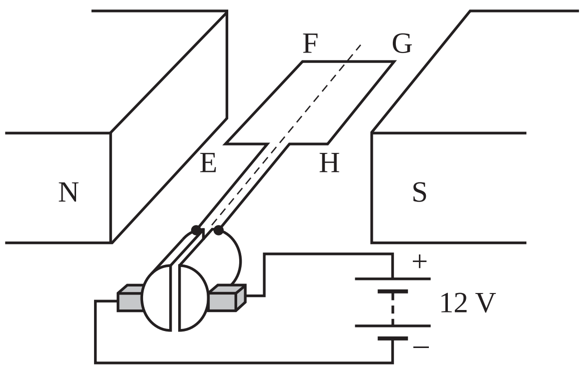


Figure 3

a. Calculate the magnitude of the total force acting on the side EF when the loop is in the position shown in Figure 3. Show your working. 2 marks

N

b. Explain the role of the commutator in a DC motor. 3 marks

✓ **Question 4** (8 marks)

An electrician is installing a power supply to a yard located 500 m from a farmhouse in order to operate a 240 V_{RMS}, 480 W light globe, as shown in Figure 4.

The connecting wires have a total resistance, R_T, of 40 Ω.

At the farmhouse, the electrician provides the required input voltage, V_{in}, to the connecting wires for the light globe to operate at 240 V_{RMS} and 480 W.

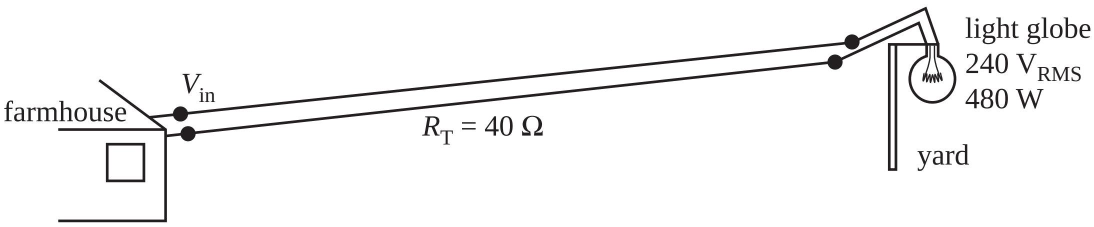


Figure 4

a. When the light globe is operating at 240 V_{RMS} and 480 W, what is the power loss in the connecting wires? Show your working. 2 marks

W

b. Calculate the RMS voltage of V_{in}. Show your working. 3 marks

V_{RMS}

c. To reduce the power loss in the connecting wires, the electrician changes the input voltage, V_{in}, and installs an 8:1 step-down transformer at the yard. After these changes, the light globe still operates at 240 V_{RMS} and 480 W, as shown in Figure 5.

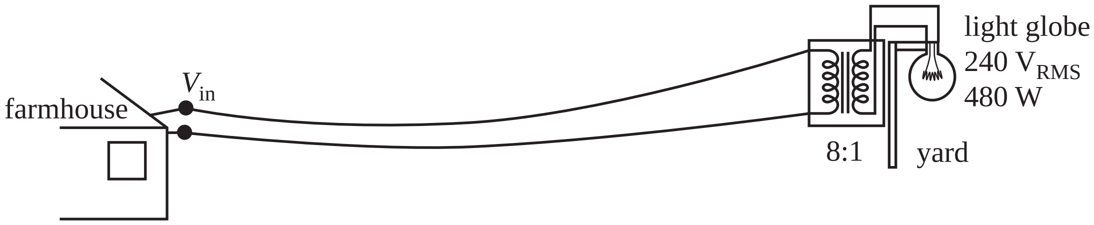


Figure 5

Calculate the RMS power loss in the connecting wires for this new situation. Show your working. 3 marks

____

____

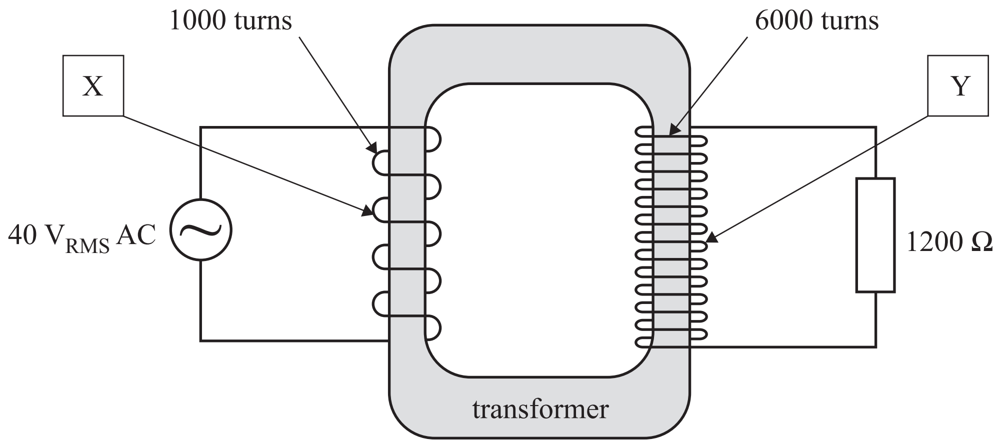
____

____

W

Use the following information to answer Questions 5 and 6.

A 40 V_{RMS} AC generator and an ideal transformer are used to supply power. The diagram below shows the generator and the transformer supplying 240 V_{RMS} to a resistor with a resistance of 1200 Ω.



✓ **Question 5**

Which of the following correctly identifies the parts labelled X and Y, and the function of the transformer?

	Part X	Part Y	Function of transformer
A.	primary coil	secondary coil	step-down
B.	primary coil	secondary coil	step-up
C.	secondary coil	primary coil	step-down
D.	secondary coil	primary coil	step-up

Question 6

Which one of the following is closest to the RMS current in the primary circuit?

A. 0.04 A

B. 0.20 A

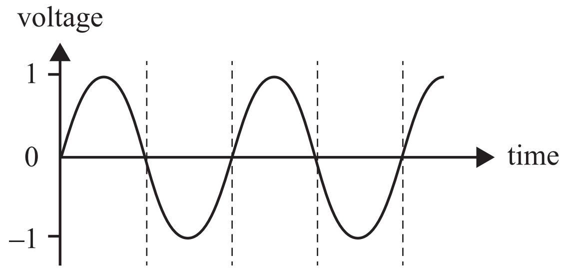
C. 1.20 A

D. 1.50 A

Question 7

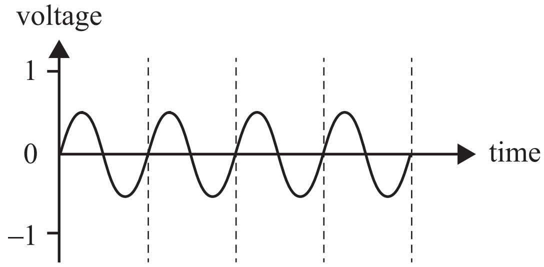
The coil of an AC generator completes 50 revolutions per second.

A graph of output voltage versus time for this generator is shown below.

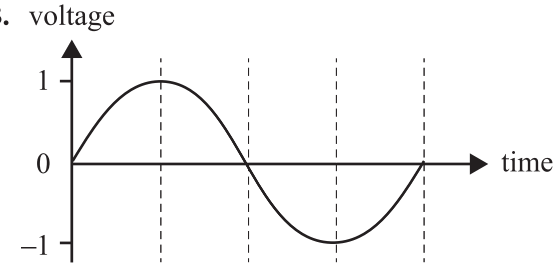


Which one of the following graphs best represents the output voltage if the rate of rotation is changed to 25 revolutions per second?

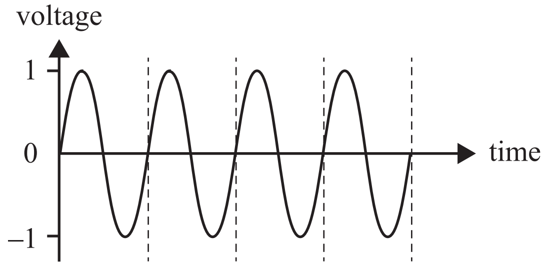
A.



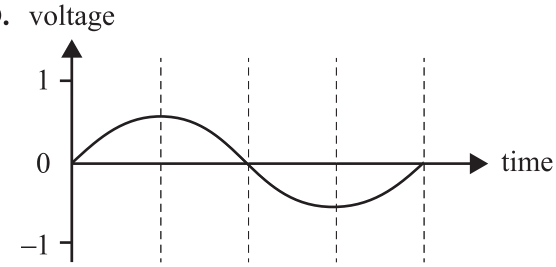
B.



C.

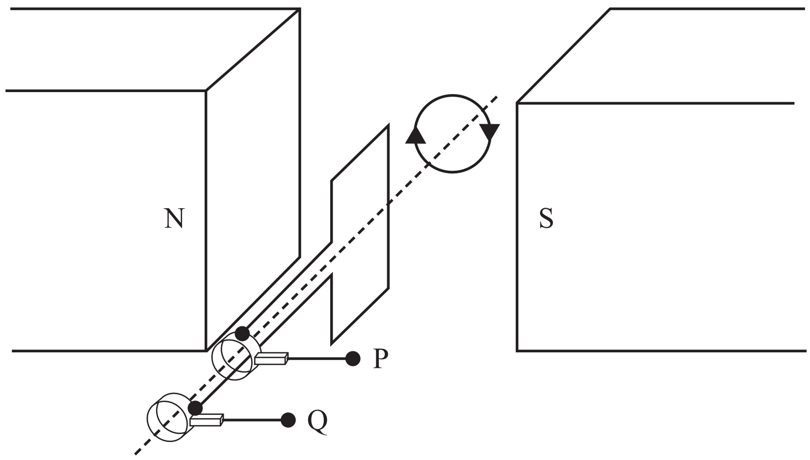


D.



Question 8

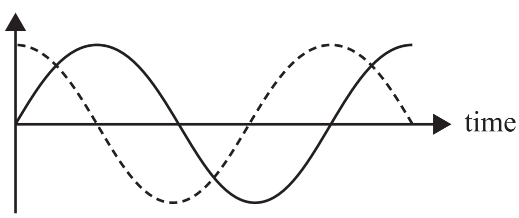
An electrical generator is shown in the diagram below. The generator is turning clockwise.

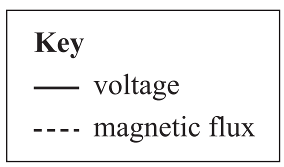


The voltage between P and Q and the magnetic flux through the loop are both graphed as a function of time, with voltage versus time shown as a solid line and magnetic flux versus time shown as a dashed line.

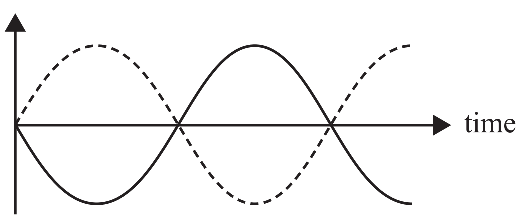
Which one of the following graphs best shows the relationships for this electrical generator?

A.

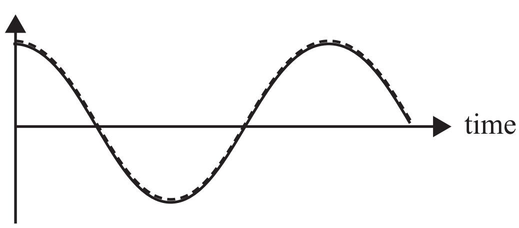




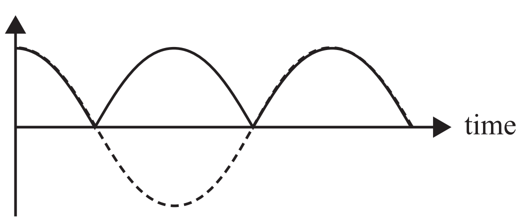
B.



C.



D.



✓ **Question 3** (6 marks)

Figure 3 shows a schematic diagram of a DC motor. The motor has a coil, JKLM, consisting of 100 turns. The permanent magnets provide a uniform magnetic field of 0.45 T. The commutator connectors, X and Y, provide a constant DC current, *I*, to the coil. The length of the side JK is 5.0 cm.

The current *I* flows in the direction shown in the diagram.

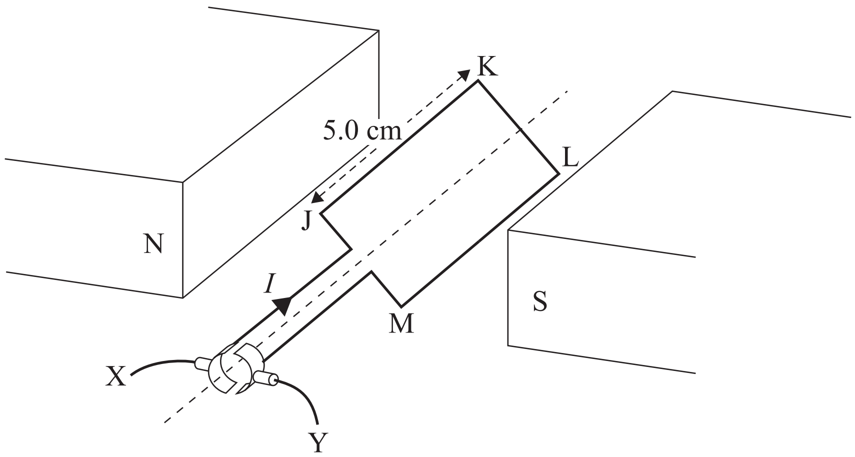


Figure 3

a. Which terminal of the commutator is connected to the positive terminal of the current supply? 1 mark

b. Draw an arrow on Figure 3 to indicate the direction of the magnetic force acting on the side JK. 1 mark

c. Explain the role of the commutator in the operation of the DC motor. 2 marks

d. A current of 6.0 A flows through the 100 turns of the coil JKLM.
The side JK is 5.0 cm in length.

Calculate the size of the magnetic force on the side JK in the orientation shown in Figure 3. Show your working. 2 marks

N

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.

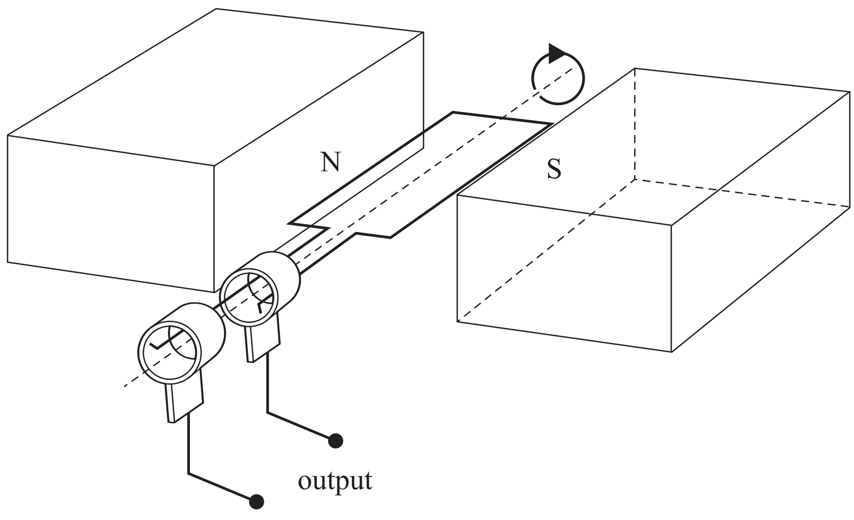


Figure 5

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

The students connect the output terminals of the piece of electrical equipment to an oscilloscope. One student rotates the loop at a constant rate of 20 revolutions per second.

c. Calculate the period of rotation of the loop. 1 mark

s

d. Calculate the maximum flux through the loop. Show your working. 2 marks

Wb

e. The loop starts in the position shown in Figure 5.

What is the average voltage measured across the output terminals for the first quarter turn? Show your working. 2 marks

V

f. State **two** ways that the amplitude of the voltage across the output terminals can be increased. 2 marks

g. Figure 6 shows the output voltage graph shown on the oscilloscope for two cycles.

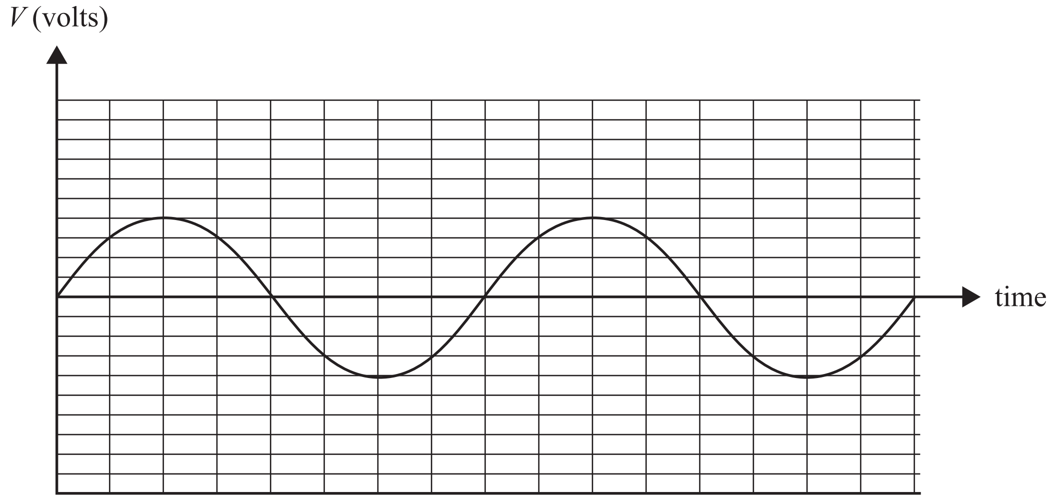


Figure 6

The students now replace the slip rings in Figure 5 with a split-ring commutator.

On Figure 7, sketch with a solid line the output that the students will now observe on the oscilloscope. Show **two** complete revolutions. The original output is shown with a dashed line. 1 mark

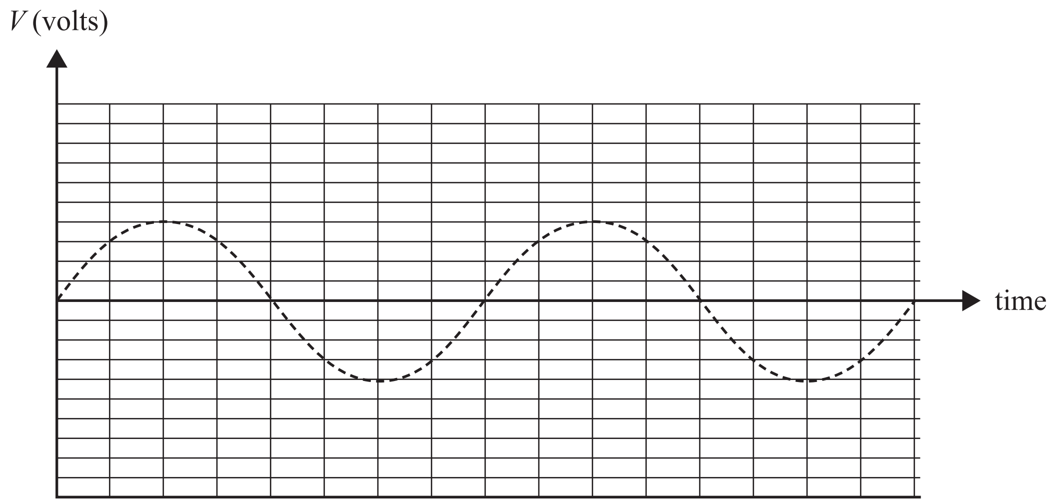
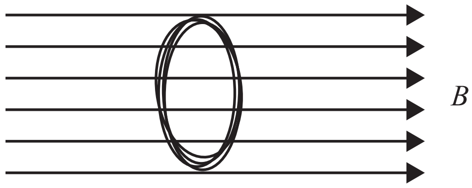


Figure 7

✓**Question 5**

A coil consisting of 20 loops with an area of 10 cm^2 is placed in a uniform magnetic field B of strength 0.03 T so that the plane of the coil is perpendicular to the field direction, as shown in the diagram below.



The magnetic flux through the coil is closest to

A. 0 Wb

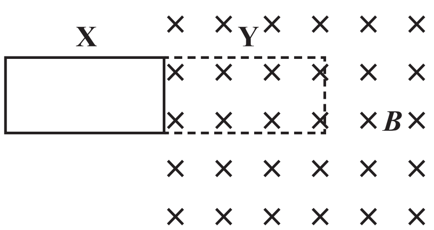
B. 3.0×10^{-5} Wb

C. 6.0×10^{-4} Wb

D. 3.0×10^{-1} Wb

✓**Question 6**

A single loop of wire moves into a uniform magnetic field B of strength 3.5×10^{-4} T over time $t = 0.20$ s from point X to point Y, as shown in the diagram below. The area A of the loop is 0.05 m^2.



The magnitude of the average induced EMF in the loop is closest to

A. 0 V

B. 3.5×10^{-6} V

C. 8.8×10^{-5} V

D. 8.8×10^{3} V

✓**Question 7**

An ideal transformer has an input DC voltage of 240 V, 2000 turns in the primary coil and 80 turns in the secondary coil.

The output voltage is closest to

A. 0 V

B. 9.6 V

C. 6.0×10^{3} V

D. 3.8×10^{7} V

SECTION A – continued

✓**Question 5** (9 marks)

A rectangular wire loop with dimensions 0.050 m × 0.035 m is placed between two magnets that create a uniform magnetic field of strength 0.2 mT. The loop is rotated with a frequency of 50 Hz in the direction shown in Figure 4. The ends of the loop are connected to a split-ring commutator to create a DC generator. The loop is initially in the position shown in Figure 4.

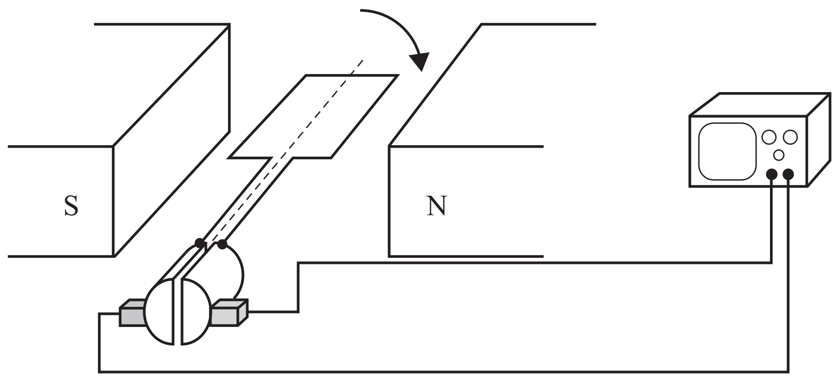


Figure 4

a. In which direction – clockwise or anticlockwise – will the induced current travel through the loop for the first quarter turn as seen from above? 1 mark

b. Calculate the average EMF measured in the loop for the first quarter turn. 3 marks

V

c. On the axes provided below, sketch the output EMF versus time, *t*, for the first two rotations. Include a scale on the horizontal axis. 3 marks

d. Suggest **two** modifications that could be made to the apparatus shown in Figure 4 that would increase the output EMF of the DC generator. 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.

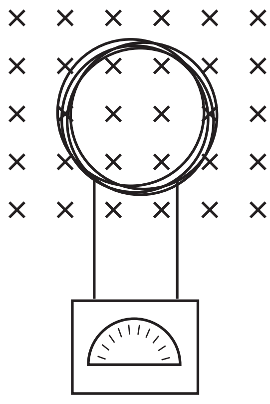


Figure 5a

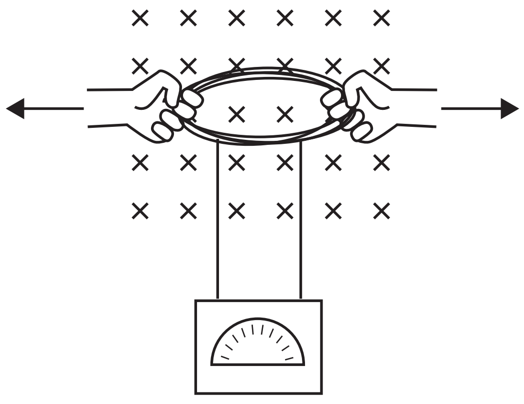


Figure 5b

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.

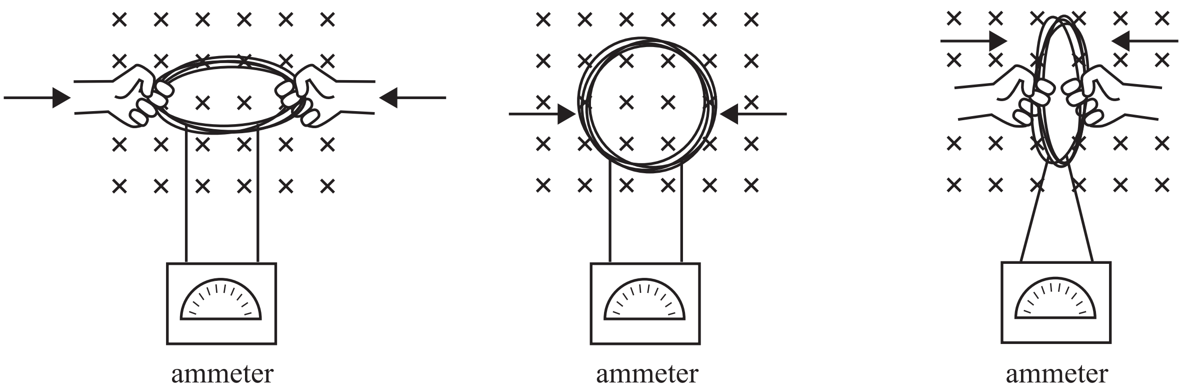


Figure 6a **Figure 6b** **Figure 6c**

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