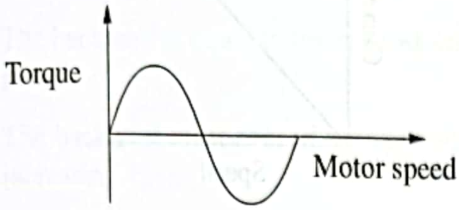
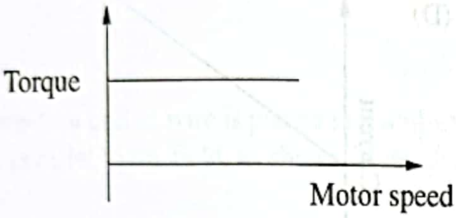
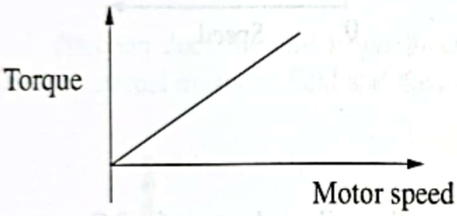
6.4 Applications of the Motor Effect

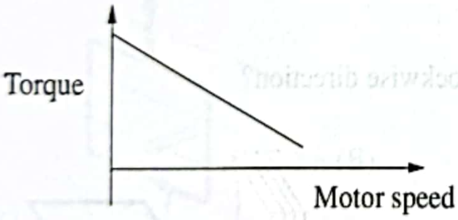
Multiple-choice questions: 1 mark each

1. Which graph best represents the change in torque for a DC motor, with a radial magnetic field, from start up to operating speed?

(A) 

(B) 

(C) 

(D) 

2013 HSC Q17

2. An electric motor is constructed using a square coil and a uniform magnetic field of strength 0.45 T. The coil has 3 turns and sides of 10 cm. A current of 0.5 A flows through the coil.

What is the maximum torque experienced by the coil as it rotates?

(A) 2.25×10^{-3} Nm

(B) 6.75×10^{-3} Nm

(C) 22.5 Nm

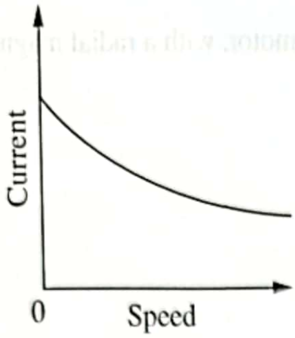
(D) 67.5 Nm

2011 HSC Q18

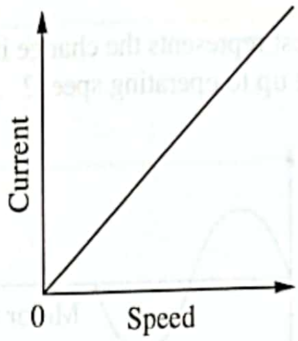
3. An electric motor is connected to a power supply of constant voltage. The motor is allowed to run at different speeds by adjusting a brake.

Which graph best shows how the current through the motor varies with speed?

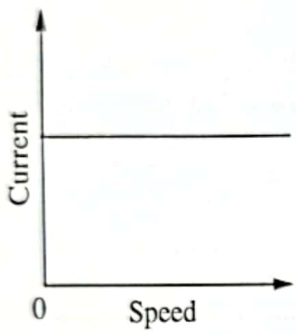
(A)



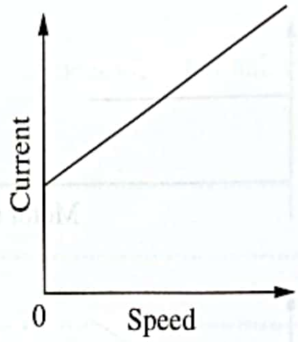
(B)



(C)



(D)

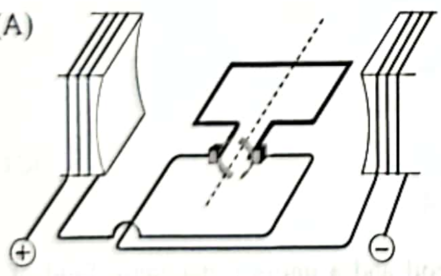


2001 HSC Q10

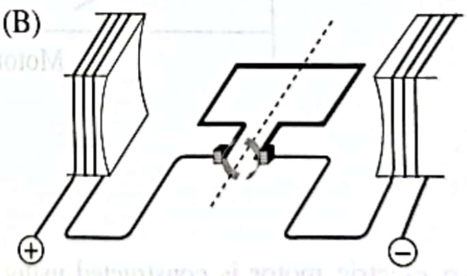
4. The diagrams show possible ways to connect the coils and rotor of a DC motor to a DC power supply.

In which circuit will the rotor turn in a clockwise direction?

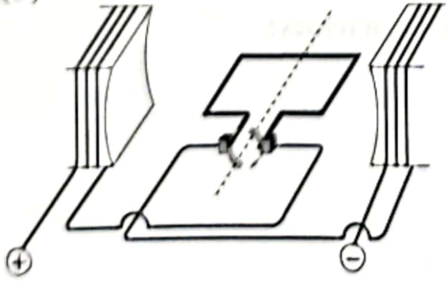
(A)



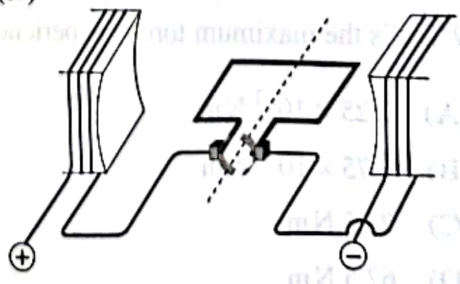
(B)



(C)



(D)



2010 HSC Q20

5. An ideal electric motor connected to a DC voltage source rotates at a constant rate of 200 revolutions per minute. There is no load on the motor.

Which of the following is a correct statement about the operation of the motor?

(A) The applied voltage must exceed the back emf in order to keep the motor running.

(B) There is no back emf because it is only produced in AC motors due to the changing flux.

(C) The back emf is equal to the applied voltage because no work is being done by the motor.

(D) The back emf must exceed the applied voltage to prevent the motor's speed from increasing.

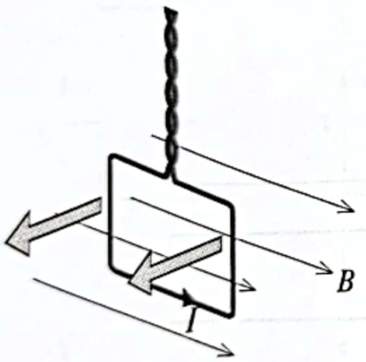
2012 HSC Q16

6. A single-turn coil of wire is placed in a uniform magnetic field B, so that the plane of the coil is parallel to the field, as shown in the diagrams. The coil can move freely.

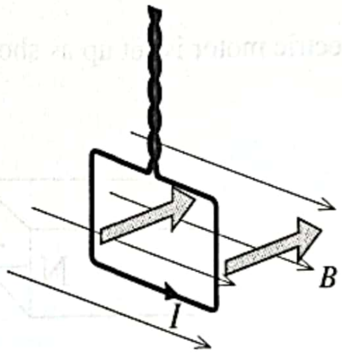
An electric current I flows around the coil in the direction shown.

In which direction does the coil begin to move as a consequence of the interaction between the external magnetic field and the current?

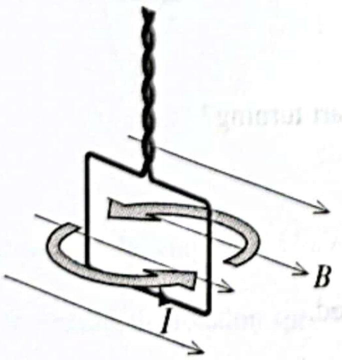
(A)



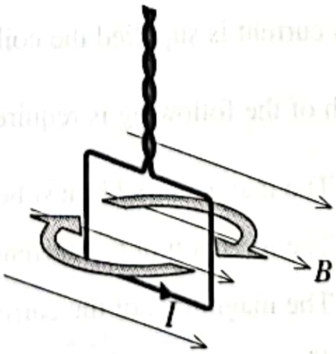
(B)



(C)

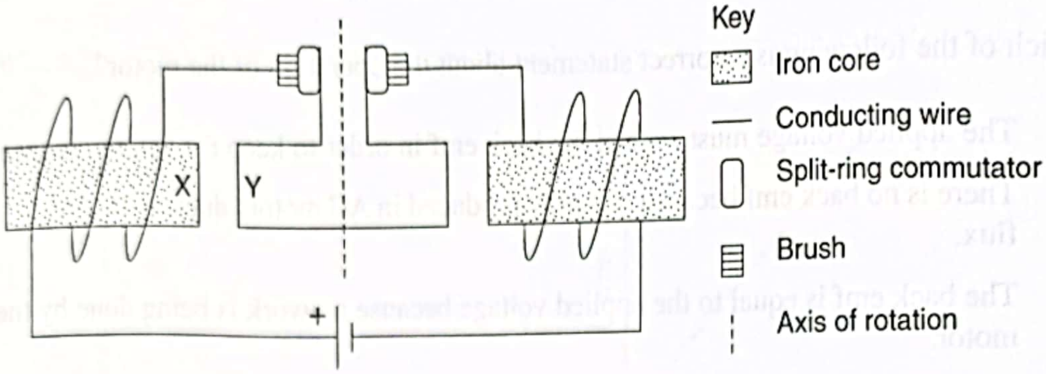


(D)



2002 HSC Q8

7. The diagram represents a DC electric motor.

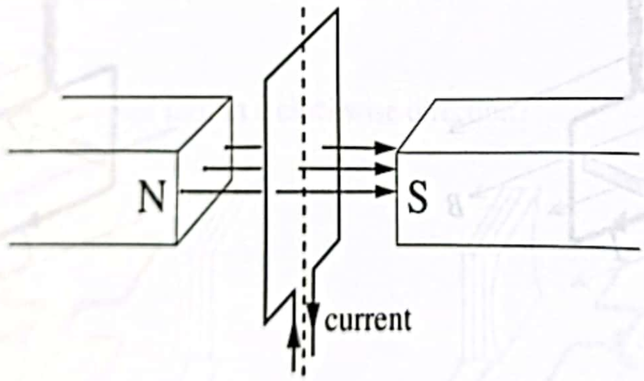


What is the polarity of the magnetic pole at X, and the direction of the motion of wire Y?

	Polarity of magnetic pole at X	*Direction of motion of wire Y*
(A)	South	Into the page
(B)	South	Out of the page
(C)	North	Into the page
(D)	North	Out of the page

2011 HSC Q12

8. An electric motor is set up as shown.



When current is supplied the coil does not turn.

Which of the following is required for the coil to start turning?

(A) The magnetic field must be increased.

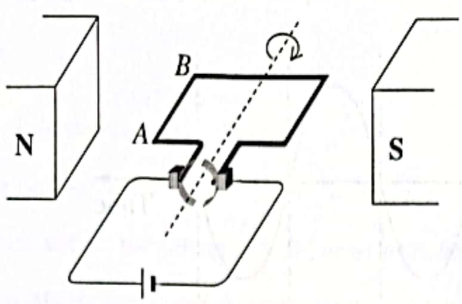
(B) The direction of the current must be reversed.

(C) The magnitude of the current must be increased.

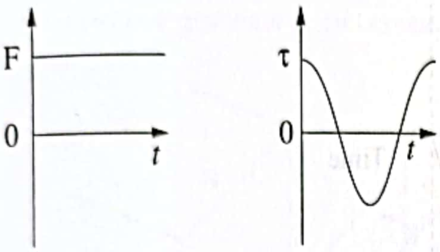
(D) The starting position of the coil must be changed.

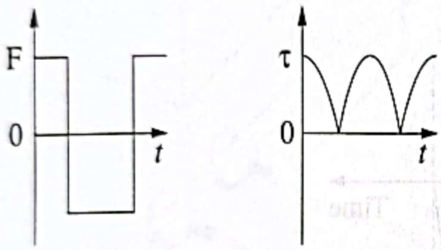
2007 HSC Q6

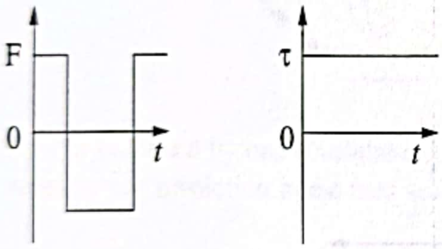
9. The diagram shows a DC motor with a constant current flowing to the rotor.

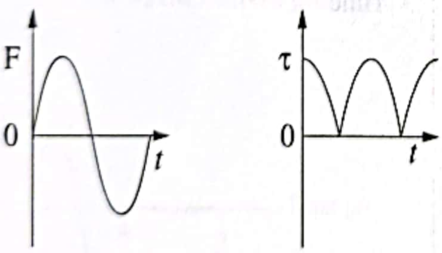


Which pair of graphs best describes the behaviour of the force F on wire AB, and the torque τ on the rotor as functions of time t?

(A) 

(B) 

(C) 

(D) 

2009 HSC Q11

10. Which of the following would increase the output of a simple DC generator?

(A) Increasing the rotation speed of the rotor

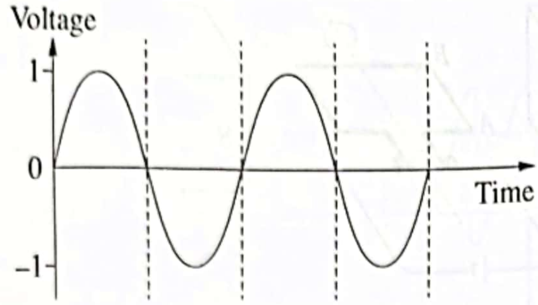
(B) Reducing the number of windings in the coil

(C) Using slip rings instead of a split ring commutator

(D) Wrapping the windings around a laminated, aluminium core

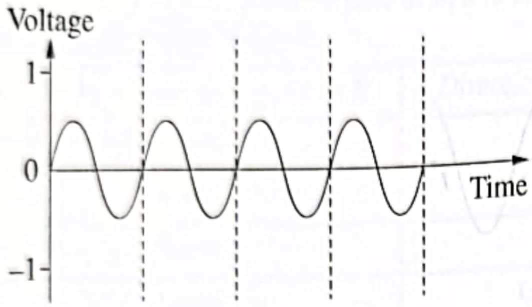
2009 HSC Q6

11. A simple AC generator was connected to a cathode ray oscillo... rotated at a constant rate. The output is shown on this graph.

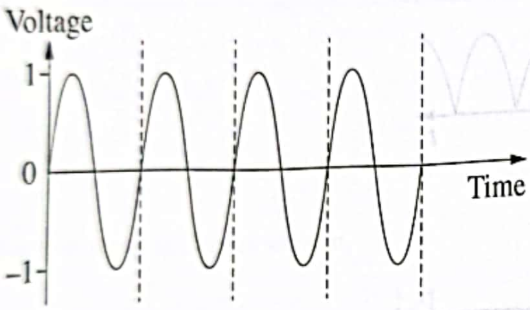


Which of the following graphs best represents the output if the rate of rotation is decreased to half of the original value?

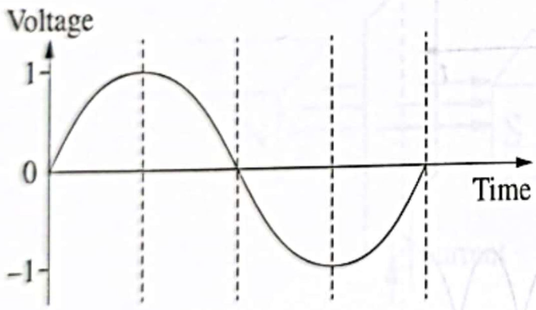
(A)



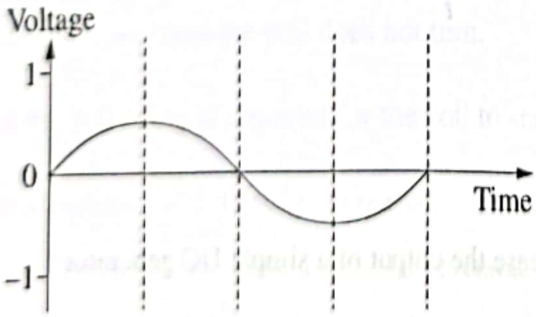
(B)



(C)

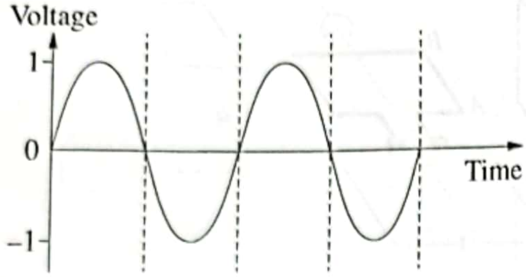


(D)



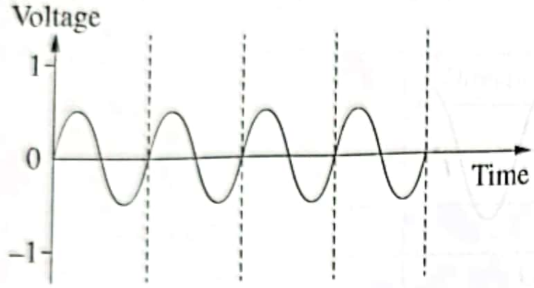
2015 HSC Q12

11. A simple AC generator was connected to a cathode ray oscilloscope and the coil was rotated at a constant rate. The output is shown on this graph.

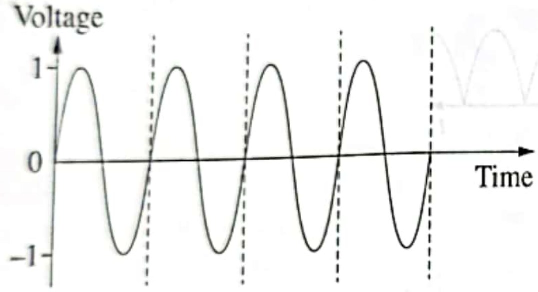


Which of the following graphs best represents the output if the rate of rotation is decreased to half of the original value?

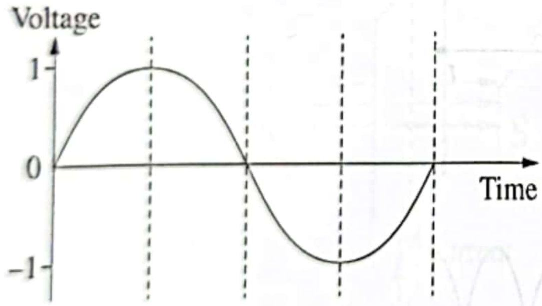
(A)



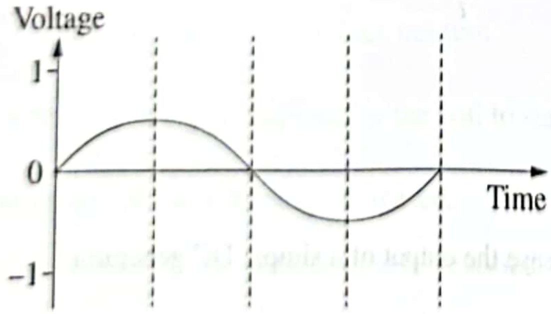
(B)



(C)



(D)



2015 HSC Q12

12. While drilling into a tough material, the DC motor in an electric drill is slowed significantly. This causes its coils to overheat.

Why do the coils overheat?

(A) The resistance of the coils increases significantly.

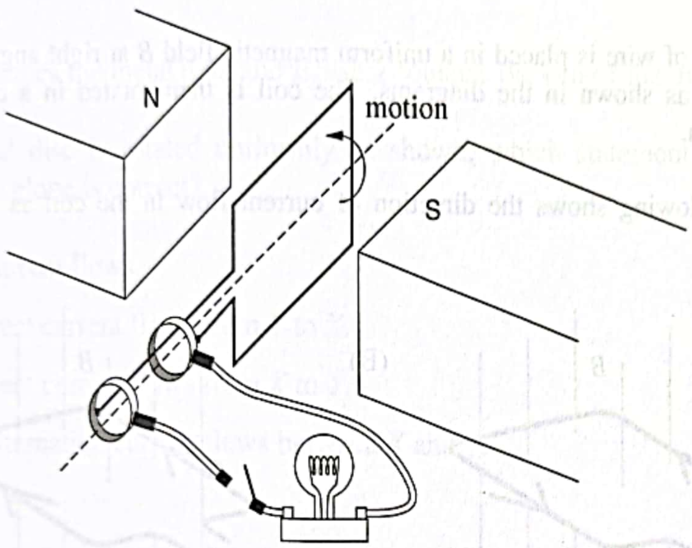
(B) The increased friction on the drill is converted to heat.

(C) The back emf decreases and so the current in the coils increases.

(D) The induced eddy currents increase and so more heat is produced.

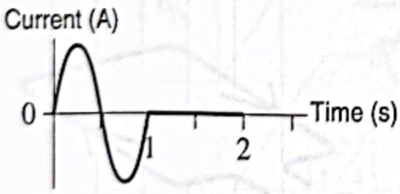
2010 HSC Q8

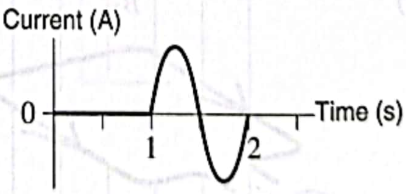
13. The diagram shows a generator circuit connected with a switch.

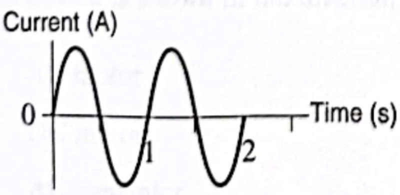


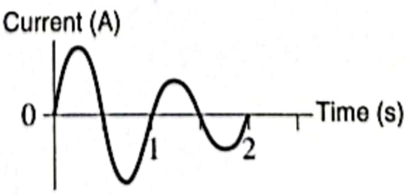
The generator is rotated by one revolution in the first second with the switch open. It is then rotated by one revolution in the next second with the switch closed.

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

(A)


(B)


(C)


(D)


2014 HSC Q14

14. An electric DC motor consists of 500 turns of wire formed into a rectangular coil of dimensions $0.2 \text{ m} \times 0.1 \text{ m}$. The coil is in a magnetic field of 1.0×10^{-3} T. A current of 4.0 A flows through the coil.

What is the magnitude of the maximum torque, and the orientation of the plane of the coil relative to the magnetic field when this occurs?

(A) 0.04 N m, parallel to the field

(B) 0.04 N m, perpendicular to the field

(C) 0.4 N m, parallel to the field

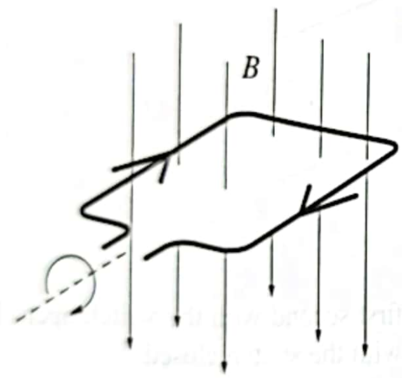
(D) 0.4 N m, perpendicular to the field

2004 HSC Q9

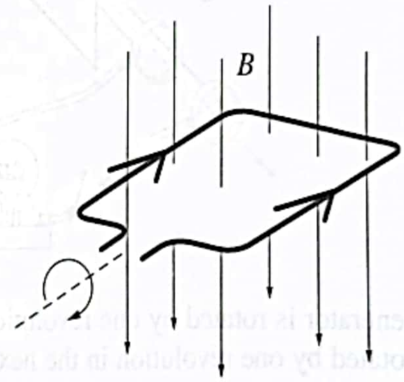
15. A single-turn coil of wire is placed in a uniform magnetic field B at right angles to the plane of the coil as shown in the diagrams. The coil is then rotated in a clockwise direction as shown.

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

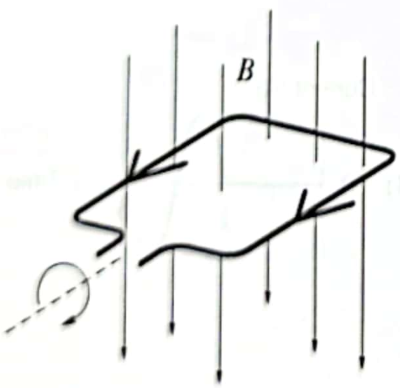
(A)



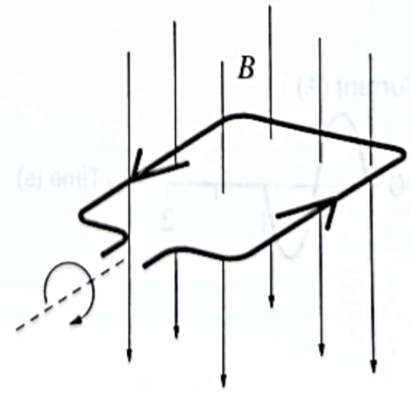
(B)



(C)

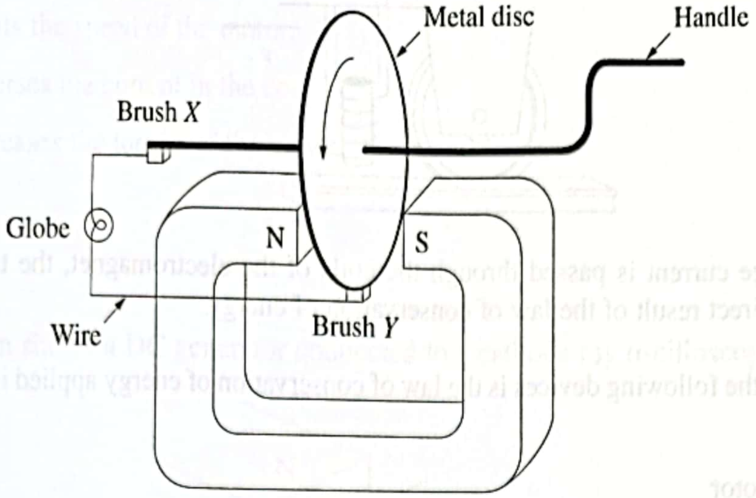


(D)



2008 HSC Q7

16. Early electric generators were often very simple. A hand-operated version is depicted below.



Brush X touches the metal axle and Brush Y touches the rim of the disc.

If the metal disc is rotated uniformly as shown, which statement about the current through the globe is correct?

(A) No current flows.

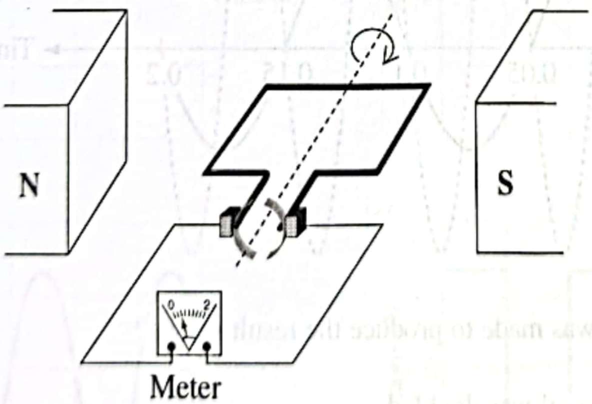
(B) A direct current flows from Y to X.

(C) A direct current flows from X to Y.

(D) An alternating current flows between X and Y.

2006 HSC Q9

17. The diagram shows a device connected to a meter.



What device is shown in the diagram?

(A) AC motor

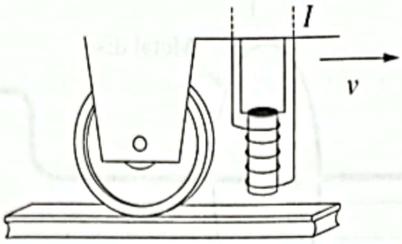
(B) DC motor

(C) AC generator

(D) DC generator

2012 HSC Q1

18. An electromagnet is attached to the bottom of a light train which is travelling from left to right, as shown.



When a large current is passed through the coils of the electromagnet, the train slows down as a direct result of the law of conservation of energy.

In which of the following devices is the law of conservation of energy applied in the same way?

(A) DC motor

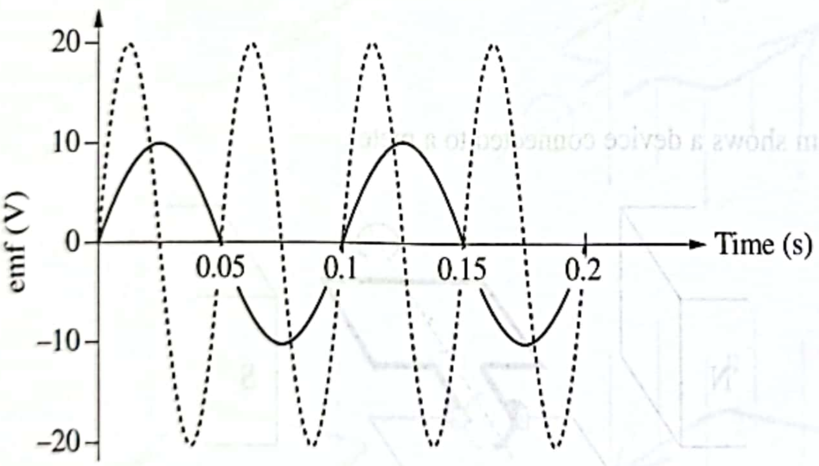
(B) Loudspeaker

(C) Induction motor

(D) Induction cooktop

2004 HSC Q11

19. In the graph shown, the solid curve shows how the emf produced by a simple generator varies with time. The dashed curve is the output from the same generator after a modification has been made to the generator.



Which modification was made to produce the result shown?

(A) The area of the coil was doubled.

(B) A split-ring commutator was added.

(C) The speed of rotation of the coil was doubled.

(D) The number of turns in the coil was quadrupled.

2007 HSC Q7

20. How does back emf affect a DC motor?

(A) It creates heat in the iron core.

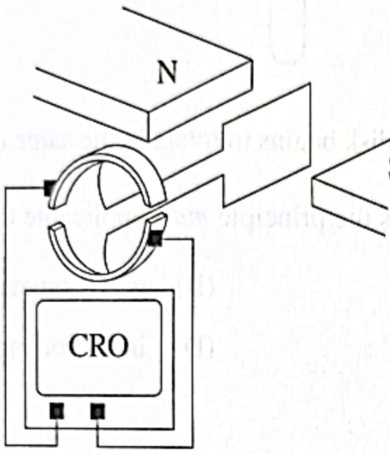
(B) It limits the speed of the motor.

(C) It reverses the current in the coil.

(D) It increases the torque of the motor.

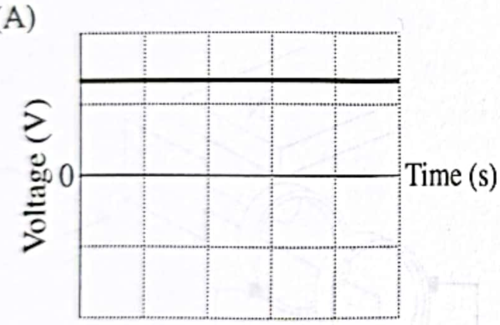
2016 HSC Q9

21. The diagram shows a DC generator connected to a cathode ray oscilloscope (CRO).

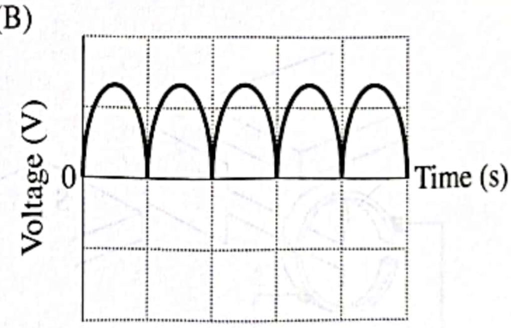


What output voltage would be observed for this generator on the CRO?

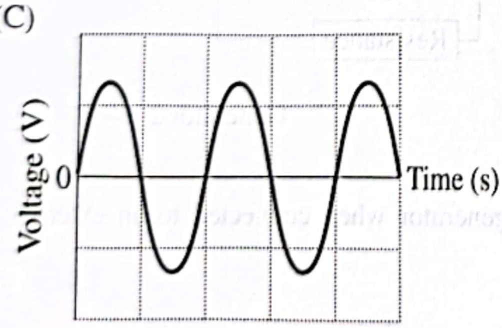
(A)



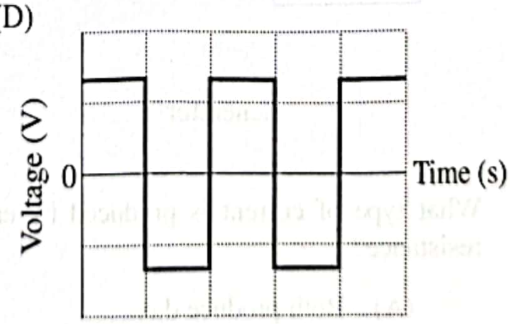
(B)



(C)

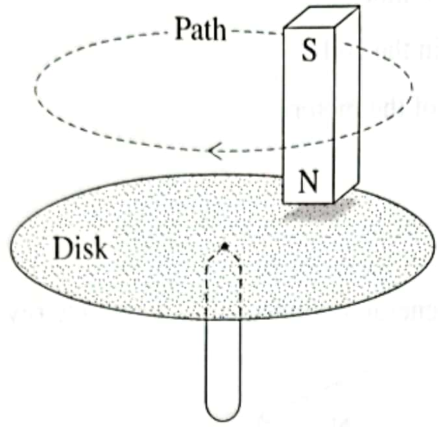


(D)



2003 HSC Q6

22. A non-magnetic metal disk is balanced on a support as shown in the diagram below. The disk is initially stationary. A magnet is moved in a circular path just above the surface of the disk, without touching it.



As a result of this movement the disk begins to rotate in the same direction as the magnet.

The observed effect demonstrates the principle *most* applicable to the operation of the

(A) DC motor

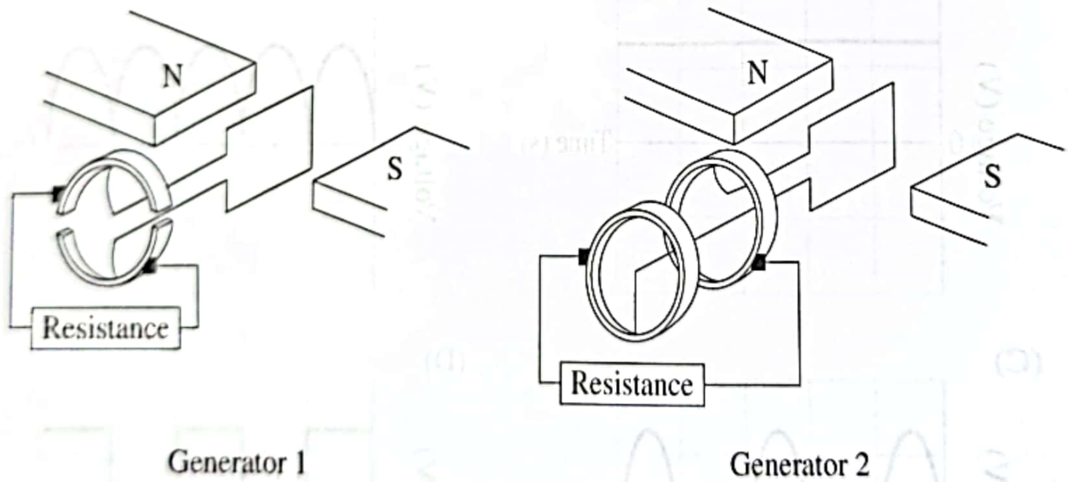
(B) galvanometer

(C) generator

(D) induction motor

2003 HSC Q7

23. Two types of generator are shown.



What type of current is produced by each generator when connected to an external resistance?

(A) Both produce d.c.

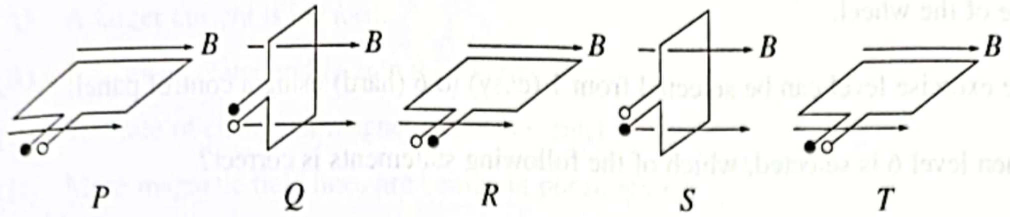
(B) Both produce a.c.

(C) Generator 1 produces d.c. and Generator 2 produces a.c.

(D) Generator 1 produces a.c. and Generator 2 produces d.c.

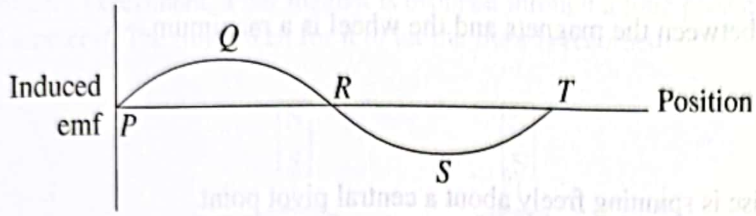
2001 HSC Q4

24. The coil of an AC generator rotates at a constant rate in a magnetic field as shown.

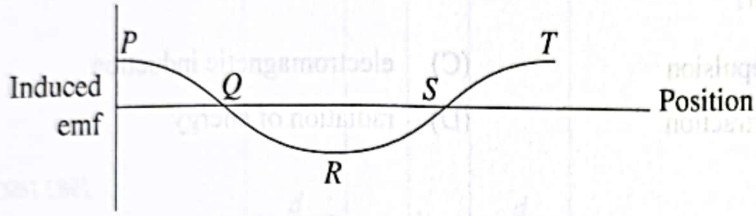


Which of the following diagrams represents the curve of induced emf against position?

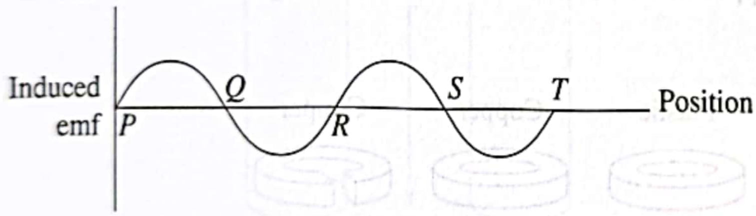
(A)



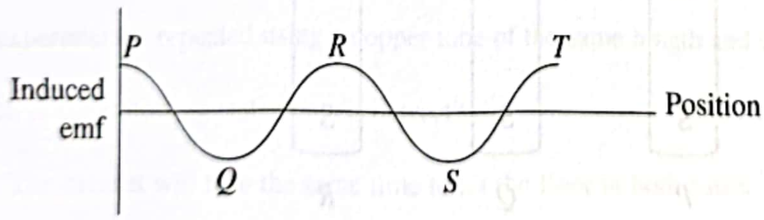
(B)



(C)



(D)



2002 HSC Q10

25. A stationary exercise bike has a solid metal wheel that is rotated by a chain connected to the pedals. An array of strong permanent magnets provides a magnetic field close to the face of the wheel.

The exercise level can be selected from 1 (easy) to 6 (hard) using a control panel.

When level 6 is selected, which of the following statements is correct?

(A) The current supplied to the bike is a minimum.

(B) The magnetic field at the wheel is a minimum.

(C) The induced current in the wheel is a maximum.

(D) The distance between the magnets and the wheel is a maximum.

2007 HSC Q9

26. A thin aluminium disc is spinning freely about a central pivot point.

When placed between the poles of a strong U-shaped magnet, what causes the disc to HSC Quickly come to rest?

(A) electrostatic repulsion

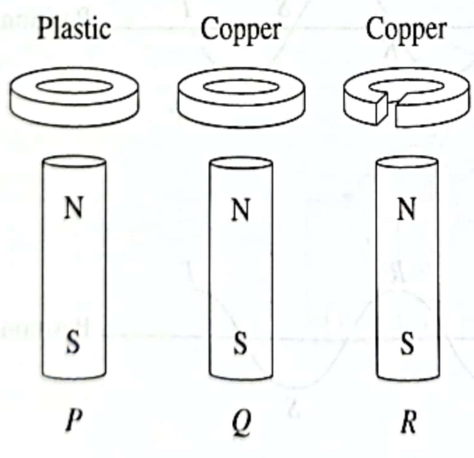
(B) electrostatic attraction

(C) electromagnetic induction

(D) radiation of energy

1982 HSC Q8 (adapted)

27. Three rings are dropped at the same time over identical magnets as shown below.



Which of the following describes the order in which the rings *P*, *Q* and *R* reach the bottom of the magnets?

(A) They arrive in the order *P*, *Q*, *R*.

(B) They arrive in the order *P*, *R*, *Q*.

(C) Rings *P* and *R* arrive simultaneously, followed by *Q*.

(D) Rings *Q* and *R* arrive simultaneously, followed by *P*.

2005 HSC Q9

28. Why is the back emf induced in a motor greater when the motor is rotating faster?

(A) A larger current is induced.

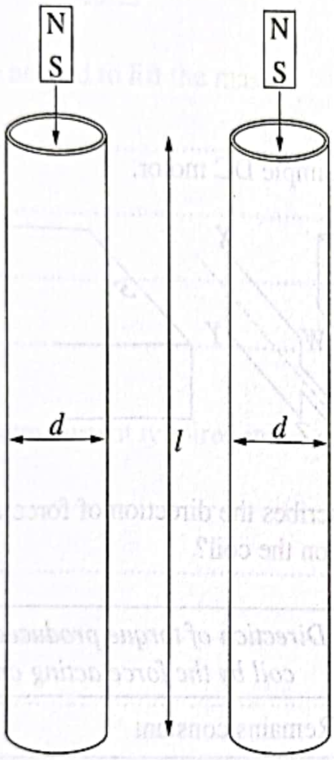
(B) It takes a greater emf to spin the motor.

(C) The rate of change of magnetic flux is greater.

(D) More magnetic field lines are being cut per rotation.

2011 HSC Q6

29. In a student experiment, a bar magnet is dropped through a long plastic tube of length l and diameter d. The time taken for it to hit the floor is recorded.



The experiment is repeated using a copper tube of the same length and diameter.

Which of the following statements is correct?

(A) The magnet will take the same time to hit the floor in both cases.

(B) The magnet will come to rest in the middle of the copper tube.

(C) The magnet will take longer to fall through the copper tube.

(D) The magnet will take longer to fall through the plastic tube.

2002 HSC Q9

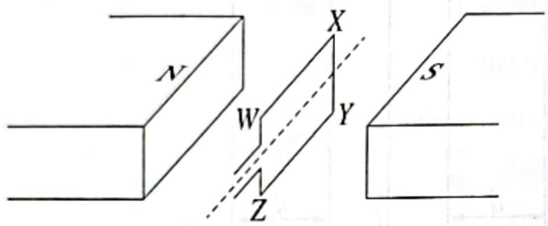
30. A motor, battery and ammeter are connected in series. When the motor is turning at full speed, the ammeter has a reading of 0.1 A. While the motor is spinning, a person holds the shaft of the motor to stop it.

Which row of the table correctly identifies the change in the ammeter reading and an explanation for the change?

	Reading on ammeter	*Explanation*
A.	Decreases	Decrease in back emf
B.	Increases	Increase in back emf
C.	Decreases	Increase in back emf
D.	Increases	Decrease in back emf

2018 HSC Q4

31. The diagram shows some parts of a simple DC motor.



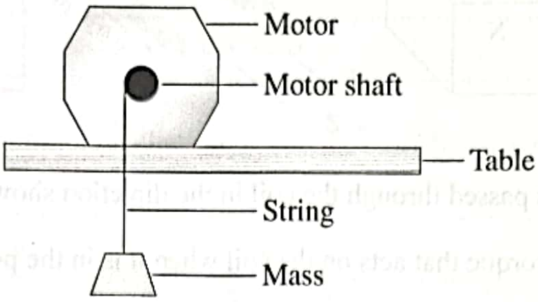
Which row of the table correctly describes the direction of force acting on side *WX* and the direction of torque this produces on the coil?

	Direction of force acting on WX	*Direction of torque produced on the coil by the force acting on WX*
A.	Remains constant	Remains constant
B.	Remains constant	Reverses every 180°
C.	Reverses every 180°	Remains constant
D.	Reverses every 180°	Reverses every 180°

2018 HSC Q10

Short-answer questions

32. A 0.05 kg mass is lifted at a constant speed by a DC motor . The motor has a coil of 100 turns in a 0.1 T magnetic field. The area of the coil is 0.0012 m^2. The motor shaft has a radius of 0.004 m.



(a) Determine the force needed to lift the mass.

....

....

....

....

(b) Calculate the minimum current required in the coil to lift the mass.

....

....

....

....

....

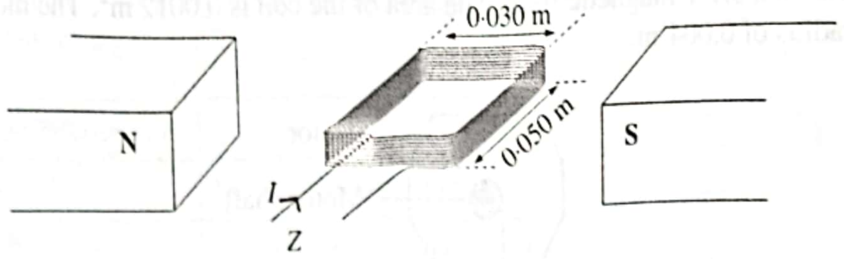
....

....

....

2013 HSC Q29 – 2 = 3 = 5 marks

33. A coil consists of ten turns of insulated copper wire ... magnets as shown in the diagram. These magnets may be assume... magnetic field of flux density 0·15 T.



A current of 2.0 A is passed through the coil in the direction shown.

(a) Calculate the torque that acts on the coil when it is in the position shown in the diagram.

....

....

(b) In what direction will the coil start to turn as seen from position *Z*. ....

(c) A device is placed at *Z* to allow current to be supplied to the coil so that the coil rotates continuously.

(i) Name the device. ....

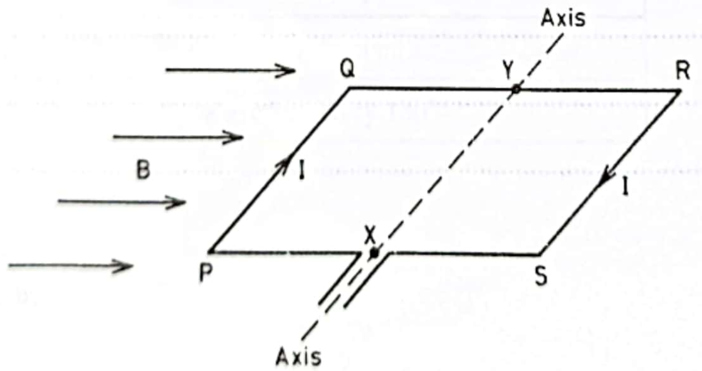
(ii) Explain how it works. ....

....

....

1999 HSC Q30 – 2 + 2 + 2 = 5 marks

34. A square coil *PQRS* of side 3.0×10^{-2} m lies in a horizontal plane with sides *PS* and *QR* parallel to a uniform magnetic field, *B*, of 1.5 T, as shown in the diagram below. The coil has 100 turns and a current of 2.0 A flows in the direction shown.



(a) What is the magnitude and direction of the force on the side *PQ*? Show your working.

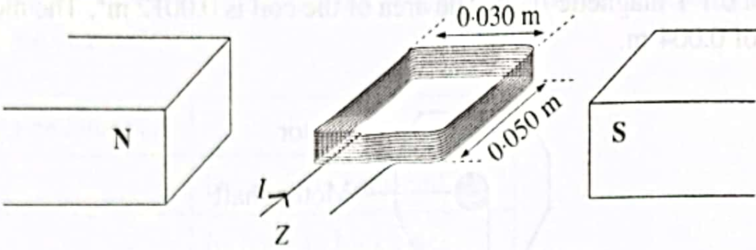
....

....

....

Question 34 continues

33. A coil consists of ten turns of insulated copper wire. It is placed between the poles of magnets as shown in the diagram. These magnets may be assumed to create a uniform magnetic field of flux density 0·15 T.



A current of 2.0 A is passed through the coil in the direction shown.

(a) Calculate the torque that acts on the coil when it is in the position shown in the diagram.

....

....

(b) In what direction will the coil start to turn as seen from position *Z*. ....

(c) A device is placed at *Z* to allow current to be supplied to the coil so that the coil rotates continuously.

(i) Name the device. ....

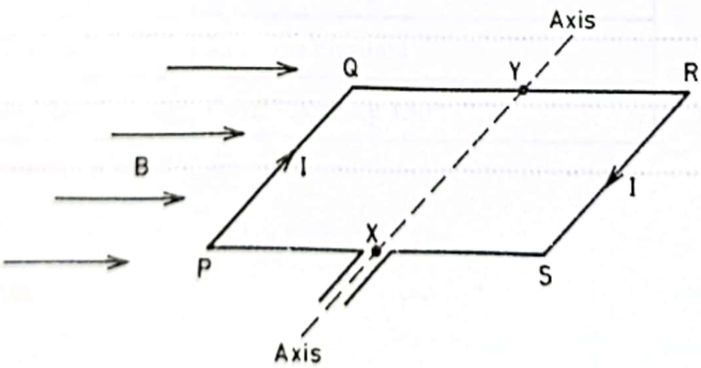
(ii) Explain how it works. ....

....

....

1999 HSC Q30 – 2 + 2 + 2 = 5 marks

34. A square coil *PQRS* of side 3.0×10^{-2} m lies in a horizontal plane with sides *PS* and *QR* parallel to a uniform magnetic field, *B*, of 1.5 T, as shown in the diagram below. The coil has 100 turns and a current of 2.0 A flows in the direction shown.



(a) What is the magnitude and direction of the force on the side *PQ*? Show your working.

....

....

....

Question 34 continues

(b) What is the flux change through the coil when it rotates about the axis, XY, through 90° from the position shown in the diagram? Show your working.

....

....

....

(c) What is the maximum torque that can act on the coil? Show your working.

....

....

....

....

End of Question 34

1986 HSC Q23 – 2 + 2 + 2 = 5 marks

35. A fan that ventilates an underground mine is run by a very large d.c. electric motor. This motor is connected in series with a variable resistor to protect the windings in the coil.

When the motor is starting up, the variable resistor is adjusted to have a large resistance. The resistance is then lowered slowly as the motor increases to its operating speed.

Explain why no resistance is required when the motor is running at high speed, but a substantial resistance is needed when the motor is starting up.

....

....

....

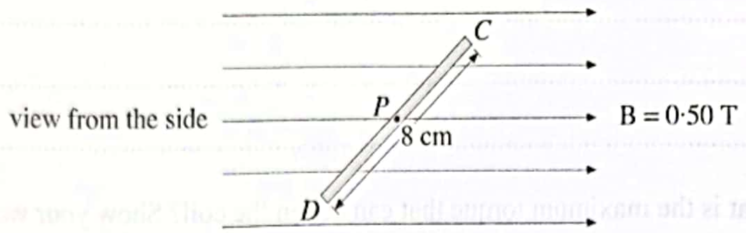
....

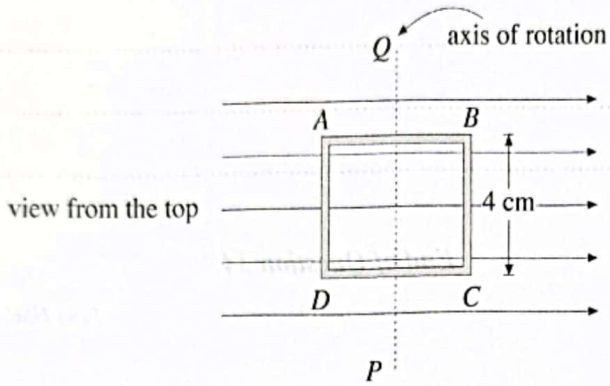
....

....

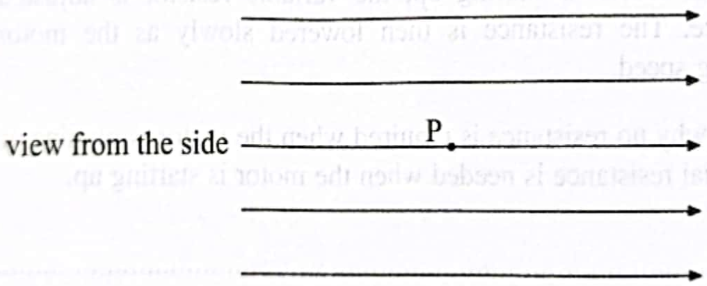
2001 HSC Q21 – 3 marks

36. A rectangular coil *ABCD* of dimensions 8.0 cm by 4.0 cm is made up of 250 turns of wire. It is placed in a uniform magnetic field with a flux density of 0.50 T. It is free to rotate about an axis, *PQ*, as shown in the diagrams below. A current of 9.0 μA flows through the coil.





(a) Complete the diagram below by drawing a sketch from the side showing the angle of the coil in the field when the torque is maximum.



(b) The coil is then rotated 180° around axis *PQ* from the position of maximum torque. Compare the torque in this position with that described in part (a).

....

(c) What is the magnitude of the maximum torque?

....

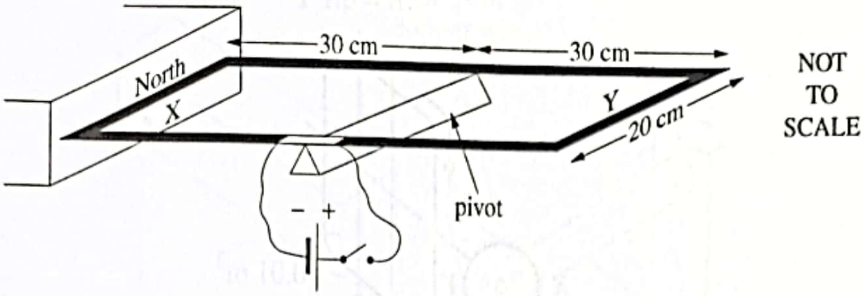
....

(d) What is the magnitude of the force on side *DC* of the coil when the torque is maximum?

....

1995 HSC Q30 – 2 + 1 + 2 + 1 = 6 marks

37. A rectangular wire loop is connected to a DC power supply. Side X of the loop is placed next to a magnet. The loop is free to rotate about a pivot.



When the power is switched on, a current of 20 A is supplied to the loop. To prevent rotation, a mass of 40 g can be attached to either side X or side Y of the loop.

(a) On which side of the loop should the mass be attached to prevent rotation?

....

(b) Calculate the torque provided by the 40 g mass.

....

....

....

(c) Calculate the magnetic field strength around side X.

....

....

....

2009 HSC Q21 – 1 + 2 + 3 = 6 marks

38. The windings of a large DC electric motor may be protected by placing a variable resistor in series with them. Prior to the motor being switched on, the operator sets this resistance at its maximum value. After switching on, the resistance is reduced to zero as the motor gathers speed.

(a) Explain why this protection may be necessary when the motor is turning slowly, but is not necessary when the motor is running at normal speed.

....

....

....

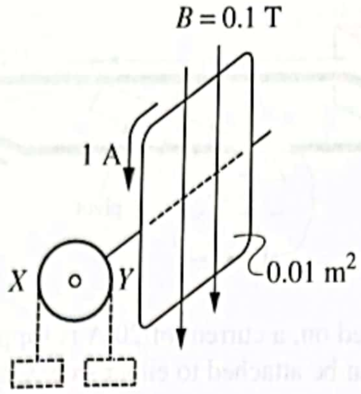
(b) Why would such protection be more likely to be needed for a direct current motor than for an alternating current motor.

....

....

1986 HSC Q17 adapted– 2 + 2 = 4 marks

39. A simple motor consists of a flat rectangular coil with n turns in a magnetic field B as shown.



The coil has an area of $0.01\ m^2$ and carries a current of 1 A. The motor drives a pulley of diameter 20 cm, and weights can be hung from either side of the pulley at point X or point Y.

(a) In order to prevent rotation, should a weight be hung at point X or at point Y? Justify your answer.

....

....

(b) What is the magnitude of the torque provided by a mass of 0.2 kg suspended from either point X or point Y?

....

....

....

....

(c) If the motor is just stopped by a mass of 0.2 kg, how many turns does the coil have?

....

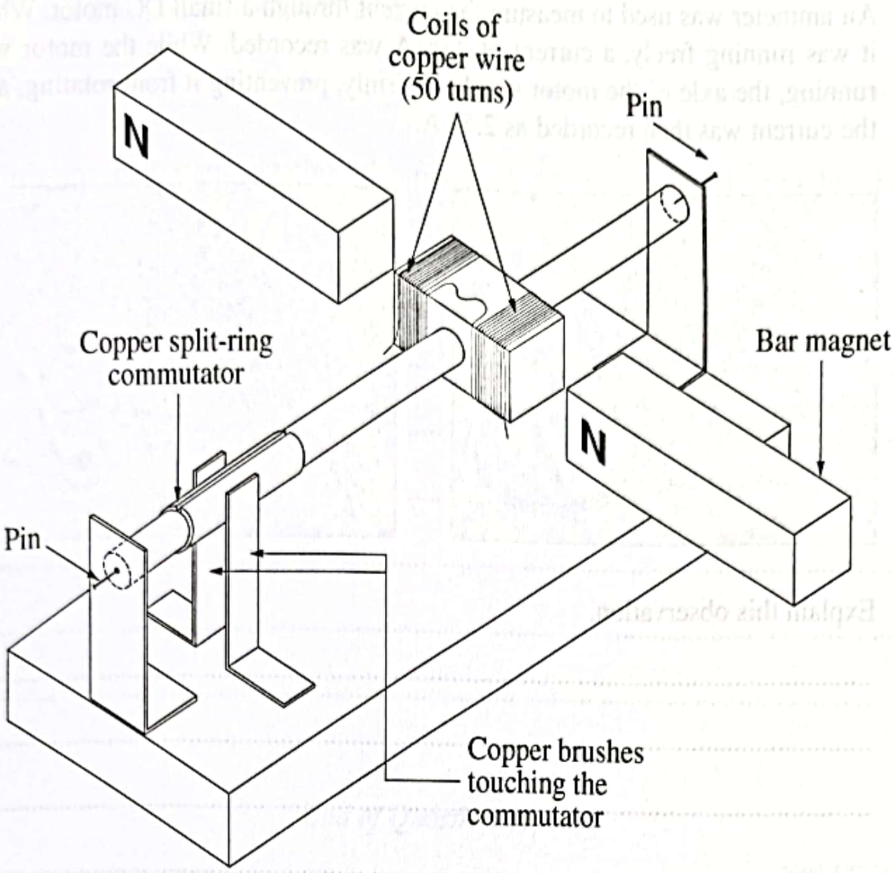
....

....

....

2007 HSC Q21 – 1 + 2 + 2 = 5 marks

40. (a) The diagram shows a two-pole DC motor as constructed by a student.



Identify THREE mistakes in the construction of this DC motor as shown in the diagram.

....

....

....

....

....

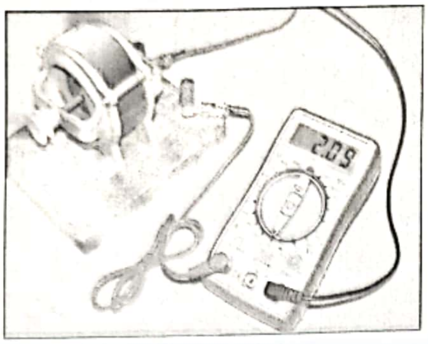
....

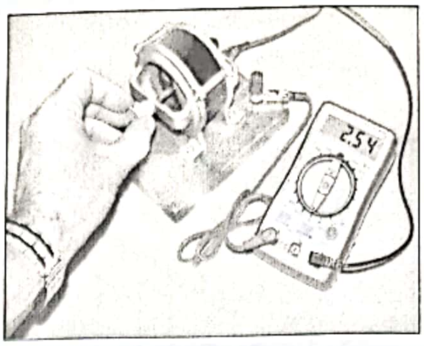
Question 40 continues

2004 HSC Q21(a), (b)

Question 40 (continued)

(b) An ammeter was used to measure the current through a small DC motor. While it was running freely, a current of 2.09 A was recorded. While the motor was running, the axle of the motor was held firmly, preventing it from rotating, and the current was then recorded as 2.54 A.





Explain this observation.

....

....

....

....

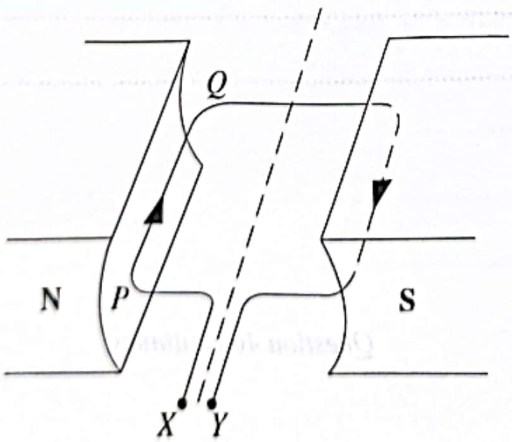
....

....

End of Question 40

2004 HSC Q21(a), (b) – 3 + 3 = 6 marks

41. The diagram shows a coil in a magnetic field. The coil can rotate freely.



The coil is connected to a power supply and, at the instant shown, terminal X is positive.

Question 41 continues

Question 41 (continued)

(a) In which direction will side PQ initially move? **1**

....

(b) When the coil starts rotating, the potential difference experienced by the electrons in the wire is less than that supplied by the power supply. **3**

Describe the origin of this effect.

....

....

....

....

....

End of Question 41

2008 HSC Q18 – 4 marks

42. (a) Outline an investigation that can be used to demonstrate the principle of an AC induction motor. **2**

....

....

....

....

(b) Explain how the motor effect is used in an AC motor. **3**

....

....

....

....

....

....

2014 HSC Q25 – 5 marks

43. A student drops a bar magnet onto a large block of copper resting on the floor. The magnet falls towards the copper, slowing down as it comes close, then landing gently.

Explain the physics responsible for this observation.

....

....

....

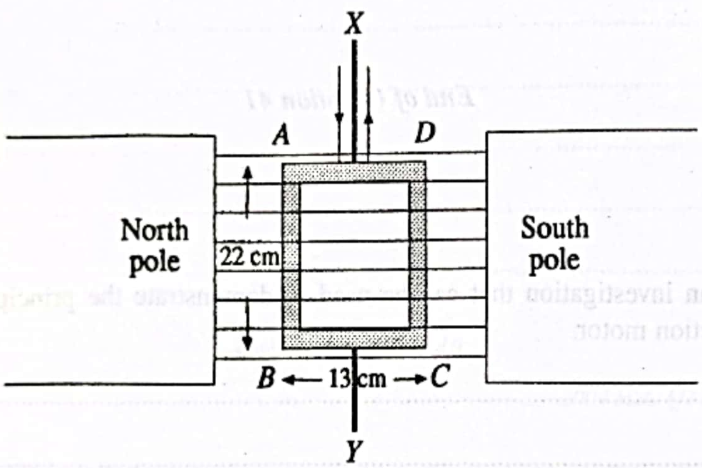
....

....

....

2006 HSC Q22(a)

44. Two large bar magnets and a vertical coil are shown in the diagram.



View from the side

The coil, *ABCD*, is able to rotate about a vertical axle, *XY*, through its centre. The coil consists of 140 turns of wire. Current can flow into and out of the coil along wires attached to the upper end of the axle.

The coil is 22 cm high and 13 cm wide. The magnetic flux density between the poles of the magnets is 0·80 tesla.

(a) Before the current in the coil is turned on, what is the flux through the coil when the plane of the coil is parallel to the field?

....

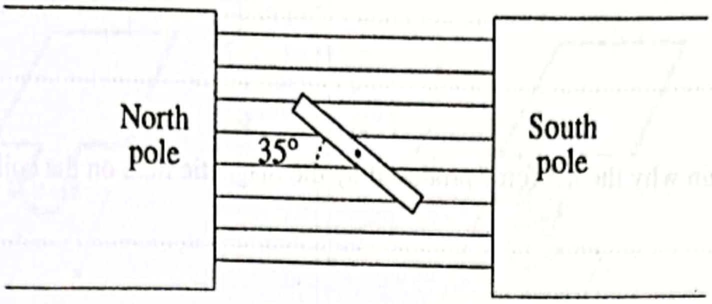
(b) When a current of 3·0 A flows through the coil, calculate the magnitude of the force on side *AB* of the coil.

....

....

Question 44 continues

(c) Calculate the torque on the coil when the plane of the coil is at an angle of 35° to the magnetic flux as shown below.



View from the top

....

....

(d) If the magnets and the coil described above are used as the basis for an electric meter, what should be added to cause the coil to stop at the correct position to indicate the current?

....

....

(e) If the magnets and the coil described above are used as the basis for an electric motor, what should be added to allow the coil to keep rotating in the same direction?

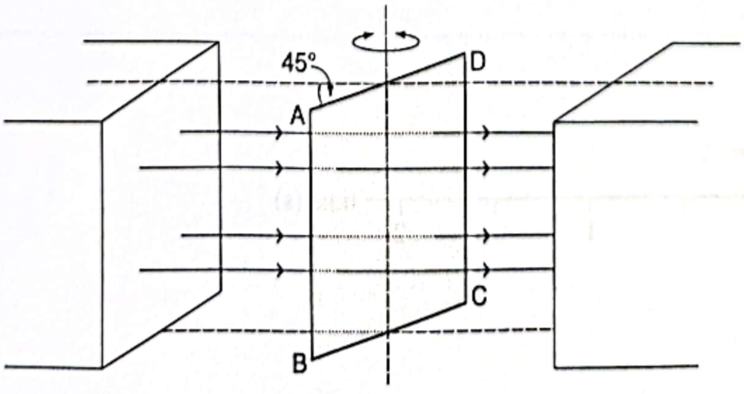
....

....

End of Question 44

1996 HSC Q30 – 1 + 2 + 2 + 2 + 1 = 8 marks

45. A single turn coil is positioned in a region of uniform magnetic field with a strength of 0.2 T. The plane of the coil is at 45° to the magnetic field. The coil is a square with 5 cm sides, and carries a current of 10.0 A.



Question 45 continues

Question 45 (continued)

(a) Calculate the magnitude of the force on side AB.

....

....

....

(b) Explain why the net force produced by the magnetic field on the coil is zero.

....

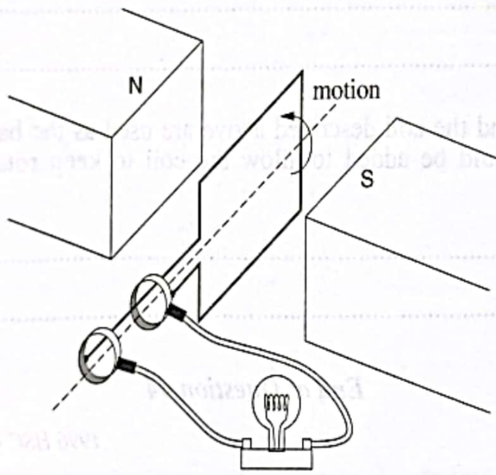
....

....

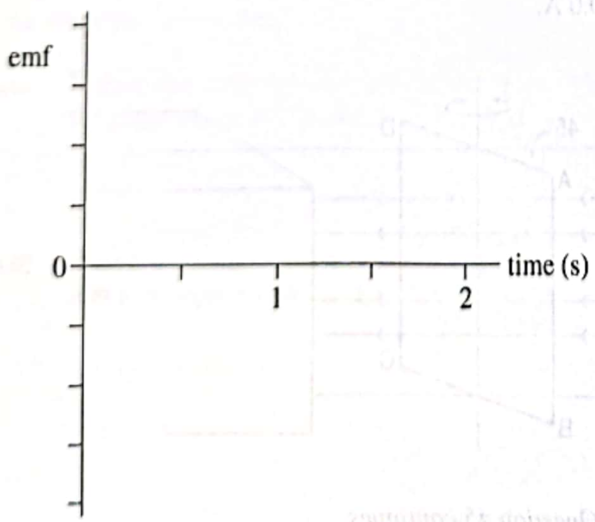
End of Question 45

2011 HSC Q27 – 2 + 2 = 44 marks

46. A generator starts at the position shown and is rotated by one revolution in the first second. It is then rotated by two revolutions in the next second.

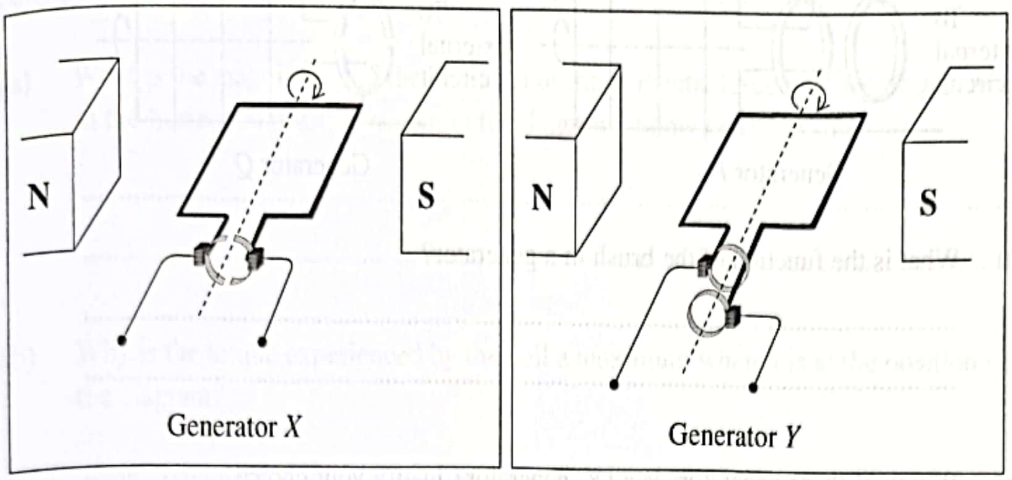


Sketch a graph on the axes showing the electromotive force (emf) produced by this generator for these two seconds.

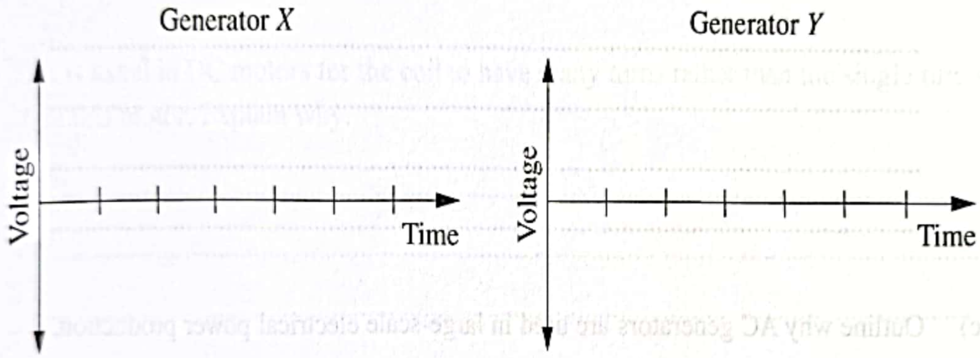


2013 HSC Q27(a) – 3 marks

47. The diagrams show two different types of generator spinning at the same number of revolutions per minute. The difference between the two generators is in the way they are connected to the external circuits.



(a) On the axes below, sketch a voltage-time graph for each generator. **2**



(b) Explain how the difference in connection to the external circuit accounts for the different output voltages. **3**

....

....

....

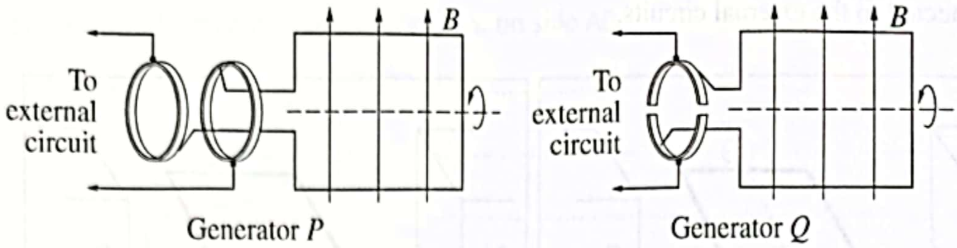
....

....

....

2008 HSC Q25 – 5 marks

48. Two types of generator are shown in the diagram.



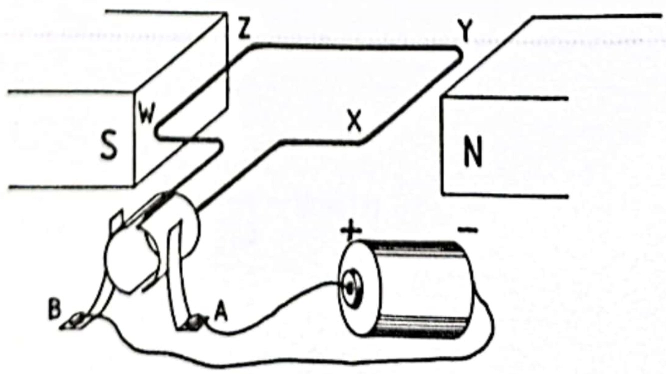
(a) What is the function of the brush in a generator? **1**

(b) Which of these generators is a DC generator? Justify your choice. **3**

(c) Outline why AC generators are used in large-scale electrical power production. **2**

2002 HSC Q22 – 6 marks

49. The diagram below shows a simple DC electric motor.



Question 49 continues

Question 49 (continued)

The square coil WXYZ is a single turn and has sides 0.20 metres long. The current through the coils 5.0 A and the uniform field strength between the magnetic poles is 0.60 T.

(a) What is the magnitude and the direction of the magnetic force on the side XY when it is in the horizontal position shown in the diagram? Show your working.

....

....

(b) Why is the torque experienced by the coil a maximum when it is at the position shown in the diagram?

....

....

....

(c) It is usual in DC motors for the coil to have many turns rather than the single turn shown in this motor. Explain why.

....

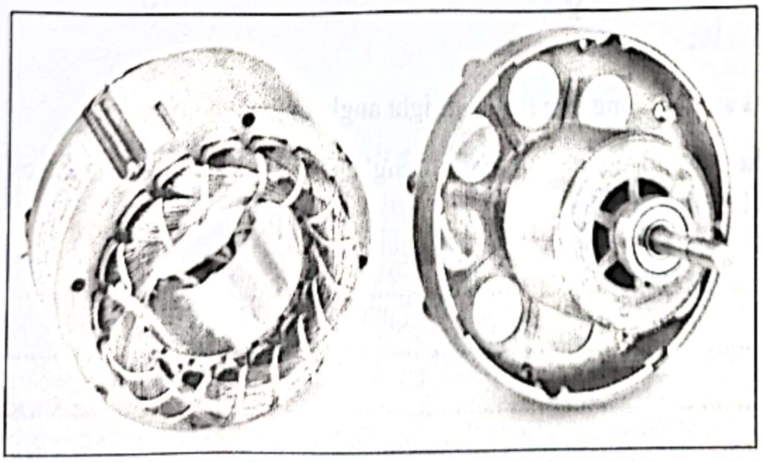
....

....

End of Question 49

1983 HSC Q23 (adapted) – 2 + 2 + 2 = 6 marks

50. The photograph below shows parts of an AC electric motor.



Question 50 continues

Question 50 (continued)

Describe the main features of this type of motor and its operation.

....

....

....

....

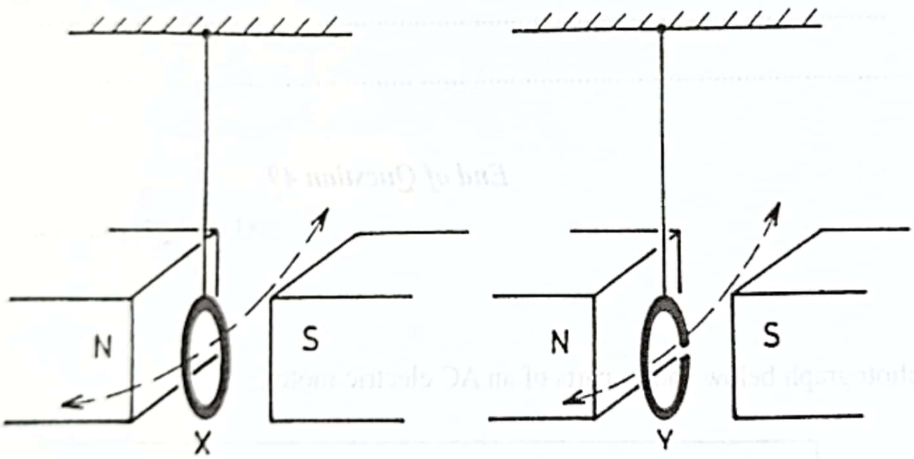
....

....

End of Question 50

2004 HSC Q22 – 3 marks

51. Consider two aluminium rings of the same radius and similar mass. Ring X is complete, Ring Y has a small gap cut through the ring. Each ring is suspended by a very light nylon thread between the poles of strong magnets, as shown below.



Each ring is set swinging in a plane at right angle to the magnetic field.

Describe the subsequent motion of each ring and account for any differences in these motions. Diagrams may be used.

....

....

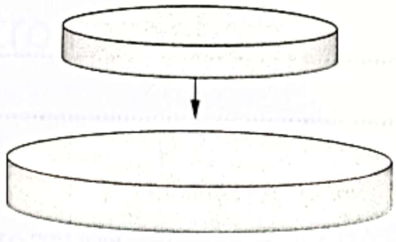
....

....

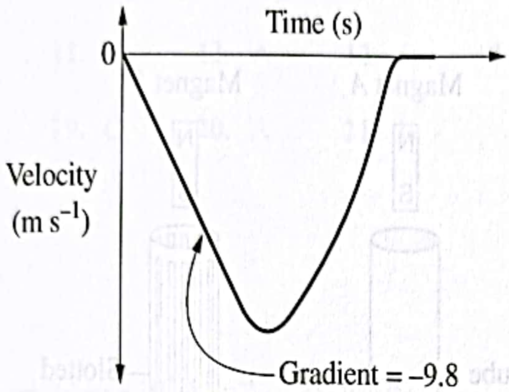
....

1990 HSC Q17 – 3 marks

52. A strong magnet is at rest a few centimetres above a solid metal disc made of a non-magnetic metal. The magnet is then dropped.



The velocity of the magnet is shown in this graph.



Account for the shape of the graph.

....

....

....

....

....

....

2016 HSC Q22(b) – 4 marks

53. (a) Explain the need for each of the following in a DC motor:

(i) split-ring commutator: ....

....

....

(ii) brushes: ....

....

....

Question 53 continues

(b) What is the maximum torque in a DC motor in which the effective area of a 300-turn coil is 1.2×10^{-3} m^2, the current is 5.0 A, and the magnetic field strength is 0.40 T.

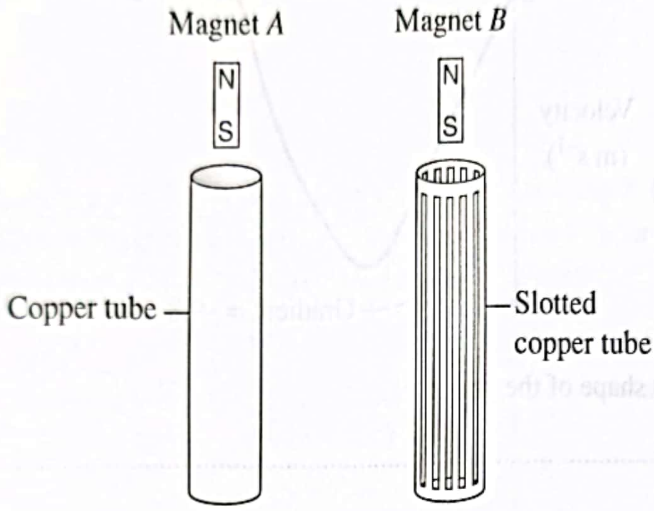
....

....

End of Question 53

1998 HSC Q22 (adapted) – 2 + 2 + 2 = 6 marks

54. Identical magnets *A* and *B* are suspended above vertical copper tubes as shown in the diagram.



The magnets are dropped at the same time. Each magnet falls straight through its tube without touching the tube walls.

Which magnet leaves its tube first and why?

....

....

....

....

....

....

....

....

....

....

2011 HSC Q25 – 4 marks

6.4 Applications of the Motor Effect

Multiple choice: 1 mark each

1. D	2. B	3. A	4. B	5. C	6. C	7. A	8. D
9. B	10. A	11. D	12. C	13. B	14. A	15. C	16. B
17. D	18. C	19. C	20. B	21. B	22. D	23. C	24. B
25. C	26. C	27. C	28. C	29. C	30. D	31. C	

Explanations:

1. D When a DC motor starts to rotate due to the current through its coils caused by the applied emf, the coils are exposed to a changing magnetic field. This is due to the relative motion of the coils and the field. A back emf is induced that works against the input voltage, reducing the current in the coil and hence the torque. The higher the rate of rotation of the motor, the higher the back emf and so the smaller the torque, as shown in (D). The graph in (C) is incorrect as it shows the opposite. Torque in a DC motor is always in the one direction, so (A) is incorrect. Torque is relatively constant over a single rotation where the armature has several coils, but not at different speeds. So (B) is incorrect.

2. B $\tau = nBIA\cos\theta = 3 \times 0.45 \times 0.5 \times (0.1 \times 0.1) \times 1 \quad [\theta = 0°]$

$= 6.75 \times 10^{-3}$ Nm ... as in (B).

3. A As the motor's speed increases, back emf in the motor coils increases (Faraday's Law). Back emf, as the name suggests, works against the constant voltage of the supply (Lenz's Law). The effect is equivalent to a reduced voltage and results in a reduced current. So the higher the speed, the lower the current, as in (A).

4. B The coils (solenoids) to the left of the rotor, plus the coils to the right of the rotor in (A) and (B) have current flowing in the same direction in each case. The left side of each coil will behave as a south pole in every case. As a result, there will be a downward force on the left side of the rotor in (A) and (C) and an upward force in (B) and (D). The right hand side of the rotor will experience an upward force in (A) and (D) and a downward force in (B) and (C). As a result of these forces, (A) will rotate anticlockwise, (B) will rotate clockwise and the forces in (C) and (D) will balance, resulting in no motion. So (B) is the answer.

5. **C** An 'ideal motor' has no energy losses. The applied voltage is equal to the back emf because it is rotating at a constant rate. So (C) is the answer. If the applied voltage is greater or less than the back emf, the motor will speed up or slow down until the applied voltage and the back emf are equal. So (A) and (D) are incorrect. DC motors do generate a back emf, so (B) is incorrect.

6. **C** A current around a coil in a magnetic field produces a torque, so both (A) and (B) are incorrect. Using the Right Hand Palm Rule (or Fleming's Left Hand Rule, etc), the current in the left vertical arm of the coil is downwards causing a force on it that is out of the page. The current is upwards in the right vertical arm of the coil, causing a force that pushes into the page. The combined result is a torque as shown in (C), and not the reverse as in (D).

7. **A** When viewed end on at *X*, the current around that solenoid is flowing clockwise, so *X* is a south pole. Using the Right Hand Palm Rule to work out the direction of motion – fingers point in direction of field (towards *X*), thumb points in direction of current in *Y* (down the page) and palm gives direction of force and hence the motion (into the page). So (A) is the answer.

[Note: The polarity of *X* can also be worked out by putting the fingers of your right hand in the direction of the conventional current, and your thumb will point to the north pole, so *X* is a south pole.]

8. **D** The coil does not move because the forces acting are at right angles to both the magnetic field and the current direction and so are in the plane of the coil. So there is no torque acting on the coil. This will not change if the magnetic field is increased, as in (A), or if the current is increased, as in (C) – as these changes will cause the forces acting on different sides of the coil to increase, but they will still not produce a torque. Reversing the current, as in (B), will reverse the direction of the forces, but they will still be balanced. So this will not result in a torque either. Changing the position of the coil will result in forces on the vertical sections of the coil that produce a torque causing the coil to spin. So (D) is the answer.

9. **B** Wire *AB* is in a region of uniform magnetic field strength. It is carrying a constant current, so it experiences a constant downwards force at 90° to both the field and the current. When the rotor crosses the split ring commutator, the current reverses and the constant force becomes upwards. After the rotor turns another 180°, the current again reverses and the force again becomes downwards. Only (B) and (C), show this variation of force with time. The torque is a maximum when the coil is parallel to the magnetic field and is zero when the coil is perpendicular to the magnetic field when the current reverses. The torque turns the coil in one direction only in a DC motor. The correct relationship between torque and time is shown in (B) and (D). Only (B) has the correct combination of both graphs.

[Note: The arrow given on the axis of the coil in the HSC was incorrect – as it shows the motion of the motor to be clockwise. Using the Right Hand Palm Rule gives that, with the field and current direction shown, the motion will be anticlockwise.]

10. **A** The output of the DC generator is related to the rate at which the coil is cutting magnetic flux, so increasing the rotation speed of the rotor would increase the output. So (A) is the answer. Reducing the number of windings would reduce the output, so (B) is incorrect. Using slip rings instead of a split ring commutator would give an AC output instead of a DC output, so (C) is incorrect. Wrapping the windings around a laminated soft iron core would increase the output, however, aluminium lacks the required magnetic properties, so (D) is incorrect.

11. **D** The induced emf in a coil is directly proportional to the rate at which the magnetic flux through the coil is changing with time. This will be halved if the rate of rotation is halved. Hence the induced emf will be halved. Hence the voltage shown should be halved and the output of the AC generator should be reduced, as shown in (D). Graphs (A) and (B) incorrectly show the frequency doubling instead of halving, while graph (C) incorrectly shows the voltage unchanged.

[Note: This could also be worked out mathematically: $E_{emf} = -n\frac{d\phi}{dt}$ where n = no. of turns on the coil.]

12. **C** The slower rotation speed of the motor would result in lower back emf and therefore a higher current in the coils causing them to heat. So (C) is the answer. Resistance does not vary greatly with increased temperature, but rather remains essentially the same, so (A) is incorrect. The increased friction is converted to heat, but this occurs between the drill bit and the material being drilled and so does not affect the coils in the motor. So (B) is incorrect. The slower rotation speed would result in less induced eddy currents rather than more, so (D) is incorrect.

13. **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.

14. **A** Maximum torque (τ) occurs when the normal to the coil's plane is perpendicular to the magnetic field.

$\theta = 90°$, so $\sin\theta = 1$

$\tau = nBIA \sin\theta = 500 \times 1.0 \times 10^{-3} \times 4.0 \times (0.2 \times 0.1) = 0.04$ N m, as in (A).

15. **C** In an AC induction motor, there is no electrical connection to the rotor. So there are no split rings and no current is supplied or conducted to the rotor. So both (B) and (D) are incorrect. The motor works as a result of interactions between the changing magnetic fields of the stator and the magnetic fields resulting from induced currents in the rotor. This can only occur when the rotor has a changing magnetic field, so (C) is the answer. No force would act on the rotor if it had a fixed magnetic field, so (A) is incorrect.

16. **B** When a conductor (the disc) is moved through a magnetic field, eddy currents are induced in the region of the magnetic field. The force produced by the eddy currents opposes the motion of the conductor that is producing them (Lenz's Law). An eddy current is produced in the small section of the disc affected by the magnetic field. In this case, the current will be downwards in the section of the disc that is in the magnetic field. As well as the return eddy currents that flow in adjacent areas of the conductor just outside the magnetic field, current can also flow from Brush *Y* to Brush *X* through the external circuit via the globe, as in (B).

17. **D** The device shows a connection via a split ring commutator between the coil and the attached circuit. Hence the device is a DC generator, as in (D). A motor requires a power supply, so both (A) and (B) are incorrect. An AC generator would not have a split ring commutator, so (C) is incorrect.

18. **C** When a large current is passed through the electromagnet, a strong magnetic field is produced. As the train is moving, eddy currents will be induced in the metal rail below the electromagnet. By Lenz's Law, these eddy currents will be directed so as to oppose the motion that produces them, so they brake the train. The law of conservation of energy is a basic rule of physics that applies to all the devices mentioned. However, only the induction motor is an example of the same application, so (C) is the answer.

19. **C** The emf produced is doubled and the frequency is also doubled, which is brought about by doubling the speed of rotation, as in (C). The output would become DC instead of alternating if (B) occurs, so (B) is incorrect. Both (A) and (D) will increase the emf, but not change the frequency. So (A) and (D) are incorrect.

20. **B** When a direct current flows through the armature of a DC motor, it results in a torque that causes the armature to rotate. As the armature rotates through the magnetic field, an emf is induced in it, as in a generator. Lenz's Law indicates that this will be a back emf opposing the applied voltage (supply emf) and so will limit the speed of the motor. Hence (B) is the answer.

21. **B** The induced output from the coil rotating in the magnetic field will be an AC voltage. The split ring commutator ensures that current only flows one way to the CRO and so changes polarity (+ or –) each half revolution of the coil. So the output to the CRO will be a fluctuating DC voltage with a minimum and maximum twice per revolution, as in (B).

22. **D** The most applicable application is an induction motor, which requires a rotating magnetic field. No external source of electricity is required. Both a DC motor as in (A) and a galvanometer as in (B) require an input of an electric current. A generator as in (C) induces an electric current but one which can be directed away from the source and used elsewhere. The experimental set-up shown in the diagram induces an internal electric (eddy) current in the disk. The magnetic field produced by these eddy currents interacts with the magnetic field of the magnet to produce the force turning the disk. This is the same principle as used in an AC induction motor, so (D) is the answer.

23. **C*** Current in the loop between the magnets reverses each 180° turn at the point where the loop is vertical between the magnets, i.e. the current induced in the coil is AC. A split ring commutator, as shown in generator 1, produces one way current (DC), as each half turn of the coil changes the end of the coil that is in contact with each half of the commutator. In generator 2, each end of the coil remains in continuous contact with a slip ring, so the current alternates in direction every half turn of the loop (AC). So (C) is the answer.

[* Note: The diagram shown here for Question 23 was used in the 2001 HSC – it has the splits in the commutator ring about 60° out of alignment, as the contacts should swap at zero current, not at maximum current. Thus a complicated emf with both AC and DC components will actually be produced, with lots of 'noise' generated by sparks at the splits. Hence (B) is also a correct answer.]

24. **B** At *P*, the left and right arms of the coil are moving perpendicular to the field, causing maximum change of flux and therefore maximum induced emf, as in (B) and (D). So both (A) and (C) are incorrect. At *Q*, no arm of the coil is effectively 'cutting' field lines, i.e. there is no change of flux and so zero induced emf. So, (B) is correct and (D) is incorrect.

25. **C** No external current is supplied to the bike, so (A) is incorrect. At the hardest exercise level, magnetic braking provides maximum resistance to peddling. For this to occur, the magnetic field at the wheel should be a maximum, not a minimum – so (B) is incorrect. The distance between the magnets and the wheel needs to be a minimum, not a maximum – so (D) is incorrect. When the distance between the magnets and the wheel is a minimum, the magnetic field at the wheel will be a maximum and the induced current in the wheel will be a maximum making it harder to pedal the exercise bike. So (C) is the answer.

26. **C** The aluminium disc is rotating in the field of the magnet, i.e. the conductor is moving relative to the field. So, eddy currents are induced, which oppose the motion (Lenz's Law). The induced currents have a braking effect, which causes the disc to quickly come to rest. So (C) is the answer.

27. **C** In *Q*, a current is induced in the copper ring as it moves through the magnetic field. By Lenz's Law, the induced current will oppose the motion causing its induction, so the fall of the ring in *Q* will be slowed by magnetic braking. *P* and *R* will fall under the influence of gravity and arrive simultaneously as the split in the ring in *R* prevents current flowing and no current can flow in *P* as the plastic is not a conductor. So (C) is the answer.

28. **C** As the armature of an electric motor begins to spin, the magnetic flux through the coil changes and an emf is induced that opposes the motion of the motor. As the motor rotates faster, the rate at which the magnetic flux changes increases and the back emf increases, so (C) is the answer. The back emf is opposite in direction to the applied voltage so the current in the coil decreases, so (A) is incorrect. The motor is already spinning to produce a back emf, so (B) is irrelevant. The number of field lines cut per rotation is a constant, so (D) is incorrect.

29. C As the magnet falls through the tubes, the material of the tubes experiences a changing magnetic field. Copper is a conductor, so in the copper tube, charges are free to move. Thus the moving magnet creates an induced emf in the copper causing eddy currents to flow. According to Lenz's Law, these currents will flow in a direction that will oppose the motion that created them. The eddy currents that are produced in the copper cause the speed of the falling magnet to decrease, as in (C). In the plastic tube, such currents cannot be created as plastic is an insulator and so the speed of the falling magnet is not affected.

[Note: Some fun park rides use eddy current braking. You may have been on a Beyond the Thrills excursion to Luna Park Sydney and ridden on the 'Hair Raiser' ride, or been on a similar ride elsewhere. Each passenger seat on such a ride contains a number of large, strong permanent magnets. As these magnets pass the copper 'fins' in the bottom section of the tower, eddy (or Foucault) currents are induced in the copper fins. These in turn produce magnetic forces. This results in a braking force which slows the seats down. This is called electromagnetic braking.]

30. D The current of 0.1 A results from the resultant of the applied emf and the back emf generated by the motor spinning at full speed. By stopping the motor spinning, the back emf is reduced considerably, so the motor current increases. This combination of effects is only given in (D).

31. C The diagram shows a simple DC motor. The split ring commutator rings reverse the emf on *WX* every 180°, as only given in (C) and (D). However, the torque continues in one direction only to keep the motor spinning. So (C) is the answer, and (D) is incorrect.

Short-answer questions

32. (a) $F = mg = 0.05 \times 9.8 = 0.49$ N

(b) $\tau = Fd = Fr = 0.49 \times 0.004 = 1.96 \times 10^{-3}$ N m

$\tau = nIAB \sin\theta$

So, $1.96 \times 10^{-3} = 100 \times I \times 0.0012 \times 0.1 \times \sin\theta$

[$\theta = 90°$ … this is the angle between the normal to the plane of the coil and the direction of B.]

$\therefore$ Minimum current, $I = \dfrac{1.96 \times 10^{-3}}{100 \times 0.0012 \times 0.1 \times 1} = 0.163$ amp

33. (a) $\tau = nIAB \sin\theta$

$= 10 \times (0.030 \times 0.050) \times 0.15 \times 2.0 \times \sin 90$

$= 4.5 \times 10^{-3}$ N m

[$\theta = 90°$ … this is the angle between the normal to the plane of the coil and the direction of B.]

(b) anticlockwise

(c) (i) split ring commutator

(ii) After each 180° rotation, each commutator ring changes its connection to the opposite brush. This reverses the direction of the current flowing in the coil and allows continuous rotation in the one direction.

34. (a) $F = nIlB \sin\theta$

$= 100 \times (3.0 \times 10^{-2}) \times 2.0 \times 1.5 \times 1$

$= 9.0$ N downward

(b) $\Phi = BA \cos\theta$

When $\theta = 90°$, $\cos\theta = 0$. So, $\Phi = 0$

When $\theta = 0°$, $\cos\theta = 1$. So, $\Phi = 1.5 \times (3.0 \times 10^{-2})^2 \times 1$

$= 1.35 \times 10^{-3}$ Wb

$\therefore \Delta\Phi = 1.35 \times 10^{-3}$ Wb

(c) $\tau = nIAB \sin\theta$

$= 100 \times 2.0 \times (3.0 \times 10^{-2})^2 \times 1.5 \times 1$

$= 0.27$ N m

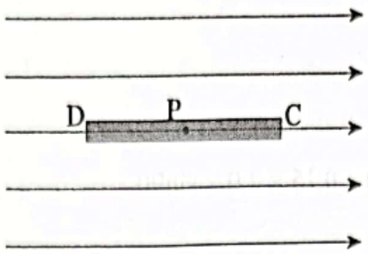
$\therefore$ Maximum $\tau = 0.27$ N m

35. When the motor is running at high speed, the rotation of the ... emf that is almost equal to the applied voltage. This back-emf reduces the net emf on the motor and so reduces the current flowing in it. Thus no resistance is required.

This back emf is proportional to the change in flux. So at low speeds, with low flux change and low back emf, a higher net current could flow. When the motor is starting up, a variable resistor, placed in series, is used to provide a substantial resistance to limit the current at start up and so prevents the motor from burning out.

36. (a)

view from the side



(b) The torque is the same, but direction is reversed.

(c) $\tau = nIAB \sin\theta$ *[Note: sin90 = 1]*

$= 250 \times (9 \times 10^{-6}) \times (0.08 \times 0.04) \times 0.5 \times 1$

$= 3.6 \times 10^{-6}$ N m

(d) 0 N *(since current flows along DC, parallel to the magnetic field)*

37. (a) Side X [Note: When the power is switched on, side X will tend to move upwards experiencing a force upwards at 90° to both I and B. The torque provided by the 40 g mass is able to balance this.]

(b) Torque, $\tau = Fd = mgd = 0.040 \text{ kg} \times 9.8 \text{ m s}^{-2} \times 0.30 \text{ m} = 0.1176 \text{ Nm} \approx 0.12 \text{ Nm}$

(c) $F_{down} = mg = F_{up} = l\,I\,B \sin\theta$

Magnetic field strength, $B = \dfrac{mg}{l \times I \times \sin\theta} = \dfrac{0.04 \times 9.8}{0.20 \times 20 \times 1} = 0.098$ T

[Note: Side Y is 60 cm away from the north pole. Only side X will be noticeably affected by this magnetic field.]

38. (a) When the motor is turning slowly, the applied voltage may cause a large current that could burn out the motor. Using a series resistor prevents this. As the motor speeds up, induced back emf results in a lower current, so this protection is no longer needed.

(b) In an AC motor, this is not a problem as AC voltage is self-limited by the continuous production of a back emf.

39. (a) Point X – Right Hand Palm Rule shows the motor spins clockwise (as seen from the pulley). So to prevent rotation, the pulley needs a weight at X to provide a balancing anticlockwise torque.

[Note: Right Hand Palm Rule is also known as the right-hand push rule.]

(b) $\tau = Fd = mgl$

$= 0.2 \text{ kg} \times 9.8 \text{ m s}^{-2} \times 0.10 \text{ m}$

$\therefore$ magnitude of torque, $\tau = 0.196 \text{ N m}$

[Note: The question only asks for the 'magnitude' of the torque, NOT its direction (which is anticlockwise).]

(c) $\tau = nIAB \sin\theta$ *[Note: sin90 = 1]*

$0.196 \text{ N m} = n \times 1.0 \text{ A} \times 0.01 \text{ m}^2 \times 0.1 \text{ T} \times 1$

$\therefore$ no. of turns in coil, $n = 196$ turns

40. (a) *Any THREE of the following:*

- There are no external power supply connections to allow power to be supplied to the copper brushes of the motor.
- There is no electrical connection between the split ring commutator and the motor coil.
- The splits in the commutator are incorrectly positioned and need to be rotated 90° and connected to the coil.
- The windings of the coil are reversed in direction on one side of the motor axle compared to the other (one is wound clockwise and the other is wound anticlockwise) – so the motor effect of one half would cancel the other.
- The orientation of the coil windings is vertical between the poles of the magnets instead of horizontal. This again would result in forces in various parts of the coil cancelling one another out.
- The coil is too big compared to the size of the magnets so that it moves well out of the intense field between the poles as it rotates.

(b) When the current flows, it causes the coil to turn. As the coil turns, the magnetic flux through the coil changes and a back emf is induced. By Lenz's Law, this back emf acts to oppose the motion, so it reduces the forward voltage driving the motor. The faster the motor is spinning the greater will be the back emf and the lower the current flowing through the motor. When the axle is prevented from rotating, no back emf is produced. Hence the full forward voltage will drive the motor causing a larger current to flow.

41. (a) Side PQ will move downwards.

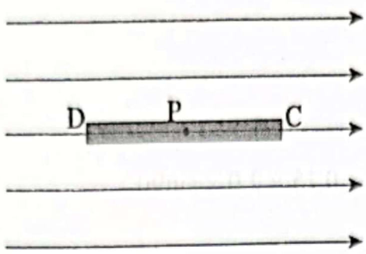
(b) When the coil starts rotating, the coil is exposed to a changing magnetic flux. This generates an emf that acts to oppose the motion (Lenz's Law). The external voltage applied to the motor is reduced by this induced back emf, which increases with the rotational speed of the motor.

35. When the motor is running at high speed, the rotation of the windings generates a back emf that is almost equal to the applied voltage. This back-emf reduces the net emf on the motor and so reduces the current flowing in it. Thus no resistance is required.

This back emf is proportional to the change in flux. So at low speeds, with low flux change and low back emf, a higher net current could flow. When the motor is starting up, a variable resistor, placed in series, is used to provide a substantial resistance to limit the current at start up and so prevents the motor from burning out.

36. (a)

view from the side



(b) The torque is the same, but direction is reversed.

(c) $\tau = nIAB \sin\theta$ *[Note: sin90 = 1]*

$= 250 \times (9 \times 10^{-6}) \times (0.08 \times 0.04) \times 0.5 \times 1$

$= 3.6 \times 10^{-6}$ N m

(d) 0 N *(since current flows along DC, parallel to the magnetic field)*

37. (a) Side X [Note: When the power is switched on, side X will tend to move upwards experiencing a force upwards at 90° to both I and B. The torque provided by the 40 g mass is able to balance this.]

(b) Torque, $\tau = Fd = mgd = 0.040 \text{ kg} \times 9.8 \text{ m s}^{-2} \times 0.30 \text{ m} = 0.1176 \text{ Nm} \approx 0.12 \text{ Nm}$

(c) $F_{down} = mg = F_{up} = l\,I\,B \sin\theta$

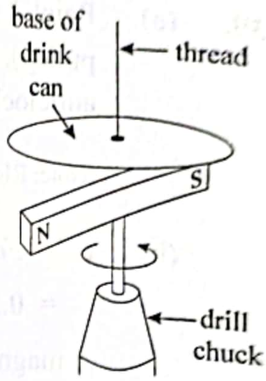
Magnetic field strength, $B = \dfrac{mg}{l \times I \times \sin\theta} = \dfrac{0.04 \times 9.8}{0.20 \times 20 \times 1} = 0.098$ T

[Note: Side Y is 60 cm away from the north pole. Only side X will be noticeably affected by this magnetic field.]

38. (a) When the motor is turning slowly, the applied voltage may cause a large current that could burn out the motor. Using a series resistor prevents this. As the motor speeds up, induced back emf results in a lower current, so this protection is no longer needed.

(b) In an AC motor, this is not a problem as AC voltage is self-limited by the continuous production of a back emf.

42. (a) Suspend the aluminium bottom from a drink can horizontally on a long thread, so it is free to rotate. Attach a magnet to the chuck of a hand drill. Rotate the drill so the magnet spins in one direction. As the magnet turns, the aluminium disc will spin in the same direction.



[Note: (1) This induces eddy currents in the disc, which produce a magnetic field opposing that of the magnet. This causes the disc to spin, following the field of the magnet. (2) The 3D diagram on the right illustrates this method. If you include a diagram in your answer, you should draw it in 2D.]

(b) Each bar of the squirrel cage rotor becomes a current-carrying conductor in a changing magnetic field, so the motor effect results in a force on each bar causing the squirrel cage to rotate. The torque remains relatively constant and in one direction because every 180° of rotation the current reverses direction as does the magnetic field. So the motor effect keeps the motor rotating.

43. The moving magnet causes the stationary copper block to experience a changing magnetic field. Since copper is a conductor, this causes an induced emf to develop in it, resulting in 'eddy currents' flowing in the conductor. According to Lenz's Law, the resulting magnetic force will oppose the motion that produced it. Hence the magnetic field produced by the induced currents in the copper will interact with the falling magnet's field, resulting in an upward braking force that opposes the magnet's motion and causes the magnet to slow down and land gently.

44. (a) Flux through the coil is zero (as the coil is parallel to the magnetic field).

(b) $F = n l I B \sin\theta$ *[Note: sin90 = 1]*

$= 140 \times (22 \times 10^{-2}) \times 3.0 \times 0.80 \times 1$

$= 73.92\text{ N} \approx 74\text{ N}$

(c) $\tau = nIAB\sin\theta$

$= 140 \times 3.0 \times (22 \times 10^{-2} \times 13 \times 10^{-2}) \times 0.80 \times \sin 55°$

$= 7.87\text{ N m} \approx 7.9\text{ N m}$

(d) A spring could be used to counteract the torque, so that the deflection of the coil could be kept proportional to the current flowing.

(e) Commutator rings would be used to alternate the direction of the current in the coil.

45. (a) $F_{AB} = I l B \sin\theta$

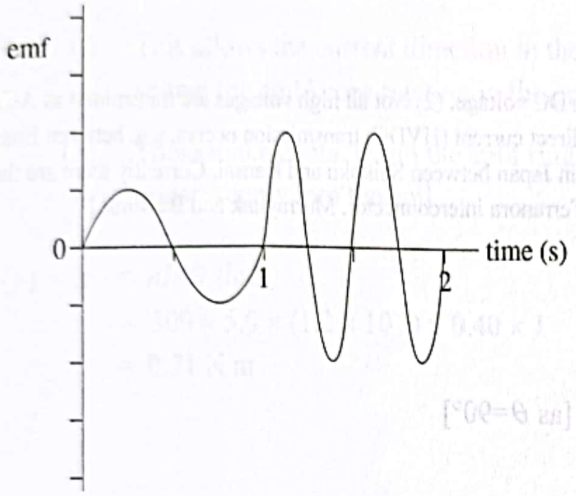
$= 10 \times 0.05 \times 0.2 \times 1$ *[Note: $\theta = 90°$, so $\sin\theta = 1$]*

$\therefore F_{AB} = 0.1$ N

(b) Although the direction of current is not specified, the current in sides AB and CD must be in the opposite direction. *B, I* and *l* are the same for each side, so F_{AB} and F_{CD} are equal in magnitude, but opposite in direction, as are F_{AD} and F_{BC}. So the net force on the coil is zero.

[Note: Even though the net force is zero, there will be a torque to make the coil rotate, because F_{CD} and F_{AB} are not acting in the one straight line.]

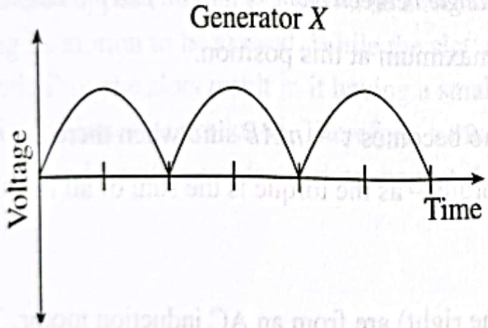
46.

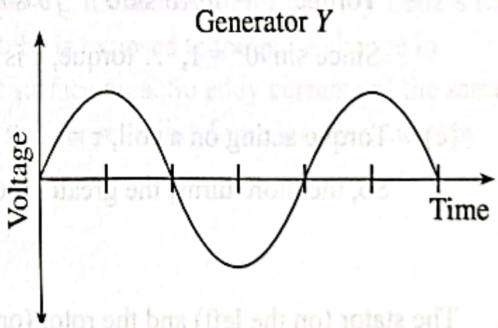


[Note:

1. Graphs will vary, but MUST have:
   - emf at 0, when t = 0, 0.5, 1, 1.25, 1.5, 1.75, 2.0 s
   - the emf maximum for t = 1 to t = 2 must be twice the emf for t = 0 to t = 1
   - frequency must double for t = 1 to t = 2
2. Positions of maximum and minimum could be reversed, as no points for the measurement of emf were given.]

47. (a)





[Note: The question does NOT indicate the positions at time = 0. Both graphs could also start with voltage at a maximum.]

(b) The coil of generator *X* is connected to the external circuit via a split ring commutator. This reverses the connection between the coil and the external circuit for every half-turn of the coil. This causes the current to flow in one direction only. The output is a fluctuating DC current.

In generator *Y*, each end of the coil has its own permanent connection to the external circuit via a continuous slip ring. The external circuit has a fluctuating AC current.

48. (a) A brush acts as a sliding contact to transfer the emf of the generator through the commutator ring(s) to an external circuit.

(b) Q – because it has a split ring commutator which rectifies the current. As the coil rotates, first one side of the ring, and then the other, makes contact with a brush. The induced emf of the coil is AC and when this changes direction, the brushes reverse the side of the coil that they are connected to, causing the emf supplied to the external circuit to be in one direction only, i.e. it becomes DC.

(c) AC generators, in combination with step-up transformers, produce the high voltages needed for transmission. This results in more efficient transmission of electricity between power stations and cities as only small currents are required, i.e. less energy is lost due to heating effects caused by the resistance of wires to the flow of electric current. AC electrical power is easily stepped down to the voltage required for local distribution to users.

[Note: (1) Transformers do not work with DC voltage. (2) Not all high voltages are transmitted as AC. In some parts of the world, high voltage direct current (HVDC) transmission occurs, e.g. between England and France, and a submarine HVDC line in Japan between Shikoku and Kansai. Currently there are three HVDC links operating in Australia, e.g. Terranora interconnector. Murraylink and Basslink.]

49. (a) $F_{XY} = lIB\sin\theta$

$= 0.20 \times 5.0 \times 0.60 \times 1$ [as θ=90°]

$= 0.6$ N ... up the page

(b) The coil is parallel to the magnetic field as in the diagram, so $\theta = 90°$.

Torque, $\tau = nIAB\sin\theta$ [*θ is the angle between plane of the coil and the magnetic field*]

Since $\sin 90° = 1$, $\therefore$ torque, τ is a maximum at this position.

(c) Torque acting on a coil, $\tau = IAB\sin\theta$ becomes $\tau = nIAB\sin\theta$ when there are n turns.

So, the more turns, the greater the torque – as the torque is the sum of all the torques.

50. The stator (on the left) and the rotor (on the right) are from an AC induction motor. The stator remains stationary. It contains a number of coil windings that are alternatively wound clockwise and anticlockwise. When the AC current supplied to the stator is flowing in one direction, the magnetic poles inwards are N-S-N-S, etc around the stator. When the current reverses, this becomes S-N-S-N etc. This changing magnetic field in the stator induces currents in the conducting rods of the rotor that oppose the changes producing them (Lenz's Law) and so, being free to rotate, the rotor spins, i.e. it becomes a motor. AC induction motors are relatively cheap to produce, but as they usually produce low power, they are not suitable for use in heavy industry.

51. Ring X slows down and quickly stops, while Ring Y swings freely.

This is because a current is induced in Ring X and sets up a force opposing the original motion (Lenz's Law). Whereas the gap in Ring Y means that the emf induced cannot generate a current and so no opposing force occurs.

52. The downward line shows the falling magnet accelerating downward at -9.8 m s^{-2} due to gravity. The changing magnetic field of the falling magnet induces eddy currents in the lower metal disc. These oppose the motion of the magnet (Lenz's Law) and decelerate its fall – as shown by the upward line. The magnet then stops ($v = 0$) when it reaches the lower disc – as shown by the horizontal line.

53. (a) (i) This allows the current direction in the coil to be reversed after each 180° rotation, so that the coil keeps rotating in the one direction.

(ii) These make contact with the split ring commutator allowing current to flow from the power supply into the coil.

(b) $\tau = nIAB \sin\theta$

$= 300 \times 5.0 \times (1.2 \times 10^{-3}) \times 0.40 \times 1$ *[as sin90° = 1]*

$= 0.71 \text{ N m}$

54. Magnet *B* will leave its tube first. The downward force of gravity will be the same on each magnet. As magnet *A* accelerates downwards through the solid tube, it induces eddy currents around the copper cylinder that result in a force opposing the motion of magnet (by Lenz's Law) causing its motion to be slowed. While the slotted tube is exposed to the same change in magnetic flux, the slots result in it having a smaller surface area. So eddy currents of the same magnitude cannot be produced. Therefore, a much smaller retarding force is experienced by magnet *B* and it will move faster than magnet *A*.