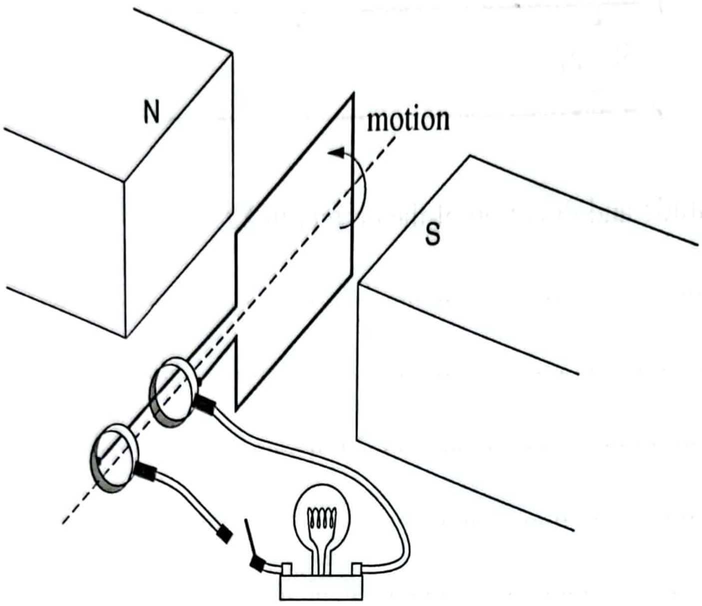
6.3 Electromagnetic induction

Multiple-choice questions: 1 mark each

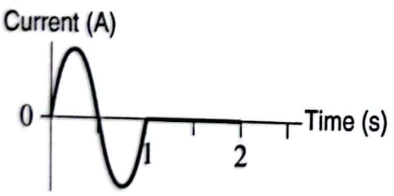
1. The diagram shows a generator circuit connected with a switch.



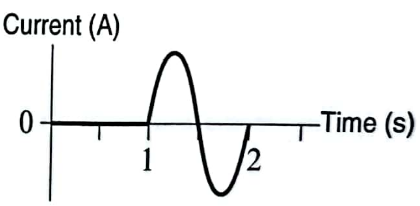
The generator is rotated by one revolution in the first second with the switch open. It is then rotated by one revolution in the next second with the switch closed.

Which graph shows the current produced by this generator for these two seconds?

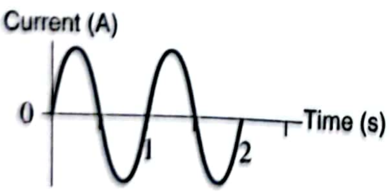
(A)



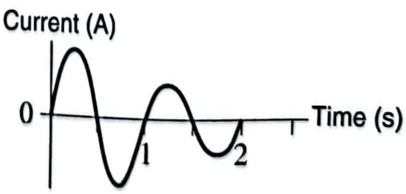
(B)



(C)



(D)

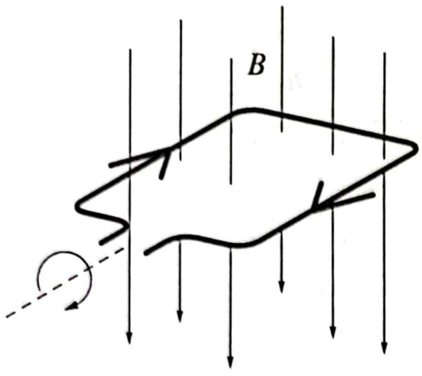


2014 HSC Q14

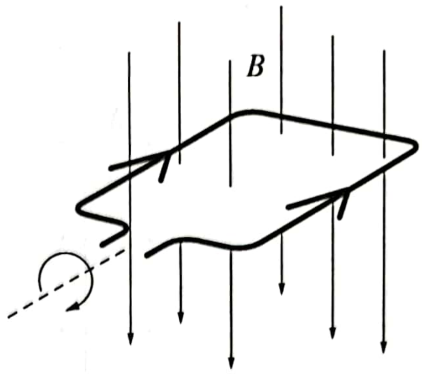
2. A single-turn coil of wire is placed in a uniform magnetic field B at right angles to the plane of the coil as shown in the diagrams. The coil is then rotated in a clockwise direction as shown.

Which of the following shows the direction of current flow in the coil as it begins to rotate?

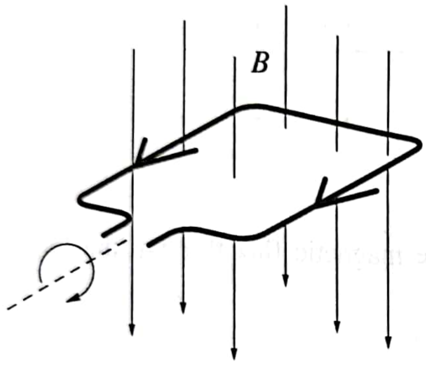
(A)



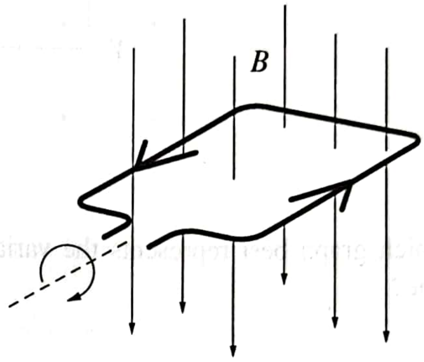
(B)



(C)

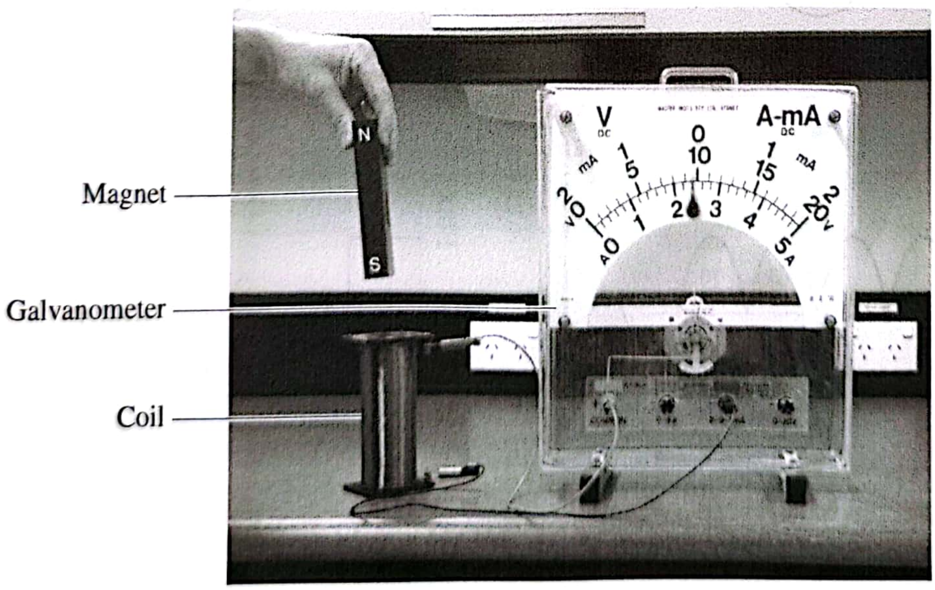


(D)



2005 HSC Q7

3. A student set up the equipment shown to carry out a first-hand investigation.



What was the student investigating?

(A) Gravity

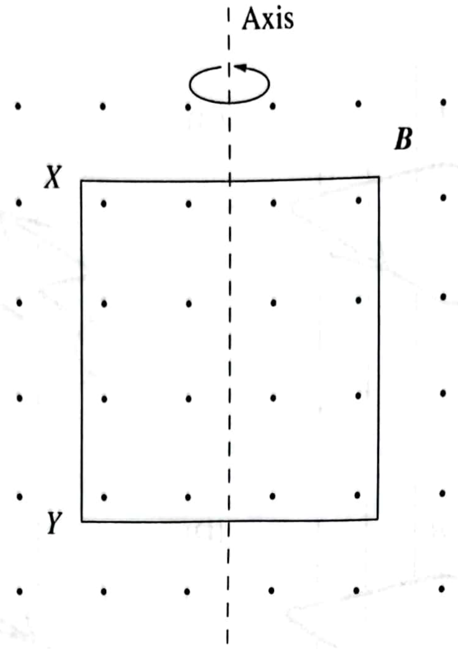
(B) The motor effect

(C) Electrostatic fields

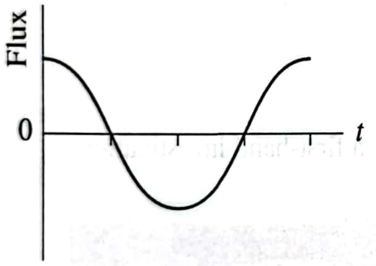
(D) Electromagnetic induction

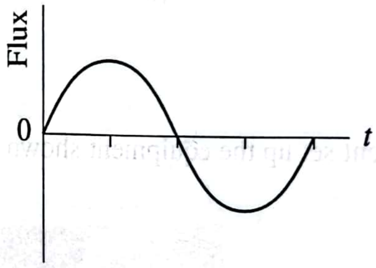
2011 HSC Q11 (adapted)

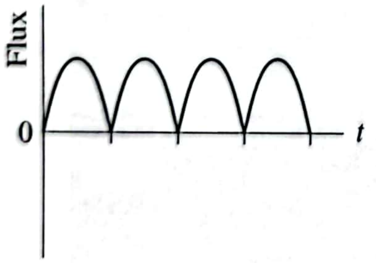
4. A square loop of wire, in a uniform magnetic field, is rotating at a constant rate about an axis as shown. The magnetic field is directed out of the plane of the page. At time $t = 0$ the plane of the loop is perpendicular to the magnetic field and side XY is moving out of the page.

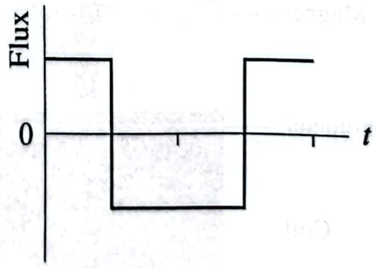


Which graph best represents the variation of the magnetic flux through the loop with time?

(A)


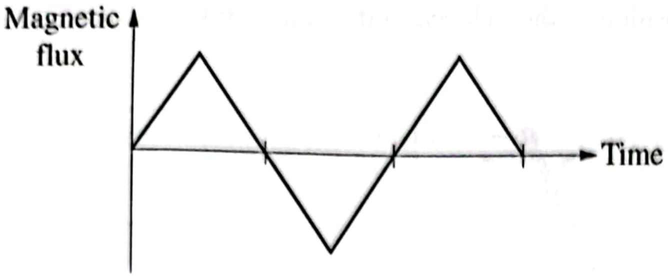
(B)


(C)


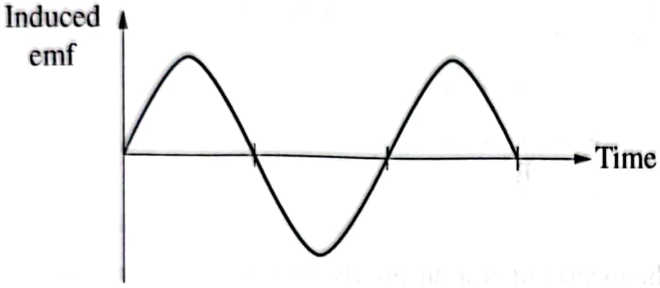
(D)


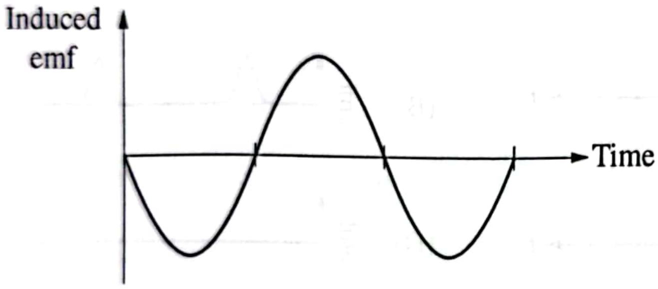
2006 HSC Q8

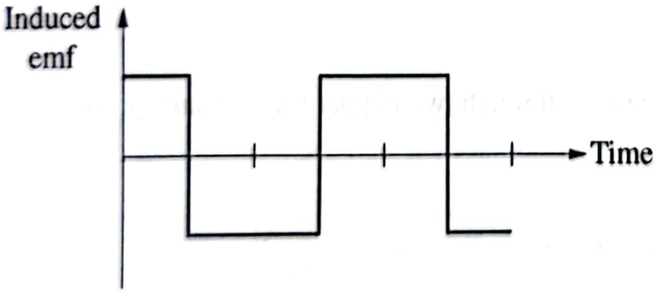
5. The variation in magnetic flux through a coil is shown below.

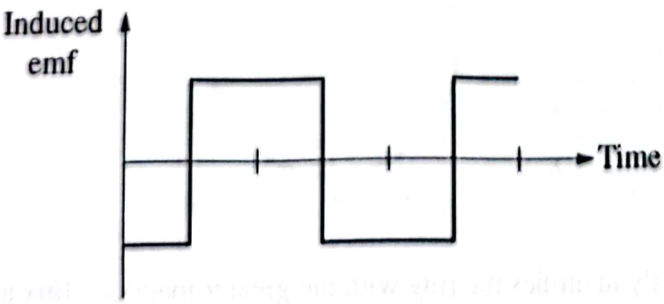


Which graph best represents the corresponding induced emf in the coil?

(A)


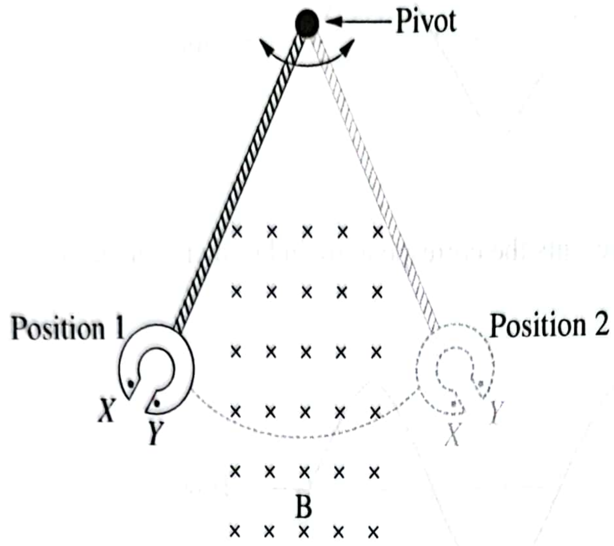
(B)


(C)


(D)


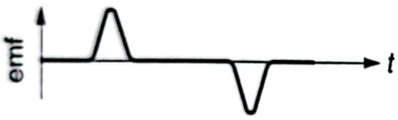
2007 HSC Q5

6. A heavy copper split ring is attached by a light insulating rod to a pivot to form a pendulum. A region of uniform magnetic field B is present as shown. As the pendulum swings from Position 1 to Position 2, the induced emf in the ring is measured between points *X* and *Y*.



Which graph best represents the measured emf during the time that the pendulum swings from Position 1 to Position 2?

(A)



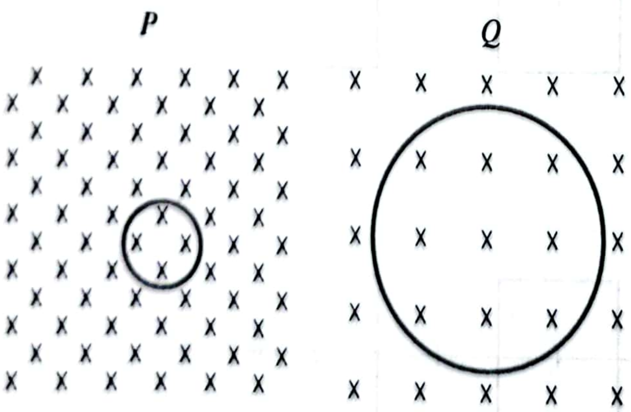
(B)

(C)

(D)

2011 HSC Q14

7. Different magnetic fields are passing through two copper rings, *P* and *Q*, as shown.



Which row of the table correctly identifies the ring with the greater magnetic flux and the ring with the greater magnetic flux density?

Question 7 continues

Question 7 (continued)

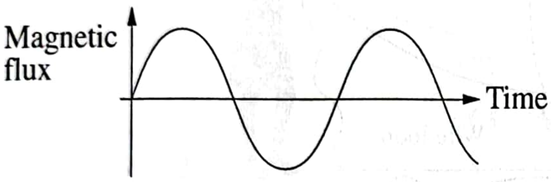
Which row of the table correctly identifies the ring with the greater magnetic flux and the ring with the greater magnetic flux density?

	Greater magnetic flux	*Greater magnetic flux density*
(A)	*P*	*P*
(B)	*Q*	*Q*
(C)	*P*	*Q*
(D)	*Q*	*P*

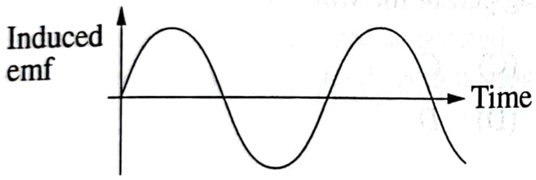
End of Question 7

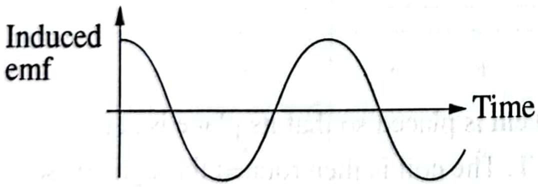
2013 HSC Q13

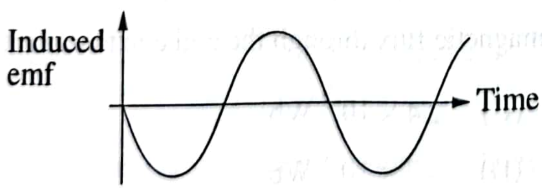
8. The graph shows variation in magnetic flux through a coil with time.

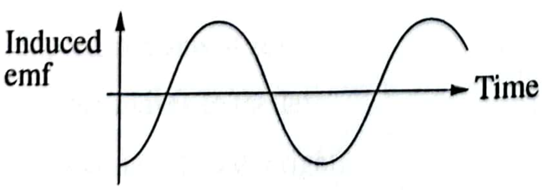


Which graph best represents the corresponding induced emf in the coil?

(A)


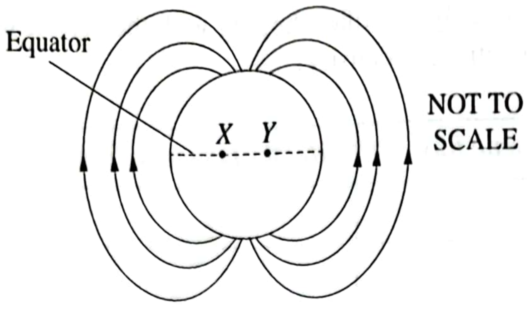
(B)


(C)


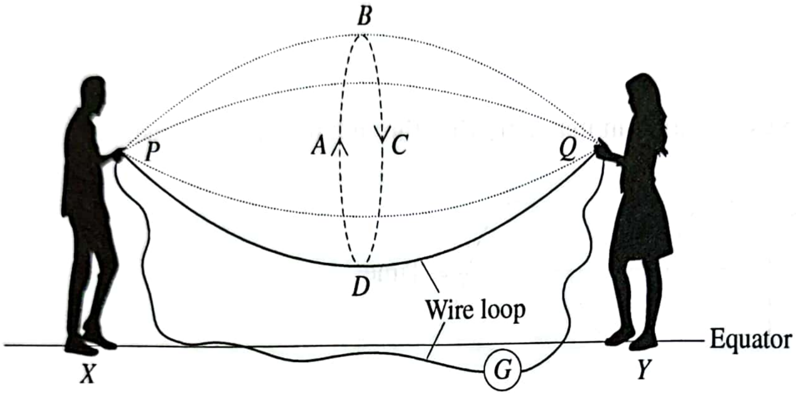
(D)


2012 HSC Q14

9. Earth's magnetic field is shown in the following diagram.



Two students standing a few metres apart on the equator at points X and Y, where Earth's magnetic field is parallel to the ground, hold a loop of copper wire between them. Part of the loop is rotated like a skipping rope as shown, while the other part remains motionless on the ground.



At what point during the rotation of the wire does the maximum current flow in a direction from P to Q through the moving part of the wire?

(A) A
(B) B
(C) C
(D) D

2017 HSC Q19

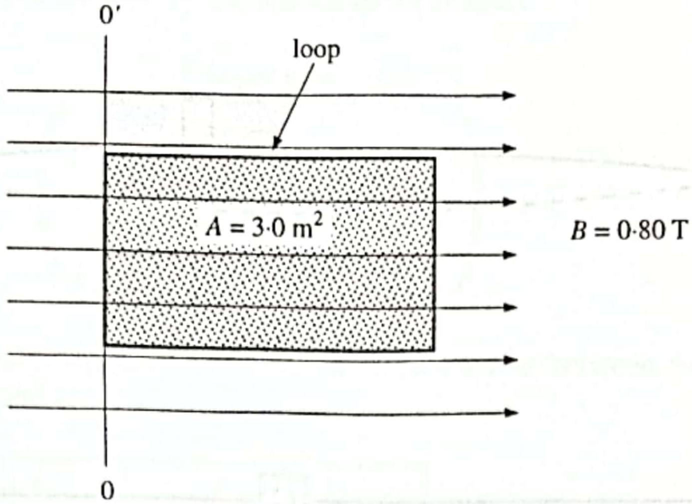
10. A circular coil of wire with diameter 5.0 cm is placed so that its plane is at right angles to a magnetic field of flux density 3.0×10^{-3} T. The coil is then rotated through 90° so that its plane is parallel to the magnetic field.

What is the magnitude of the change of magnetic flux through the coil due to this rotation?

(A) 5.9×10^{-6} Wb
(B) 1.2×10^{-5} Wb
(C) 2.4×10^{-5} Wb
(D) 4.7×10^{-5} Wb

1997 HSC Q12

11. A rectangular loop of area 3.0 m^2 is placed in a uniform magnetic field of 0.80 T. The plane of the loop is parallel to the field direction, as shown below.



The loop is rotated 60° about the axis 0—0′.

Which of these answers is closest to the magnitude of the change in the magnetic flux through the loop?

(A) 2.4 Wb

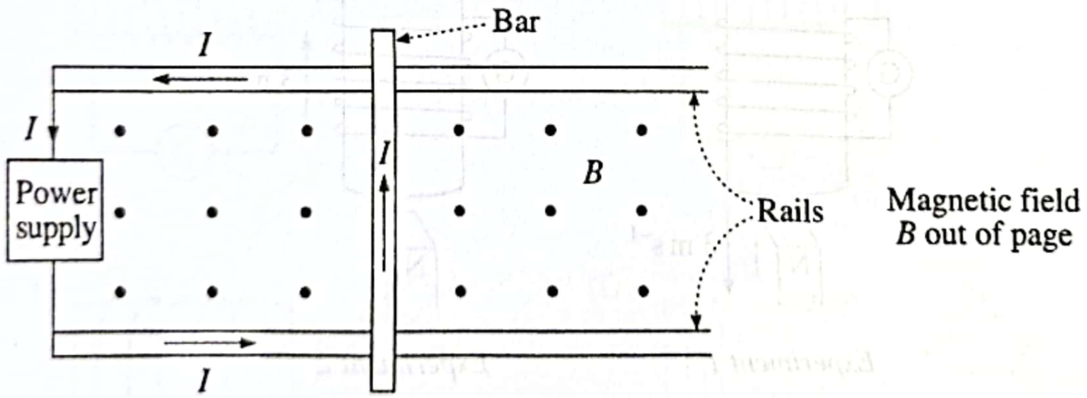
(B) 2.1 Wb

(C) 1.2 Wb

(D) zero

1998 HSC Q11 (adapted)

12. A rectangular bar makes electrical contact with parallel metal rails and is able to move freely. This arrangement is within a uniform magnetic field that is perpendicular to the rails as shown below. The rails are connected to a power supply at one end. A current I is passed around the circuit in the direction shown. The bar is at rest before the current is switched on.



When the current is switched on, which of the following best describes the initial motion of the bar?

(A) The bar remains at rest.

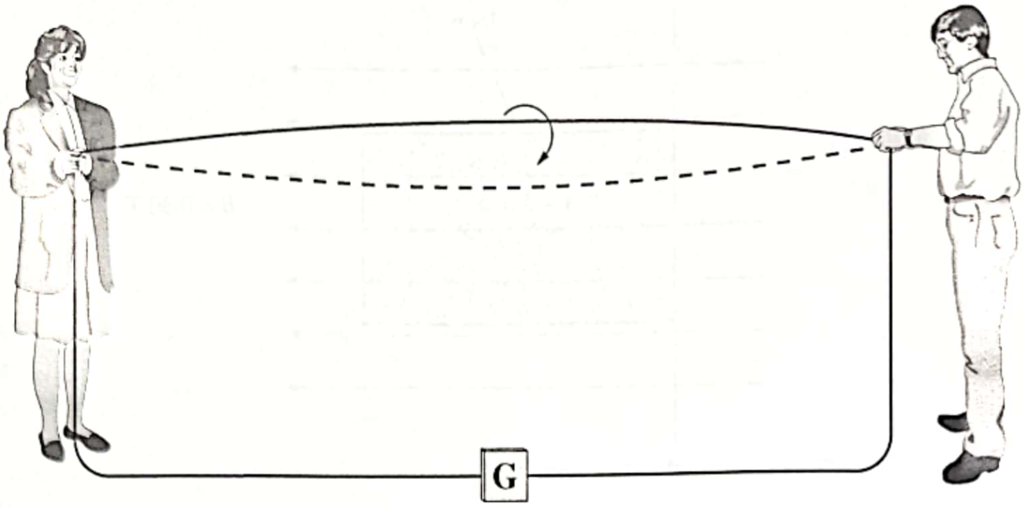
(B) The bar moves to the left.

(C) The bar moves to the right.

(D) The bar rotates.

1998 HSC Q13 (adapted)

13. In a particular experiment a long length of copper wire of very low resistance is rotated by two students. The ends of the wire are connected to a galvanometer, G, and a current is detected.



Which of the following is LEAST likely to affect the amount of current produced?

(A) The length of the rotating wire

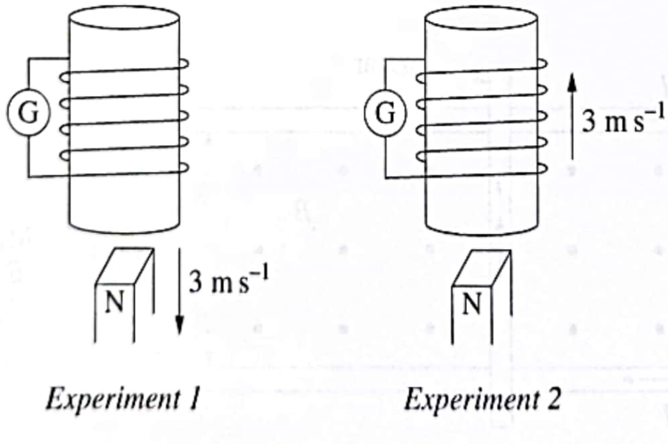
(B) The thickness of the rotating wire

(C) The speed with which the wire is rotated

(D) Whether the wire is oriented north-south or east-west

2005 HSC Q6

14. The diagram shows two experiments. In *Experiment 1*, the magnet is moved away from the coil. In *Experiment 2*, the coil is moved away from the magnet.



Why is the same electromotive force (emf) produced in both experiments?

(A) Energy is conserved.

(B) The motor effect generates the same force.

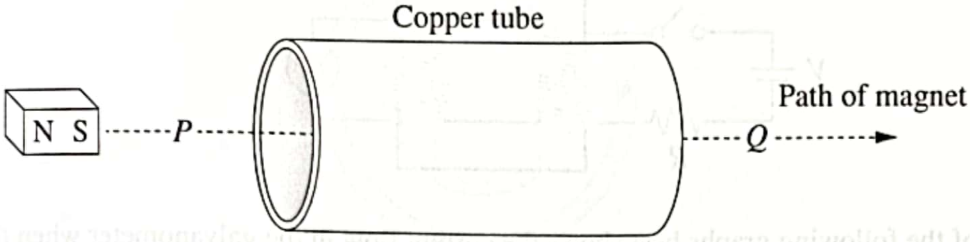
(C) The relative motion between the coil and the magnet is the same.

(D) Both the direction of the magnetic field and the direction of the motion change.

2014 HSC Q10

15. A magnet passes through a copper tube at constant velocity along the path shown.

A current is induced in the tube by the motion of the magnet.



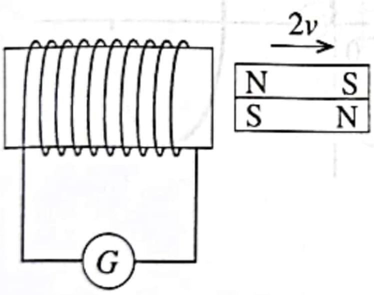
Which row of the table correctly describes the forces acting between the tube and the magnet at points P and Q?

	Force at P	*Force at Q*
(A)	Attraction	Repulsion
(B)	Repulsion	Attraction
(C)	Attraction	Attraction
(D)	Repulsion	Repulsion

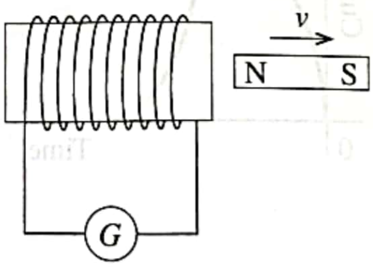
2016 HSC Q7

16. Which movement of the magnet(s) will produce the greatest deflection of the galvanometer?

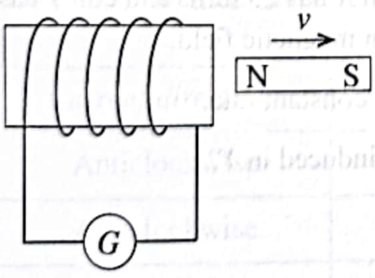
(A)



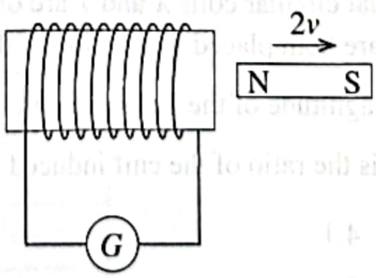
(B)



(C)

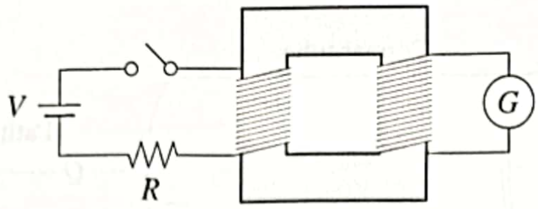


(D)



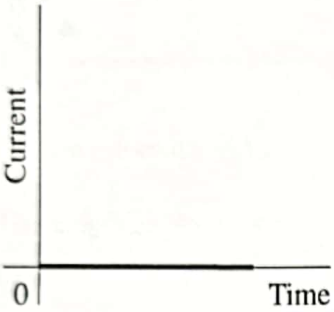
2016 HSC Q8

17. The primary coil of a transformer is connected to a battery, a resistor and a switch. The secondary coil is connected to a galvanometer.

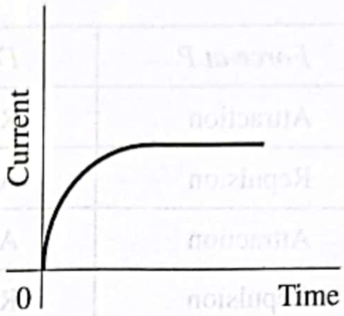


Which of the following graphs best shows the current flow in the galvanometer when the switch is closed?

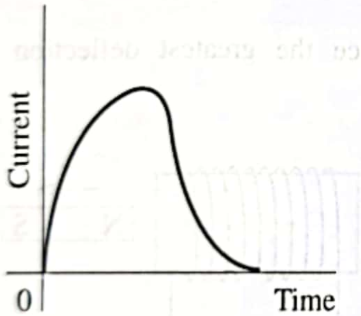
(A)



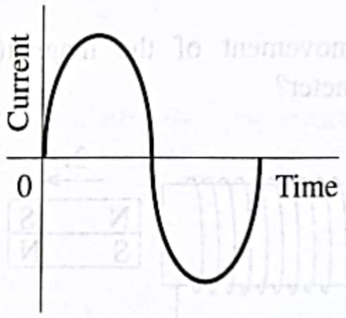
(B)



(C)



(D)



2005 HSC Q8

18. Two flat circular coils X and Y are of equal area. Coil X has 25 turns and coil Y has 100 turns. They are both placed in a region of the same uniform magnetic field.

The magnitude of the field strength is decreased at a constant rate.

What is the ratio of the emf induced in X to the emf induced in Y?

(A) 4:1

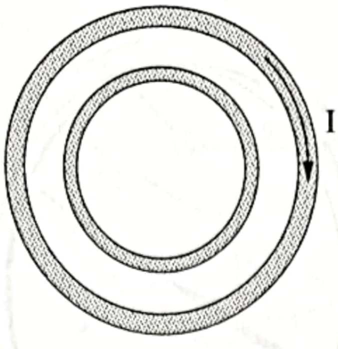
(B) 2:1

(C) 1:1

(D) 1:4

1984 HSC Q9

19. Two copper rings lie in the same plane as shown.



An increasing current flows clockwise around the outer ring.

What happens in the inner ring?

(A) A decreasing clockwise current flows.

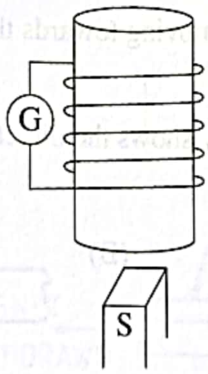
(B) A decreasing anticlockwise current flows.

(C) An increasing clockwise current flows.

(D) An increasing anticlockwise current flows.

2010 HSC Q11

20. The diagram shows a magnet moving upward into a coil.

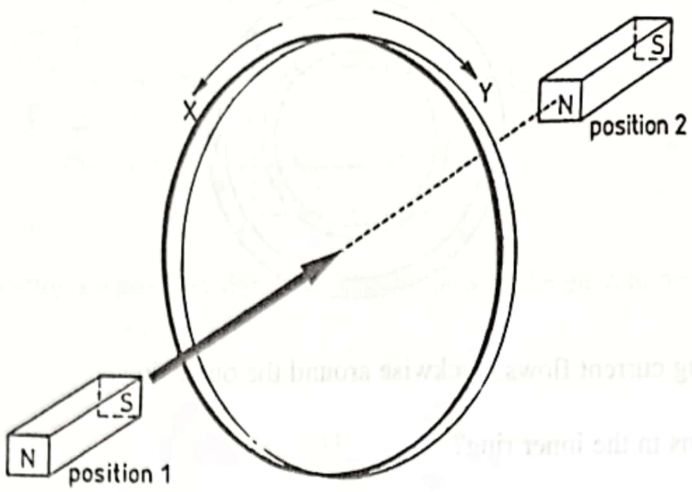


Which row of the table correctly identifies the direction of the induced current as viewed from the top, and the direction of the magnetic field inside the coil?

	Current direction	*Magnetic field direction*
(A)	Anticlockwise	↓
(B)	Anticlockwise	↑
(C)	Clockwise	↑
(D)	Clockwise	↓

2014 HSC Q7

21. A bar magnet is moved in a straight line from position 1 to position 2 through a copper ring, as shown below.



As the magnet moves from position 1 to position 2, in what direction does the current induced in the ring flow?

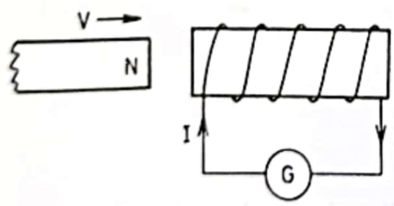
(A) X, then Y
(B) Y, then X
(C) X throughout
(D) Y throughout

1990 HSC Q10 (adapted)

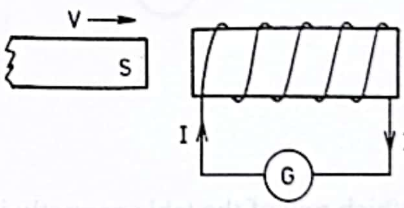
22. A permanent magnet near a coil is either moving towards the coil with velocity v or is stationary ($v = 0$).

Which of the following diagrams correctly shows the direction of the current in the coil?

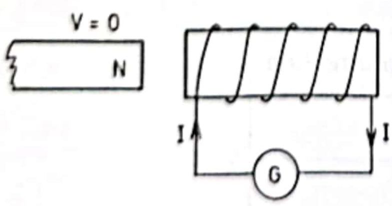
(A)



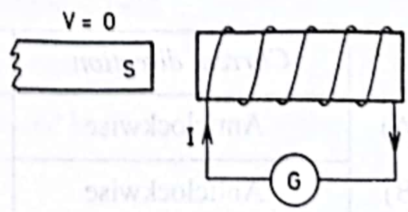
(B)



(C)

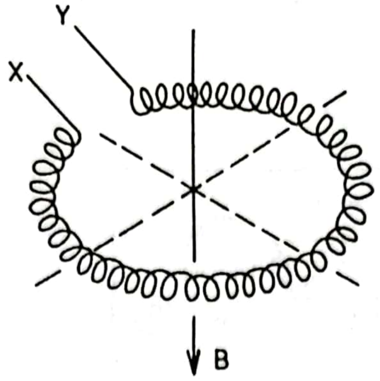


(D)



1986 HSC Q9 (adapted)

23. A circular loop of coiled wire with an area of $0.50\ m^2$ is placed in a uniform magnetic field of 2.30 T, perpendicular to the plane of the loop as shown below.



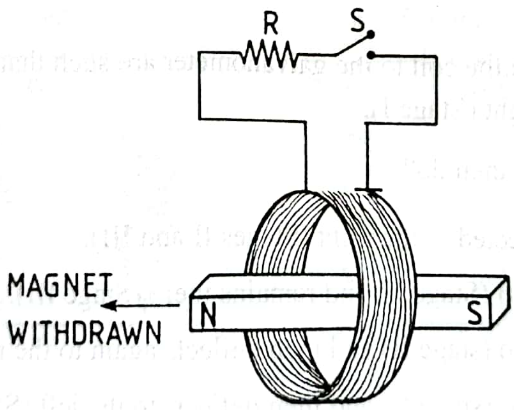
The area enclosed by the loop is then decreased from $0.50\ m^2$ to $0.20\ m^2$ in a time of 0.30 s.

As a result, what is the average emf induced across the terminals X and Y?

(A) 0.10 volt
(B) 1.00 volt
(C) 1.15 volt
(D) 2.30 volt

1986 HSC Q10

24. A bar magnet is placed at the centre of a large coil. The coil is connected with a switch, S, and a resistor, R, as shown below.



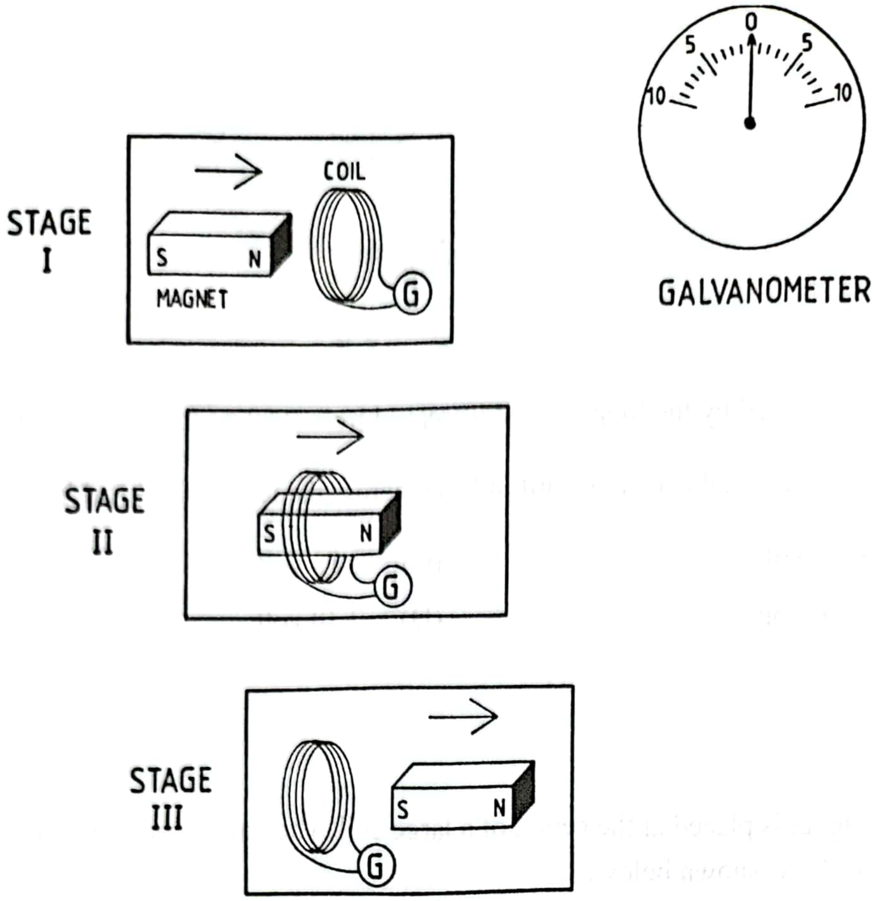
The magnet is withdrawn HSC Quickly from the coil in the direction shown by the arrow in the diagram.

What is the amount of energy required to remove the magnet?

(A) Zero, whether the switch is open or closed.
(B) Non-zero, but the same whether the switch is open or closed.
(C) More if the switch is opened than if it is closed.
(D) More if the switch is closed than if it is open.

1984 HSC Q10 (adapted)

25. The diagrams below show three stages (I, II and III) in the [illegible] speed through a coil of many turns. The coil is connected to a sensitive galvanometer (G) whose needle is in a central-zero position when no current flows.



The connections from the coil to the galvanometer are such that the needle of the galvanometer first deflects to the right (Stage I).

What does the needle then do?

(A) Remains deflected to the right (Stages II and III).

(B) Returns to zero (Stage II) and remains there (Stage III).

(C) Returns to zero (stage II) and then deflects again to the right (Stage III).

(D) Returns to zero (stage II) and then deflects to the left (Stage III).

1983 HSC Q10

26. What is an essential requirement for the operation of a step-down transformer?

(A) A laminated iron core

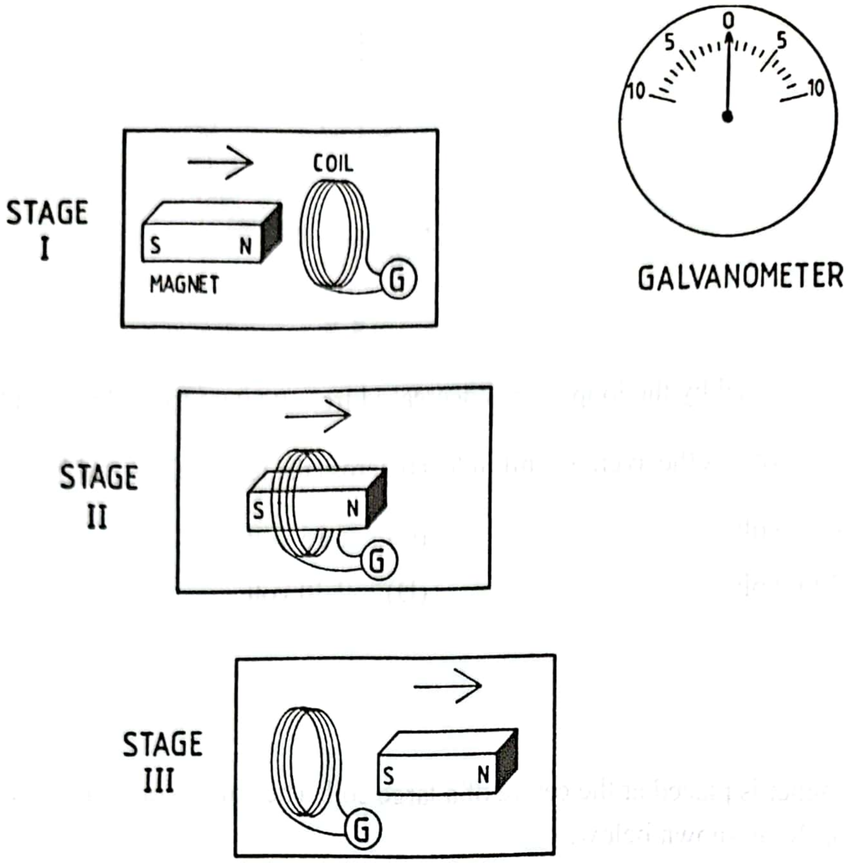
(B) A non-conducting core

(C) A magnetic interaction between the primary and secondary coils

(D) An electrical connection between the primary and secondary coils

2009 HSC Q8

25. The diagrams below show three stages (I, II and III) in the movement of a magnet at constant speed through a coil of many turns. The coil is connected to a sensitive galvanometer (G) whose needle is in a central-zero position when no current flows.



The connections from the coil to the galvanometer are such that the needle of the galvanometer first deflects to the right (Stage I).

What does the needle then do?

(A) Remains deflected to the right (Stages II and III).

(B) Returns to zero (Stage II) and remains there (Stage III).

(C) Returns to zero (stage II) and then deflects again to the right (Stage III).

(D) Returns to zero (stage II) and then deflects to the left (Stage III).

1983 HSC Q10

26. What is an essential requirement for the operation of a step-down transformer?

(A) A laminated iron core

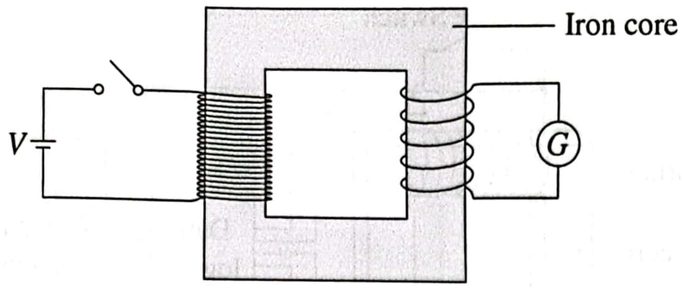
(B) A non-conducting core

(C) A magnetic interaction between the primary and secondary coils

(D) An electrical connection between the primary and secondary coils

2009 HSC Q8

27. The diagram shows an ideal transformer.



When the switch is closed, the pointer on the galvanometer deflects.

How could the size of the deflection be increased?

(A) Decrease the number of primary coils

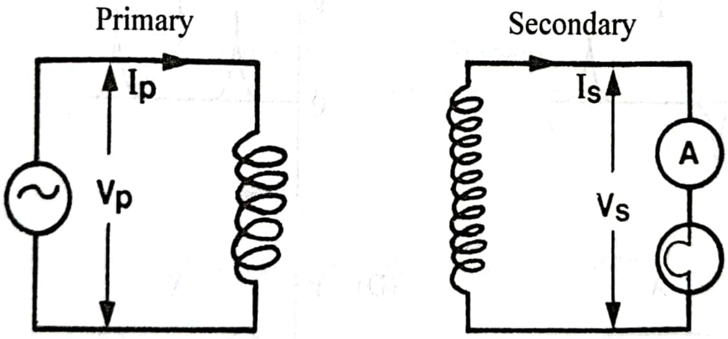
(B) Decrease the number of secondary coils

(C) Replace the iron core with a copper core

(D) Place a resistor in series with the galvanometer

2015 HSC Q18

28. The diagram below represents an ideal transformer with more turns of wire in the secondary coil than the primary coil.



The voltage across the primary coil is V_P

The voltage across the secondary coil is V_S

The current flowing in the primary coil is I_P

The current flowing in the secondary coil is I_S

Which of the following statements is correct?

(A) $I_P < I_S \quad V_P < V_S$

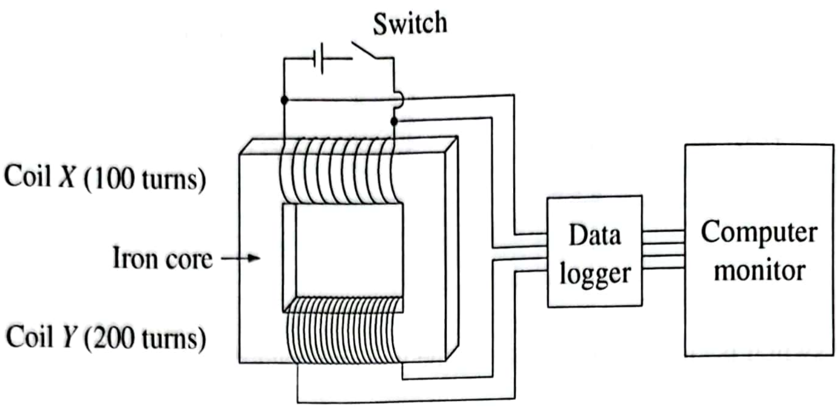
(B) $I_P > I_S \quad V_P < V_S$

(C) $I_P < I_S \quad V_P > V_S$

(D) $I_P > I_S \quad V_P > V_S$

Adapted 1985 HSC Q10

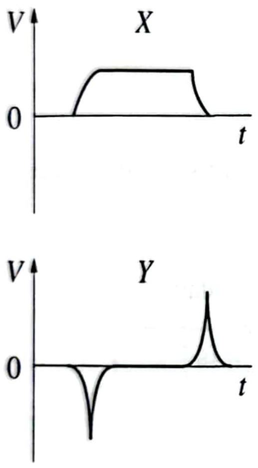
29. The apparatus shown is designed to investigate the operation of a transformer.



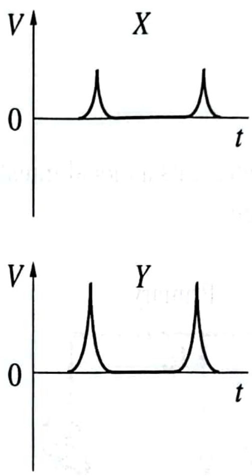
A student closes the switch for a short time, then opens it. The data logger records values of voltage for both coils for the duration of the investigation. The data logger software displays the results as a pair of voltage–time graphs on a computer monitor.

Which pair of graphs best depicts the student's results?

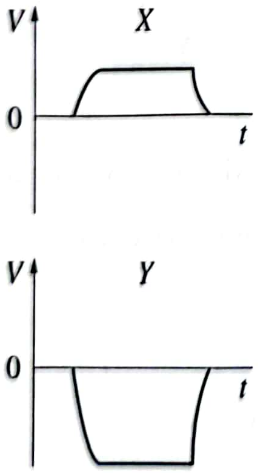
(A)



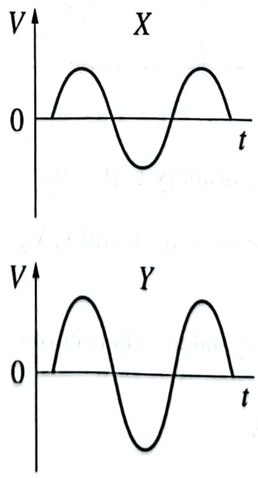
(B)



(C)

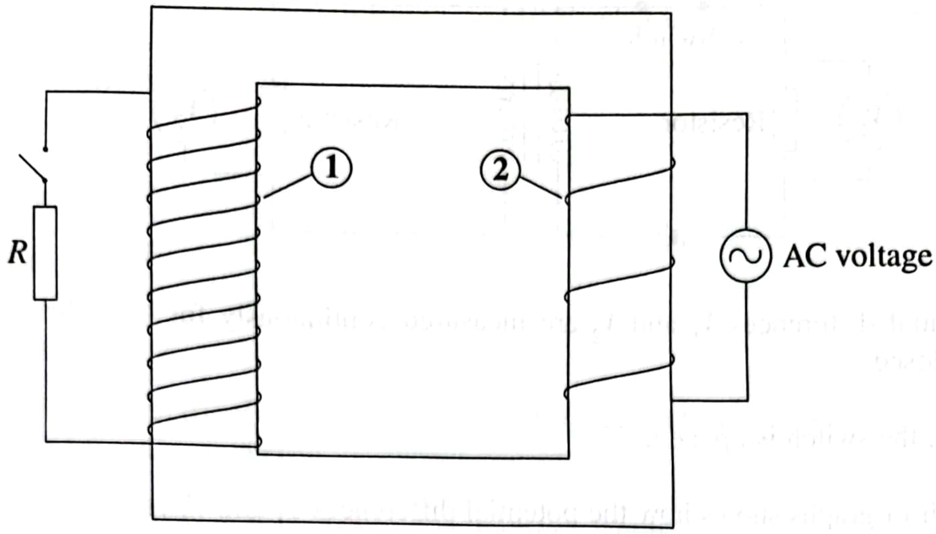


(D)



2006 HSC Q10

30. The diagram shows a model of a transformer in a circuit.



Which of the following correctly identifies Part 1 and Part 2 and the function of this transformer?

	Part 1	*Part 2*	*Function of transformer*
(A)	Primary coil	Secondary coil	Step-up
(B)	Secondary coil	Primary coil	Step-down
(C)	Primary coil	Secondary coil	Step-down
(D)	Secondary coil	Primary coil	Step-up

2010 HSC Q10

31. Which law best applies to the operation of an electrical transformer?

(A) Conservation of Mass

(B) Conservation of Energy

(C) Conservation of Charge

(D) Conservation of Momentum

2011 HSC Q5

32. AC electricity transmitted at 33,000 V is required for use at 240 V.

What would be the primary/secondary turns ratio for a transformer that would do this?

(A) $\frac{33{,}000}{240}$

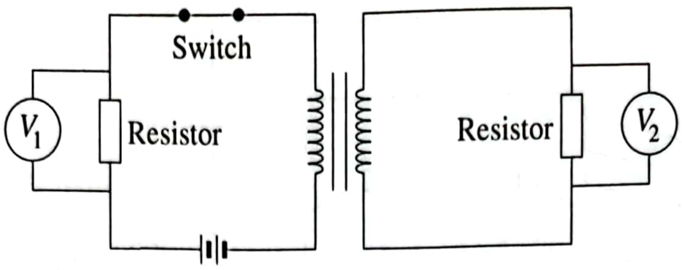
(B) $\frac{240}{33{,}000}$

(C) $240 \times 33{,}000$

(D) $\frac{33{,}000}{1}$

1989 HSC Q9

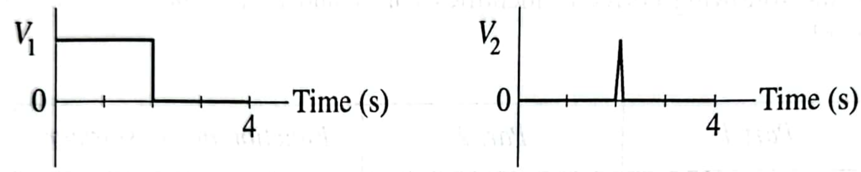
33. The diagram shows a DC circuit containing a transformer.

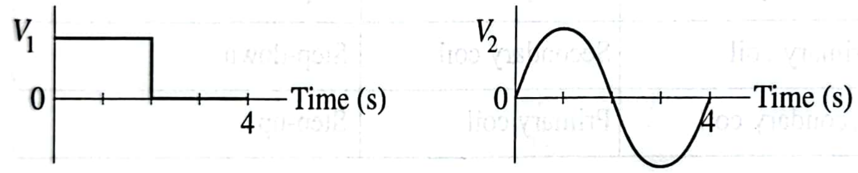


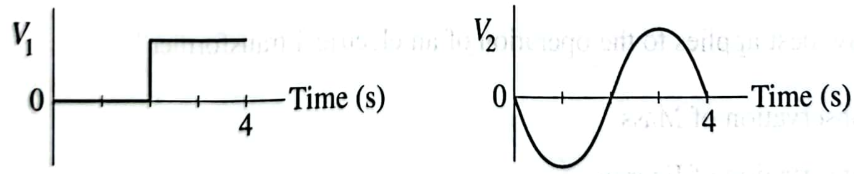
The potential differences V_1 and V_2 are measured continuously for 4 s. The switch is initially closed.

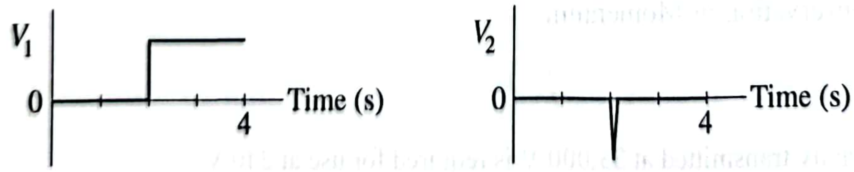
At $t = 2$ s, the switch is opened.

Which pair of graphs shows how the potential differences V_1 and V_2 vary with time over the 4-second interval?

A. 

B. 

C. 

D. 

2017 HSC Q14

34. A transformer has a primary coil with 60 turns and a secondary coil with 2300 turns.

If the primary voltage to the transformer is 110 V, what is the secondary voltage?

(A) 2.4×10^{-4} V

(B) 2.4×10^{2} V

(C) 1.3×10^{3} V

(D) 4.2×10^{3} V

2001 HSC Q11

35. Why do some electrical appliances in the home need a transformer instead of operating directly from mains power?

(A) They require a voltage lower than the mains voltage.

(B) They require a source of energy that is DC rather than AC.

(C) They require an alternating current at a frequency other than 50 Hz.

(D) They consume less energy than a similar device without a transformer.

2004 HSC Q7

36. A transformer which has 60 turns in the primary coil is used to convert an input of 3 V into an output of 12 V.
Which description best fits this transformer?

	Type of transformer	*Number of turns in secondary coil*
(A)	Step up	15
(B)	Step down	240
(C)	Step up	240
(D)	Step down	15

2004 HSC Q8

37. A neon sign requires a 6000 V supply for its operation. A transformer allows the neon sign to operate from a 240 V supply.

What is the ratio of the number of secondary turns to the number of primary turns for the transformer?

(A) 1 : 40

(B) 1 : 25

(C) 25 : 1

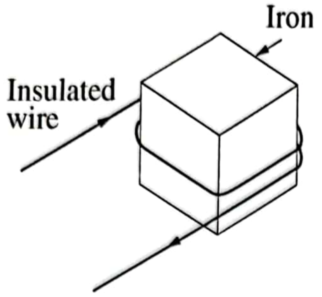
(D) 40 : 1

2003 HSC Q8

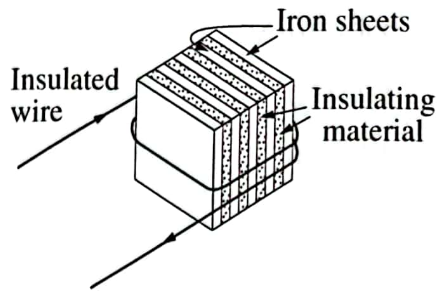
38. A transformer is to be designed so that it is efficient, with heating by eddy currents minimised. The designer has some iron and insulating material available to build the transformer core. The windings are to be made with insulated copper wire.

Which of the following designs minimises the energy losses in the core?

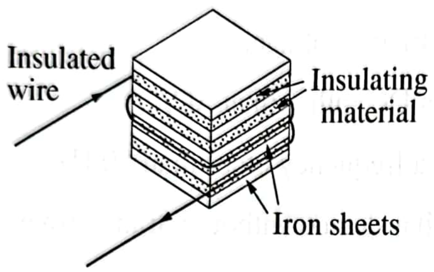
(A)



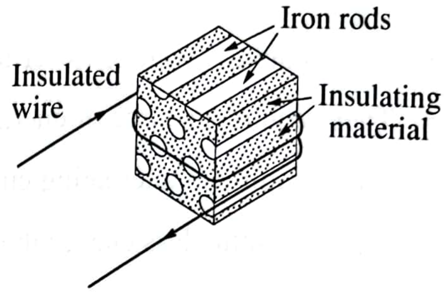
(B)



(C)



(D)



2005 HSC Q10

39. Eddy currents are a major source of energy loss in an iron core transformer.

What is one way to minimise this energy loss?

(A) Laminate the iron core with an insulator

(B) Put fewer turns of wire in the primary coil

(C) Operate the transformer with a higher current

(D) Decrease the distance between the primary and secondary coils

2013 HSC Q7

40. Some mobile phones are recharged at a power point using a charger that contains a transformer.

What is the purpose of the transformer?

(A) To convert AC at the power point to DC

(B) To convert DC at the power point to AC

(C) To increase the AC voltage at the power point

(D) To decrease the AC voltage at the power point

2016 HSC Q1

41. Why is an iron core used in a transformer?

(A) To limit eddy currents

(B) To reduce the heat generated

(C) To separate the magnetic fields

(D) To increase the linkage of the flux

2014 HSC Q8

42. The cathode ray tube and transistor circuits in a conventional television rely on transformers.

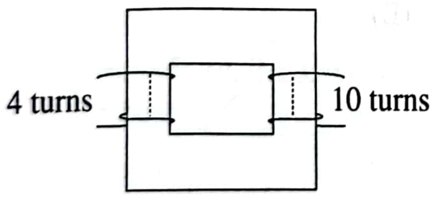
What transformation of the 240 V AC input voltage do these components require?

	Cathode ray tube	*Transistor circuits*
(A)	Step-up	Step-down
(B)	Step-down	Step-up
(C)	Step-up	Step-up
(D)	Step-down	Step-down

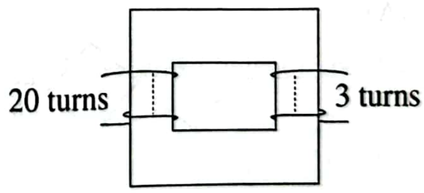
2008 HSC Q10

43. Which of the following ideal transformers could be used to convert an input voltage of 20 volts AC to an output voltage of 2 volts AC?

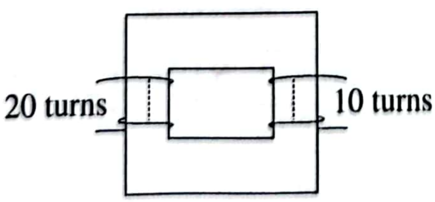
(A)



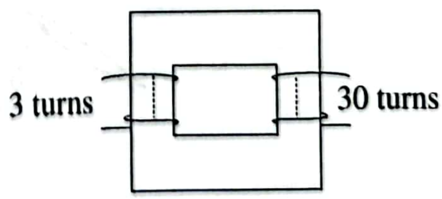
(B)



(C)



(D)



2012 HSC Q10

44. What is the role of a transformer at an electrical power station?

(A) To reduce heating in the transmission lines by stepping up the voltage

(B) To reduce heating in the transmission lines by stepping up the current

(C) To increase heating in the transmission lines by stepping up the voltage

(D) To increase heating in the transmission lines by stepping up the current

2002 HSC Q6

45. Why is high voltage used to transmit electrical energy from power stations to users?

(A) It helps to protect the system from lightning strikes.

(B) It allows the supporting structures to have smaller insulators.

(C) It minimises the effects of the electrical resistance of the wires.

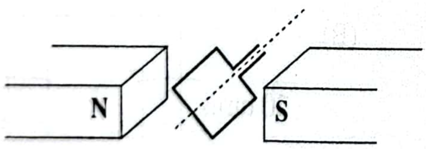
(D) It ensures that, even with voltage losses, 240 V will still reach the user.

2010 HSC Q9

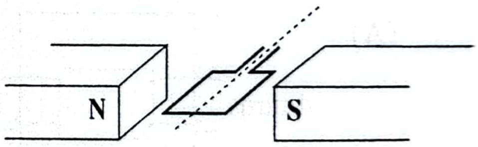
46. A coil of wire is in a uniform magnetic field between two magnets. The coil of wire is rotated about an axis.

In which of the following diagrams is the magnetic flux through the coil greatest?

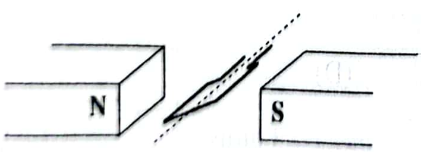
(A)



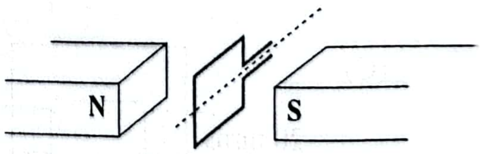
(B)



(C)



(D)



1999 HSC Q12

47. Two straight metal rods, P and Q, have the same length. They are each pivoted at one end and rotated with the same angular velocity so that they sweep out horizontal circular paths as shown in diagrams X and Y. A constant current I is flowing along each rod, as shown.

In diagram X, a constant magnetic field is applied *at right angles to the plane* of the circular path. In diagram Y, a uniform magnetic field of the same magnitude is applied *in the plane* of the circular path.

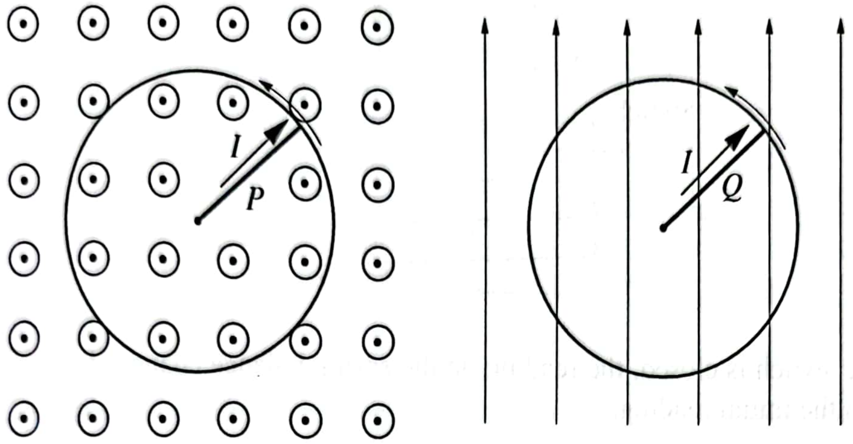


Diagram X Diagram Y

Which of the following statements about the forces acting on rod P and rod Q is correct?

(A) The magnitude of the force on P is exactly the same as the magnitude of the force on Q at all times.

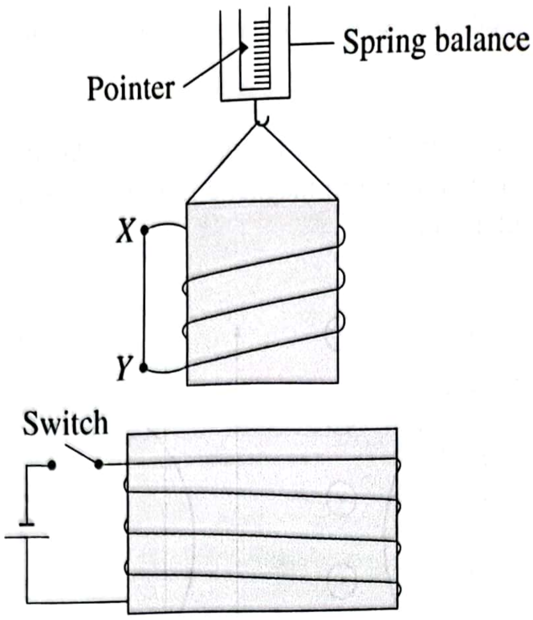
(B) The magnitude of the force on P is constant and the magnitude of the force on Q is zero.

(C) The magnitude of the force on P is constant and the magnitude of the force on Q varies with time.

(D) The magnitude of the force on P varies with time and the magnitude of the force on Q is constant.

2001 HSC Q14

48. An experiment is set up as shown.



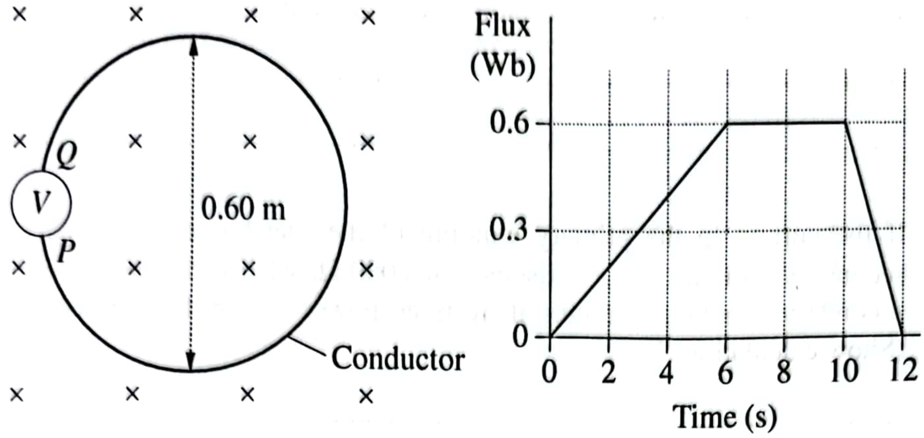
When the switch is closed, the reading on the spring balance changes immediately, then returns to the initial reading.

Which row of the table correctly shows the direction of the current through the straight conductor XY and the direction in which the pointer on the spring balance initially moves?

	Direction of current through the straight conductor	*Direction in which the pointer initially moves*
A.	From X to Y	Down
B.	From X to Y	Up
C.	From Y to X	Down
D.	From Y to X	Up

2018 HSC Q18

49. The diagram shows an electric circuit in a magnetic field directed into the page. The graph shows how the flux through the conductive loop changes over a period of 12 seconds.



(a) Calculate the maximum magnetic field strength within the stationary loop during the 12-second interval.

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(b) Calculate the maximum voltage generated in the circuit by the changing flux. In your answer, indicate the polarity of the terminals *P* and *Q* when this occurs.

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2017 HSC Q27 – 2 + 3 = 5 marks

50. The primary winding of a transformer contains 2000 turns. The primary AC voltage is 23 000 volts and the output voltage is 660 000 volts.

(a) Calculate the number of turns on the secondary winding.

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(b) If the current in the primary winding of the transformer is 100 A, and the secondary winding has a resistance of 2000 Ω, what is the power loss in the secondary winding, assuming there is no power loss in the primary winding? (Show calculations.)

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2014 HSC Q24 – 2 + 3 = 5 marks

51. The electrical supply network uses a.c. and a variety of transformers between the generating stations and the final consumer.

Explain why transformers are used at various points in the network.

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2001 HSC Q20 – 4 marks

52. (a) State Lenz's law.

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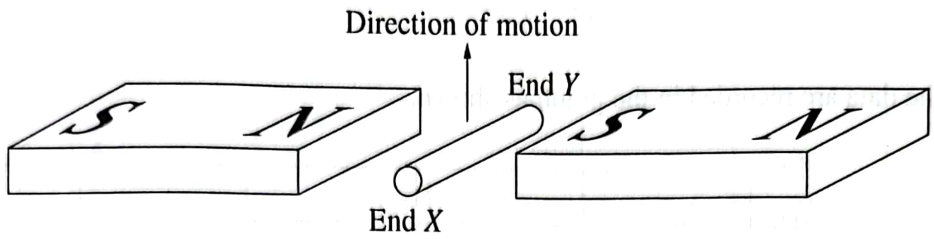
(b) When the metal rod is moved upwards through the magnetic field as shown in the diagram, an emf is induced between the two ends.



(i) Which end of the rod is negative?

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(ii) Explain how the emf is produced in the rod.

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(c) Explain how the principle of induction can be used to heat a conductor.

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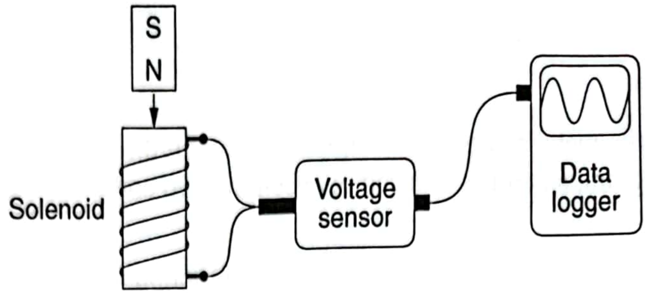
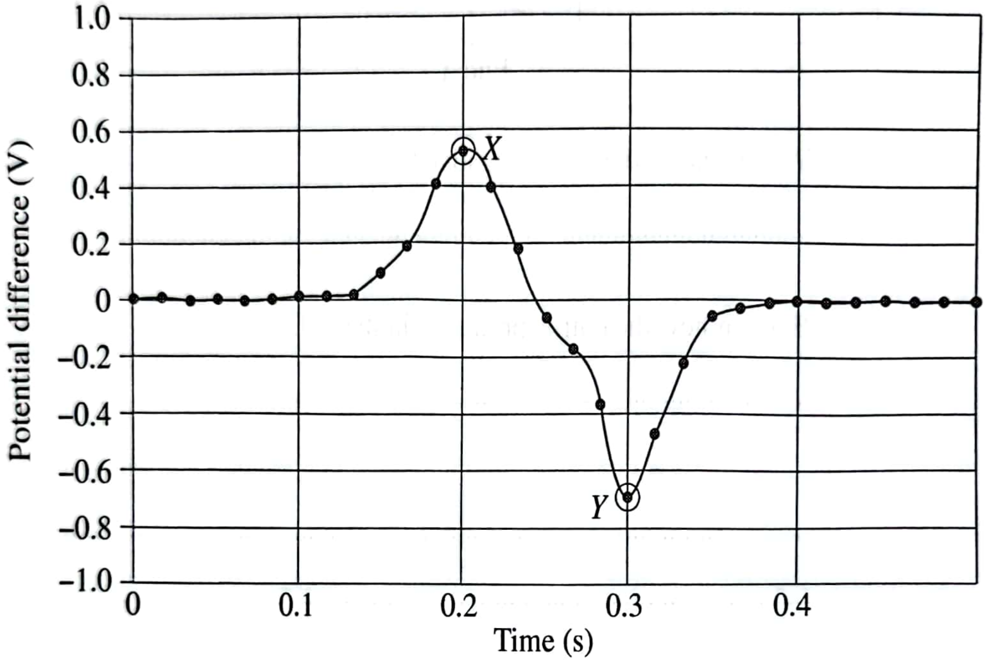
2002 HSC Q23 – 1 + 1 + 3 + 2 = 7 marks

53. A bar magnet is dropped through the centre of a solenoid connected to a data logger as shown.



The data are recorded in the graph as shown.



(a) Why is the magnitude of the potential difference at *Y* greater than at *X*?

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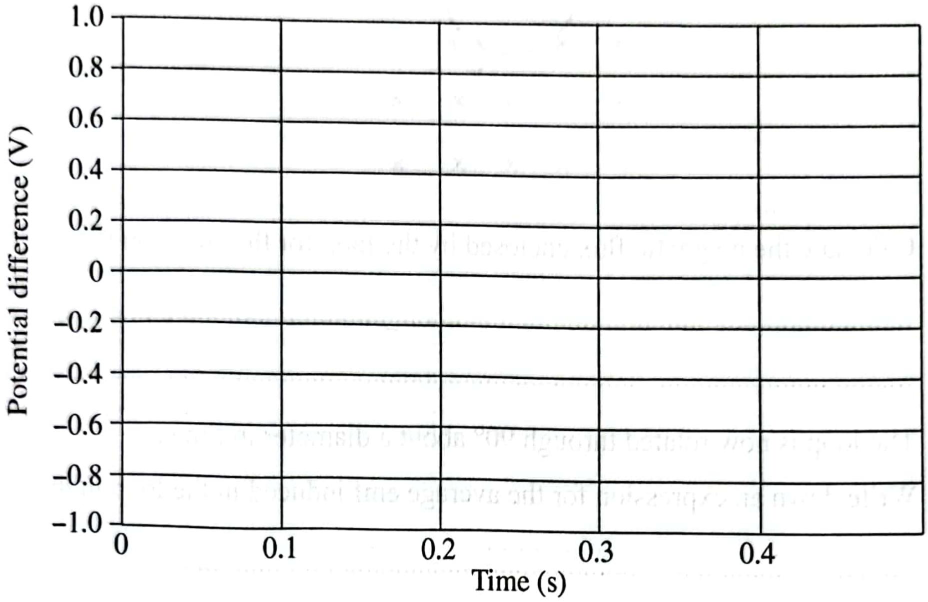
Question 53 continues

Question 53 (continued)

(b) The magnet is dropped again with two changes being made.

1. It is dropped from a greater height.
2. The south pole of the magnet is pointing down.

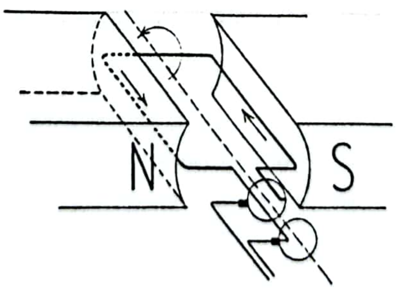
Sketch a graph that represents the most likely outcome of this new experiment.



End of Question 53

2010 HSC Q26 – 2 + 3 = 5 marks

54. As shown in the diagram below, an electric generator, in its simplest form, needs a rotating rectangular coil of conducting wire and one or more magnets.



(a) Describe how the magnetic flux through the coil changes as the coil rotates through one revolution.

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(b) Use Faraday's Law to explain the generation of an emf in the coil.

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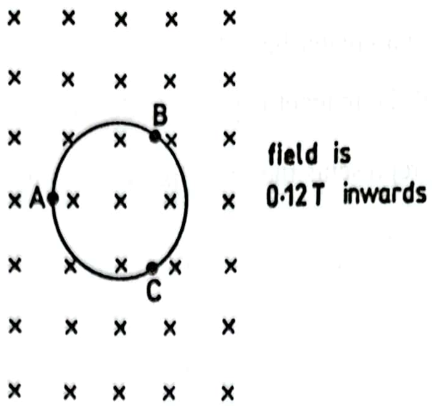
1987 HSC Q17 – 3 + 2 = 5 marks

55. A circular loop of wire of area 2.0×10^{-3} m^2 is placed with its plane perpendicular to a magnetic field of intensity 0.12 T, as shown below.



(a) Calculate the magnetic flux enclosed by the loop for the situation shown.

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(b) The loop is now rotated through 90° about a diameter in time t.

Write down an expression for the average emf induced in the loop in this time.

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1990 HSC Q23(a), (b) – 2 + 2 + 4 marks

56. Use a flowchart to show how electrical energy is transferred from a power station to its point of use.

2011 HSC Q26(a) – 3 marks

57. The diagram shows a label on a transformer used in an appliance.

Input:	240 V AC	5.0 A
Output:	2 kV AC	1.0 A

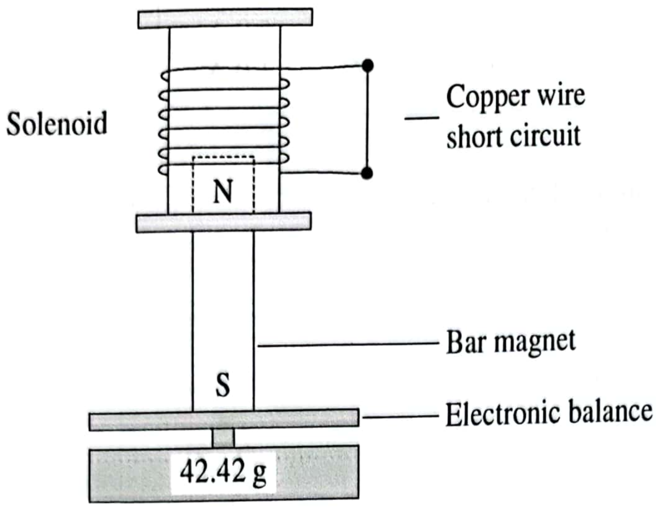
Explain why the information provided on the label is not correct. Support your answer with calculations.

2015 HSC Q25(b) – 3 marks

58. Explain how applications of transformers have affected society.

2016 HSC Q26 – 5 marks

59. A bar magnet is placed on a sensitive electronic balance as shown in the diagram. A hollow solenoid is held stationary, such that the magnet is partly within the solenoid.



The solenoid is then lifted straight up without touching the magnet. The reading on the balance is observed to change briefly.

(a) Why does a current flow in the solenoid?

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(b) Explain the reason for changes in the reading on the electronic balance as the solenoid is removed.

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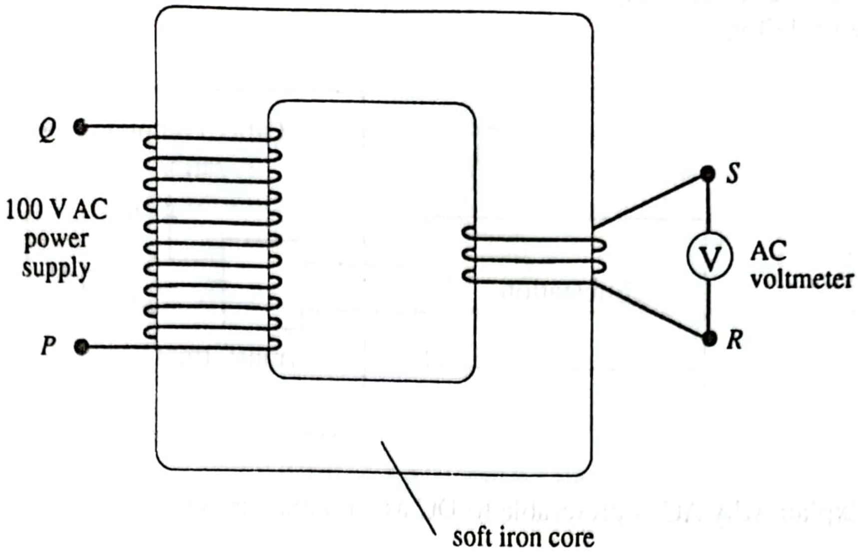
2012 HSC Q22 – 2 + 4 = 6 marks

60. The diagram below shows a simple transformer.



(a) If terminals P and Q are connected to a 100 V AC power supply, what can you predict about the reading on a voltmeter between R and S? Explain your answer.

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(b) Explain why the transformer would not work if the AC power supply was replaced by a DC power supply.

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(c) What is the function of the soft iron core?

....

(d) Why are most transformer cores laminated?

....

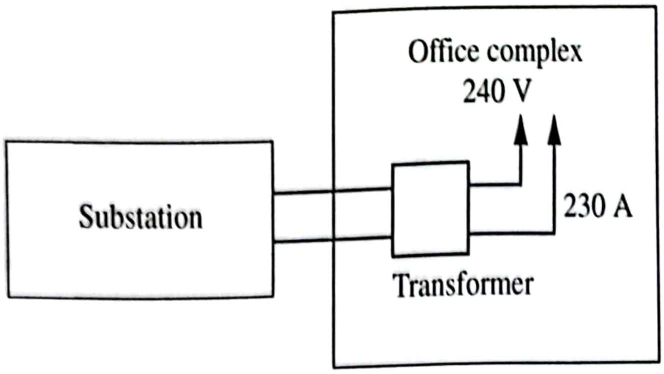
(e) A conducting wire replaces the voltmeter across RS and allows a large current to flow through the secondary coil.

Explain the effect this would have on the current in the primary coil.

....

1993 HSC Q23 – 2 + 2 + 1 + 1 + 2 = 6 marks

61. An electricity substation delivers a current of 10 A at a voltage of 6 kV to an office complex. The office complex uses a transformer to provide a current of 230 A at a voltage of 240 V.



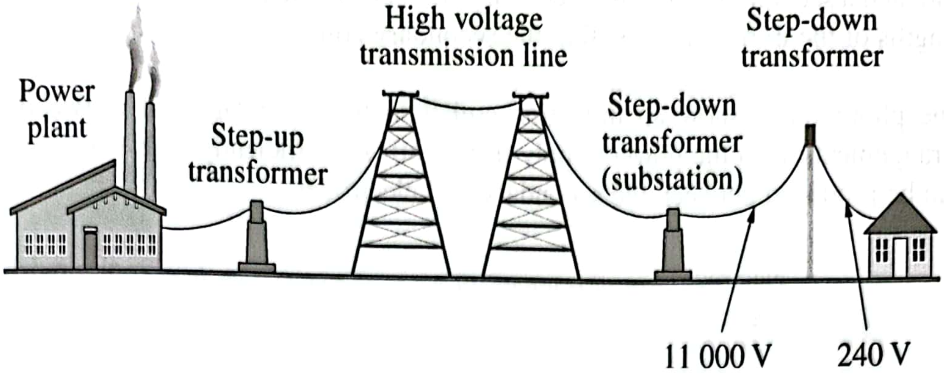
(a) Explain why AC is preferable to DC as an input current for transformers.

(b) Outline possible causes of energy loss in the transformer.

(c) Calculate the energy lost by the transformer in eight hours.

2007 HSC Q26 – 2 + 2 + 2 = 6 marks

62. A schematic diagram of a system to supply electricity to a house is shown below.



The step-down transformer in the substation has a turns ratio of 30 : 1.

(a) What is the voltage carried by the high voltage transmission line?

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....

(b) Identify the causes of the two main energy losses in the transmission of electricity between the power plant and the house.

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(c) What steps can be taken to reduce energy losses when transmitting electrical energy over large distances?

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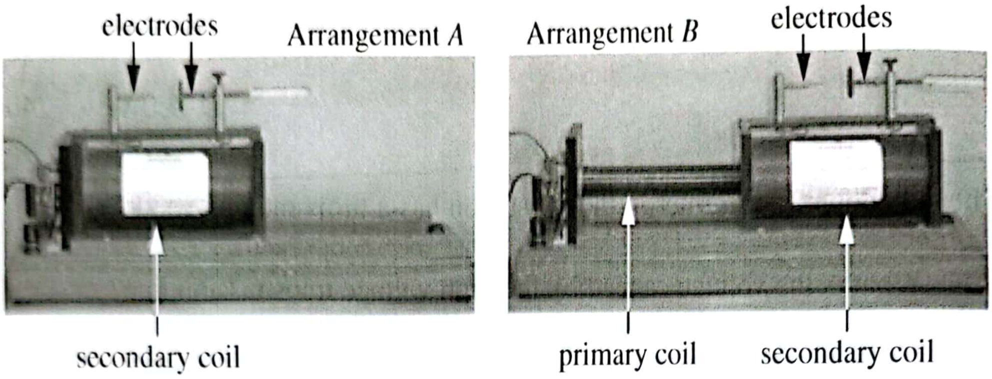
2005 HSC Q22 (adapted) – 1 + 2 + 2 + 5 marks

63. An induction coil is a type of transformer that allows a sma... ...ed up to a higher voltage. An induction coil consists of a primary coil wound around an iron core and a secondary coil. The secondary coil can be moved sideways so that different lengths of the iron core are within the secondary coil.

The photographs show an induction coil with the secondary coil in two different arrangements with the power supply turned off. At sufficiently high voltages a spark can be produced between the secondary coil electrodes.



(a) Which arrangement would produce a spark when the power supply is turned on? Justify your choice.

....

....

(b) Explain how different voltages are induced when the secondary coil is moved to different positions.

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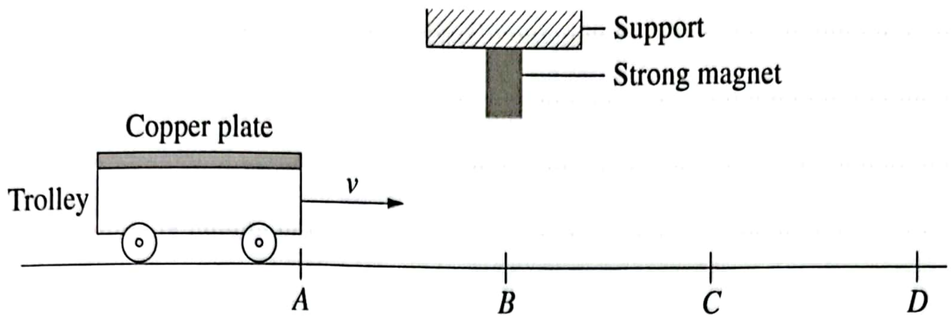
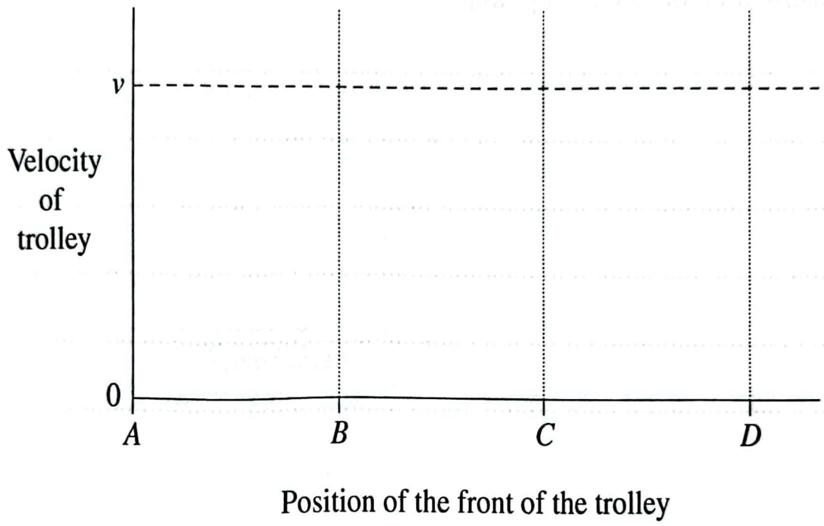
2008 HSC Q26 – 1 + 2 = 3 marks

64. A copper plate is attached to a lightweight trolley. The trolley moves at an initial velocity, v, towards a strong magnet fixed to a support.



The dashed line on the graph shows the velocity of the trolley when the magnet is not present.

On the axes, sketch the graph of the velocity of the trolley as it travels from A to D under the magnet, and justify your graph.



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2015 HSC Q28 – 5 marks

65. Outline TWO features of high-voltage transmission lines that contribute to the safe transmission of electricity.

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2018 HSC Q24 – 2 marks

(This is similar to 2014 HSC Q5)

66. Explain why the development of transformers was necessary to enable the large-scale distribution of electrical power.

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2008 HSC Q22 – 3 marks

6.3 Electromagnetic induction

Multiple choice: 1 mark each

1. B	2. A	3. D	4. A	5. D	6. A	7. D	8. D
9. C	10. A	11. B	12. C	13. B	14. C	15. B	16. D
17. C	18. D	19. D	20. B	21. B	22. A	23. D	24. D
25. D	26. C	27. A	28. B	29. A	30. D	31. B	32. A
33. A	34. D	35. A	36. C	37. C	38. B	39. A	40. D
41. D	42. A	43. D	44. A	45. C	46. D	47. C	48. B

Explanations:

1. B With the switch initially open, no current can flow in the first second. Current can only flow in the circuit once the switch is closed at $t = 1$ s. Only (B) shows this.

2. A Current cannot flow in different directions in the same wire, so (B) and (C) are incorrect. Lenz's Law states that the induced current flows in the direction that will oppose the motion that produced it. Using the right-hand rule (or similar), (A) is the answer and (D) is incorrect.

3. D The apparatus shown could only be used to investigate electromagnetic induction, as in (D).

4. A Initially ($t = 0$), and the loop *XYB* is in the plane of the paper and encloses a maximum number of magnetic field lines, so the graph must have maximum flux at $t = 0$. When it has rotated 90°, the loop is parallel to the magnetic field, so the flux enclosed is zero. When the loop has rotated 180°, maximum flux is again enclosed but the direction relative to the loop is now opposite. At 270° rotation, zero flux is again enclosed. So (A) is the answer.

5. D The magnetic flux graph shows an initial steady increase in magnetic flux to a maximum value followed by a steady decrease in flux. This is then repeated. A steady increase in magnetic flux will induce a constant current (shown by a horizontal line), not a varying current as shown in (A) and (B). The induced current will be opposite in sign to the flux (Lenz's Law), so the induced current will initially be negative as in (D), not positive, as in (C). So (D) is the answer.

6. **A** An induced emf is only produced between points X and Y when the split ring is exposed to a change in the external magnetic field. This occurs as the pendulum enters zone B and again as it leaves zone B. As it enters zone B, the magnetic field strength increases and as it leaves zone B, the magnetic field strength decreases. So the induced emf will have opposite signs, as in (A) and not the same sign, as in (B). While the split ring is within zone B, there is no change in field strength, so there is no emf and therefore (C) is incorrect. (D) is incorrect as it shows no emf.

7. **D** Ring P (4 field lines) encloses less flux than ring Q (9 field lines). So Q has greater magnetic flux. The field lines in P are closer together than those in Q, so P has greater magnetic flux density than Q. So (D) is the answer.

8. **D** Induced emf is greatest when rate of change of magnetic flux is at a maximum. This occurs when magnetic flux is zero (slope of graph at this point shows the rate of change is a maximum). Induced emf is zero when the magnetic flux value is at a maximum or minimum (slope of graph at this point is zero). This is when the changing of magnetic flux is zero. The induced emf will be opposite in sign to the magnetic flux (Lenz's Law), so initially it will be negative. So (D) is the answer.

9. **C** As on the upper diagram, Earth's north magnetic pole actually behaves as the south pole of a magnet and Earth's magnetic field runs from south to north (i.e. up the page in the globe diagram). The Right Hand Palm Rule indicates that current will flow from P to Q when the wire is moving downwards at point C and that current will flow from Q to P at point A. So (C) is the answer and (A) is incorrect. At points B and D, no current will flow in the copper wire as the rotating conductor is not cutting lines of magnetic flux.

10. **A** Initial flux $= BA = B\pi r^2 = 3 \times 10^{-3} \times \pi \times (\frac{5\times10^{-2}}{2})^2 = 5.9 \times 10^{-6}$ Wb

Final flux = 0 (as no field lines through area when it is parallel to the field)

$\therefore$ change of flux, $\Delta\Phi = 5.9 \times 10^{-6}$ Wb, as in (A).

11. **B** $\Delta\Phi = BA.\sin60 - BA\sin0$

$= (0.80 \times 3.0 \times \sin60) - 0$

$= 2.078$ Wb ... as in (B).

12. **C** The Right Hand Palm Rule is used. Finger (I) point up the page. Palm (= B) faces upwards for field out of page. Thumb indicates force to the right. Answer is (C).

13. **B** The induced emf is proportional to the rate of change in flux. The longer the wire, the greater the volume enclosed by the rotating wire, so higher flux and more current, so (A) is incorrect. A thicker wire will not change the rate of changing flux and copper is a good conductor, so any change in current will be negligible, so (B) is the answer. Increasing the speed of rotation of the wire will increase the rate of change of flux producing a proportional increase in current, so (C) is incorrect. If the wire is orientated north south, it is parallel to the Earth's magnetic field so the wire will cut much less flux than if it is orientated east-west and is transverse to the Earth's field, so (D) is incorrect.

14. C In both cases, the coil and magnet are separating, so their relative motion is the same. So (C) is the answer. In both cases, work is done, so energy is not conserved. So (A) is incorrect. The motor effect is not involved and the direction of the magnetic field remains the same, so (B) and (D) are incorrect.

15. B As the magnet moves towards the copper tube at P, a current is induced in the copper. Lenz's Law tells us that the induced current will be in such a direction that it will try to reverse the change in magnetic field inducing it. So it will be a *repulsive* force acting to slow the magnet's motion. As the magnet leaves the copper pipe, the induced current will again act to reverse the change in the magnetic field. So the magnet will be *attracted* back towards the copper pipe. Hence (B) is the only possible answer.

16. D A galvanometer detects small electrical currents. A moving magnet will produce a changing magnetic flux, which induces a current. The greatest induced current will produce the biggest deflection of the galvanometer. The higher the number of coils, the greater will be the induced current. (A), (B) and (D) all have more coils than (C). However in (D), the magnet is moving twice as fast as in (B) and (C), so (D) will result in the greatest current. Hence (D) is the answer, and (B) and (C) are incorrect. (A) is incorrect as the orientation of the two magnets reduces the magnetic flux through the coil.

17. C A transformer is normally an AC electrical device. A changing magnetic field associated with the primary coil induces an emf in the secondary coil. With a DC power supply, a changing magnetic field only occurs while the current builds up immediately after the switch is closed. Once a steady DC current develops in the circuit, the magnetic field no longer changes. The secondary coil will only have a brief induced current immediately after the switch is closed which will cease as soon as the primary current becomes constant. This is only shown in (C).

18. D The two flat coils are both in the same magnetic field, have equal areas and are subjected to the same rate of change of flux.
The only difference is that coil X has 25 turns and coil Y has 100 turns.
$\therefore$ $\text{emf}_Y = 4 \times \text{emf}_X$. So the answer is (D).

19. D An increasing current causes an increasing magnetic field around the outer ring. This results in an increasing induced current that flows in the opposite direction in the inner ring to oppose the magnetic field of the outer ring. So (D) is the only possible answer.

20. B The south pole of the magnet is moving up towards the solenoid. The induced current in the solenoid sets up a magnetic field with a south pole at the bottom that opposes the motion of the magnet. Using the right hand grip rule: you point your thumb towards the end of the solenoid that acts like a north pole of a bar magnet – this gives the magnetic field direction as *upwards* (↑), then the curl of your fingers show that the current is moving *anticlockwise* … as shown in (B).

21. **B** The induced current will produce a magnetic field to oppose the change in the inducing field. So, initially the current will flow in direction Y, as in (B) and (D). So (A) and (C) are incorrect. However, after the magnet has moved through the coil, the change in the inducing field is opposite. So, the induced current flows towards X. Hence (B) is the answer and (D) is incorrect.

22. **A** The induced current in the coil will produce a field that opposes the magnetic field change causing it. This induced current produces a north pole at the left end of the coil, opposing the motion of the magnet. So diagram (A) is correctly showing the direction of the current. In (B), the current shown would also produce a north pole in the coil that would attract the moving magnet, so the current is in the wrong direction. No current will be induced in either (C) or (D), as there is no changing field to produce a current.

23. **D** emf, $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$

$$= -1 \times \frac{0.5 - 0.2}{0.3} \times 2.3 \qquad [\text{since } \Phi = B_{\parallel}A]$$

$$= 2.3\text{ V} \ \ldots \text{ as in (D)}$$

24. **D** When the switch is closed, an induced current can flow, opposing the motion. So, more energy is required to move the magnet than if the switch is open. So (D) is the answer.

25. **D** The current induced in the coil opposes the change in magnetic field that induces it. Therefore, the current in Stage I will be opposite to the current in Stage III. So the needle will deflect firstly to one side, return to zero when the magnet is in the coil, and then deflect to the other side, as in (D).

26. **C** The essential requirement is the magnetic interaction, so (C) is answer. An electrical transformer normally consists of *a soft iron core* and two or more coils. A changing current in the primary coil creates an alternating magnetic field in the core. The transformer couples most of the flux through the secondary coil(s). This in turn induces alternating voltage (or emf) in the secondary coil(s). The features in (A) and (B) improve a transformer's efficiency but are not essential, so (A) and (B) are incorrect. The primary and secondary coils must be separated electrically and not connected, so (D) is incorrect.

27. **A** This is designed as a step-down transformer as the primary solenoid has more coils than the secondary solenoid. However, it has a DC power source. So it is NOT operating as an ideal transformer using AC. At the instant the switch is closed, a current will begin to flow in the primary solenoid inducing a sudden emf in the secondary coil. This is given by: $V_s = V_p \times \frac{n_s}{n_p}$. So, by decreasing the number of primary coils (n_p), the secondary induced emf (V_s) is increased. If V_s increases, so will the current. So (A) is the answer. Decreasing the number of secondary coils would reduce the sudden induced emf. So current will decrease, making (B) incorrect. Copper cannot be used instead of iron in the core, as it is not magnetic. So (C) is incorrect. A resistor in series would reduce the current and hence the deflection. So (D) is incorrect.

such transients on the current when the switch is first ... 'ideal', it is not being used as such, as it is connected to DC. If it were ... ...ult in the current increasing in the secondary coil and so a greater deflection in an AC galvanometer, as Power in = Power out, so $V_1I_1 = V_2I_2$. (3) In this set-up, the galvanometer will briefly deflect to one side and then return to zero, as the DC current builds in the primary coils to become constant (with no changing magnetic flux).]

28. B If $N_S > N_P$ then $V_P > V_S$ ... as in both (A) and (B), and not in (C) and (D).

But $V_PI_P = V_SI_S$ in an ideal transformer.

So if $V_P < V_S$ then $I_P > I_S$. So the answer is (B).

29. A Coil *X* is connected to a DC source. When the switch is closed, the current in coil *X* will rapidly increase to its equilibrium value (shown by a flat section of the curve) and will rapidly decrease to zero when the switch is re-opened. Only (A) and (C) show this. Coil *Y* is the secondary coil which only experiences an emf during the period at the start and at the finish when the current is changing in coil *X*, the primary coil. There is no emf in the secondary coil when the current is constant in coil *X*. So (A) is the answer and (C) is incorrect.

30. D Coil 2 is connected to the AC power supply and so it is the primary coil. So Coil 1 is the secondary coil. So (A) and (C) are incorrect. Since Coil 1 has more turns than Coil 2, the transformer is a step-up transformer. So (D) is the answer and (B) is incorrect.

31. B The operation of an electrical transformer is based on the Conservation of Energy, as in (B). The amount of energy you put in equals the amount of energy you get out less the amount of energy that is converted into heat energy due to the electrical resistance of the solenoid winding and due to induced eddy currents in the iron core. Conservation of Mass, Charge and Momentum are irrelevant to the operation of a transformer, so (A), (C) and (D) are incorrect.

32. A $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ so $\frac{n_p}{n_s} = \frac{33{,}000}{240}$ ... as in (A).

33. A The switch in the left hand circuit is initially closed, so there will be a steady current flowing in this circuit until the switch is opened at $t = 2$ s. At this instant, the current will rapidly drop to zero and the voltage across the resistor will drop to zero. V_1 is only shown correctly in the left hand graphs in (A) and (B). However, with no change of current in the left hand circuit except at the instant $t = 2$ s, the right hand circuit will have no induced current except at $t = 2$ s. Hence there will only be a brief spike of voltage (V_2) across the resistor at $t = 2$ s. Only (A) correctly shows this variation of voltage with time.

34. D Substituting into the formula $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ gives $\frac{110 \text{ Volts}}{V_s} = \frac{60}{2300}$

$\therefore$ secondary voltage, $V_S = 4217$ Volts $\approx 4.2 \times 10^3$ Volts, as in (D).

... Hence (A) is the answer. It does not change AC to DC, nor does it change the AC frequency, so (B) and (C) are incorrect. A transformer is less than 100% efficient, so the appliance will consume more energy, not less, so (D) is incorrect.

36. C A change from 3V to 12V is a step up in voltage, as in (A) or (C). So (B) and (D) are incorrect.

Since $\frac{V_s}{V_p} = \frac{n_s}{n_p}$ Substituting: $\frac{12}{3} = \frac{n_s}{60}$ $\therefore n_s = 240$ turns So (C) is the answer.

37. C The primary circuit of the transformer receives the input voltage. The secondary circuit produces the output voltage. The input voltage is 240 V and the output is 6000 V. The ratio of the number of secondary turns to primary turns $\frac{n_s}{n_p}$ is found using: $\frac{V_p}{V_s} = \frac{n_p}{n_s}$

$\therefore \frac{V_s}{V_p} = \frac{n_s}{n_p} = \frac{6000}{240} = \frac{25}{1}$ ... as in (C), and not the reverse as in (B).

38. B Transformers can lose energy as *iron losses* due to the production of heat by eddy currents induced in the iron core. To overcome this problem, the resistance to current flow must be increased without interfering with the channelling of magnetic flux by the iron. The use of a solid iron core will maximise eddy currents, so (A) is incorrect. By using iron sheets separated by insulating material, as in (B), the magnetic field is still channelled through the coil but the eddy currents are substantially reduced. So (B) is the answer. In (C) and (D), the iron sheets and rods are discontinuous through the length of the coil, so the magnetic flux will not be channelled through the coil. So (C) and (D) are incorrect.

39. A The iron core in the transformer is used to channel the magnetic flux. Laminating this core with insulating layers disrupts the eddy currents, but not the magnetic channeling. So (A) is the answer.

40. D A transformer is used to increase (step-up) or decrease (step-down) AC voltages. The transformer within the charger of a mobile phone decreases the AC voltage of the power supply (~240 V) to the low voltage (~5.0 V) needed to recharge the phone, as in (D). Hence (C) is incorrect. A transformer cannot convert AC to DC, nor DC to AC. So (A) and (B) are both incorrect.

41. D The iron core in the transformer is used to channel the magnetic flux from the primary to the secondary coil, thereby increasing the linkage. So (D) is the answer and (C) is incorrect. An iron core does not limit eddy currents, as this is brought about by the insulating laminations. So (A) is incorrect. The iron core helps to dissipate the heat generated, but this is not why it is used. So (B) is incorrect.

35. **A** A transformer either steps up or steps down AC voltage, and is used to adjust the AC mains voltage to suit the appliance. Hence (A) is the answer. It does not change AC to DC, nor does it change the AC frequency, so (B) and (C) are incorrect. A transformer is less than 100% efficient, so the appliance will consume more energy, not less, so (D) is incorrect.

36. **C** A change from 3V to 12V is a step up in voltage, as in (A) or (C). So (B) and (D) are incorrect.

Since $\frac{V_s}{V_p} = \frac{n_s}{n_p}$ Substituting: $\frac{12}{3} = \frac{n_s}{60}$ $\therefore n_s = 240$ turns So (C) is the answer.

37. **C** The primary circuit of the transformer receives the input voltage. The secondary circuit produces the output voltage. The input voltage is 240 V and the output is 6000 V. The ratio of the number of secondary turns to primary turns $\frac{n_s}{n_p}$ is found using: $\frac{V_p}{V_s} = \frac{n_p}{n_s}$

$\therefore \frac{V_s}{V_p} = \frac{n_s}{n_p} = \frac{6000}{240} = \frac{25}{1}$ … as in (C), and not the reverse as in (B).

38. **B** Transformers can lose energy as *iron losses* due to the production of heat by eddy currents induced in the iron core. To overcome this problem, the resistance to current flow must be increased without interfering with the channelling of magnetic flux by the iron. The use of a solid iron core will maximise eddy currents, so (A) is incorrect. By using iron sheets separated by insulating material, as in (B), the magnetic field is still channelled through the coil but the eddy currents are substantially reduced. So (B) is the answer. In (C) and (D), the iron sheets and rods are discontinuous through the length of the coil, so the magnetic flux will not be channelled through the coil. So (C) and (D) are incorrect.

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42. **A** Cathode ray tubes require a high voltage to operate, so the household 240 V supply must be increased by a *step-up* transformer. Transistor circuits only operate at a very low voltage, so the household electricity supply must be decreased using a *step-down* transformer. So (A) is the only possible answer.

43. **D** If the ratio of input voltage to output voltage is 20:2 or 10:1, the ratio of the number of turnings of the primary and secondary coils must also be 10:1. Only the transformer in (D) has this ratio. So (D) is the answer.

44. **A** Power stations generate high output voltages (≈ 20 kV). Heating in transmission wires results in considerable loss (or waste) of energy if electricity is distributed across large distances at low voltages. Step-up transformers are therefore used at power stations to achieve very high distribution voltages (e.g. ≈ 330 kV in NSW). This reduces the current (since $P = VI$) and so minimises power losses through heating, since power loss in the wires is given by I^2R, where R is the resistance of the wires. So (A) is the answer.

45. **C** High voltage is used to transmit electrical energy from power stations to local distribution sub-stations that send 240 V power to users. Energy transmitted at high voltage has a lower current, so less energy is lost in transmission. So (C) is the answer. High voltage transmission towers have lightning conductors to minimise the effect of lightning strikes, as high voltage does not protect against lightning. So (A) is incorrect. High voltage requires bigger insulators and not smaller insulators, so (B) is incorrect. Transformers along the local distribution network and not the high voltage from a power station ensure that 240 V reaches the user, so (D) is incorrect.

46. **D** The flux is greatest when the coil presents the greatest area to the magnetic field, i.e. when the coil is at 90° to the magnetic field, as in (D). Both (A) and (C) are incorrect as they are at an angle to the magnetic field, so that the magnetic flux through the coil is reduced. (B) is incorrect because the coil is parallel to the field and the flux is zero.

[Note: Do not confuse maximum torque with maximum flux! Maximum torque arises when the coil is in the position shown in (B), when flux is zero.]

47. **C** The force on a constant current in a uniform magnetic field depends on the angle between the current and the normal to the field (a factor of $\cos\theta$). In Diagram X, angle θ is always 90° so the magnitude of the force on P is constant as in (B) and (C), and so (A) and (D) are incorrect. In Diagram Y, angle θ varies periodically from 0° to 90°, so the magnitude of the force on Q varies with time. Only (C) has the correct combination, and so (B) is incorrect.

48. **B** The lower solenoid is connected to a DC power source, so there will only be a change in flux for an instant after the switch is closed. This flux change will induce an instantaneous current in the upper coil that is opposed to the effect causing it. Therefore, the field (B) will be upward in the upper coil and downward in the lower coil. Using the right hand grip rule, this means the instantaneous current will be from X to Y and the spring balance point will briefly be displaced upwards ... as given in (B).

49. (a) Maximum magnetic field strength (B) occurs at maximum magnetic flux (Φ).

Maximum magnetic flux occurs from $t = 6$ s to $t = 10$ s and is 0.6 Wb

$$\therefore \text{ maximum } B = \frac{\Phi}{A} = \frac{\Phi}{\pi r^2} = \frac{0.60}{\pi \times 0.30^2} = 2.12 \text{ T} \approx 2.1 \text{ T}$$

(b) Maximum voltage (*emf* or ε) is produced when the rate of change of flux is greatest, i.e. from $t = 10$ s to $t = 12$ s.

By Faraday's Law, $\varepsilon = -\dfrac{\Delta\Phi}{\Delta t} = \dfrac{0 - 0.60}{12 - 10} = \dfrac{-0.60}{2} = 0.3 \text{ V}$

Terminal P will be positive and Terminal Q will be negative (using Lenz's Law).

[Note: Since the emf is produced by a decreasing flux into the page, the current must flow clockwise to produce a flux into the page.]

50. (a) $\dfrac{V_p}{V_s} = \dfrac{n_p}{n_s}$ Substituting, $\dfrac{23{,}000}{660{,}000} = \dfrac{2000}{n_s}$

$\therefore$ number of turns, $n_s = 2000 \times \dfrac{660{,}000}{23{,}000} = 57{,}391$ turns

(b) $\dfrac{V_p}{V_s} = \dfrac{I_p}{I_s}$ Substituting: $\dfrac{23{,}000}{660{,}000} = \dfrac{I_s}{100}$

$\therefore I_s = \dfrac{23{,}000 \times 100}{660{,}000} = 3.4848 \text{ A}$

$\therefore$ power loss, $P_{loss} = VI = RI.I = RI_s^2 = 2000 \times 3.4848^2 = 24{,}288 \text{ W} \approx 24.3 \text{ KW}$

[Note: (1) This calculation assumes the power loss is small. (2) In a real step-up transformer like this, ohmic power losses could be expected to be much greater in the primary coil than in the secondary coil, since the primary coil carries a very much higher current.]

51. Transformers are used to change voltages within AC circuits. Transformers enable power stations to be located well away from cities. This minimises risks of health problems associated with air pollution from burning coal and yet still supplies the necessary voltage for consumer use. Power stations generate high output voltages (~20 kV). Considerable energy losses occur in transmission lines if electricity is distributed across large distances at low voltages, so step-up transformers are used at power stations to achieve very high distribution voltages (e.g. ~330 kV in NSW) and low current to minimise power losses through heating. Step-down transformers at regional and suburban substations are used to lower the voltage to a safe level for distribution to consumers. Small step-up transformers along local power lines maintain this voltage within an acceptable range, e.g. industry requires 415 V and homes require 240 V.

52. (a) An induced emf always gives rise to a current that creates a magnetic field that opposes the original change in flux through the circuit that induced the emf.

(b) (i) End *X*.

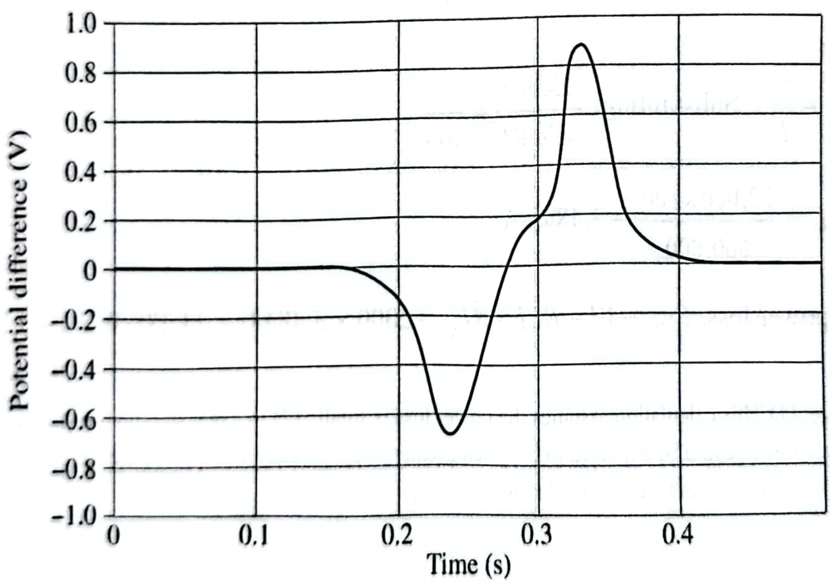
(ii) As the rod moves through the magnetic field, electrons that are free to move in the metal experience a force in a direction at right angles both to their movement (up the page) and to the direction of the magnetic field (left to right across the page). Using the right-hand palm rule, the direction of the force is towards End *X*, and so it becomes negatively charged. This leaves a deficiency of electrons, i.e. a positive charge, at End *Y*. So between the ends there is an emf.

(c) An alternating current in a conductor produces an alternating magnetic field. If another conductor is nearby in this field, eddy currents will be induced by the changing magnetic flux. These eddy currents will produce heat energy, thus heating the nearby conductor.

[Note: This is the basis of induction cooktops.]

53. (a) Potential difference depends on the rate of change of magnetic flux. When dropped, the magnet accelerates downwards due to gravity, so its exit velocity is greater than when it entered and, as a result, the rate of change of flux is greater. Hence the potential difference is greater in magnitude at *Y* than at *X*.

(b)



[Note: You can have other values for *X* and *Y*, however make sure that your values for *X* and *Y* are opposite in sign as shown here because the south pole is now downwards. Also, the values for *X* and *Y* must be further apart because the magnet has dropped from a greater height and so the potential difference will be greater.]

54. (a) Magnetic flux, $\Phi = B_{\parallel}A$. Since B is constant and A is variable, Φ will change due to the rotation of the coil. When the coil is parallel to B, A will be a minimum and so Φ will be a minimum. When perpendicular to B, A will be a maximum and so Φ is a maximum.

(b) Using Faraday's Law, the changing magnetic flux in the circuit over time is equal in magnitude to the emf induced in the coil, i.e. $\varepsilon = \frac{\Delta\Phi}{\Delta t}$.

55. (a) $\Phi = B_{\parallel}A = 0.12 \times 2.0 \times 10^{-3} = 2.4 \times 10^{-4}$ Wb

(b)
$$\begin{aligned} \text{emf, } \varepsilon &= -N\frac{\Delta\Phi}{\Delta t} \\ &= -1 \times \frac{0 - 2.4 \times 10^{-4}}{t} \\ &= \frac{2.4 \times 10^{-4}}{t}\ \text{V} \end{aligned}$$

56.

AC GENERATORS AT POWER STATION

↓

STEP-UP TRANSFORMERS

↓

HIGH VOLTAGE TRANSMISSION LINES

↓

STEP-DOWN TRANSFORMERS

↓

REGIONAL TRANSMISSION LINES

↓

STEP-DOWN TRANSFORMERS

↓

LOCAL DISTRIBUTION TO HOUSEHOLDS & INDUSTRY

57. From the data given: Input: $P_{in} = VI = 240 \times 5 = 1200$ W

Output: $P_{out} = VI = 2000 \times 1 = 2000$ W

The input information is valid for a domestic appliance, as domestic electricity is supplied at 240V and up to 15A.

However, output power > input power. This is not consistent with the law of conservation of energy. A transformer cannot be more than 100% efficient and there are usually some small energy losses in an operating transformer. So the output power cannot be greater than the input power. Hence the label is incorrect.

OR The relationship $\frac{V_p}{V_s} = \frac{I_s}{I_p}$ should apply to a transformer.

However, $\frac{V_p}{V_s} = \frac{240}{2 \times 10^3} = 1.2 \times 10^{-1}$ and $\frac{I_s}{I_p} = \frac{1}{5} = 2.0 \times 10^{-1}$

$\therefore \frac{V_p}{V_s} \neq \frac{I_s}{I_p}$ Hence the label is incorrect.

58. Since transformers can step-up and step-down AC electricity, they enable electrical power to be distributed over large distances. Hence power stations can be located well away from cities. This has minimised the risks of health problems associated with air pollution from burning coal and yet still supplies the necessary power for consumer use.

Transformers have enabled the safe use of electrical appliances that require low voltage and allowed the operation/recharging of electronic devices on 240 V power supply. These devices have enabled rapid communication and data processing, thus changing how people interact and allowing them to work either from an office, at home or when travelling.

59. (a) When the solenoid is lifted upwards, the copper wire coil experiences a change in magnetic flux. So an emf is induced between the ends of the coil and produces a current. The copper wire short circuit completes the circuit, which allows the current to flow.

(b) According to Lenz's Law, the magnetic field that is produced by the induced current in the copper coil will oppose the motion that produced it. So as the solenoid is being removed, the induced emf will produce a magnetic field that attracts the solenoid back downward towards the magnet. This causes an upward force on the magnet, which reduces the reading on the balance. Once the solenoid is completely removed, there will no longer be an electromagnetic force and the balance reading will return to its original value (42.42 g).

60. (a) It will be less than 100 V (around 27 V) – due to there being less coils between R and S than between P and Q and $\frac{V_p}{V_s} = \frac{N_p}{N_s}$.

(b) An emf would not be produced in the secondary coil as a DC supply would not give a changing magnetic flux.

(c) It concentrates the magnetic flux in the secondary coil.

(d) To reduce the eddy currents that decrease the efficiency of a transformer.

(e) The current in the primary coil will increase as $V_p I_p = V_s I_s$.

61. (a) A DC current produces a constant magnetic flux, whereas an AC current has a continually changing flux. A transformer needs a changing flux in order to work, so that a current can be induced in the secondary coil, so AC current is needed.

(b) *Any TWO of the following:*

- Energy can be lost as heat due to the resistance of the copper of the primary and secondary coils.
- Energy can be lost due to eddy currents within the conductor of the primary and secondary coils.
- Energy can be lost due to eddy currents within the iron core (although this can be minimised by using a laminated core).
- Energy can be lost due to incomplete magnetic coupling between the primary and secondary coils.

(c) $P_{in} = V_p I_p = 6 \times 10^3 \text{ V} \times 10 \text{ A} = 6 \times 10^4 \text{ W}$

$P_{out} = V_s I_s = 240 \text{ V} \times 230 \text{ A} = 5.52 \times 10^4 \text{ W}$

Rate of energy loss $= (6 \times 10^4 - 5.52 \times 10^4) = 4.8 \times 10^3 \text{ W} (\equiv \text{J s}^{-1})$

$\therefore$ Energy lost in 8 hours $= (4.8 \times 10^3) \text{ W} \times (8 \times 60 \times 60) \text{ s}$

$= 1.3824 \times 10^8 \text{ J}$

$= 1.4 \times 10^8 \text{ J}$

62. (a) $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ So in this case: $\frac{V_p}{11{,}000} = \frac{30}{1}$ $\therefore V_p = 330{,}000 \text{ V}$ [or 330 kV]

(b) 1. The high current used results in heat loss in overcoming resistance in the wires of the transmission grid, as $P_{loss} = I^2 R$.

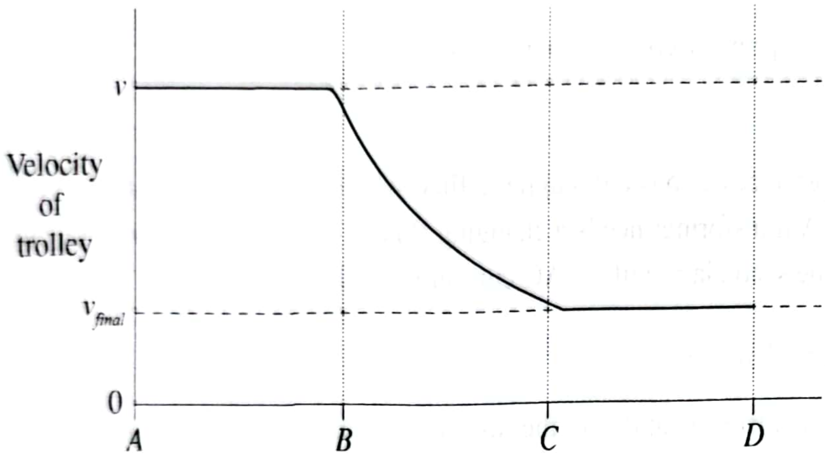
2. Eddy currents induced in the transformers at every stage heat up the transformers causing energy to be lost in the form of heat.

(c) A transformer's iron core is constructed from many layers of iron, each coated with an insulator to reduce heat loss due to eddy currents. To reduce power loss, transformers are used to step up the voltage to a high voltage (with low current) before transmission.

63. (a) Arrangement A – the primary coil is inserted fully into the secondary coil, so the magnetic flux from the primary coil is more completely linked with the secondary coil.

(b) As the secondary coil is moved, the primary coil is further inside the secondary coil. Hence the greater the degree of magnetic coupling and the higher the voltage obtained from the secondary coil. Therefore, at each position, as the primary coil is further inside the secondary coil, the AC voltage induced will increase.

64.



As the trolley passes under the strong magnet, its velocity will be reduced. The movement of the copper plate in the strong magnetic field induces eddy currents in it (Faraday's Law). These produce a magnetic field that opposes the motion that induced it (Lenz's Law). The force produced has a braking effect on the trolley. The kinetic energy of the trolley is transformed into heat energy in the copper plate.

[Note: Because the strength of the induced eddy currents is proportional to the speed of the train, the induced eddy currents and hence the braking effect will be greatest when v is high as the trolley first reaches the magnet and will be reduced as the trolley slows because the rate of change of flux through the copper plate is reduced as v decreases.]

65. 1. An earth wire located above the transmission wires – this will conduct a lightning strike to Earth as it is grounded through the pylons.
2. Large ceramic insulators between the transmission wires and pylons – these prevent sparking or short-circuiting.

66. Transformers enable AC electricity to be stepped up to high voltage for transmission and stepped down for local supply. This avoids large and costly transmission line power losses as a smaller current is required, avoids possible overheating of conductors as would occur with DC transmission, and makes the supply and distribution of AC cheaper and more efficient than DC electricity. Transformers enable generators to be set up near the energy source and the power carried over much longer distances to users in a city. This avoids having pollution from local power stations in cities, as would be needed with a DC network.