CLASS XII – PHYSICS (042)
STEP-BY-STEP SOLUTIONS AND MARKING SCHEME

Chapter 6: Electromagnetic Induction – Practice Paper (35 Marks)

Answer key – Section A

Q.	1	2	3	4	5	6	7	8	9
Ans.	(c)	(a)	(b)	(d)	(a)	(b)	(d)	(d)	(a)

Marks are shown in square brackets. Equivalent correct methods are acceptable. Take $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}.

SECTION A

Q.1 (c)

Approaching the north pole increases the flux through the coil. By Lenz's law the coil produces a field that opposes the increase, i.e. its face towards the magnet becomes a north pole. That face is north when the current is anticlockwise as seen from the magnet side. Two north poles face each other, so the coil repels the magnet. **[1]**

Q.2 (a)

$\varepsilon = A\,(\Delta B/\Delta t) = \pi(0.05)^2 \times (0.4/0.2) = 7.85 \times 10^{-3} \times 2 = 15.7$ mV. The inward flux decreases, so the induced field must be inward: the current is clockwise. **[1]**

Q.3 (b)

$\varepsilon = -N\,d\Phi/dt$. Between 2 s and 4 s the flux is constant, so $\varepsilon = 0$. The largest slope is 6 mWb in 1 s (4 s to 5 s): $\varepsilon = 100 \times 6 \times 10^{-3}/1 = 0.6$ V. **[1]**

Q.4 (d)

The field of the wire at the loop is into the page and increasing, so the induced field is out of the page: anticlockwise current. The loop's side near the wire then carries a current opposite to I (downward), so the forces are repulsive: the loop is repelled (it tends to reduce the flux). **[1]**

Q.5 (a)

The plane is at 30° to B, so the normal makes 60° with B. $\Phi = BA\cos 60° = 0.5 \times (0.2)^2 \times 0.5 = 1.0 \times 10^{-2}$ Wb. **[1]**

Q.6 (b)

$L = \mu_0 N^2 A/l$. For B: $(2N)^2/(l/2) = 8N^2/l$, so $L_B/L_A = 8$. **[1]**

Q.7 (d)

$dI/dt = 4/2 = 2$ A s^{-1}, so $\varepsilon = L\,dI/dt = 0.5 \times 2 = 1$ V. At t = 2 s, I = 4 A: $U = \tfrac{1}{2}LI^2 = \tfrac{1}{2} \times 0.5 \times 16 = 4$ J. **[1]**

Q.8 (d)

A is false: when v is parallel to B the flux swept is zero and there is no motional emf ($\varepsilon = Blv\sin\theta = 0$). R is true: the Lorentz force $q\,v \times B$ vanishes for v parallel to B. **[1]**

Q.9 (a)

Both true and R explains A: if the induced current aided the change, the force would keep accelerating the magnet with no work done, creating energy from nothing. Lenz's law ensures work must be done against the induced current's field. **[1]**

SECTION B

Q.10

The left side (5 cm) is still in the field and moves with v: $\varepsilon = Blv = 0.4 \times 0.05 \times 0.2 = 4 \times 10^{-3}$ V = 4 mV. **[1]**

$I = \varepsilon/R = 4 \times 10^{-3}/0.1 = 0.04$ A = 40 mA. The inward flux decreases, so the induced field is inward: the current is clockwise. **[1]**

Q.11

(a) From the graph, peak emf $\varepsilon_0 = 20$ V and period T = 20 ms, so $\nu = 1/T = 50$ Hz. **[1]**

(b) $\varepsilon = \varepsilon_0 \sin 2\pi\nu t = 20 \sin(2\pi \times 50/600) = 20 \sin(\pi/6) = 20 \times 0.5 = 10$ V. **[1]**

Q.12 (A)

$M = \mu_0 N_1 N_2 \pi r_1^2 / l = (4\pi \times 10^{-7})(200)(400)(\pi \times 4 \times 10^{-4})/0.4 \approx 3.2 \times 10^{-4}$ H. **[1]**

$\varepsilon = M\, dI/dt = 3.16 \times 10^{-4} \times 5 \approx 1.6 \times 10^{-3}$ V = 1.6 mV. **[1]**

Q.12 (B)

$\varepsilon = L|\Delta I/\Delta t| = 0.4 \times 5/0.1 = 20$ V. **[1]**

$U = \tfrac{1}{2} LI^2 = \tfrac{1}{2} \times 0.4 \times 25 = 5$ J. **[1]**

Q.13

$\omega = 2\pi \times 120/60 = 4\pi$ rad $s^{-1} = 12.56$ rad s^{-1}. $\varepsilon = \tfrac{1}{2} B\omega R^2 = \tfrac{1}{2} \times 0.2 \times 12.56 \times (0.5)^2 \approx 0.31$ V. **[1]**

The emf does not change: the spokes are connected in parallel between axle and rim, so each spoke has the same emf; more spokes do not add emf. **[1]**

SECTION C

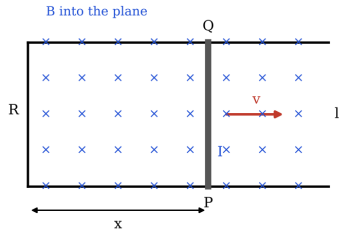
Q.14

(a) $\varepsilon = Blv = 0.25 \times 0.5 \times 4 = 0.5$ V. **[1]**

(b) $I = \varepsilon/R = 0.5/2 = 0.25$ A. The force on a positive charge, q v × B, with v to the right and B into the page, is upward, so the current in the rod flows from P to Q (and through R from the top rail to the bottom rail). **[1]**

(c) Magnetic force on the rod $F = BIl = 0.25 \times 0.25 \times 0.5 \approx 3.1 \times 10^{-2}$ N, opposing the motion (Lenz); an equal external force is needed. Power $P = Fv = 0.03125 \times 4 = 0.125$ W ($= I^2R = 0.125$ W). **[1]**

Q.15 (A)

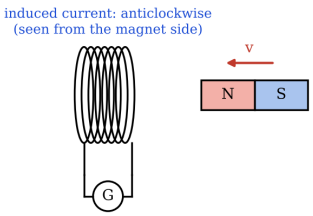


Let RS = l and PQ at distance x from RS in a field B perpendicular to the plane. The area of the loop PQRS is lx, so the flux is $\Phi = Blx$. **[1]**

As the rod moves with speed v, x changes: $\varepsilon = -d\Phi/dt = -Bl\, dx/dt$. **[1]**

Since $|dx/dt| = v$, the magnitude of the emf is $\varepsilon = Blv$ (motional emf). **[1]**

Q.15 (B)



Lenz's law: the polarity of the induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it. **[1]**

As the north pole approaches, the flux through the coil increases. The induced current flows so as to oppose this increase: anticlockwise as seen from the magnet's side, making that face a north pole, which repels the magnet. **[1]**

If the current were in the opposite direction, the coil would attract the magnet, which would accelerate with no work done, and its kinetic energy would keep increasing, violating energy

conservation. In the correct case work must be done to push the magnet, and this work appears as Joule heat in the coil. **[1]**

Q.16

(a) Between 0 and 2 s, $dI_1/dt = 6/2 = 3$ A s^{-1}. From $|\varepsilon| = M\, dI/dt$, $M = 0.9/3 = 0.3$ H. **[1]**
(b) Between 4 s and 5 s, $dI_1/dt = -6$ A s^{-1}, so $|\varepsilon| = 0.3 \times 6 = 1.8$ V. The current is falling (it was rising earlier), so the polarity of the emf is opposite to that in 0 to 2 s. **[1]**
(c) Between 2 s and 4 s I_1 is constant, $dI_1/dt = 0$, the flux through C_2 does not change and the induced emf is zero. **[1]**

SECTION D

Q.17 (Case study)

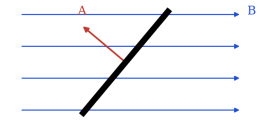
(i) **(b)** $\varepsilon = NBA\omega \sin \omega t$ is maximum when $\sin \omega t = 1$, i.e. when the plane of the coil is parallel to the field (the flux changes fastest). **[1]**
(ii) **(b)** $\varepsilon_0 = NBA(2\pi\nu) = 100 \times 0.1 \times 10^{-2} \times 314 = 31.4$ V. **[1]**
(iii) **(c)** $\varepsilon_0 \propto \omega$: doubling the speed doubles the peak emf to 62.8 V and the frequency to 100 Hz. **[1]**
(iv) **(b)** $\omega t = 314/300 \approx 1.047$ rad $= 60°$, so $\varepsilon = 31.4 \sin 60° = 31.4 \times 0.866 \approx 27.2$ V. **[1]**
OR (iv) (b) $\varepsilon_0 \propto N\nu$; N is doubled and ν is halved, so the peak emf is unchanged at 31.4 V. **[1]**

SECTION E

Q.18 (A)

Self-induction: the production of an induced emf in a coil when the current through the same coil changes (and hence its own flux linkage changes); $\varepsilon = -L\, dI/dt$, and the emf opposes the change of current (back emf). **[1]**
To raise the current against the back emf, the rate of work done is $dW/dt = |\varepsilon|I = LI\, dI/dt$, so $dW = LI\, dI$. **[1]**
$W = \int_0^I LI\, dI = \tfrac{1}{2}LI^2$, stored as magnetic energy $U = \tfrac{1}{2}LI^2$. **[1]**
Numerical: $L = \mu_0 N^2 A/l = (4\pi \times 10^{-7})(1000)^2(4 \times 10^{-4})/0.5 \approx 1.0 \times 10^{-3}$ H. **[1]**
$U = \tfrac{1}{2}LI^2 = \tfrac{1}{2} \times 1.0 \times 10^{-3} \times 4 = 2.0 \times 10^{-3}$ J. **[1]**

Q.18 (B)



loop turning with angular speed ω; θ = ωt is the angle between A (normal) and B

Principle and working: an emf is induced in a coil when the flux through it changes; rotating a coil in a uniform field changes the angle θ between A and B and hence the flux. The coil (armature) rotates between the poles of a magnet; its ends are joined to slip rings, and carbon brushes press on the rings to connect to the external circuit. (Labelled diagram: coil, magnet poles, axle, slip rings, brushes.) **[1]**
With $\theta = \omega t$, the flux linked is $\Phi = BA \cos \omega t$ for each turn. **[1]**
$\varepsilon = -N\, d\Phi/dt = NBA\omega \sin \omega t = \varepsilon_0 \sin \omega t$, with $\varepsilon_0 = NBA\omega$. **[1]**
Numerical: $\varepsilon_0 = NBA(2\pi\nu) = 50 \times 0.5 \times 0.04 \times 314 = 314$ V. **[1]**
With $\theta = 60°$: $\varepsilon = \varepsilon_0 \sin 60° = 314 \times 0.866 \approx 272$ V. **[1]**

— End of Solutions —