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Civil Services Preliminary Examination

— 2001-2010 —

*Useful for Engineering Services Preliminary Examination,
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Electrical Engineering

Detailed Solutions

Topicwise Presentation



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Civil Services Preliminary Examination Previous Years Solved Papers : Electrical Engineering

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First Edition: 2016

Preface

Civil Services Examination is considered as a pioneer job in India which is being preferred by engineers. There was a need of good book, which contains error free questions with apt solutions that even a beginner student can understand. I am glad to launch the first edition of this book.



B. Singh (Ex. IES)

MADE EASY team has made deep study of previous exam papers of Civil Services Preliminary Examination and observed that a good percentage of questions are asked in Engineering Services Exam as well as State Services Exam. Therefore it is advisable to study this book before one takes the exam. This book is also useful for GATE and other competitive examinations for engineering graduates.

The first edition of this book is prepared with due care to provide complete solutions to all questions with accuracy. I would like to give credit of publishing this book to MADE EASY Team for their hard efforts in solving previous years papers in a limited time frame.

I have true desire to serve student community by providing good source of study and quality guidance. I hope this book will be proved as an important tool to succeed in competitive exams. Any suggestions from the readers for improvement of this book are most welcome.

With Best Wishes

B. Singh

CMD, MADE EASY Group

Previous Years Solved Papers

Civil Services Preliminary Exam.

Electrical Engineering

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Vector Analysis

1. The divergence of a vector $\vec{A} = \vec{i}x^2 + \vec{j}6y^2 + \vec{k}z^3$ at point P in space whose coordinates are $(2, 4, 1)$ is
- (a) 55 (b) 65
(c) 50 (d) 40

[CSE-2002]

Electrostatics

2. The value of electric field at a distance of 1 m from an infinite line charge of density 1 C/m is
- (a) $\frac{1}{2\pi\epsilon_0}$ (b) $2\pi\epsilon_0$
(c) $\frac{\epsilon_0}{2\pi}$ (d) $\frac{\epsilon_0}{4\pi}$

[CSE-2001]

3. The unit normal to the equipotential surface $\phi = \text{constant } c$ is, in general, given by

- (a) ϕ (b) $\frac{-\nabla\phi}{|\nabla\phi|}$
(c) $\frac{\nabla\phi}{|\nabla\phi|}$ (d) $\frac{\pm\nabla\phi}{|\nabla\phi|}$

[CSE-2003]

4. The force between a charge q and a grounded infinite conducting plane kept at a distance d from it is given by

- (a) $\frac{q}{4\pi\epsilon_0 d^2}$ (b) $\frac{q^2}{4\pi\epsilon_0 d^2}$
(c) $\frac{q}{16\pi\epsilon_0 d^2}$ (d) $\frac{q^2}{16\pi\epsilon_0 d^2}$

[CSE-2004]

5. A metallic sphere with charge $-Q$ is placed inside a hollow conducting sphere with radius R carrying a charge $+Q$. Potential at a given point outside the hollow sphere
- (a) depends on the positions of the metallic sphere.

- (b) is solely decided by the charge on the outer sphere.
(c) is always zero whatever may be the position of the inner sphere.
(d) is zero only when both spheres are concentric.

[CSE-2005]

6. Which one of the following is not correct?
- (a) Equation $\nabla_0 (-\epsilon \nabla V) = \rho_v$ may be regarded as Poisson's equation for an inhomogeneous medium.
(b) Two potential functions V_1 and V_2 satisfy Laplace's equation within a closed region and assume same values on its surface. Then, V_1 must be equal to V_2 .
(c) The capacitance of a capacitor filled with a linear dielectric is independent of the charge on the plates and the potential difference between the plates.
(d) A parallel plate capacitor connected to a battery stores twice as much charge with a given dielectric as it does with air as dielectric, then susceptibility of dielectric is 2.

[CSE-2006]

7. A potential field is given by: $V = 3x^2y - yz$. Which one of the following expresses an electric field at $P(2, -1, 4)$?

- (a) $12\hat{i} - 8\hat{j}$ (b) $12\hat{i} - \hat{j}$
(c) $12\hat{i} + 8\hat{j} + \hat{k}$ (d) $12\hat{i} - 8\hat{j} - \hat{k}$

[CSE-2006]

8. A spherical volume of radius ' a ' has a uniform charge density ρ . What is the electric displacement D on the surface of the sphere?

- (a) $\frac{4}{3}\rho a^3$ (b) $\pi\rho a^2$
(c) $\frac{1}{3}\rho a$ (d) $\frac{4}{3}\pi\rho a^2$

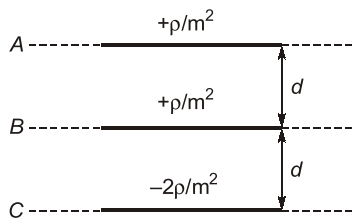
[CSE-2007]

9. An infinitely long line charge of density ρ , lies along z -axis. What is the electric field at a point $(R, 0, 0)$?

(a) $\hat{a}_z \left(\frac{\rho}{4\pi R} \right)$ (b) $\hat{a}_y \left(\frac{\rho}{2\pi \epsilon_0 R} \right)$
 (c) $\hat{a}_x \left(\frac{\rho}{2\pi \epsilon_0 R} \right)$ (d) $\hat{a}_x \left(\frac{\rho}{2\pi R} \right)$

[CSE-2007]

10. Three infinite parallel charged plates A, B, C carry charge density $+\rho$, $+\rho$ and -2ρ respectively, as shown in the figure below. What is the ratio of two potential differences $(V_A - V_B)$ and $(V_B - V_C)$?



- (a) 1 : 1 (b) 1 : 2
 (c) 1 : 3 (d) 1 : 4

[CSE-2008]

11. Which one of the following statements is correct? The polarizability of a conducting metallic sphere is
- proportional to the cube of the radius of the sphere.
 - proportional to the radius of the sphere.
 - cannot be determined as the sphere is metallic.
 - independent of the dimensions of the metallic sphere.

[CSE-2008]

12. What is the unit for dipole moment?
- Coulomb-metre²
 - Coulomb/volt-s
 - Debye unit
 - Gauss

[CSE-2008]

13. Which one of the following is correct?

Given the field $\vec{E} = \left(-\frac{16}{r^2} \right) \vec{a}_r$ in spherical

coordinates, the potential of point $A \left(2, \pi, \frac{\pi}{2} \right)$

with respect to point $B(4, 0, \pi)$ is

- (a) 4 V (b) -4 V
 (c) -3 V (d) 3 V

[CSE-2009]

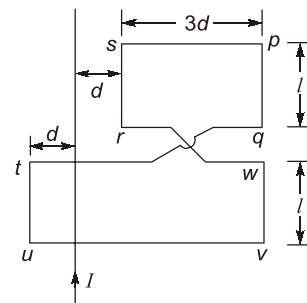
14. The Kirchhoffs current law is implicit in the expression

(a) $\nabla \cdot \vec{D} = \rho_0$ (b) $\int_s \vec{J} \cdot d\vec{s} = 0$
 (c) $\nabla \cdot \vec{B} = 0$ (d) $\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$

[CSE-2010]

Magnetostatics

15. In the given figure, if the magnetic flux through the rectangular loop 'pqrsp' due to the infinite the current I is ϕ , the flux linked with double rectangular loop 'pqtuvwrs' will be



- (a) 3ϕ (b) 2ϕ
 (c) ϕ (d) zero

[CSE-2001]

16. A circular disc of radius R carries a uniform surface charge density. When it revolves at a uniform angular velocity about its centre and in its own plane, the magnetic flux density at the centre of the disc is B .

If the radius of the disc is doubled and the original charge spread out uniformly on the extended area, the magnetic field at the centre would be

- (a) $B/4$ (b) $B/2$
 (c) B (d) $2B$

[CSE-2002]

17. Consider the following statements with regard to force per unit length between two stationary, long parallel filamentary currents:

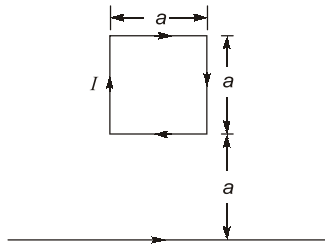
- It is directly proportional to the product of the magnitudes of the currents.
- It satisfies Newton's third law.
- it is attracting if the currents are in the same direction.

Which of these statements are correct?

- (a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

[CSE-2002]

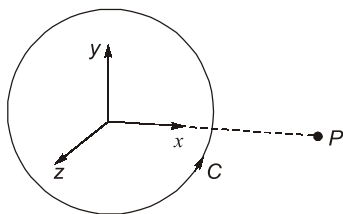
18. A square loop and an infinitely long conductor, each carries a current I as shown in the figure given below. What is the force on the loop?



- (a) $\frac{\mu_0 I^2}{4\pi}$ away from the conductor
(b) $\frac{\mu_0 I^2}{4\pi^2}$ towards the conductor
(c) $\frac{\mu_0 I^2}{4\pi} \log_e 2$ away from the conductor
(d) $\frac{\mu_0 I^2}{4\pi} \log_e 2$ towards the conductor

[CSE-2005]

19. The magnetic vector potential at the point P due to the current loop C shown in the below figure is in the direction of



- (a) \vec{a}_x (b) \vec{a}_y
(c) \vec{a}_z (d) $\frac{\vec{a}_x + \vec{a}_y}{\sqrt{2}}$

[CSE-2005]

20. How is the magnetic field dH from a short section dL of a current carrying wire, given by Biot-Savart's law expressed?

- (a) $dH = IdL/4\pi r^2$
(b) $dH = IdL \sin \theta/4\pi r$
(c) $dH = IdL \sin \theta/4\pi r^2$
(d) $dH = I r^2 dL \sin \theta/4\pi r^2$

[CSE-2006]

21. Which of the following represents the Maxwell's curl equation for static magnetic field?

- (a) $\nabla \times \vec{B} = \mu_0 \vec{j}$ (b) $\nabla \times \vec{B} = 0$
(c) $\nabla \cdot \vec{B} = \mu_0$ (d) $\nabla \cdot \vec{B} = 0$

[CSE-2006]

22. Which one of the following is correct?

Within a conductor carrying a current ' I ' with a constant current density across its cross-section, the magnetic field strength ' H ' at any distance ' r ' from the centre of the conductor (radius of the conductor is ' R ') is given by

- (a) $H = \frac{Ir}{(2\pi R)}$ (b) $H = \frac{Ir}{(2\pi R^2)}$
(c) $H = \frac{Ir}{(2\pi R^3)}$ (d) $H = \frac{Ir}{(2\pi R^4)}$

[CSE-2009]

23. If the magnitude of the magnetic flux B at a distance of 1 m from an infinitely long straight filamentary conducting wire is 2×10^{-6} Wb/m², what is the current in the wire?

- (a) 1 A (b) 10 A
(c) 100 A (d) 1000 A

[CSE-2010]

Time Varying EMT Field

24. In a source-free imperfect dielectric medium (specified by loss tangent $\tan \delta$), Maxwell's curl equation can be written as:

- (a) $\nabla \times \vec{H} = j\omega \epsilon \vec{E} (1 + j \tan \delta)$
(b) $\nabla \times \vec{H} = j\omega \epsilon \vec{E} (1 - j \tan \delta)$
(c) $\nabla \times \vec{H} = -j\omega \epsilon \vec{E} (1 + j \tan \delta)$
(d) $\nabla \times \vec{H} = -j\omega \epsilon \vec{E} (1 - j \tan \delta)$

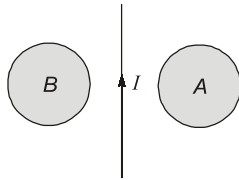
[CSE-2004]

25. An electric field in a charged medium with a time-varying magnetic field has

- (a) $\vec{\nabla} \cdot \vec{E} = 0; \vec{\nabla} \times \vec{E} = 0$
(b) $\vec{\nabla} \cdot \vec{E} \neq 0; \vec{\nabla} \times \vec{E} \neq 0$
(c) $\vec{\nabla} \cdot \vec{E} = 0; \vec{\nabla} \times \vec{E} \neq 0$
(d) $\vec{\nabla} \cdot \vec{E} \neq 0; \vec{\nabla} \times \vec{E} = 0$

[CSE-2004]

26. For the current I decreasing in the indicated direction, the e.m.f. in the two loops A and B shown in the figure below, is in the direction



- (a) clockwise in A and anticlockwise in B
 (b) anticlockwise in A and clockwise in B
 (c) clockwise in both A and B
 (d) anticlockwise in both A and B

[CSE-2005]

27. Match List-I with List-II and select the correct answer using the code given below the lists:

List-I

- A. $\nabla \cdot \vec{J} + \frac{\partial \rho}{\partial t} = 0$
 B. $\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$
 C. $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$
 D. $\nabla \cdot \vec{D} = \rho$

List-II

1. Modified Kirchhoff's Current Law
 2. Modified Ampere's Law
 3. Faraday's Law
 4. Gauss' Law

Codes:

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

[CSE-2007]

28. What does a time-rate of change of electric displacement lead to?
- (a) Convection current
 (b) Conduction current
 (c) Displacement current
 (d) No current flow

[CSE-2008]

29. Match List-I (Quantity) with List-II (Expression) and select the correct answer:

List-I

- A. Power flow density
 B. Impedance of media
 C. Joule heating
 D. Velocity of light

List-II

1. $\vec{E} \times \vec{H}$
 2. \vec{E} / \vec{H}
 3. $\vec{E} \cdot \vec{H}$
 4. \vec{E} / \vec{B}

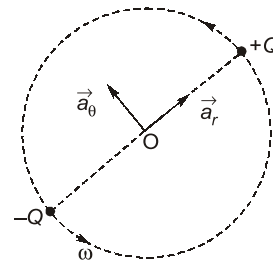
Codes:

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

[CSE-2009]

Electromagnetic Waves

30. An electric dipole ($-Q, Q$) revolved with a uniform angular velocity ' ω ' in a circle about its center 'O'. When the dipole is in the position shown in the given figure, the direction of the displacement current density at 'O' is



- (a) \vec{a}_r (b) $-\vec{a}_r$
 (c) \vec{a}_θ (d) $-\vec{a}_\theta$ [CSE-2001]

31. The cooking of the food in the microwave oven is based on the principle of
- (a) magnetic hysteresis loss
 (b) dielectric loss
 (c) both magnetic hysteresis loss and dielectric loss
 (d) evaporation of water

[CSE-2001]

32. A plane wave propagates in a direction having direction cosines $(1/\sqrt{2}, 1/\sqrt{2}, 0)$. The equation of the phase fronts is
- (a) $xy = \text{constant}$ (b) $x/y = \text{constant}$
 (c) $x + y = \text{constant}$ (d) $x - y = \text{constant}$

[CSE-2003]

33. **Assertion (A):** A circularly polarised wave incident at the Brewster angle becomes linearly polarised.

Reason (R): A wave composed of both parallel and perpendicular components incident at Brewster angle produces a reflected wave with only E component polarised parallel to the interface.

- (a) Both A and R are true, and R is the 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.

[CSE-2003]

34. The E-field of a uniform plane wave propagating in a dielectric medium is given by

$$E(t, z) = \hat{a}_x 2 \cos\left(10^8 t - \frac{z}{\sqrt{3}}\right) - \hat{a}_y \sin\left(10^8 t - \frac{z}{\sqrt{3}}\right) \text{ (V/m)}$$

What is the dielectric constant of the medium?

- (a) $\frac{1}{\sqrt{3}}$ (b) 3
 (c) $\sqrt{3}$ (d) 9

[CSE-2004]

35. A plane wave with an instantaneous expression for the electric field

$$\vec{E}(z, t) = \hat{a}_x E_{10} \sin(\omega t - kz) + \hat{a}_y E_{20} \sin(\omega t - kz + \phi) \text{ is}$$

- (a) Linearly polarized
 (b) Circularly polarized
 (c) Elliptically polarized
 (d) Horizontally polarized

[CSE-2004]

36. Which one of the following statements is correct? When an electromagnetic wave strikes the air-dielectric interface at an angle

- (a) the normal electric field components have the same value.
 (b) the tangential magnetic field components are continuous.
 (c) the electromagnetic wave is reflected back according to Snell's law.
 (d) the electromagnetic wave is diffracted.

[CSE-2005]

37. Match the relationship of items given in **List-I (Medium)** with the **List-II (Expression for Intrinsic Impedance)** and select the correct answer using the code given below:

All symbols have their usual meanings.

List-I

- A. Free space
 B. Perfect dielectric
 C. Partially conducting medium
 D. Conducting medium

List-II

1. $\sqrt{\frac{\omega\mu}{\sigma}} \cdot \angle 45^\circ$
 2. $\sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}}$
 3. $\sqrt{\frac{\mu}{\epsilon}}$
 4. $\sqrt{\frac{\mu_0}{\epsilon_0}}$

Codes:

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

[CSE-2006]

38. An electromagnetic field in free space (μ_0, ϵ_0) is given by:

$$\vec{E} = \vec{a}_x E_0 \cos(\omega t - k_0 z) \text{ V/m}$$

$$\vec{H} = \vec{a}_y E_0 \sqrt{\frac{\epsilon_0}{\mu_0}} \cos(\omega t - k_0 z) \text{ A/m}$$

where $k_0 = \omega \sqrt{\mu_0 \epsilon_0}$. What is the average power per unit area associated with this wave?

- (a) $\frac{\bar{a}_z E_0^2}{\pi}$ (b) $\frac{\bar{a}_z E_0^2}{120\pi}$
 (c) $\frac{\bar{a}_z E_0^2}{240\pi}$ (d) $\frac{\bar{a}_z E_0^2}{300\pi}$

$$\left(\text{Given: } \sqrt{\frac{\mu_0}{\epsilon_0}} = 120\pi \right)$$

[CSE-2007]

39. A wave propagating in a lossless dielectric has the field components:

$$\vec{E} = 500 \cos(10^7 t - \beta z) \vec{a}_x \text{ V/m, and}$$

$$\vec{H} = \frac{500}{180\pi} \cos(10^7 t - \beta z) \vec{a}_y \text{ A/m}$$

If the wave velocity is 1.5×10^8 m/s, the medium has

- (a) $\mu_r = 4, \epsilon_r = 1$ (b) $\mu_r = 3, \epsilon_r = \frac{4}{3}$
 (c) $\mu_r = 1, \epsilon_r = 4$ (d) $\mu_r = 2.25, \epsilon_r = 1$

(Given: $\sqrt{\frac{\mu_0}{\epsilon_0}} = 120\pi$)

[CSE-2007]

40. The skin depth of an electromagnetic wave in two dissipative media A and B is δ and 2δ , respectively. If the velocity of the wave in medium A is V , what is the velocity of the wave in medium B?

- (a) $\frac{V}{4}$ (b) $\frac{V}{2}$
 (c) V (d) $2V$

[CSE-2008]

41. Which one of the following correctly represents index of refraction (n) in terms of relative permittivity (ϵ_r)?

- (a) $n = \epsilon_r^2$ (b) $n = \frac{1}{(\epsilon_r^2)}$
 (c) $n = \frac{1}{(\sqrt{\epsilon_r})}$ (d) $n = (\sqrt{\epsilon_r})$

[CSE-2008]

42. If $\vec{H} = \vec{a}_x H_x - \vec{a}_y H_y$ represents the H-field in a transverse plane of an em wave travelling in the Z-direction, then what is the \vec{E} -field in the wave?

- (a) $Z_0 |\vec{a}_x H_y - \vec{a}_y H_x|$
 (b) $Z_0 |\vec{a}_x H_y + \vec{a}_y H_x|$
 (c) $Z_0 |-\vec{a}_x H_y - \vec{a}_y H_x|$
 (d) $Z_0 |-\vec{a}_x H_y + \vec{a}_y H_x|$

[CSE-2009]

43. For a material with conductivity $\sigma = 10^{-2}$ s/m and $\epsilon = 3\epsilon_0$, at what frequencies the conduction current density will be equal to displacement current density?

- (a) $\frac{1}{60}$ MHz (b) 60 MHz
 (c) 6.0 MHz (d) $\frac{1}{6}$ MHz

[CSE-2009]

44. A plane wave is propagating in a material characterized by $\epsilon_r = 2.25$, $\mu_r = 1$ and $\sigma = 0$. What is the value of β in rad/m, when the electric field is given by:

$$\vec{E} = 10 \cos(3 \times 10^{10} t - \beta z) \vec{a}_x \text{ V/m}$$

- (a) 125 (b) 150
 (c) 175 (d) 200

[CSE-2010]

Transmission Line

45. Smith's charts are used to obtain the impedance relations along a

- (a) lossless transmission line for different load conditions.
 (b) lossy transmission line for different load conditions.
 (c) lossy transmission line terminated at a load equal to line characteristic impedance.
 (d) lossless transmission line terminated at a load equal to line characteristic impedance.

[CSE-2001]

46. **Assertion (A):** A low voltage standing wave ratio (VSWR) is the goal in a transmission line.

Reason (R): The higher the VSWR, the greater is the mismatch on the line.

- (a) Both A and R are true, and R is the 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.

[CSE-2001]

47. A lossless line of length $\lambda/4$ and characteristic impedance Z_0 transforms a resistive load R into an impedance (Z_0^2/R). When the line is $\lambda/2$ long, the transformed impedance will be

- (a) (Z_0^2/R) (b) $2(Z_0^2/R)$
 (c) Z_0 (d) R

[CSE-2002]

48. A generator of 50Ω internal impedance and operating at 1 GHz feeds a 75Ω load via a coaxial line of characteristic impedance 50Ω . The voltage standing wave ratio on the feed line is

(a) 0.50 (b) 1.50
(c) 1.75 (d) 2.50

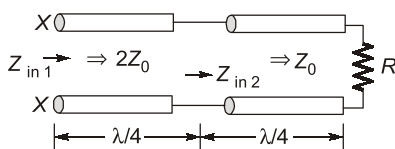
[CSE-2002]

49. How long (in terms of wavelength) should the short-circuited lossless line be so as to appear as an open circuit at the input terminals?

(a) $l = \frac{\lambda}{4}$ (b) $l = \frac{\lambda}{2}$
(c) $l = \frac{\lambda}{3}$ (d) $l = \lambda$

[CSE-2004]

50. A structure consisting of two loss-less lines, each $\lambda/4$ long and terminated in a resistance R , is shown in the figure given below. The lines have characteristic impedances of $2Z_0$ and Z_0 respectively as shown. What is the impedance measured at the end XX?



(a) R (b) $4R$
(c) Z_0^2/R (d) $4Z_0^2/R$

[CSE-2005]

51. Match **List-I (Expression)** with **List-II (Coefficient)** and select the correct answer using the code given below :

List-I

- A. $\rho = \frac{Z_L - Z_0}{Z_L + Z_0}$
B. $\rho = \frac{Z_0 - Z_L}{Z_L + Z_0}$
C. $\rho = \frac{2Z_L}{Z_0 + Z_L}$
D. $\rho = \frac{2Z_0}{Z_0 + Z_L}$

List-II

1. Reflection coefficient for voltage
2. Transmission coefficient for voltage
3. Reflection coefficient for current
4. Transmission coefficient for current
5. Standing-wave ratio

Codes:

	A	B	C	D
(a)	1	2	5	4
(b)	4	3	2	1
(c)	1	3	2	4
(d)	4	2	5	1

[CSE-2005]

52. Match **List-I (Parameters)** with **List-II (Range of values)** and select the correct answer using the code given below the lists:

List-I**List-II**

- | | |
|------------------------------------|------------------|
| A. Reflection coefficient at input | 1. 0 to ∞ |
| B. VSWR | 2. 1 to ∞ |
| C. Input impedance | 3. -1 to $+1$ |
| D. Phase shift magnitude | 4. 0 to 2π |

Codes:

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

[CSE-2006]

53. For a parallel plate transmission line with perfectly conducting plates of width w and separated by a lossless dielectric slab of thickness d , the characteristic impedance Z_0 is p times the intrinsic impedance η of the dielectric medium where

(a) $p = \frac{d}{w}$ (b) $p = \frac{w}{d}$
(c) $p = \sqrt{\frac{d}{w}}$ (d) $p = \sqrt{\frac{w}{d}}$

[CSE-2007]

54. Which one of the following statement is correct? The condition which does not guarantee distortion less transmission is

(a) at low frequencies, $R \gg \omega L$ and $G \gg \omega C$
(b) at high frequencies, $R \ll \omega L$ and $G \ll \omega C$
(c) $C = GL/R$
(d) $R = G = 0$

[CSE-2009]

Answers		Electromagnetic Theory													
1.	(a)	2.	(a)	3.	(d)	4.	(d)	5.	(c)	6.	(d)	7.	(d)	8.	(c)
9.	(c)	10.	(b)	11.	(a)	12.	(c)	13.	(b)	14.	(b)	15.	(b)	16.	(b)
17.	(d)	18.	(a)	19.	(b)	20.	(c)	21.	(a)	22.	(b)	23.	(b)	24.	(b)
25.	(b)	26.	(b)	27.	(a)	28.	(c)	29.	(a)	30.	(d)	31.	(b)	32.	(c)
33.	(c)	34.	(b)	35.	(c)	36.	(c)	37.	(d)	38.	(c)	39.	(b)	40.	(c)
41.	(d)	42.	(b)	43.	(b)	44.	(b)	45.	(a)	46.	(a)	47.	(a)	48.	(b)
49.	(a)	50.	(b)	51.	(c)	52.	(d)	53.	(a)	54.	(a)	55.	(b)	56.	(a)
57.	(d)	58.	(d)	59.	(d)	60.	(c)	61.	(a)	62.	(b)	63.	(d)	64.	(c)
65.	(a)	66.	(b)	67.	(c)	68.	(a)	69.	(b)	70.	(c)	71.	(d)	72.	(c)
73.	(c)	74.	(c)	75.	(a)										

Explanations

1. (a)

Divergence of a vector \vec{A} is given by

$$\nabla \cdot \vec{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

$$\vec{A} = \vec{i} x^2 + \vec{j} 6y^2 + \vec{k} z^3$$

$$\frac{\partial A_x}{\partial x} = 2x$$

$$\frac{\partial A_y}{\partial y} = 12y$$

$$\frac{\partial A_z}{\partial z} = 3z^2$$

$$\nabla \cdot \vec{A} = 2x + 12y + 3z^2$$

$$\begin{aligned} (\nabla \cdot \vec{A})_{(2, 4, 1)} &= (2)(2) + 12(4) + 3(1)^2 \\ &= 4 + 48 + 3 = 55 \end{aligned}$$

2. (a)

Electric field due to infinite line charge with charge density λ at a distance r

$$|\vec{E}| = \frac{\lambda}{2\pi\epsilon_0 r}$$

Given, $\lambda = 1 \text{ C/m}$, $r = 1 \text{ m}$

$$|\vec{E}| = \frac{1}{2\pi\epsilon_0 (1)} = \frac{1}{2\pi\epsilon_0}$$

3. (d)

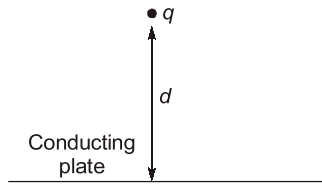
Ψ -constant represents an equipotential surface. Electric field,

$$\vec{E} = - \underset{\substack{\uparrow \\ \text{Gradient}}}{\nabla} \Psi$$

Electric field is always perpendicular to the equipotential surface. So any unit vector in the direction of \vec{E} represents a unit vector normal to Ψ . Unit vector in the direction of

$$\hat{E} = \frac{\pm \vec{E}}{|\vec{E}|} = \frac{\pm \nabla \Psi}{|\nabla \Psi|}$$

4. (d)



According to image theory, charge configuration above an infinite conducting plane may be replaced by charge configuration itself, its image and an equipotential surface in place of conducting plane. For given configuration as per image theory.

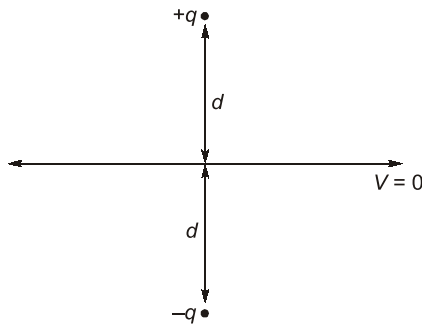


Image is taken as $-q$ because only then $V = 0$. Force between $+q$ and conducting plane will be same as that of force between $+q$ and $-q$

$$|\vec{F}| = \frac{(q)(q)}{4\pi\epsilon_0 (2d)^2} = \frac{q^2}{16\pi\epsilon_0 d^2}$$

5. (c)

There will be a redistribution of charge on outer sphere so that center of charge distribution will always be the center of metallic sphere. So net charge = 0 for any point outside. Potential = 0 irrespective of position of inner sphere.

6. (d)

Capacitance,

$$C = \frac{\epsilon_0 \epsilon_r A}{d} \quad (\text{For parallel plate capacitor})$$

$$C \propto \epsilon_r$$

All other parameters are constant,

$$\frac{C_1}{C_2} = \frac{\epsilon_{r1}}{\epsilon_{r2}}$$

Charge,

$$q = CV$$

For constant voltage $q \propto C$,

$$\frac{q_1}{q_2} = \frac{\epsilon_{r1}}{\epsilon_{r2}}$$

Given,

$$q_2 = 2q_1$$

\Rightarrow

$$\epsilon_{r2} = 2\epsilon_{r1}$$

$$\epsilon_{r1} = 1 \quad (\text{Air})$$

\Rightarrow

$$\epsilon_{r2} = 2$$

Susceptibility,

$$\chi_e = \epsilon_r - 1$$

$$\chi_{e2} = \epsilon_{r2} - 1$$

$$= 2 - 1 = 1$$

7. (d)

Electric field,

$$\vec{E} = -\nabla V$$

$$= -\frac{\partial V}{\partial x} \hat{i} - \frac{\partial V}{\partial y} \hat{j} - \frac{\partial V}{\partial z} \hat{k}$$

$$\frac{\partial V}{\partial x} = 6xy$$

$$\frac{\partial V}{\partial x} = (3x^2 - z)$$

$$\frac{\partial V}{\partial z} = -y$$

$$\vec{E} = -6xy \hat{i} - (3x - z) \hat{j} + y \hat{k}$$

$$(\vec{E})_{(2, -1, 4)} = -6(2)(-1) \hat{i} - (3(2) - 4) \hat{j} + \hat{k}(-1)$$

$$= 12 \hat{i} - 8 \hat{j} - \hat{k}$$

8. (c)

According to Gauss's law total electric flux Ψ through any closed surface is equal to total charge enclosed by that surface,

$$\Psi = \oint \vec{D} \cdot \vec{ds} = Q_{\text{encl.}}$$

$D \rightarrow$ electric flux density or electric displacement

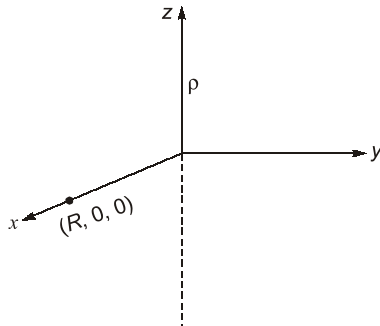
$$Q_{\text{encl.}} = (\rho) (\text{volume})$$

$$= (\rho) \left(\frac{4}{3} \pi a^3 \right)$$

$$\oint \vec{D} \cdot \vec{ds} = (D)(4\pi a^2) = \rho \cdot \frac{4}{3} \pi a^3$$

$$D = \frac{1}{3} \rho a$$

9. (c)



Electric field due to an infinite line charge,

$$|\vec{E}| = \frac{\rho}{2\pi\epsilon_0 r}$$

 $r \rightarrow$ distance (horizontal)Here, $r = R$ Direction of field will be along \hat{a}_x

$$\vec{E} = \frac{\rho}{2\pi\epsilon_0 R} \hat{a}_x$$

10. (b)

Electric field due to a charged sheet = $\frac{\rho_s}{2\epsilon_0}$ $\rho_s \rightarrow$ surface charge densityPotential at distance r from sheet = $E \cdot d$ $V_{AB} \rightarrow$ Potential at sheet A due to B

$$V_{AB} = \frac{\rho_s}{2\epsilon_0} \cdot d = \frac{\rho}{2\epsilon_0} \cdot d$$

$$V_{AC} = -\frac{2\rho}{2\epsilon_0}(2d) = -\frac{2\rho d}{\epsilon_0}$$

$$\begin{aligned} V_A &= V_{AB} + V_{AC} \\ &= \frac{\rho d}{2\epsilon_0} - \frac{2\rho d}{\epsilon_0} = -\frac{3\rho d}{2\epsilon_0} \end{aligned}$$

$$V_{BA} = V_{AB} = \frac{\rho d}{2\epsilon_0}$$

$$V_{BC} = -\frac{2\rho}{2\epsilon_0}(d) = -\frac{\rho d}{\epsilon_0}$$

$$\begin{aligned} V_B &= V_{BA} + V_{BC} \\ &= \frac{\rho d}{2\epsilon_0} - \frac{\rho d}{\epsilon_0} = -\frac{\rho d}{2\epsilon_0} \end{aligned}$$

$$V_C = V_{CA} + V_{CB}$$

$$V_{CA} = \frac{\rho}{2\epsilon_0}(2d) = \frac{\rho d}{\epsilon_0}$$

$$V_{CB} = \frac{\rho}{2\epsilon_0}(d) = \frac{\rho d}{2\epsilon_0}$$

$$V_C = \frac{\rho d}{2\epsilon_0} + \frac{\rho d}{\epsilon_0} = \frac{3\rho d}{2\epsilon_0}$$

$$\begin{aligned} V_A - V_B &= -\frac{3\rho d}{2\epsilon_0} + \frac{\rho d}{2\epsilon_0} \\ &= -\frac{2\rho d}{2\epsilon_0} = -\frac{\rho d}{\epsilon_0} \end{aligned}$$

$$\begin{aligned} V_B - V_C &= -\frac{\rho d}{2\epsilon_0} - \frac{3\rho d}{2\epsilon_0} \\ &= -\frac{4\rho d}{2\epsilon_0} = -\frac{2\rho d}{\epsilon_0} \end{aligned}$$

$$(V_A - V_B) : (V_B - V_C) = 1 : 2$$

11. (a)

$$\alpha_e = 4\pi\epsilon_0 R^3$$

 $\alpha_e \rightarrow$ Electric polarizability $R \rightarrow$ Radius of sphere

$$\alpha_e \propto R^3$$

12. (c)

Dipole moment, $p = q \cdot d$ $q \rightarrow$ charge, $d \rightarrow$ distanceunit of $p \rightarrow$ C.m which is also called Debye.

13. (b)

Electric field,

$$\vec{E} = -\nabla V$$

$$= -\frac{\partial V}{\partial r} \hat{a}_r \quad (\text{for spherical coordinates})$$

$$-\frac{16}{r^2} = -\frac{\partial V}{\partial r}$$

Integrating both sides,

$$dV = \frac{16}{r^2} dr$$

$$V = -\frac{16}{r} + C$$

$$A \rightarrow \left(2, \pi, \frac{\pi}{2}\right), \quad B \rightarrow (4, 0, \pi)$$

$$V_A = -\frac{16}{2} + C = -8 + C$$

$$V_B = -\frac{16}{4} + C = -4 + C$$

$$\begin{aligned} V_{AB} &= V_A - V_B \\ &= -8 + C + 4 - C = -4 \text{ V} \end{aligned}$$

14. (b)

As per Kirchoff's current law, current entering a point (node) is equal to current leaving the point.
Also as per continuity equation,

$$\nabla \cdot \vec{J} = -\frac{\partial \rho_v}{\partial t}$$

$$\frac{\partial \rho_v}{\partial t} = 0 \quad \text{at a point}$$

$$\nabla \cdot \vec{J} = 0$$

Further as per divergence theorem

$$\int_V \nabla \cdot \vec{J} = \oint \vec{J} \cdot d\vec{s}$$

$$\text{so,} \quad \oint \vec{J} \cdot d\vec{s} = 0$$

15. (b)

Flux \propto (Area)

Magnetic flux,

$$\phi_1 = \phi$$

for loop $pqrst \propto$ (area)

$$\phi \propto (3dl)$$

Magnetic flux for loop $tuvw \rightarrow \phi_2 + \phi_3$

Due to direction of current and consequent magnetic field the flux setup in the area of loop $tuvw$ left to wire is opposite to that of field to the right side of wire. Further total flux in loop $tuvw$ is sum of flux on left and right side area.

Area of left side $\rightarrow (d)(l)$

Area of right side $\rightarrow (4d)(l)$

$$\phi_2 \propto (d)(l)$$

$$\phi_3 \propto (4dl)$$

ϕ_2 is opposite of ϕ_3 .

Net flux of loop $tuvw \propto (3dl)$

Total flux of both loop $\propto (3dl + 3dl)$

$$\phi' \propto 6dl$$

$$\text{so,} \quad \phi' = 2\phi$$

16. (b)

Magnetic field due to charge disc with surface charge density ' σ_1 ', radius ' R_1 '

$$B_1 = \mu_0 \sigma_1 \omega R_1$$

$$\sigma_1 = \frac{Q}{\pi R_1^2} \quad (Q \rightarrow \text{Charge})$$

For,

$$R_2 = 2R_1$$

$$\sigma_2 = \frac{Q}{\pi R_2^2} = \frac{Q}{\pi (2R_1)^2} = \frac{\sigma_1}{4}$$

$$B_2 = \mu_0 \sigma_2 \omega R_2$$

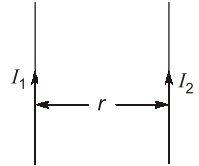
$$= \mu_0 \left(\frac{\sigma_1}{4} \right) (\omega) (2R_1)$$

$$= \frac{1}{2} \mu_0 \sigma_1 \omega R_1 = \frac{1}{2} B_1$$

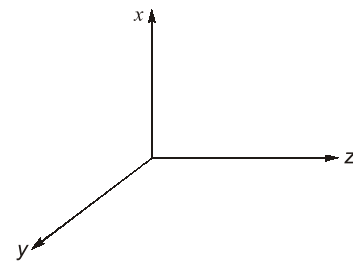
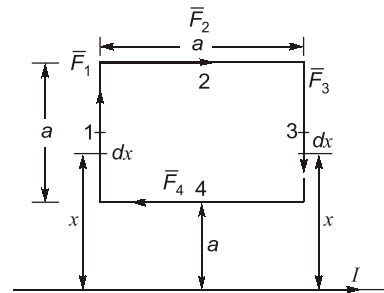
17. (d)

$$\bullet \quad \frac{\text{Force}}{\text{Length}} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

$$\frac{F}{\Delta L} \propto I_1 I_2$$



- It satisfies Newton's third law.
- Current in same direction – Attraction
In opposite direction – Repulsion

18. (a)

$$\text{Force,} \quad \vec{F} = I(l \times \vec{B})$$

$$d\vec{F}_1 = I(dl \times \vec{B})$$

$$\vec{B} \text{ at } x \rightarrow \frac{\mu_0}{4\pi} \frac{I}{x} \hat{a}_y,$$

$$d\vec{l} = dx \vec{a}_x$$

$$d\vec{F}_1 = I \left(\frac{\mu_0}{4\pi} \frac{I}{x} dx \right) \hat{a}_z$$

$$d\vec{F}_1 = \int d\vec{F}_1 = \frac{\mu_0 I^2}{4\pi} \hat{a}_z \int_a^{2a} \frac{dx}{x}$$

$$\vec{F}_1 = \frac{\mu_0 I^2}{4\pi} \ln 2 \hat{a}_z$$

Similarly, $\bar{F}_3 = -\frac{\mu_0 I^2}{4\pi} \ln 2 \hat{a}_z$

$$\bar{F}_1 + \bar{F}_3 = 0$$

$$\bar{F}_4 = (I)(a) \frac{\mu_0}{2\pi} \cdot \frac{I}{a} \cdot \hat{a}_x = \frac{\mu_0 I^2}{2\pi} \hat{a}_x$$

$$\bar{F}_2 = -(I)(a) \left(\frac{\mu_0}{2\pi} \cdot \frac{I}{2a} \right) \cdot \hat{a}_x$$

$$= -\frac{\mu_0}{2\pi} I^2 \hat{a}_x$$

$$\bar{F} = \bar{F}_2 + \bar{F}_4$$

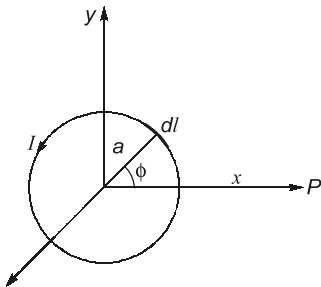
$$= \frac{\mu_0 I^2}{4\pi} \hat{a}_x$$

(Away from conductor)

19. (b)

Magnetic vector potential due to line charge

$$\bar{A} = \frac{\mu_0 I}{4\pi} \oint \frac{d\bar{l}}{R}$$



$$d\bar{l} = (a \cdot d\phi) \hat{a}_\phi$$

(Cylindrical coordinates)

Also conversion of \hat{a}_ϕ into cartesian coordinates

$$\hat{a}_\phi = -\hat{a}_x \sin \phi + \hat{a}_y \cos \phi$$

But for point P, $\phi = 0$

$$\hat{a}_\phi = \hat{a}_y$$

so, direction of \bar{A} at P is \hat{a}_y .

20. (c)

According to Biot-savart law,

$$|d\bar{H}| = \frac{I d\bar{l} \sin \theta}{4\pi r^2}$$

21. (a)

As per ampere's circuital law,

$$\begin{aligned} \oint \bar{B} \cdot d\bar{l} &= \mu_0 \iint \bar{J} \cdot d\bar{S} \\ &= \iint (\nabla \times \bar{B}) \cdot d\bar{S} = \mu_0 \iint \bar{J} \cdot d\bar{S} \\ &= \nabla \times \bar{B} = \mu_0 \bar{J} \end{aligned}$$

22. (b)

As per ampere's circuital law,

$$\oint \bar{H} \cdot d\bar{l} = I_{\text{encl.}}$$

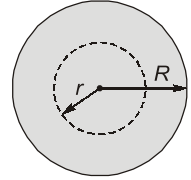
For constant current density,

$$\begin{aligned} \frac{I'}{\pi r^2} &= \frac{I}{\pi R^2} \\ I' &= I \cdot \frac{r^2}{R^2} \end{aligned}$$

$$I_{\text{encl.}} = I' = \frac{I r^2}{R^2}$$

$$\oint H d\bar{l} = H \oint d\bar{l} = H \cdot 2\pi r = \frac{I r^2}{R^2}$$

$$H = \frac{I r}{2\pi R^2}$$



23. (b)

Magnetic field density due to infinite wire

$$B = \frac{\mu_0 I}{2\pi a}$$

Given, $a = 1 \text{ m}$

$$B = 2 \times 10^{-6} \text{ Wb/m}^2$$

$$\mu_0 = 4\pi \times 10^{-7}$$

$$2 \times 10^{-6} = \frac{(4\pi)(10^{-7})}{2\pi} \cdot \frac{I}{1} = 2 \times 10^{-7} I$$

\Rightarrow

$$I = 10 \text{ Amp.}$$

24. (b)

For a lossy dielectric Maxwell an equation

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

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

$$\begin{aligned} \text{so, } \nabla \times \bar{H} &= j\omega\epsilon \left(1 - j \frac{\sigma}{\omega\epsilon} \right) \bar{E} \\ &= j\omega\epsilon (1 - j \tan \delta) \bar{E} \end{aligned}$$

25. (b)

In a charged medium and time varying magnetic field,

$$\nabla \cdot \vec{E} = \frac{\rho_v}{\epsilon}$$

so, $\nabla \cdot \vec{E} \neq 0$

$$\nabla \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t}; \quad \frac{\partial \vec{H}}{\partial t} \neq 0$$

so, $\nabla \times \vec{E} \neq 0$

26. (b)

Direction of induced emf and consequent current should be such that field produced by this current in loops strengthen the field produced by 'I' (Lenz law). Anticlockwise in 'A' and clockwise in 'B' produces the field that strengthen the field by 'I'.

27. (a)

- Gauss law $\nabla \cdot \vec{D} = \rho$

- Kirchoff current law,

$$\nabla \cdot \vec{J} = -\frac{\partial \rho}{\partial t} \quad (\text{Continuity equation})$$

- Modified ampere's law,

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

- Faraday's law,

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

28. (c)

Maxwell's equation for time varying field,

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

$\vec{J} \rightarrow$ Conduction current density

$\frac{\partial \vec{D}}{\partial t} = \vec{J}_d \rightarrow$ Displacement current density

29. (a)

By Poynting theorem,

$$P_D = \vec{E} \times \vec{H} \quad (\text{Power flow density})$$

Characteristic impedance,

$$\eta = \frac{\vec{E}}{\vec{H}} = \sqrt{\frac{\mu}{\epsilon}}$$

Also,

$$\vec{B} = \mu \vec{H}$$

$$\frac{\vec{E}}{\vec{B}} = \frac{\vec{E}}{\mu \vec{H}} = \frac{1}{\mu} \sqrt{\frac{\mu}{\epsilon}} = \frac{1}{\sqrt{\mu \epsilon}}$$

(Velocity of light)

30. (d)

As per Maxwell's equation,

$$\nabla \times \vec{H} = \vec{J}_c + \vec{J}_d$$

$\vec{J}_c \rightarrow$ Conduction current density

$\vec{J}_d \rightarrow$ Displacement current density

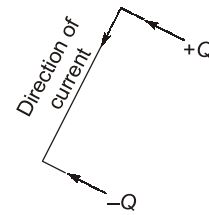
For this system,

$$\nabla \times \vec{H} = 0$$

so,

$$\vec{J}_d = -\vec{J}_c$$

Direction of current is direction of movement of positive charge.



Direction of $\vec{J}_c \rightarrow \vec{a}_\theta$

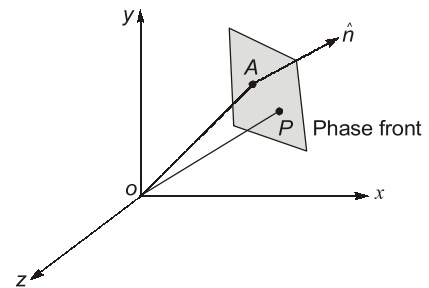
Direction of $\vec{J}_d \rightarrow (-\vec{a}_\theta)$

31. (b)

Microwave oven heats food by the process of dielectric heating. Microwave radiation penetrates into food upto 1-2 inches and heat the water into the food uniformly.

32. (c)

Phase front is a plane perpendicular to the direction of wave motion.



Let \hat{n} be a unit vector in the direction of wave propagation.

Here, $\hat{n} = \frac{1}{\sqrt{2}}\hat{a}_x + \frac{1}{\sqrt{2}}\hat{a}_y$

P is any point on phase front

$$\overline{OP} = \vec{r} = x\hat{a}_x + y\hat{a}_y + z\hat{a}_z$$

Equation of phase front is $\hat{n} \cdot \vec{r} = \text{constant}$

$$\left(\frac{1}{\sqrt{2}}\hat{a}_x + \frac{1}{\sqrt{2}}\hat{a}_y \right) \cdot (x\hat{a}_x + y\hat{a}_y + z\hat{a}_z) = \text{constant}$$

$$\frac{x}{\sqrt{2}} + \frac{y}{\sqrt{2}} = \text{constant}$$

or, $x + y = \text{constant}$

33. (c)

- A circularly polarised (C.P.) wave is composed of both s and p -polarised wave. When C.P. wave is incident at Brewster angle or polarization angle, p -component is completely transmitted which is a linearly polarized wave.
- Reflected wave is s -polarized in which \vec{E} is perpendicular to plane of incidence.

34. (b)

$$\begin{aligned} \text{Velocity of wave} &= v = \frac{\omega}{\beta} \\ &= \frac{1}{\sqrt{\mu\epsilon}} = \frac{1}{\sqrt{\mu_0\epsilon_0}} \cdot \frac{1}{\sqrt{\epsilon_r}} \end{aligned}$$

For this medium,

$$\mu = \mu_0, \epsilon = \epsilon_0\epsilon_r$$

$$\omega = 10^8 \text{ rad/sec.}$$

$$\beta = \frac{1}{\sqrt{3}} \text{ m}^{-1}$$

$$v_p = \sqrt{3}(10^8) = \frac{1}{\sqrt{\mu_0\epsilon_0}} \cdot \frac{1}{\sqrt{\epsilon_r}}$$

$$\sqrt{3} \times 10^8 = (3 \times 10^8) \times \frac{1}{\sqrt{\epsilon_r}}$$

$$\Rightarrow \epsilon_r = 3$$

35. (c)

For a wave,

$$\vec{E}(z, t) = E_{10} \sin(\omega t - kz)\hat{a}_x + \hat{a}_y E_{20} \sin(\omega t + kz) + \phi$$

Polarization is elliptical,

$$\vec{E} = \hat{a}_x E_x + \hat{a}_y E_y$$

- For $E_{10} = E_{20}$ and $\phi = \pm 90^\circ$, wave will be circularly polarized.

- For E_y 180° out of phase or in phase with E_x wave is linearly polarized.

36. (c)

EM wave reflected as per Snell's law where angle of incidence = Angle of reflection.

37. (d)

$$\text{Free space} = \sqrt{\frac{\mu_0}{\epsilon_0}}$$

$$\text{Perfect dielectric} = \sqrt{\frac{\mu}{\epsilon}}$$

Partially conducting medium or lossy dielectric

$$= \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}}$$

$$\text{Conducting medium} = \sqrt{\frac{\omega\mu}{\sigma}} \angle 45^\circ$$

38. (c)

$$\vec{P} = \vec{E} \times \vec{H} \quad (\text{Poynting vector})$$

Time average of poynting vector is average power per unit area.

$$\vec{E} = E_0 e^{-\alpha z} \cos(\omega t - \beta z) \vec{a}_x$$

$$\vec{H} = \frac{E_0}{|\eta|} e^{-\alpha z} \cos(\omega t - \beta z - \theta_\eta) \vec{a}_y$$

$$\vec{P}_{\text{avg}}(z) = \frac{E_0^2}{2|\eta|} e^{-2\alpha z} \cos\theta_\eta \vec{a}_z$$

For given waves in free space,

$$\eta = 120\pi = \sqrt{\frac{\mu_0}{\epsilon_0}}, \theta_\eta = 0, \alpha = 0$$

$$|\vec{P}_{\text{avg}}(z)| = \frac{E_0^2}{(2)(120\pi)} = \frac{E_0^2}{240\pi}$$

$$\vec{P}_{\text{avg}}(z) = \frac{E_0^2}{240\pi} \vec{a}_z$$

39. (b)

$$v = 1.5 \times 10^8$$

$$= \frac{1}{\sqrt{\mu\epsilon}} = \frac{1}{\sqrt{\mu_0\epsilon_0}} \cdot \frac{1}{\sqrt{\mu_r\epsilon_r}}$$

so,

$$\mu_r\epsilon_r = 4$$

...(1)