2021 Sec 4 Physics Chapter 19

Electromagnetic Induction - ANSWERS

Example 19.1

(a) When the magnet is plunged into the coil, there is a momentary rate of cutting of magnetic field lines from the magnet by the coil.
(OR there is a momentary increase in the magnetic lines of force linked to the coil).
By Faraday's law of electromagnetic induction, an e.m.f. is induced in the coil which drives a momentary induced current, hence the galvanometer deflected to one side before going back to zero.

(b) See diagram.

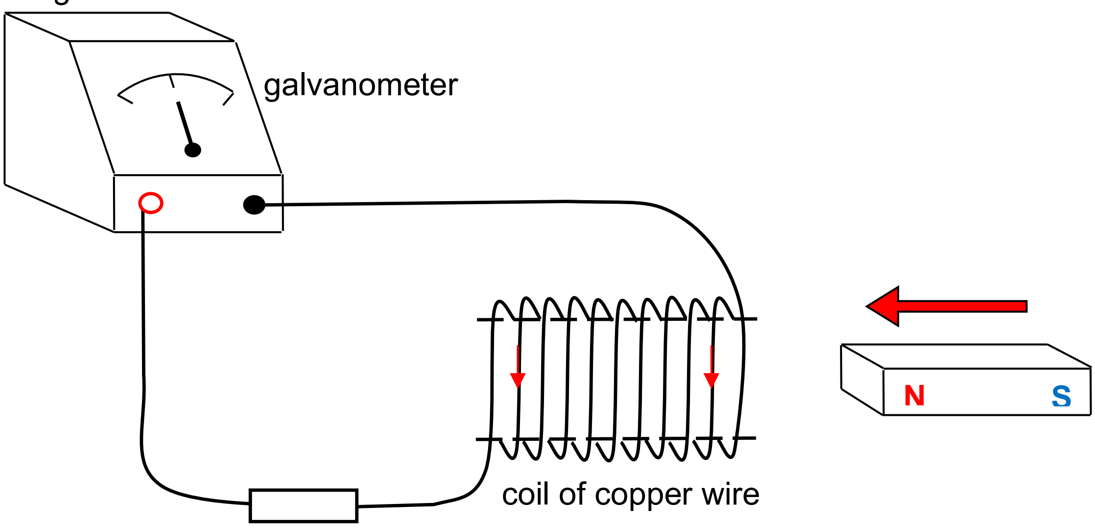


Fig. 19.1a

(c) When the magnet was held stationary inside the coil, there is no rate of cutting of magnetic field lines by the coil.
(OR there is no change in magnetic lines of force linked to the coil)
Hence, by Faraday's law, there is no induced e.m.f. and no induced current, and the galvanometer does not deflect.

(d) When the N-pole is withdrawn from the coil, there is a momentary rate of cutting of the magnetic field lines by the coil.
(OR there is a momentary decrease in the magnetic lines of force linked to the coil.
By Faraday's law, an e.m.f. is induced in the coil which drives an induced current in the coil, so the galvanometer deflects momentarily.
As the change (motion of magnet) is in the opposite direction to (a) above, the induced e.m.f. is in the opposite direction, hence the induced current flows in the opposite direction, by Lenz's law of electromagnetic induction. The galvanometer deflects in the opposite direction.

Example 19.2

(a) The rotating spindle causes the magnet attached to it to rotate. There is a <u>constant rate of cutting</u> of magnetic field lines by the coil. <u>By Faraday's law</u>, an e.m.f. is induced in the coil, hence the galvanometer pointer deflects.

(b) When the wind speed increases, the spindle and the magnet rotates with a greater speed. There is a <u>higher rate of cutting</u> of magnetic field lines by the coil. <u>By Faraday's law</u>, this induces a greater e.m.f. and hence the galvanometer shows a larger deflection (in the same direction).

(c)

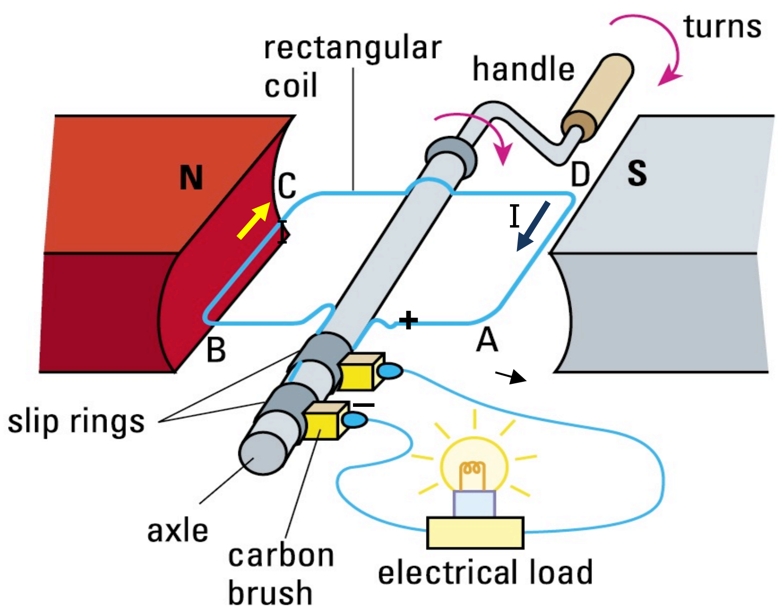
- Use a <u>stronger magnet (or have more turns in the coil of wire</u>) to produce a greater rate of cutting of magnetic field lines by the coil.
- Use <u>larger cups</u> exposed to the wind, so that there is greater force acting on them to produce greater turning moments. Hence the spindle will turn at a greater speed to produce a greater rate of cutting of magnetic field lines by the coil.

Example 19.3

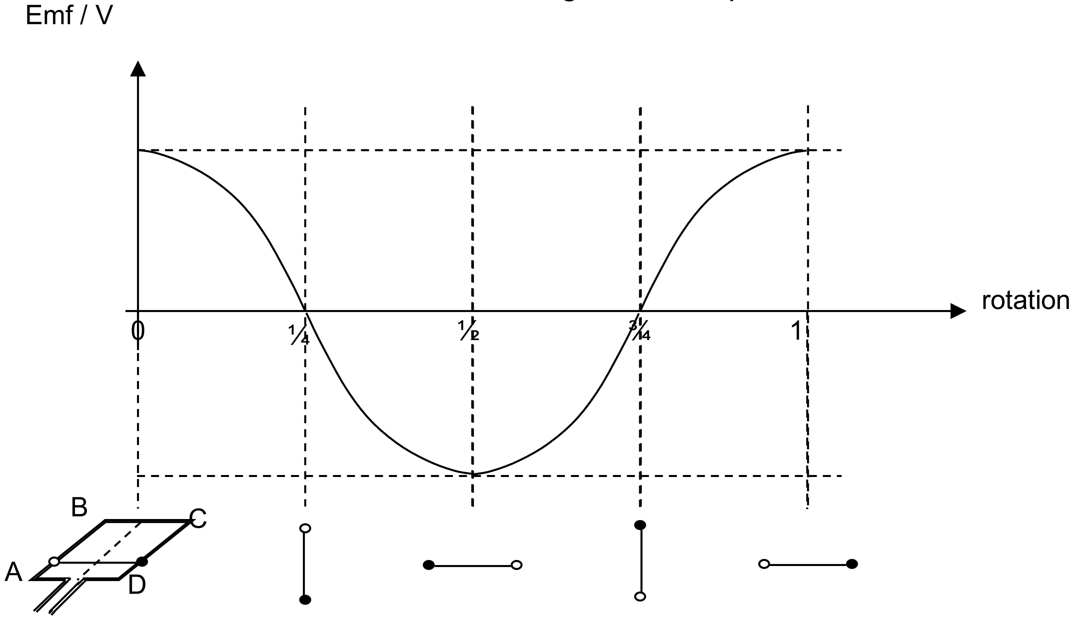
(a) <u>Slip rings</u>: to allow firm contact between the coil and the two carbon brushes and at the same time maintain freedom of rotation (without twisting the wires of the coil).
<u>Carbon brush</u>: to maintain good electrical contact between the external circuit and the rotating slip rings so as to transfer the alternating e.m.f. generated to the external circuit.

(b) When the coil is rotating, it cuts the magnetic field lines between the magnetic poles. The <u>rate of cutting of magnetic field lines</u> decreases from a maximum (when the coil is horizontal) to a minimum (when the coil is vertical) and the cycle repeats. <u>By Faraday's Law</u>, a varying e.m.f is induced in the coil.

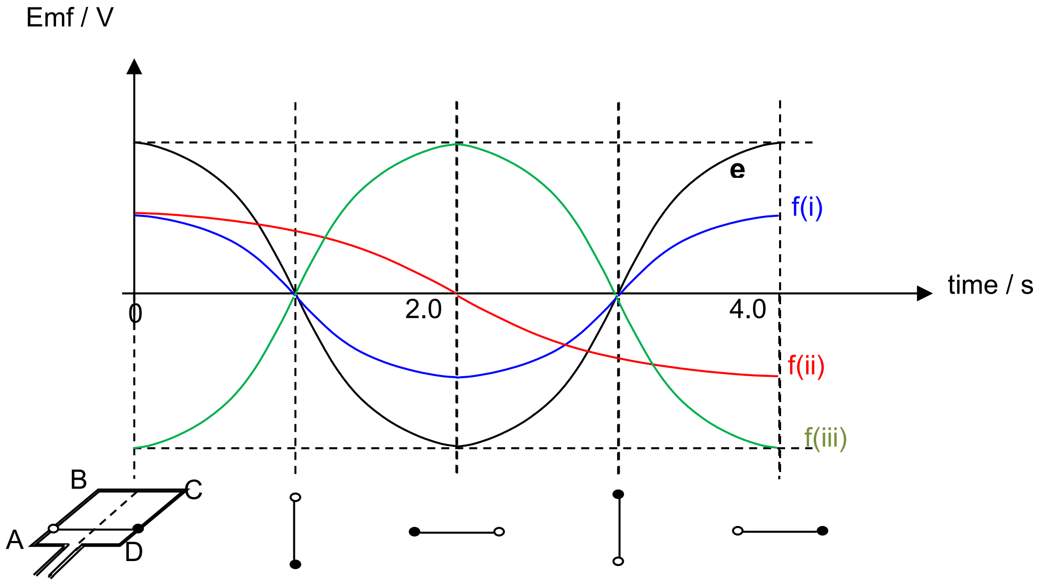
(c) (i) draw I current in the coil (B to C to D to A)
(ii) draw current through the bulb (clockwise)
(iii) + & - signs on carbon brushes



(d) Sketch the graph which shows the variation of the induced e.m.f. of the a.c. generator when the coil **ABCD** turns through one complete rotation.



(e) Sketch the graph which shows the variation of the induced e.m.f. of the a.c. generator over time for the same complete rotation which took 4.0 s.



(g)

- Replace the slip rings with a split-ring commutator
- Place a d.c. power supply in the external circuit.

Example 19.4

(a) (i) When the switch S is closed, the current flowing in coil P sets up an increasing magnetic flux that links with coil Q and becomes constant quickly. By Faraday's law, this rate of increase in magnetic flux linked with coil Q induces an e.m.f in Q. Hence, this drives a momentary current in Q which causes a momentary deflection in the galvanometer. When the current and magnetic flux become constant, there is no induced e.m.f. and the deflection becomes zero.

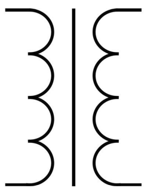
(ii) The current in coil P sets up a magnetic field in P with a South pole on its right end (using right-hand grip rule). By Lenz's law, to oppose this change in magnetic flux in P, the induced current in Q flows in a direction to set up a South pole on its left end. Since both coils have South poles facing each other, they repel and slide apart a little.

(b) When S is opened, the current decreases to zero and there is a decreasing magnetic flux in P. By Lenz's law, to oppose this change in magnetic flux in P, the induced current in coil Q flows in the opposite direction to that in (a)(ii) and North pole is induced on the left end of Q. Since both coils now have opposite poles facing each other, they attract and slide towards each other a little. The galvanometer shows a momentary deflection in the opposite direction.

(c) Unlike soft iron, wood is non-magnetic and does not increase the magnetic field through the coils. There is a weaker magnetic flux linkage between the two coils P and Q, the induced e.m.f. and induced current are smaller. Hence, the momentary deflection in the galvanometer and the repulsion between the coils will be smaller.

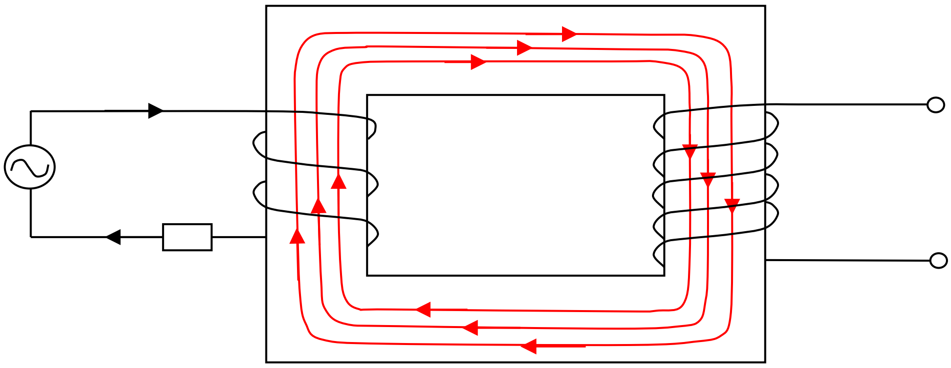
19.3.2 The transformer

Circuit symbols: Transformer

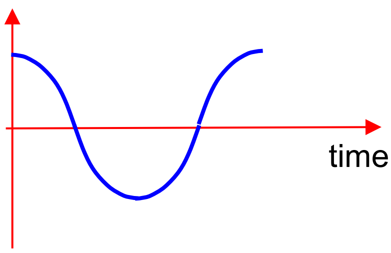


Example 19.5

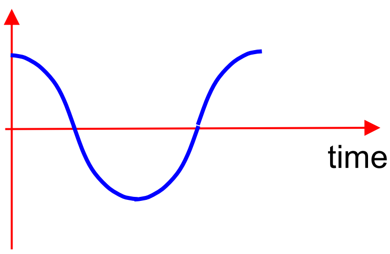
(a)



(b)(i)



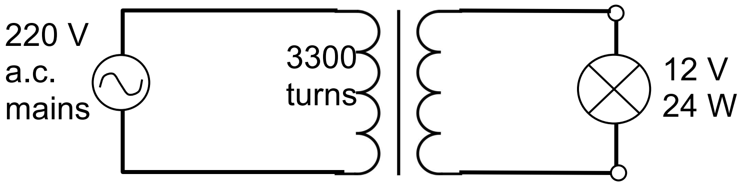
(ii)



(c) The varying current sets up the varying magnetic field in the left-hand coil and this is linked the right-hand coil. By Faraday's law, a varying e.m.f. is induced in the right-hand coil. This drives a varying induced current which sets up a varying magnetic field in the right-hand coil such as to oppose the change producing it, by Lenz's law.

Example 19.6

(a)



(b) (i) $V_s / V_p = N_s / N_p$ ➔ $N_s = (V_s / V_p) \times N_p$

$N_s = (12/220) \times 3300) = 180$ turns

(ii) $I = P/V = 24/12 = 2.0$ A

(iii) $I_p V_p = I_s V_s = P$ ➔ $I_p = P / V_p$

$I_p = 24/220 = 0.109 \approx 0.11$ A

Example 19.7

(a) turns ratio = $N_s / N_p = 80 / 1600 = 0.050$ (2 s.f.)

(b) $V_s / V_p = N_s / N_p$ ➔ $V_s = (N_s / N_p) \times V_p = 0.050 \times 240$

$V_s = 12$ V

(c) $P = I_p V_p = I_s V_s$ ➔ $I_s = P / V_s = 40 / 12$

$I_s = 3.33 \approx 3.3$ A

(d) $V = IR = 3.33 \times 2.5 = 8.325 \approx 8.3$ V (2 sf)

(e) power dissipated in leads: $P_{leads} = I^2R = (3.33)^2 (2.5) = 27.7 \approx 28$ W (2 s.f.)

(f) total input power = power dissipated in leads + power dissipated in lamp

$P_s = P_{lamp} + P_{leads}$,

$P_{leads} = P_s - P_{lamp} = I_s V_s - P_{lamp}$

$= 40 - 27.7 = 12.3 \approx 12$ W (2 s.f.)

Example 19.8

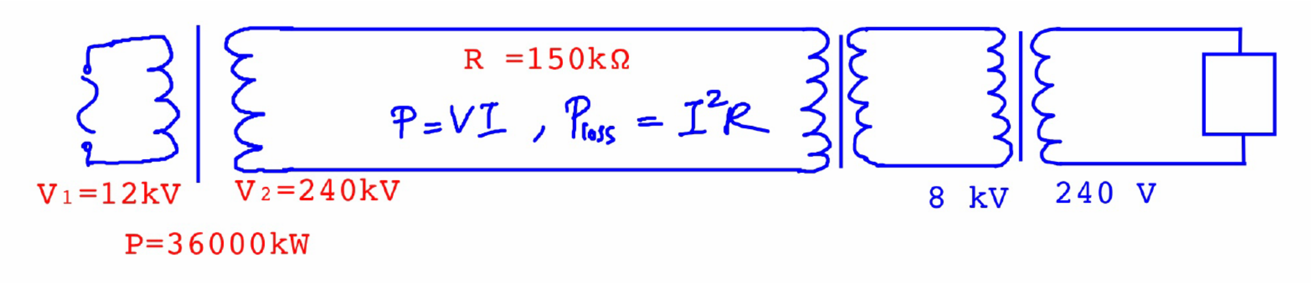
(a)

- When electrical power is transmitted at high voltage, the current in the transmission cables would be small. This would minimize the power loss in the cables.
- Smaller currents would allow relatively thinner cables to be used for power transmission to save cost.

(b)

- a.c. voltages can easily be stepped up or down by transformers cheaply and efficiently with very little loss of power. (d.c. voltages can be changed in magnitude, but it is difficult and expensive.)
- a.c. voltages produced by a.c. generators are cheaper to produce than direct voltages that are converted from chemicals.

Example 19.9



(a) (i) Turns ratio $= N_S / N_P = \dfrac{240\,000}{12\,000}$

$= 20$

(ii) No, the step-up transformer does not change the energy being transmitted.

(b) (i) Assume no power lost in the transformer.

Current, $I = P / V = \dfrac{36\,000\,000}{240\,000} = 150$ A

(ii) Power lost in the transmission line, $P = I^2R = 150^2 \times 150$

$= 3375\,000 \approx 3.4 \times 10^6$ W

Percentage power loss $= \dfrac{3375\,000}{36\,000\,000} \times 100\%$

$= 9.375 \approx 9.4$ %

Example 19.10

(a) P = VI ➔ I = P / V = 3000 W / 240 V = 12.5 A

(b) rate of heat loss in distribution cable, $P = I^2 R = 12.5^2 \times 0.5$
$= 78.13 \approx 78$ W (2 s.f.)

(c) rate of heat loss in transmission lines, $P = I^2 R = 0.062^2 \times 150$
$= 0.5766 = 0.58$ W (2 s.f.)

(d) The current flowing in the distribution cable is about 200 times more than that flowing in the transmission lines, although its resistance is 100 times smaller than in the transmission line. As rate of heat generated is given by $P = I^2R$ (square of current), the heat generated in (b) is much more than in (c).

Exercises

Answers

1	A	2	C	3	C
4	A	5	A	6	B
7	D	8	D	9	C

10 (a) Figure 10.1: an electromagnet.
Figure 10.2: a transformer.

(b) In Figure 10.1, *P* is the north pole (use the right hand grip rule).
In Figure 10.2, *P* is alternately north pole and south pole as the current flowing through it is a.c.

(c) Figure 10.2: As the coil *P* is connected to the a.c., the alternating current causes a changing magnetic field which is linked to the coil *Q* through the horseshoe core. By Faraday's law of electromagnetic induction, there is an e.m.f. induced in the coil wound for *Q* and thus a voltage reading in the voltmeter across coil Q.

(d) For Figure 10.1, adjust the rheostat to reduce the resistance, so that more current can flow through the coil.
For Figure 10.2, increase the number of turns of coil on *Q* or decrease the number of turns of coil on *P*.