POSTAL Book Package 2021

Electrical Engineering

Objective Practice Sets

Electromagnetic Theory

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4 CHAPTER
Time Varying Electromagnetic Field

Q.1 When a magnetic flux cuts across 200 turns at the rate of 2 Wb/s, the induced voltage is
(a) 400 V (b) 100 V
(c) 600 V (d) 0 V

Q.2 The flux through each turn of a 100-turn coil is $(t^3 - 2t)$ mWb, where t is in seconds. The induced emf at t = 2 sec. is
(a) –1 V (b) 4 mV
(c) 0.4 V (d) 1 V

Q.3 **Assertion (A):** The total e.m.f. induced in a circuit is equal to the time rate of decrease of the total magnetic flux linking the circuit.
Reason (R): Changing magnetic field will induce on electric field.
(a) Both A and R are true and R is a correct explanation of A.
(b) Both A and R are true but R is not a correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

Q.4 **Assertion (A):** Motional induction or flux cutting law gives the e.m.f. induced in a moving conductor w.r.t. observer in a magnetic field.
Reason (R): The motional emf equation depends on the velocity of the conductor and its position.
(a) Both A and R are true and R is a correct explanation of A.
(b) Both A and R are true but R is not a correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

Q.5 A rectangular loop of length a = 1 meter and width b = 80 cm is placed in a uniform magnetic field. What is the maximum value of induced emf if the magnetic flux density B = 0.1 Wb/m^2 is constant and the loop rotates about the x-axis with a frequency of 50 Hz?
(a) 32.65 volts (b) 18.54 volts
(c) 28 volts (d) 25.13 volts

Q.6 An electromagnetic field is said to be conservative when
(a) $\nabla^2 E = \mu E\left(\frac{\partial^2 E}{\partial t^2}\right)$
(b) $\nabla^2 H = \mu\epsilon\left(\frac{\partial^2 H}{\partial t^2}\right)$
(c) Curl of the field is zero
(d) divergence of the field is zero

Q.7 Match the following differential with integral forms of Maxwell's equations:

List-I	List-II
A. $\nabla \times E = 0$	1. $\oint H \cdot dl = \oint J \cdot ds$
B. $\nabla \cdot D = \rho$	2. $\oint E \cdot ds = 0$
C. $\nabla \times B = \mu_0 J$	3. $\oint B \cdot ds = 0$
D. $\nabla \cdot B = 0$	4. $\varepsilon\oint E \cdot ds = \oint \rho dV$

Codes:

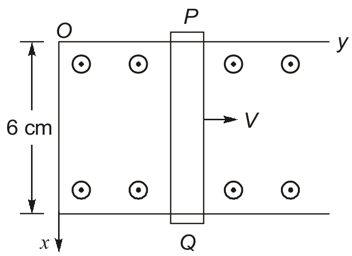
	A	B	C	D
(a)	4	2	1	3
(b)	2	4	1	3
(c)	2	4	3	1
(d)	4	2	3	1

Q.8 The Maxwell equation $\nabla \times \bar{H} = J + \frac{\partial \bar{D}}{\partial t}$ is based on
(a) Ampere's law (b) Gauss' law
(c) Faraday's law (d) Coulomb's law

Q.9 The electric and magnetic fields travel through a medium of perfect insulator. The modified Maxwell's equations are
(a) $\nabla \cdot \vec{D} = 0$, rest 3 not changed
(b) $\nabla \cdot \vec{D} = 0, \nabla \times \vec{E} = \vec{0}$, rest 2 not changed
(c) $\nabla \cdot \vec{D} = 0, \nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t}$, rest 2 not changed
(d) None changed

Q.28 A parallel plate capacitor with plate area of 5 cm^2 and plate separation of 3 mm has a voltage 50 $\sin 10^3 t$ applied to its plate. Calculate the displacement current assuming $\varepsilon = 2\varepsilon_0$ at $t = 0$.

Q.29 A conductivity bar can slide freely over two conducting rails as shown in figure.



What is the magnitude of maximum induced voltage in the bar if the bar is stationed at $y = 8$ cm and $B = 2\cos 10^6 t\, \hat{a}_z$ mWb/m^2?

Q.30 In a material for which conductivity $\sigma = 6$ Siemen/m and $\varepsilon_r = 1$, the electric field intensity is $E = 150 \sin 10^{10} t$ V/m. What is the frequency at which the displacement and conduction current densities will be equal (in GHz)?

Q.31 A square loop of wire 25 cm has voltmeter (of inifinite impedance) connected in series with one sode, the plane of looop is perpendicular to the magnetic field and the frequency is 5 MHz. If the maximum intensity is 3 A/m, then the voltage indicated by the meter when the loop is placed in the alternating field would be

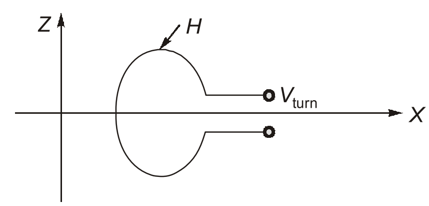
Q.32 A square loop of 2 m side is placed in xy-plane with its centre at the origin and sides along the co-ordinate axes. If the magnetic flux density in the region is given by,

$$\vec{B} = (2\hat{a}_x + 3\hat{a}_y + 5\hat{a}_z)e^{-0.5t} \text{ Wb/m}^2$$

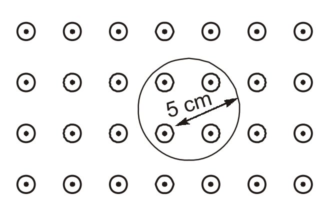
The emf induced in the loop at $t = 10$ sec will be ________ mV.

Q.33 An electron (q_1) is moving in free space with velocity 10^5 m/s towards a stationary electron (q_2) far away. The closest distance that this moving electron gets to the stationary electron before the repulsive force diverts its path is _____ $\times 10^{-8}$ m. [Given, mass of electron $m = 9.11 \times 10^{-31}$ kg, charge of electron $e = -1.6 \times 10^{-19}$C, and permittivity $\varepsilon_0 = (1/36\pi) \times 10^{-9}$ F/m]

Q.34 A circular turn of radius 1 m revolves at 60 rpm about its diameter aligned with the x-axis as shown in the figure. The value of $\mu_r = 2$. If a uniform magnetic field intensity $\vec{H} = 2\times 10^7 \hat{z}$ A/m is applied, then the peak value of the induced voltage, V_{turn} (in volts) is ______.



Q.35 Consider a one-turn circular loop of wire place in a uniform magnetic field as shown in the figure. The plane of the loop is perpendicular to the field line. The resistance of the loop is 0.4 Ω, and its inductance is negligible. The magnetic flux density is $B(t) = 0.25 \sin\omega t$ Tesla. Where $\omega = 2\pi \times 50$ rad/s. The power absorbed (in watt) by the loop from the magnetic field is ______.



Q.36 A ring having a cross-sectional area of 500 mm^2, a circumference of 200 mm and $\phi = 600\ \mu$Wb has a coil of 200 turns wound around it. Relative permeability of ring is 380. Calculate the magnetising current.

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Answers Time Varying Electromagnetic Field

1. (a)	2. (a)	3. (b)	4. (c)	5. (d)	6. (c)	7. (b)	8. (a)	9. (c)
10. (d)	11. (a)	12. (d)	13. (b)	14. (a)	15. (b)	16. (c)	17. (b)	18. (b)
19. (a)	20. (b)	21. (b)	22. (a)	23. (a)	24. (a)	25. (c)	26. (d)	27. (a)
28. (147.4)		29. (9.6)	30. (90)	31. (2.45)	32. (67.379)		33. (5.058)	
34. (992.20)		35. (0.47)	36. (2.49)					

Explanations Time Varying Electromagnetic Field

1. (a)

Induced emf,

$$e = N\frac{d\Phi}{dt} = 200 \times 2$$
$$= 400 \text{ volt}$$

2. (a)

Given, $\Phi = (t^3 - 2t)$ mWb

$\therefore \quad \frac{d\Phi}{dt} = (3t^2 - 2)$ mWb/sec

Emf induced is

$$e = -N\frac{d\Phi}{dt}$$
$$= -[100 \times (3t^2 - 2)] \times 10^{-3} \text{ volt}$$

$\therefore \quad e|_{t=2s} = -[100 \times (3 \times 2^2 - 2) \times 10^{-3}]$ volt

$$= -(100 \times 10^{-3} \times 10) = -1 \text{ volt}$$

3. (b)

Both assertion and reason are individually correct statements.

Since induced emf,

$$e = \frac{-d\psi}{dt} \quad (\psi = \text{total flux}),$$

thus due to negative sign, the total emf induced is equal to the time rate of decrease of the total magnetic flux linking the circuit. (The negative sign supports the Lenz's law).

4. (c)

- Assertion (A) is a correct statement since the motional induction or flux cutting law are given by

$$V = \int (\vec{v} \times \vec{B}) \cdot d\vec{l} \text{ volts}$$

or, $V = vBl$ volts

- Motional emf equation depends only on the velocity of the conductor and not its position. Thus, reason (R) is not a correct statement.

5. (d)

The induced emf in uniform magnetic field is given by

$$v = \omega (ab) B \sin \omega t$$

or, $v = \omega AB \sin \omega t$

(where, $A = ab$ = Area of rectangular loop)

or, $|v| = |2\pi f AB \sin\omega t|$

$$= |2\pi \times 50 \times 1 \times 80 \times 10^{-2} \times 0.1|$$
$$= 25.13 \text{ volts}$$

6. (c)

$$\nabla \times E = 0 \text{ for conservative field}$$

7. (b)

Maxwell's equation:

$$\nabla \cdot D = \rho_v$$

or, $\oint D \cdot ds = \int \rho_v \cdot dv$

$$\nabla \cdot B = 0$$

or, $\oint B \cdot ds = 0$

$$\nabla \times E = 0$$

or, $\oint E \cdot dl = 0$

$$\nabla \times H = J$$

or, $\oint H \cdot dl = \int J \cdot ds$

8. (a)

$$\nabla \times H = J + \frac{\partial D}{\partial t} \quad \text{(modified Ampere's law)}$$

$\Rightarrow \oint H \cdot dl = I_{en}$ = Ampere's law

9. (c)

Since, perfect insulator $\therefore \rho = 0$

$\nabla \cdot D = 0$ and J = current density = 0

$\therefore \quad \nabla \times H = \frac{\partial D}{\partial t}$

10. (d)

This is a moving loop in time varying field, so both transformer emf and motional emf are present.

11. (a)

$\frac{\partial \vec{D}}{\partial t}$ refers to displacement current through the dielectric medium. Presence of this term in the Faraday's law conforms to the principle of conservation of charge.

12. (d)

emf will be induced in both the coil due to rate of change of magnetic field. Since coil 2 is split so no current will flow in it so no Joule heating but in coil 1 Joule heating will occur as current flows through it.

13. (b)

- Curl of static electric field is always zero i.e. it is conservative.
- Div of steady magnetic field is always zero. No monopole can exist.
- Curl of time-varying electric field is never zero.

14. (a)

Maxwell's equations comprise of Gauss's, Faraday's and Ampere's equations which help studying the application of electromagnetic field to any medium. These equations can be represented in point as well as integral form.

15. (b)

Induced emf in the conductor

$$= V = v \times B$$

$$|V| = 50 \times 1.5 \qquad 75 \text{ Volts}$$

16. (c)

$$\nabla \times \vec{H} = \vec{J}_e + \frac{\partial \vec{D}}{\partial t}$$

since free space is a perfect dielectric medium.

$$\therefore \quad \sigma = 0$$

$$\therefore \quad \vec{J}_e = \sigma \vec{E} = 0$$

$$\therefore \quad \boxed{\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t}} \text{ for free space}$$

17. (b)

For a lossy dielectric Maxwell an equation

$$\nabla \times \bar{H} = (\sigma + j\omega\epsilon)\,\bar{E}$$

Also, $$\tan\delta = \frac{\sigma}{\omega\epsilon}$$

so, $$\nabla \times \bar{H} = j\omega\epsilon\left(1 - j\frac{\sigma}{\omega\epsilon}\right)\bar{E}$$

$$= j\omega\epsilon(1 - j\tan\delta)\,\bar{E}$$

18. (b)

Given, $B = 0.5 \text{ Wb/m}^2$

$\omega = 377$ rad/s

$\gamma = 0.5$ m

$$\text{Emf developed} = \frac{1}{2}\omega b a^2$$

$$= \frac{1}{2} \times 377 \times 0.5 \times (0.5)^2$$

$$E = 23.56 \text{ V}$$

20. (b)

$$\because \quad \frac{J_C}{J_D} = \frac{\sigma}{\omega\varepsilon} = \frac{I_C A}{I_D A}$$

$$I_D = I_C \cdot \frac{\omega\varepsilon}{\sigma}$$

$$= 1 \times \frac{2\pi \times 60 \times 10^{-9}}{5.8 \times 10 \times 36}$$

$$I_D = 5.76 \times 10^{-11} \text{ A}$$

21. (b)

Since the loop begins outside of any magnetic field, therefore initial magnetic flux is zero.

The final flux is,

$$\phi = B\cdot A = 10X(\pi X 0.05^2)$$

$$= 0.078 \text{ Wb}$$

Using Faraday's law, emf induced in the loop is given by,

$$e = -N\frac{\Delta\phi}{\Delta t}$$

$$= -25 \times \frac{0.07}{10} = -0.175 \text{ V}$$

$$|e| = 0.175 \text{ V}$$

22. (a)

$$\omega = \frac{2\pi}{60}N = 2\pi f$$

35. Sol.

Area of loop:

$$\Rightarrow \quad A = \pi r^2$$
$$= \pi(0.05)^2$$
$$B(t) = 0.25 \sin\omega t, \; R = 0.4\ \Omega$$
$$P = i^2 R$$

$$\because \quad e = -\frac{d\phi}{dt} = -\frac{d}{dt}(BA)$$
$$= -\frac{d}{dt}(0.25 \times \pi \times 25 \times 10^{-4} \times \sin\omega t)$$
$$= -0.25 \times \pi \times 25 \times 10^{-4} \times \omega \cos\omega t$$
$$= -1.96 \times 10^{-3} \times \omega \cos\omega t$$

$$\therefore \quad P_{avg} = \frac{e_{rms}^2}{R}$$
$$= \int_0^T \frac{(1.96 \times 100\pi \times 10^{-3})^2}{0.4} \times \cos^2 \omega t \, d(\omega t)$$
$$= (1.96 \times 100\pi \times 10^{-3})^2 \times \frac{1}{2 \times 0.4}$$
$$= 0.47 \text{ Watt}$$

36. Sol.

$$\because \quad \text{Reluctances} = \frac{l}{\mu A}$$
$$= \frac{200 \times 10^{-3}}{4\pi \times 10^{-7} \times 380 \times 500 \times 10^{-6}}$$
$$S = 0.83 \times 10^6 \text{ A/Wb}$$

$\because$ Magnetomotive force (F) = $NI = \phi s$

$$\therefore \quad 200 \times I = 600 \times 10^{-6} \times 0.83 \times 10^6$$
$$I = \frac{600 \times 0.83}{200} = 2.49 \text{ A}$$

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