

CHAPTER IV : ELECTROMAGNETISM

Formative Practice 4.1 [Force on a Current-carrying Conductor in a Magnetic Field]

1. With the aid of a labelled diagram, explain the meaning of catapult field.
2. Figure 4.15 shows the arrangement of apparatus to study the effect of a force on a current-carrying conductor.
 - (a) What is the direction of the current in the copper wire *XY* when the switch of the direct current power supply is turned on?
 - (b) Explain the motion of the copper wire *XY* and state the direction of the motion. 🧠

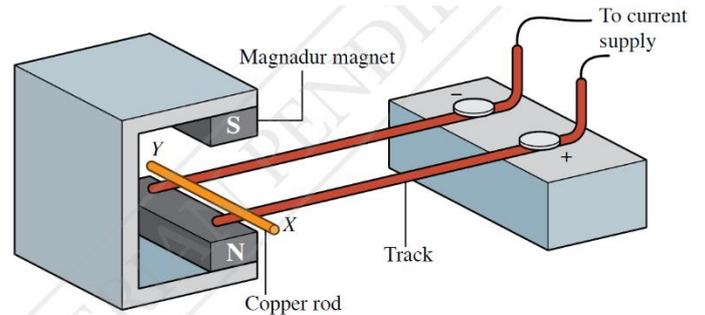


Figure 4.15

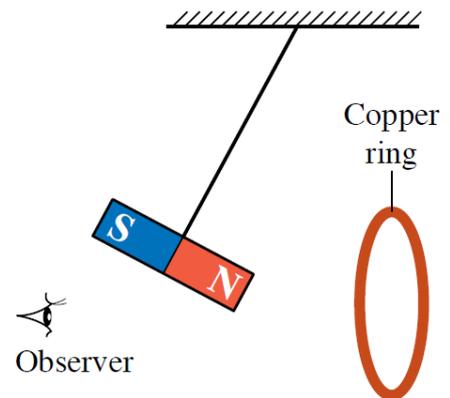
3. State three factors that affect the speed of rotation of a motor.
4.
 - (a) Compare and contrast the structure of a brushed motor with a brushless motor.
 - (b) State two advantages of brushless motor compared to brushed motor.

Formative Practice 4.2 [Electromagnetic Induction]

1. What is the meaning of electromagnetic induction?

2. (a) State Faraday's law.
(b) Use Faraday's law to explain the effect of the speed of rotation of the coil on the magnitude of the induced e.m.f. in a current generator.

3. Figure 4.30 shows a simple pendulum with a bar magnet as the bob oscillating near a copper ring.
(a) Explain the production of current in the copper ring when the bar magnet is moving towards the ring. 🧠



- (b) At the position of the observer in front of the ring as shown in Figure 4.30, state whether the current in the copper ring is clockwise or anti-clockwise.

- (c) Explain the effect of the current in the copper ring on the motion of the bar magnet. 🧠

Formative Practice 4.3 [Transformer]

1. A step-down transformer is connected to an alternating current power supply. Explain the working principle of the transformer.

2. A pupil collects the following information on a transformer:

(a) Calculate the efficiency of the transformer.

Primary voltage = 120 V

Secondary voltage = 6 V

Primary current = 0.25 A

Secondary current = 4.80 A

(b) Explain two factors that cause the transformer to be non-ideal.

3. Explain how an induction cooker can heat up food in a steel pot.

4. Transformers are used in the electrical energy transmission and distribution system.

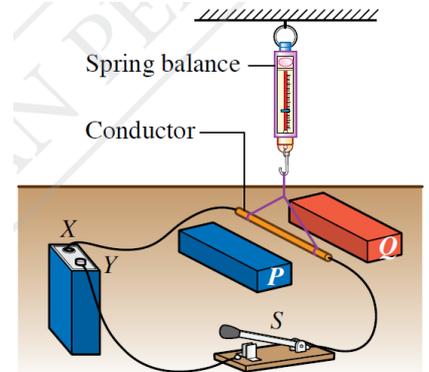
State the type of transformer used:

(a) before transmission of electrical energy

(b) at the distribution substation

Summative Practice Electromagnetism

1. Figure 1 shows a conductor hanging from a sensitive spring balance in between a pair of Magnadur magnets.
(a) Suggest the polarity of dry cell *X, Y* and the polarity of magnets *P, Q* such that the reading of the spring balance increases when switch *S* is turned on.



- (b) Explain why the reading of the spring balance can increase in 1(a). 🧠

- (c) Suggest improvements that need to be made to further increase the reading of the spring balance.

2. With the aid of a labelled diagram, explain how Fleming's left-hand rule is used to determine the direction of the force on a current-carrying conductor in a magnetic field.

3. Figures 2 and 3 show the induced currents produced when there is relative motion between a bar magnet and a solenoid.

(a) What is the meaning of induced current?

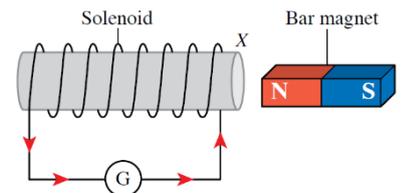


Figure 2

(b) Based on the direction of the current given in Figures 2 and 3, state the magnetic polarities at ends X and Y of the solenoid.

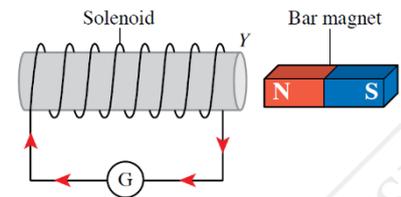


Figure 3

(c) State the direction of motion of the bar magnet in Figure 2 and Figure 3. 🧠

(d) Suggest two ways to increase the magnitude of the induced current in Figure 3.

4. A transformer is used to step down voltage from 240 V to 6 V for an electronic equipment. The current in the primary coil is 0.18 A. What is the current in the secondary coil? State the assumption that needs to be made in your calculation.

5. Figure 4 shows two identical metal balls and a copper tube. One of the balls is a neodymium magnet while the other is a steel ball.



Figure 4

Design an activity that can identify which ball is the neodymium magnet. Explain the physics principle used in your activity. 🧠

6. Figure 5 shows a wooden block with a bar magnet tied to it sliding with an acceleration down a smooth track. When the block arrives at mark X on the track, the switch is turned on.
- (a) What is produced in the solenoid? Explain your answer.

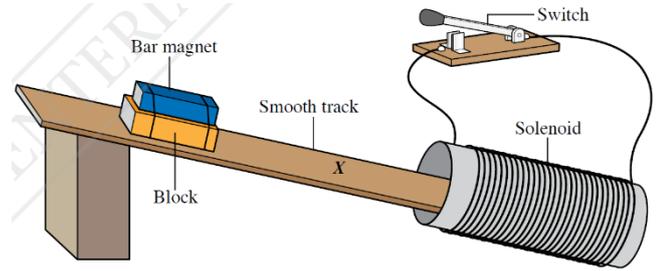


Figure 5

- (b) Explain the motion of the block after the switch is turned on. 🧠
- (c) Based on your answers in 6(a) and (b), discuss the effectiveness of electromagnetic braking in stopping a moving object. 🧠

7. Figure 6 shows a transformer with a bulb at its output terminals.

- (a) Calculate the value of I_s .
- (b) What assumption needs to be made in your calculation in 7(a)?

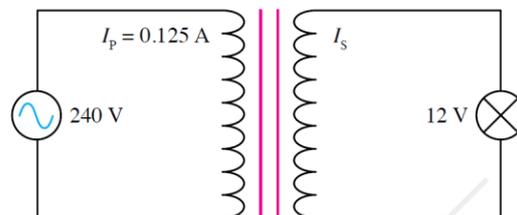


Figure 6

8. A pupil investigated the operation of a transformer and gathered data as shown in Figure 7. Calculate the efficiency of the transformer and suggest improvements to the design of the transformer to increase its efficiency. 🧠

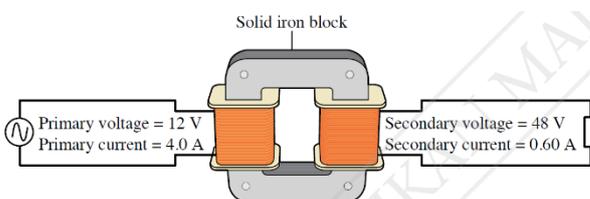


Figure 7

9. Figure 8 shows the design of a simple direct current motor that can produce a force to rotate a disc connected to the axle of the motor. A pupil who constructed the motor according to the design made the following observations:

- speed of rotation of the disc is slow
- speed of rotation of the disc cannot be controlled
- rotation of the disc is not smooth
- the dry cell loses its power in a short time

Study the design of the motor and suggest improvements to the design that can overcome the weaknesses identified by the pupil. 🧠

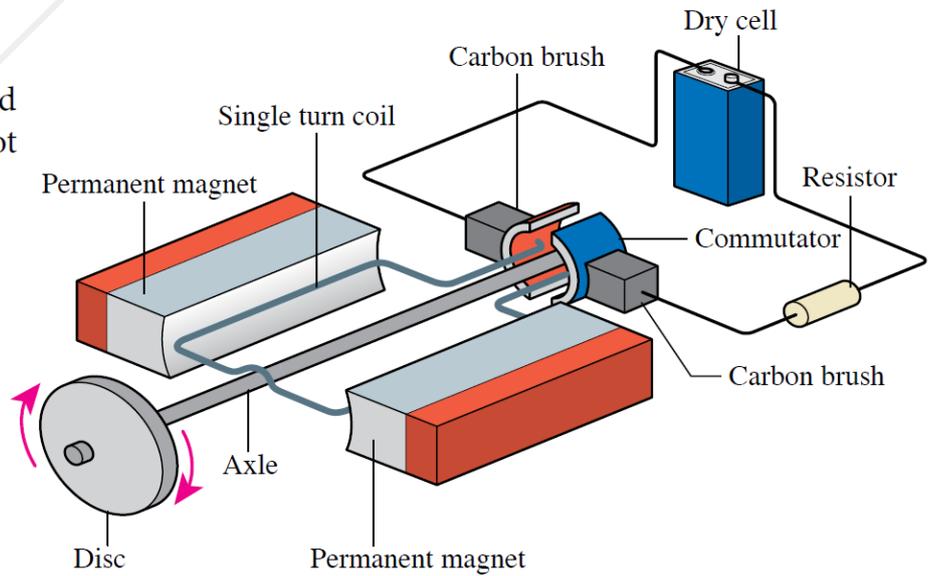
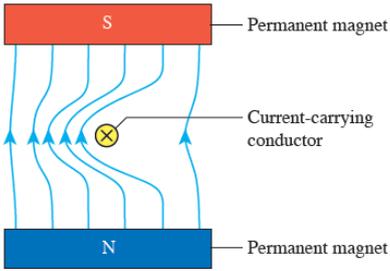


Figure 8

Formative Practice 4.1

1. A catapult field is a resultant magnetic field produced by the interaction between the magnetic field from a current-carrying conductor with the magnetic field from a permanent magnet.



2. (a) X to Y
 (b) The current in copper wire XY produces a magnetic field that superimposes with the magnetic field from the permanent magnet. The two magnetic fields combine to produce a catapult magnetic field. The catapult magnetic field exerts a force on wire XY and moves the wire. The direction of motion of wire XY is to the right.
 3. Current in the coil, number of turns of the coil, strength of magnetic field
 4. (a) Both consist of a coil and permanent magnets
 Brushed motor: The permanent magnet is stationary while the coil rotates
 Brushless motor: The coil is stationary while the magnet rotates
 (b) Lower level of operational sound
 Lower maintenance cost

Formative Practice 4.2

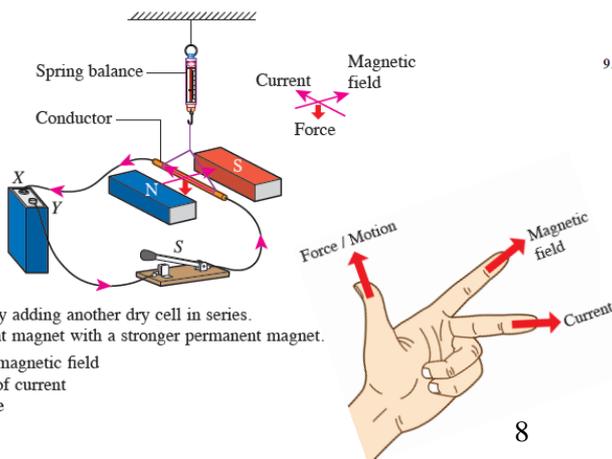
1. Electromagnetic induction is the production of an induced e.m.f. in a conductor when there is relative motion between the conductor and a magnetic field or when the conductor is in a changing magnetic field.
 2. (a) Faraday's law states that the magnitude of induced e.m.f. is directly proportional to the rate of cutting of magnetic flux.
 (b) When a coil rotates and cuts magnetic field lines, an e.m.f. is induced in the coil. If the speed of rotation is increased, the rate of cutting of magnetic flux increases. According to Faraday's law, the induced e.m.f. increases.
 3. (a) When the bar magnet moves towards the copper ring, magnetic field lines are cut by the ring. An induced e.m.f. is produced in the ring. This induced e.m.f. produces an induced current in the copper ring.
 (b) Anti-clockwise.
 (c) According to Lenz's law, the anti-clockwise current produces a magnetic north pole to oppose the motion of the bar magnet.
 This causes the motion of the bar magnet to be slowed down.

Formative Practice 4.3

1. The alternating voltage produces an alternating current in the primary coil. The alternating current produces a changing magnetic field. The magnetic field is linked to the secondary coil through the soft iron core. The changing magnetic field induces an alternating voltage in the secondary coil. The number of turns of the secondary coil is less than the number of turns of the primary coil. The voltage across the secondary coil is lower than the voltage across the primary coil. Therefore, the transformer steps down voltage.
 2. (a) Efficiency, $\eta = \frac{\text{Output power}}{\text{Input power}} \times 100\%$
 $= \frac{V_s I_s}{V_p I_p} \times 100\%$
 $= \frac{6 \times 4.80}{120 \times 0.25} \times 100\%$
 $= 96.00\%$
 (b) The resistance of the coil causes heating of the coil when a current flows through it. This results in energy loss in the form of heat. Hysteresis caused by the magnetisation and demagnetisation of the soft iron core results in energy loss in the form of heat.
 3. The alternating current in the coil produces a changing magnetic field. The changing magnetic field induces eddy currents in the base of the pot. The eddy currents flow along a path of low resistance and heats up the base of the pot.
 4. (a) Step-up transformer
 (b) Step-down transformer

Summative Practice

1. (a) X: negative, Y: positive, P: north, Q: south
 (b) When switch S is turned on, current flows in the circuit from Y to X. The direction of the magnetic field from the permanent magnet is from north to south. According to Fleming's left-hand rule, a force acts on the conductor in the downward direction.



- (c) Increase the current by adding another dry cell in series. Replace the permanent magnet with a stronger permanent magnet.
 2. Fore finger: Direction of magnetic field
 Middle finger: Direction of current
 Thumb: Direction of force

3. (a) Induced current is the current produced in a conductor when there is relative motion between the conductor and a magnet that causes the conductor to cut magnetic field lines.
 (b) X: north pole
 Y: south pole
 (c) Figure (a): Direction of motion of magnet to the left
 Figure (b): Direction of motion of magnet to the right
 (d) Increase the number turns of the solenoid
 Increase the speed of motion of the magnet

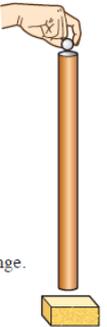
$$V_s I_s = V_p I_p$$

$$6 \times I_s = 240 \times 0.18$$

$$I_s = 7.2 \text{ A}$$

The loss of energy from the transformer can be neglected, that is the transformer is ideal.

5. The copper tube is held vertically with a piece of sponge below it. Release the metal balls one by one to fall through the copper tube onto the sponge. The ball that takes a shorter time to fall onto the sponge is the steel ball. The ball that takes a longer time to fall onto the sponge is the neodymium magnet ball.
 When the neodymium magnet ball falls, magnetic field lines cut the copper tube. Eddy currents are induced in the copper tube. According to Lenz's law, the eddy currents will produce a magnetic field that opposes the motion of the neodymium ball.
 Since the neodymium magnet is a strong magnet and copper is a good conductor. The eddy currents produce a strong magnetic field. Therefore, the fall of the neodymium magnet ball is slowed down.



6. (a) Induced current is produced in the solenoid. The motion of the bar magnet towards the solenoid causes the cutting of magnetic field lines by the solenoid. An e.m.f. is induced across the solenoid. When the switch is turned on, the induced e.m.f. produces an induced current in the solenoid.
 (b) The motion of the block will experience a deceleration. According to Lenz's law, the induced current produces a magnetic pole at the end of the solenoid that is the same as the pole of the bar magnet so that the motion of the bar magnet is opposed.
 (c) Electromagnetic braking is more effective than braking that uses frictional force.
 - does not need human action to activate the braking process
 - does not need electric power to produce a braking force
 - the magnitude of the braking force is controlled by factors such as the strength of the magnet and number of turns of the solenoid, that is factors that can be fixed during the construction of the system.

7. (a) $V_s I_s = V_p I_p$
 $12 \times I_s = 240 \times 0.125$
 $I_s = 2.5 \text{ A}$
 (b) The transformer is ideal

8. Efficiency, $\eta = \frac{\text{Output power}}{\text{Input power}} \times 100\%$
 $= \frac{V_s I_s}{V_p I_p} \times 100\%$
 $= \frac{48 \times 0.6}{12 \times 4.0} \times 100\%$
 $= 60.00\%$
 - Use laminated soft iron core
 - The secondary coil is wound on top of the primary coil

Problem	Suggestion for improvement	Explanation
Slow speed of rotation	Add more turns to the coil	The magnitude of the force on the coil is increased
	Use stronger permanent magnets	The magnitude of the force on the coil is increased
	Use finer copper wire to construct the coil	The coil will not be too heavy although the number of turns has increased
Speed of rotation of the disc cannot be controlled	Connect a rheostat in the circuit	The current in the coil can be adjusted. Therefore, the magnitude of the force that rotates the coil can be controlled. Hence, the speed of rotation can be controlled.
Rotation of the disc is not smooth	Prepare four sets of coils wound on a soft iron core and a commutator with eight parts	The coil experiences a force that is more uniform
Dry cell loses its power quickly	Connect a few similar dry cells in parallel	The total internal resistance of the dry cell is reduced