GATE

2018

EMFT

ELECTRICAL ENGINEERING

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CONTENTS

CHAPTER - 1
INTRODUCTION

1.1 INTRODUCTION

1. Scalar
It refers to a quantity whose value may be repeated by a single real number (either +ve, -ve). x, y, z, we used in basic algebra to represents the scalar quantities e.g. mass, time, temperature, work etc.

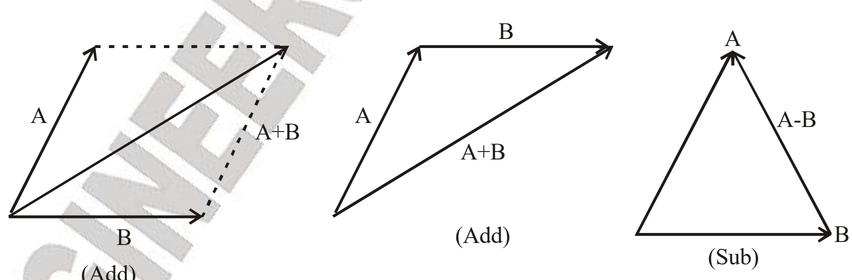
2. Vector
It refers to the quantity has both magnitude and direction in space. Vector quantity can be defined in n-dimensional space in more advanced application e.g. force, velocity, displacement, acceleration.

Vector is represented by arrow whose direction is appropriately chosen and whose length is proportional to the magnitudes of vectors.

3. Field
If at each point of a region there is a corresponding value of some physical function that region is called field. Fields may be classified as scalar/ vector depending upon the type of function involved.

(i) Scalar Field
If the value of physical function at each point is a scalar quantity, then the field is scalar field.
Example of scalar fields is Temperature of atmosphere.

(ii) Vector Field
If the value of function at each point is a vector quantity then the field is vectors field.
Example
Wind velocity of atmosphere; Forced on a charge particle in electric Field effect.



3D vector is completely represented by its projection on the x, y, z, axis coordinate.

$$\vec{A} = A_x \hat{a}_x + A_y \hat{a}_y + A_z \hat{a}_z$$

ASSIGNMENT

1. Which among the following is a valid form of Maxwell's equation?
(a) $\nabla\cdot B = \rho_v$ (b) $\nabla\cdot E = \rho_v$
(c) $\nabla\times B = J$ (d) $\nabla\cdot D = \rho_v$

2. Divergence theorem is defined as:
(a) $\oint D.dl = \int(\nabla.D)\,ds$
(b) $\oint D.ds = \int(\nabla\times D)dv$
(c) $\oint D.ds = \int(\nabla.D)\,dv$
(d) $\oint D.dl = \int(\nabla\times D)\,ds$

3. Which of the following pair of quantities have the same units?
(a) $\overline{D}, \rho_v$ (b) $\overline{E}, \overline{H}$
(c) $\overline{D}, \rho_s$ (d) $\in_0$, μ_0

4. Which of the following is TRUE?
(a) $\int H.ds = \oint\left(J + \frac{\partial D}{\partial t}\right).dl$
(b) $\oint H.dl = \oint\left(J + \frac{\partial D}{\partial t}\right).ds$
(c) $\oint H.ds = \int\left(J + \frac{\partial D}{\partial t}\right).dl$
(d) $\oint H.dl = \int\left(J + \frac{\partial D}{\partial t}\right).ds$

5. The potential of an electric dipole varies as $1/{*}r^2$. The electric field intensity varies as:
(a) $1/r^2$ (b) $1/r^3$
(c) $1/r$ (d) Independent of r

6. Units of vector magnetic potential are:
(a) Amp./m^2 (b) Amp./m
(c) Weber/m^2 (d) Weber/m

7. An infinite line charge lies on the z–axis. The surface having non-zero flux cutting through it is _______.
(a) z=constant (b) ϕ=constant
(c) ρ=constant (d) All the above
(e) None of these

8. An infinite line charge lies on the x–axis. The surface having zero flux cutting through it is _______.
(a) x = 0 (b) y = 0
(c) z = 0 (d) All of these

9. Units of the magnetic dipole moment are ________.
(a) A/m (b) A–m
(c) A/m^2 (d) A–m^2

10. Which of the following defines magnetic flux (Weber) exactly?
(a) $\frac{\text{Work done}}{\text{Current} - \text{element}} = \frac{W}{Idl}$
(b) $\frac{\text{Work done}}{\text{Current}} = \frac{W}{I}$
(c) $\frac{\text{Work done}}{\text{Volt}} = \frac{W}{V}$
(d) None of these

11. If $\overline{D} = \frac{5}{r^2}\sin\theta\,\overline{a}_r$, the flux leaving the r=constant surface is _____.
(a) Independent of r (b) Dependent on 1/r
(c) Dependent on $1/r^2$ (d) Dependent on $1/r^3$
(e) None of these

12. Magnetic Boundary conditions for two magnetic materials can be stated as:
(a) $H_1=H_2$ and $H_{t1}=H_{t2}$
(b) $H_{t1}=H_{t2}$ and $\mu_1 H_{n1}=\mu_2 H_{t2}$
(c) $H_{n1}=H_{n2}$ and $H_{t1}=H_{t2}$
(d) $H_1=H_2$, and $H_{t2}=H_{n1}=H_{n2}$

GATE QUESTIONS

1. If the vector function:

$\vec{F} = \hat{a}_x(3y - k_1 z) + \hat{a}_y(k_2 x - 2z) - \hat{a}_z(k_3 y + z)$ is ir-rotational, then the values of the constants k_1, k_2 and k_3 respectively, are

[GATE - 2017]

(a) 0.3, –2.5, 0.5 (b) 0.0, 3.0, 2.0
(c) 0.3, 0.33, 0.5 (d) 4.0, 3.0, 2.0

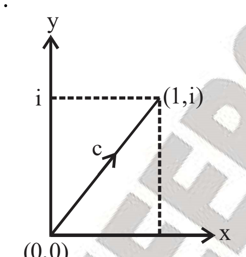
2. The smaller angle (in degrees) between the planes $x + y + z = 1$ and $2x - y + 2z = 0$ is ___.

[GATE - 2017]

3. A three dimensional region R of finite volume is described by
$x^2 + y^2 \le z^3;\ 0 \le z \le 1,$
where x, y, z are real. The volume of R (up to two decimal places) is ____.

[GATE - 2017]

4. Consider the line integral $I = \int_c (x^2 + iy^2)dz$ where z is x + iy. The line c is shown in the figure below:

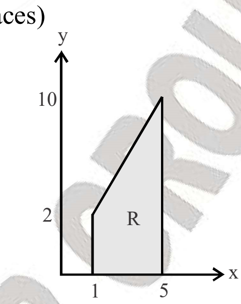


The value of I is

[GATE - 2017]

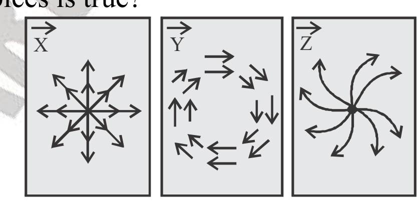
(a) $\frac{1}{2}i$ (b) $\frac{2}{3}i$
(c) $\frac{3}{4}i$ (d) $\frac{4}{5}i$

5. Let $I = c\iint_R xy^2 dxdy$, where R is the region shown in the figure and $c = 6 \times 10^{-4}$. The value of I equals ___. (Give the answer up to two decimal places)



[GATE - 2017]

6. The figures shows diagrammatic representations of vector fields $\vec{X}, \vec{Y},$ and $\vec{Z}$, respectively. Which one of the following choices is true?



[GATE - 2017]

(a) $\nabla.\vec{X} = 0, \nabla \times \vec{Y} \ne 0, \nabla \times \vec{Z} = 0$

(b) $\nabla.\vec{X} \ne 0, \nabla \times \vec{Y} = 0, \nabla \times \vec{Z} \ne 0$

(c) $\nabla.\vec{X} \ne 0, \nabla \times \vec{Y} \ne 0, \nabla \times \vec{Z} \ne 0$

(d) $\nabla.\vec{X} = 0, \nabla \times \vec{Y} = 0, \nabla \times \vec{Z} = 0$

7. Let x and y be integers satisfying the following equations :
$2x^2 + y^2 = 34$
$x + 2y = 11$
The value of (x +y) is _____.

[GATE - 2017]

8. Consider a function f(x, y, z) given by
$F(x,y,z) = (x^2 + y^2 - 2z^2)(y^2 + z^2)$
The partial derivative of this function with respect to x at the point x = 2, y = 1 and z = 3 _____.

CHAPTER - 2
TIME VARYING FIELD

2.1 CONTINUITY EQUATION

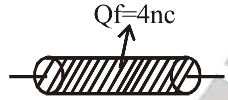
It states that $\oiint_s \vec{J}\cdot\vec{ds} = -\frac{d}{dt}\iiint_v P_v(dv)$

$\therefore I = -\frac{dQ}{dv}$

It states that charge cannot be destroyed if the charge disappear than current flow out of the specimen.

or Production of current is decrease or decrement of charge

Example.



In above figure

$Q_i = 10$ nc, $Q_f = 4$nc and $\Delta t = 3\mu$sec

$$I = -\frac{dQ}{dt} = -\frac{(Q_f - Q_i)}{\Delta t}$$

$$I = -\frac{(4-10)\times 10^{-9}}{3\times 10^{-6}} = 2\text{msec}$$

2.1.1 Types of Continuity

1. Integral form of Continuity

$$\oiint_s \vec{J}\cdot\vec{ds} = -\frac{d}{dt}\iiint_v \rho_v dv = -\iiint \frac{\partial \rho_v}{\partial t} dv \quad \ldots(i)$$

Above equation indicates that

(i) The closed surface integral of volume current density integrated over closed surface 'S' is always equal to volume integral of negative rate of change of volume charge density integrated over volume 'ν' which is enclosed by closed surface 'S' in the electromagnetic region.

(ii) This equation represents the principle of conservation of charge in terms of electromagnetic parameter.

2. Differential form of Continuity

Using the divergence theorem

$$\oiint_s \vec{J}\cdot\vec{ds} = \iiint_v (\nabla\cdot\vec{J})dv \quad \ldots(ii)$$

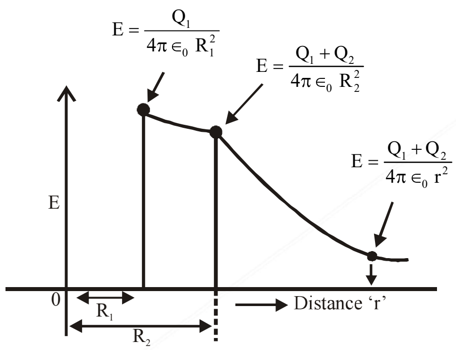
From equation (i) and (ii)

$$\iiint (\nabla\cdot\vec{J})dv = -\iiint \frac{\partial \rho_v}{\partial t} dv$$

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

ASSIGNMENT

1. The given figure represents the variation of electric field 'E'



(a) Due to a spherical volume charge $Q=Q_1,+Q_2$
(b) Due to two concentric shells of charges Q_1 and Q_2 uniformly distributed over spheres of radii R_1 and R_2
(c) Due to two point charges Q_1 and Q_2 located at any two points 'r' (=R_1 and R_2)
(d) In a single spherical shell of charges Q uniformly distributed, $Q = Q_1 + Q_2$

2. Two small diameter 5 g dielectric balls can slide freely on a vertical non-conducting thread. Each ball carries a negative charge of 2 μC. If the lower ball is restrained form moving, then the separation between the two balls will be
(a) 8570 mm (b) 857 mm
(c) 85.7 mm (d) 8.57 mm

3. Solutions of Laplace's equation, which are continuous through the second derivative are called______.
(a) Bessel functions
(b) Odd functions
(c) Harmonic functions
(d) Fundamental functions

4. Charge needed within a unit sphere centered at the origin for producing a potential field, $V = -\frac{6r^5}{\epsilon_0}$, for r≤1 is
(a) 12π C (b) 60π C
(c) 120πC (d) 180π C

5. The region between two concentric conducting cylinders with radii of 2 and 5 cm contains a volume charge distribution of $-10^{-8}(1+10r)$ C/m^3. If E_r and V both are zero at the inner cylinder and $\epsilon=\epsilon_0$, the potential V at the outer cylinder will be
(a) 0.506V (b) 5.06 V
(c) 50.6 V (d) 506 V

6. For electromagnetic wave propagation in free space, the free space is defined as
(a) $\sigma = 0, \epsilon = 1, \mu \neq 1, \vec{p} \neq 0, \vec{j} = 0$
(b) $\sigma = 0, \epsilon = 1, \mu = 1, \vec{p} \neq 0, \vec{j} = 0$
(c) $\sigma \neq 0, \epsilon > 1, \mu = 1, \vec{p} \neq 0, \vec{j} = 0$
(d) $\sigma = 0, \epsilon = 1, \mu = 1, \vec{p} \neq 0, \vec{j} \neq 0$

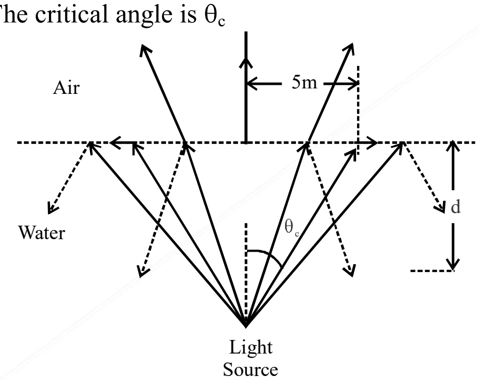
7. Assertion (A): Net charge within a conductor is always zero.
Reason (R): The conductor has a very large number office electrons
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are trite but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

8. The energy stored per unit volume in an electric field (with usual notations) is given by
(a) $1/2\epsilon H^2$ (b) $1/2\epsilon E$
(c) $1/2\epsilon E^2$ (d) ϵE^2

9. A positive charge of Q coulombs is located at point A (0, 0, 3) and a negative charge of magnitude Q coulombs is located at point B(0, 0, -3). The electric field intensity at point C(4. 0. 0) is in the
(a) Negative x-direction

GATE QUESTIONS

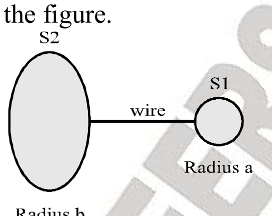
1. The permittivity of water at optical frequencies is 1.75 ε_0. It is found that an isotropic light source at a distance d under water forms an illuminated circular area of radius 5m, as shown in the figure.
The critical angle is θ_c



The value of d (in meter) is __________.

[GATE - 2017]

2. Two conducting spheres S1 and S2 of radii a and b (b > a) respectively, are placed far apart and connected by a long, thin conducting wire, as shown in the figure.



For some charge placed on this structure, the potential and surface electric field on S1 are V_a and E_a, and that on S2 are V_b and E_b respectively. Then, which of the following is CORRECT?

[GATE - 2017]

(a) $V_a = V_b$ and $E_a < E_b$
(b) $V_a > V_b$ and $E_a > E_b$
(c) $V_a = V_b$ and $E_a > E_b$
(d) $V_a > V_b$ and $E_a = E_b$

3. The expression for an electric field in free space is $E = E_0(\hat{x} + \hat{y} + j2\hat{z})e^{-j(\omega t - kx + ky)}$, where x, y, z represent the spatial coordinates, t represents time, and ω, k are constants, This electric field:

[GATE - 2017]

(a) Does not represent a plane wave
(b) Represents a circularly polarized plane wave propagating normal to the z-axis.
(c) Represents an elliptically polarized plane wave propagating along the x-y plane.
(d) Represents a linearly polarized plane wave.

4. An optical fiber is kept along the $\hat{Z}$ direction. The refractive indices for the electric fields along $\hat{X}$ and $\hat{Y}$ direction in the fiber are n_x = 1.5000 and n_y = 1.5001, respectively ($n_x \neq n_y$ due to the imperfection in the fiber cross – section). The free space wavelength of a light wave propagating in the fiber is 1.5μm. if the light wave is circularly polarized at the input of the fiber, the minimum propagation distance after which it becomes linearly polarized, in centimeters, is ______.

[GATE - 2017]

5. Two electric charges q and –2q are placed at (0, 0) and (6, 0) on the x-y plane. The equation of the zero equi-potential curve in the x-y plane is_______.

[GATE - 2016]

(a) $x = -2$
(b) $y = 2$
(c) $x^2 + y^2 = 2$
(d) $(x+2)^2 + y^2 = 16$

6. A parallel plate capacitor filled with two dielectrics is shown in the figure below. If the electric field in the region A is 4 kV/ cm, the electric field in the region B, in kV/cm is_____.

[GATE - 2016]

ESE OBJ QUESTIONS

1. Gauss's theorem states that total electric flux Φ emanating from a closed surface is equal to
[EE ESE - 2017]
(a) Total current density on the surface
(b) Total charge enclosed by that surface
(c) Total current on the surface
(d) Total charge density within the surface

2. Which of the following equations represent Gausss law adapted to a homogeneous isotropic medium?
1. $\oint_s \vec{D}.\vec{ds} = \oint v\rho dv$
2. $\nabla \times \vec{H} = \vec{D}$
3. $\nabla \times \vec{J} + \rho = 0$
4. $\nabla.\vec{E} = \dfrac{\rho}{\varepsilon}$
5. $\nabla^2.\phi = 0$

Select the correct answer using the codes given below:
[EE ESE - 2017]
(a) 1 and 4 only (b) 2 and 3 only
(c) 3 and 5 only (d) 1, 2, 4 and 5 only

3. If a positively charged body is placed inside a spherical hollow conductor, what will be the polarity of charge inside and outside the hollow conductor?
[EE ESE - 2017]
(a) Inside positive, outside negative
(b) Inside negative, outside positive
(c) Both negative
(d) Both positive

4. "Electric flux enclosed by a surface surrounding a charge is equal to the amount of charge enclosed." This is the statement of:
[EE ESE - 2017]
(a) Faraday's law
(b) Lenz's law
(c) Modified Ampere's law
(d) Gauss's law

5. The total flux at the tend of a long bar magnet is 50μWb. The end of the bar magnet is withdrawn through a 1000–turn coil in 1/10 second. The e.m.f generated across the terminals of the coil is :
[EC ESE - 2017]
(a) 5V (b) 10V
(c) 25 V (d) 50 V

6. A conductor of length 1m moves at right angles to a uniform magnetic field of flux density 2 Wb/m^2 with a velocity of 50/s. What is the value of the induced e..m.f When the conductor moves at an angle of 30° to the direction of the field ?
[EC ESE - 2017]
(a) 75V (b) 50 V
(c) 25 V (d) 12.5 V

7. An electromagnetic wave is transmitted into a conducting medium of conductivity σ. The depth of penetration is_____.
[EC ESE - 2017]
(a) Directly proportional to frequency
(b) Directly proportional to square root of frequency
(c) Inversely proportional to frequency
(d) Inversely proportional to frequency
(e) Inversely proportional to square root of frequency.

8. A plane y = 2 carries and infinite sheet of charge 4 nC/m^2. If the medium is free space, what is the force on a point charge of 5 mC located at the origin?
[EC ESE - 2017]
(a) $0.54\pi\overline{a_y}N$ (b) $0.18\pi\overline{a_y}N$
(c) $-0.36\pi\overline{a_y}N$ (d) $-0.18\pi\overline{a_y}N$

9. A parallel-plate air capacitor as shown below has a total charge Q and a breakdown voltage V. A slab of dielectric constant 6 is inserted as shown. The maximum breakdown voltage and

CHAPTER - 3
STATIC MAGNETIC FIELD

3.1 BIOT SAVART'S LAW

It is an ampere law for current Element.

$I\vec{dL}$ = a small zero length D.C current carrying wire as the basic cause of magnetic field. It is called as current element.

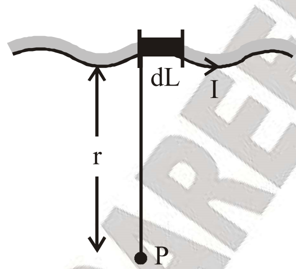
$$\vec{H} = \frac{I\vec{dL} \times \hat{a}_r}{4\pi r^2} \text{ A/m}$$

Above is the equation of magnetic field

H (direction) = I (flow direction) × Radial Direction for current

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

$$\vec{B} = \frac{\mu\, I\vec{dL} \times \hat{a}_r}{4\pi r^2} \text{ wb/m}^2$$



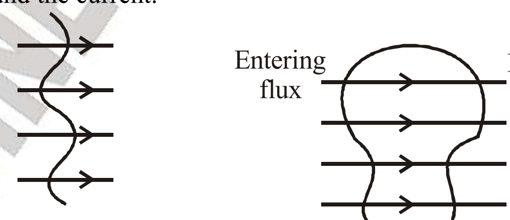
Magnetic force is weakest force.

3.1.1 Basic Current Element

$$I\vec{dL} = J_s\vec{ds} = J_v\vec{dv}$$

1.Magnetic field lines are always closed in nature.

2.They are always around the current.



Open surface | Closed surface

$\int \vec{B}.\vec{ds} = \sum \psi_m$ = vector | $\oint \vec{B}.\vec{ds} = 0$

3.Magnetic field line do not Start/End at point i.e. they lane no source & no sink.

ASSIGNMENT

1. For distortion less transmission through a channel, the channel should be such that
(a) Its attenuation response is an even function and phase response is an odd function of frequency
(b) Its attenuation response is flat and phase response is linear with frequency
(c) The ratio of line inductance to line capacitance is constant
(d) Its termination is by a matched impedance

2. Match List-I (Laws) with List-II (Applications) and select the correct answer:
List-I
A. Ampere's Law
B. Biot's Law
C. Coulomb's Law
D. Gauss's Law
List-II
To find the
(i) Force on a charge
(ii) Force due to a current carrying conductor
(iii) Electric flux density at a point
(iv) Magnetic flux density at a point
Codes:
(a) A-iii, B-ii, C-i, D-iv
(b) A-iv, B-ii, C-i, D-iii
(c) A-iv, B-i, C-ii, D-iii
(d) A-iii, B-i, C-ii, D-iv

3. A solid cylindrical conductor of radius 'R' has a uniform current density. The magnetic field 'H' inside the conductor at a distance 'r form the axis of the conductor is
(a) $1/2\pi r$ (b) $1/4\pi r$
(c) $1r/2\pi R^2$ (d) $1r/4\pi R^2$

4. In a hundred-turn coil if the flux through each turn is $(t^3 - 2t)$m Wb, the magnitude of the induced emf in the coil at a time of 4s is
(a) 46mV (b) 56 mV
(c) 4.6 V (d) 5.6 V

5. Consider the following statements regarding a plane wave propagating through free space:
Consider the following statements regarding a plane wave propagating through free space:
1.'E' is perpendicular to the direction of propagation
2.'H' is perpendicular to the direction of propagation
3.'E' is perpendicular to the direction of field 'H'
Which of these statements are correct?
(a) l and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

6. What is the magnetic dipole moment in A.m^2 for a square current loop having the vertices t the points A(10, 0, 0), B(0, 10, 0) and with current 0.01 A flowing in the sense ABCDA?
(a) $2\bar{a}_z$ (b) $-2\bar{a}_z$
(c) $4\bar{a}_z$ (d) $4(\bar{a}_z + \bar{a}_y)$

7. Current density $\bar{J}$, in cylindrical co-ordinate system is given as:
$$J(r,\theta,z) = 0 \text{ for } 0 < r < a = J_0(r/a^2)\bar{I}_z \text{ for } a < r < b$$
Where is the unit vector along z-coordinate axis. In the region, a<r<b, what is the expression for the magnitude of magnetic field intensity vector $(\bar{H})$?
(a) $\frac{J_0}{r^2}(r^3 - a^3)$ (b) $\frac{J_0}{r^2}(r^3 + a^3)$
(c) $\frac{J_0(r^3 - a^3)}{3a^2 r}$ (d) $\frac{J_0}{2\pi r}(r^3 - a^3)$

8. Which one of the following is the correct expression for torque on a loop in magnetic field $\bar{B}$? (Here $\bar{M}$ is the loop moment)
(a) $\bar{T} = \nabla.\bar{B}$ (b) $\bar{T} = \bar{M}.\bar{B}$
(c) $\bar{T} = \bar{M} \times \bar{B}$ (d) $\bar{T} = \bar{B} \times \bar{M}$

GATE QUESTIONS

1. A soft-iron toroid is concentric with a long straight conductor carrying a direct current I. If the relative permeability μ_r of soft-iron is 100, the ratio of the magnetic flux densities at two adjacent points located just inside and just outside the toroid is _______.

[GATE - 2016]

2. Faraday's law of electromagnetic induction is mathematically described by which one of the following equations?

[GATE - 2016]

(a) $\nabla \bullet \vec{B} = 0$ (b) $\nabla \bullet \vec{D} = \rho_v$

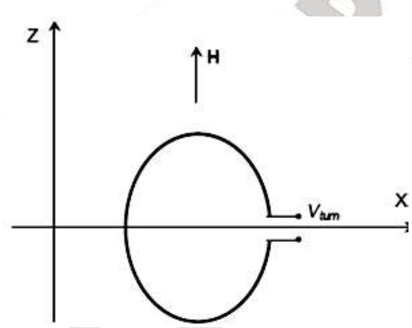
(c) $\nabla \times \vec{E} = -\dfrac{\partial \vec{B}}{\partial t}$ (d) $\nabla \times \vec{H} = \sigma\vec{E} + \dfrac{\partial \vec{D}}{\partial t}$

3. A uniform and constant magnetic field B = $\hat{z}$ B exists in the $\hat{z}$ direction in vacuum. A particle of mass m with a small charge q is introduced into this region with an initial velocity $v = \hat{x}v_x + \hat{z}v_z$. Given that B, m, q, v_x and v_z are all non-zero, which one of the following describes the eventual trajectory of the particle?

[GATE - 2016]

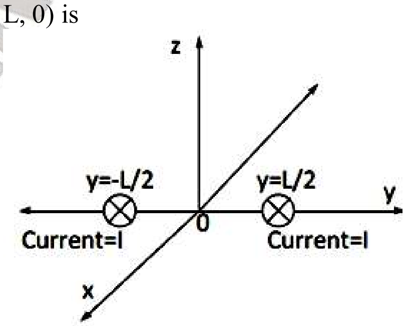
(a) Helical motion in the zˆ direction
(b) Circular motion in the xy plane
(c) Linear motion in the zˆ direction
(d) Linear motion in the xˆ direction

4. A circular turns of radius 1m revolves at 60 rpm about its diameter aligned with the x – axis as show in the figure. The value of μ_0 is $4\pi \times 10^{-7}$ in SI unit. If a uniform magnetic field intensity $\vec{H} = 10^7 \hat{z} A/m$ is applied, then the peak value of the induced voltage, V_{turn} (in Volts), is _________.



[GATE - 2015]

5. A steady current I is flowing in the – x direction through each of two infinitely long wires at $y = \pm\dfrac{L}{2}$ as shown in the figure. The permeability of the medium is μ_0. The $\vec{B}$ - field at (0, L, 0) is



[GATE - 2015]

(a) $-\dfrac{4\mu_0 I}{3\pi L}\hat{Z}$ (b) $+\dfrac{4\mu_0 I}{3\pi L}\hat{Z}$

(c) 0 (d) $-\dfrac{3\mu_0 I}{4\pi L}\hat{Z}$

6. A region shown below contains a perfect conducting half – space and air. The surface current $\vec{K_s}$ on the surface of the perfect conductor is $\vec{K_s} = \hat{x}2$ amperes per meter. The

CHAPTER - 4
ELECTRO MAGNETIC FIELD

4.1 UNIFORM PLANE WAVE

Equation of Electromagnetic Wave

$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ (Derived from faraday law of electromagnetic induction)

$\nabla \times \vec{H} = \sigma \vec{E} + \frac{\partial \vec{D}}{\partial t}$ (Ampere circuital law)

These two maxwell equations are responsible for generation of em waves. Time variation of one will induce the orthogonal wave of second field & vice-versa. This process keeps on repeating during the propagation of energy & energy is a form of disturbance and that disturbance is represented or carried over in the form of electromagnetic wave. Time varying field is must for the generation of em waves.

4.1.1 Generation Of Em-Wave

If there is an electric flux then their energy is transforming between electric and magnetic energy. Energy is in the alternating form.

$\text{Electric field} = \frac{1}{2} \in E^2;$

$\text{Magnetic field} = \frac{1}{2} \mu H^2$

1. Condition of EM-Wave

(i) If the DC is present then no wave is propagated

(ii) When time varying electric field and magnetic field is present.

(iii) This flow of energy takes place sometimes in the form of electrical energy and sometimes in the form of magnetic energy. This is a continuous process for alternating fields and hence electromagnetic waves propagate through this medium with a fix amount of energy.

(iv) When energy present and disturbance and created that disturbance travel through the distance and the wave travel .Wave direction is generated for the propagation.

$$\nabla \times \vec{E} = -\frac{\partial B}{\partial t} \qquad \ldots(i)$$

$$\nabla \times \vec{H} = \sigma \vec{E} + \frac{\partial \vec{D}}{\partial t} \qquad \ldots(ii)$$

Taking curl of equation (i) in both sides

$$\nabla \times (\nabla \times \vec{E}) = \nabla \times \left(\frac{-\partial B}{\partial t} \right)$$

$$(\nabla \cdot \vec{E})\nabla - (\nabla^2 E) = \frac{-\partial}{\partial t} (\nabla \times \mu H)$$

(v) Assuming medium to be homogeneous the only way 'μ' can be taken out is

$$(\nabla \cdot \vec{E})\nabla - (\nabla^2 \vec{E}) = -\mu \frac{\partial}{\partial t} (\nabla \times \vec{H})$$

ASSIGNMENT

1. If $H=0.5^{-0.1x}\sin(10^6t-2x)\ a_y$ A/m the wave travels in _____
(a) + y direction (b) –y direction
(c) –x direction (d) + x direction

2. If $E=10\cos(10^8t-3y)\ a_x$ V/m, the medium is _______
(a) Lossless dielectric of $\in_R >>1$
(b) Lossy dielectric of $\in_R=1$
(c) Lossy dielectric of $\in_R>>1$
(d) Free–space

3. In a given medium if $\sigma/\omega\in=1.732$ the E and H have a phase difference of
(a) 0º (b) 30º
(c) 60º (d) 90º

4. In a good conducting material an EM wave at 100 MHz has a depth of penetration of 5μm, then v_p (Phase velocity) of the wave is _____
(a) 10π km/s
(b) π km/s
(c) 20 km/s
(d) Data not sufficient

5. Units of the term $\sigma/\in$ are _______
(a) Seconds (b) Second
(c) Ohms × Farads (d) Farads/ohms

6. A wave $E=25\cos(10^8t-3x+4z)\ a_y$ has a propagation direction of
(a) $3a_x$ (b) $-4a_z$
(c) $-3a_x$ (d) $4a_z$
(e) $3a_x-4a_z$ (f) $-3a_x+4a_z$

7. The skin depth of Cu at 100MHz is 4μm. if the operating frequency is 400 MHz the skin depth is ______
(a) Same
(b) 8 μm
(c) 2 μm
(d) Data not sufficient

8. If $H=450\sin(10^8t-x)\ a_z$ A/m is a magnetic field of an EM wave in a perfect dielectric, then $\in_R$ of the medium is _______
(a) 3 (b) 1/3
(c) 9 (d) 1/9

9. In the above problem (8), the E has magnitude of ____
(a) 450 × 120π (b) 450/120π
(c) 450 × 40π (d) 450 × 30π
(e) 450 × 20π

10. If a plane wave satisfies the equation $\frac{\partial^2 E_x}{\partial z^2}=\frac{1}{c^2}\frac{\partial E_x}{\partial t^2}$, the wave propagates in ______
(a) x direction
(b) z direction
(c) Any direction in xz plane
(d) y direction

11. If a material of a given σ has a large α at a frequency f, < f, the attenuation is _______
(a) Greater than at f
(b) Lesser than at f
(c) Exactly same as at f
(d) α never depends on f

12. The phase shift between E and H fields in a good conductor depends on
(a) Frequency of the wave
(b) Is always 90º
(c) Is always 45º
(d) Depends on σ of the conductor

13. The E of EM wave is given by $E=50\sin(10^7t+Kz)\ \hat{j}$ V/m. Which of the following are TRUE?
(a) The wave propagates along y axis
(b)The wavelength is 188.5 m
(c) The wave number K =0.33 rad/m
(d) The wave attenuates as it travels.

GATE QUESTIONS

1. If a right-handed circularly polarized wave is incident normally on a plane perfect conductor, then the reflected wave will be

[GATE - 2016]

(a) Right-handed circularly polarized
(b) Left-handed circularly polarized
(c) Elliptically polarized with a tilt angle of 45°
(d) horizontally polarized

2. The electric field of a uniform plane wave travelling along the negative z direction is given by the following equation:

$$\vec{E}_w^i = (\hat{a}_x + j\hat{a}_y)E_0 e^{jkz}$$

This wave is incident upon a receiving antenna placed at the origin and whose radiated electric field towards the incident wave is given by the following equation:

$$\vec{E}_a = (\hat{a}_x + 2\hat{a}_y)E_I \frac{1}{r} e^{-jkr}$$

The polarization of the incident wave, the polarization of the antenna and losses due to the polarization mismatch are, respectively,

[GATE - 2016]

(a) Linear,Circular (clockwise), –5dB
(b) Circular(clockwise),Linear, –5dB
(c) Circular(clockwise),Linear, –3dB
(d) Circular(anti clockwise), Linear, –3dB

3. The electric field of a plane wave propagating in a lossless non-magnetic medium is given by the following expression

$$E(x,t) = a_x 5\cos(2\pi \times 10^9 t + \beta z)$$

$$+ a_y 3\cos\left(2\pi \times 10^9 t + \beta z - \frac{\pi}{2}\right)$$

The type of the polarization is

[GATE - 2015]

(a) Right Hand Circular.
(b) Left Hand Elliptical.
(c) Right Hand Elliptical.
(d) Linear.

4. The electric field component of a plane wave traveling in a lossless dielectric medium is given by $\vec{E}(z.t)\hat{a}_y 2\cos\left(10^s t - \frac{z}{\sqrt{2}}\right) V/m$ .The wavelength (m m) for the wave is _____.

[GATE - 2015]

5. The electric field of a uniform plane electromagnetic wave is

$$\vec{E} = (\vec{a}_x + j4\vec{a}_y)\exp[j(2\pi \times 10^7 t - 0.2z)]$$

[GATE - 2015]

The polarization of the wave is
(a) Right handed circular
(b) Right handed elliptical
(c) Left handed circular
(d) Left handed elliptical

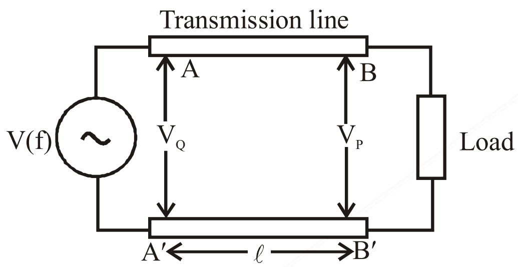
6. The electric field intensity of a plane wave traveling in free space is give by the following expression $E(x, t) = a_y 24\pi\cos(\omega t - k_0 x)$ (V/m)
In this field, consider a square area 10cm x 10 cm on a plane x + y = 1. The total time-averaged power (in mW) passing through the square area is ______.

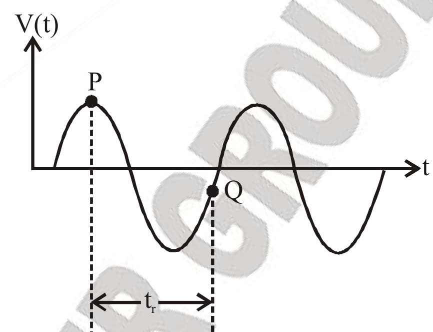
[GATE - 2015]

7. Consider a uniform plane wave with amplitude (E_0) of 10 V/m and 1.1 GHz frequency travelling in air, and incident normally on a dielectric medium with complex relative permittivity (ε_r) and permeability (μ_r) as shown in the figure.

CHAPTER - 5
TRANSMISSION LINE

5.1 TRANSIT TIME EFFECT





1. No Signal can travel with infinite velocity. That is to say that if a voltage or current changes at some location, its effect cannot be felt instantaneously at some other location. There is a finite delay between the 'cause' and the effect. This is called the ' Transit Time' effect.
2. Consider the two-conductor line which is connected to a sinusoidal signal generator of frequency '*f*' at one end and a load impedance at the other end. Due to the transit time effect the voltage applied at AA' will not appear instantaneously at BB'.
3. Let the signal travel with velocity ν along the line. Then the Transit time

$$t_\gamma = \frac{l}{\nu}$$

Where l is length of line.
4. At some instant let the voltage at AA' be V_p. Then V_p. will appear at BB' only after t_γ. However, during this time the voltage at AA' changes to (say) V_Q.

5.1.1 Important Observation

1. Even for ideal conductors i.e., no resistance, there is a voltage difference between AA' and BB'
2. When is transmit-time effect important?
Ideally the transit time effect should be included in analysis of all electrical circuits. However if the time period of the signal $T=1/f$ is much larger than the transit time, we may ignore the effect of transmit time. That is, the transit time effect can be neglected if

$$T >> t_r$$

$$\frac{1}{f} >> \frac{1}{\nu}$$

$$\frac{\nu}{f} >> l$$

Since $\frac{\nu}{f}$ =wavelength λ, we get

$$\therefore \lambda >> l$$

ASSIGNMENT

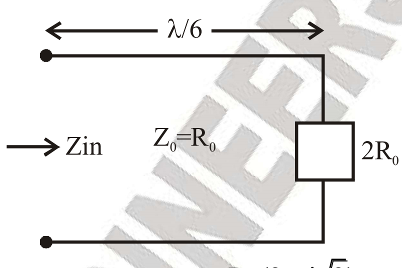
1. When $Z_l > Z_0$, the VSWR on a line is its
(a) Normalized load impedance
(b) Normalized input impedance
(c) Characteristic impedance
(d) Load impedance

2. A lossless TL has a length of 50cm with L=10μH/m and C=40 pF/m. if it is operated at 30 MHz, its electrical length is
(a) 28º (b) 48º
(c) 108º (d) 40π

3. A line has a velocity of 1.5×10^8 m/s with an ideal dielectric having $\in_R=4$ between the cables. The line is
(a) Lossy but not having distortion
(b) Lossless and distortion
(c) Lossy and distortionless
(d) None of these

4. On a Smith chart the concentric circle with R= 0 circle is
(a) R=Constant circle (b) X=1 circle
(c) $|\Gamma|$=constant circle (d) None of these

5. The input impedance of the line shown below is



(a) $2R_0$ (b) $\dfrac{R_0(2+j\sqrt{3})}{(1+j2\sqrt{3})}$
(c) $\dfrac{R_0}{2}$ (d) $R_0\left(\dfrac{1+j}{1-j}\right)$

6. A certain line having R_0 = 400Ω and length =λ, is = open at both ends. The impedance at a point λ/4 from one end is
(a) 0 (b) 400Ω
(c) ∝ (d) 200Ω

7. A 50Ω lossless line is terminated by a load impedance of 75Ω. If the signal power is 100mW, the power dissipated by the load is
(a) 80 mW (b) 20 mW
(c) 96 mW (d) 4 mW

8. A short circuited line has
$Z_{in} = jZ_0/\sqrt{3}$ The Length of the line is
(a) λ/8 (b) λ/6
(c) λ/12 (d) λ/4

9. A TL has an attenuation of 0.3 dB/km. After 10km from the source, the fraction of the power is
(a) 1/2 (b) 1/3
(c) 1/4 (d) 1/10

10. A lossy TL is terminated by load Z_L and has Characteristic impedance Z_0 and open circuit input impedance $Z_{OC.}$ The Z_{in} of the line is
(a) $\dfrac{Z_0^2(Z_{OC}+Z_L)}{Z_0^2+Z_LZ_{OC}}$ (b) $\dfrac{Z_0^2(Z_L-Z_{OC})}{Z_0^2-Z_LZ_{OC}}$
(c) $\dfrac{Z_{OC}^2}{Z_0^2+Z_LZ_{OC}}$ (d) $\dfrac{Z_0^2+Z_LZ_{OC}}{Z_L+Z_{OC}}$

11. A line of 75Ω impedance is terminated with 100Ω load. Its maximum impedance on the line is
(a) 100Ω (b) 56Ω
(c) 156Ω (d) 126Ω

12. Which of the following circles will never intersect each other on a Smith chart?
(a) R=0 circle and X=1 circle
(b) R=1 circle and X=0 circle

GATE QUESTIONS

1. A two wire transmission line terminates in a television set. The VSWR measured on the line is 5.8. The percentage of power that is reflected from the television set is ______.

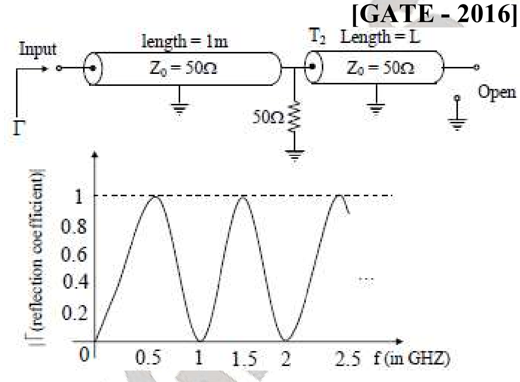
[GATE - 2017]

2. The voltage of an electromagnetic wave propagating in a coaxial cable with uniform characteristic impedance is $V(\ell) = e^{-\gamma\ell + j\omega t}$ Volts, where ℓ is the distance along the length of the cable in meters, $\gamma = 90.1 + j40)m^{-1}$ is the complex propagation constant, and $\omega = 2\pi \times 10^9$ rad/s is the angular frequency. The absolute value of the attenuation in the cable in dB/meter is ______.

[GATE - 2017]

3. A microwave circuit consisting of lossless transmission lines T_1 and T_2 is shown in the figure. The plot shows the magnitude of the input reflection coefficient Γ as a function of frequency f. The phase velocity of the signal is transmission lines is 2×10^8 m/s.

[GATE - 2016]



4. The propagation constant of a lossy transmission line is (2 +j5) m-1 and its characteristic impedance is (50 + j0) Ω at $\omega = 10^6$ rad S^{-1}. The values of the line constants L,C,R,G are, respectively.

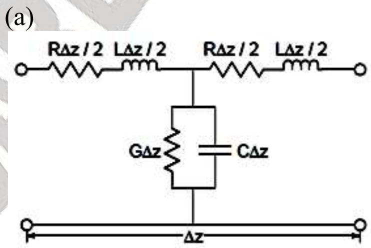
[GATE - 2016]

(a) L = 200 μH/m, C = 0.1μF/m, R = 50 Ω/m, G = 0.02 S/m
(b) L = 250 μH/m, C = 0.1μF/m, R = 100 Ω /m, G = 0.04 S/m
(c) L = 200μH/m, C = 0.2μF/m, R = 100 Ω /m, G = 0.02 S/m
(d) L = 250μH/m, C = 0.2μF/m, R = 50 Ω /m, G = 0.04 S/m

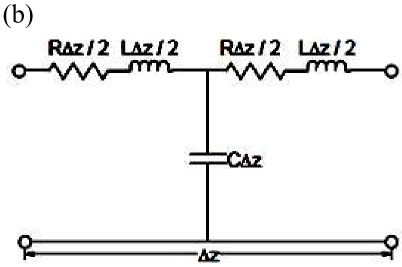
5. A coaxial cable is made of two brass conductors. The spacing between the conductors is filled with Teflon ($\varepsilon_r = 2.1$, tan δ=0). Which one of the following circuits can represent the lumped element model of a small piece of this cable having length Δz?

[GATE - 2015]

(a)



(b)



(c)

CHAPTER - 6
WAVE GUIDE'S

6.1 INTRODUCTION
The guided structure used for transmission and reception of signal from transmitter to antenna and antenna to receiver at microwave frequency. At high frequency take place in E/H format in contrast low frequency V/I format. The propagation of energy at high frequency can be both guided or unguided wireless transmission is the example of later and guided structure is example of former. At high frequency the waves at reflected from the walls of the guided structure through the phenomena of reflection. If the guided walls are not perfectly conducting then wave absorption take place which result in the wave losses as discussed earlier in EM wave propagation. The material in side guided structure is dielectric material which also should be perfectly dielectric otherwise this dielectric loss will be the second contributing factor for the wave loss and these wave losses appear in from of attenuation.

α_d = dielectric loss

α_c = conduction loss

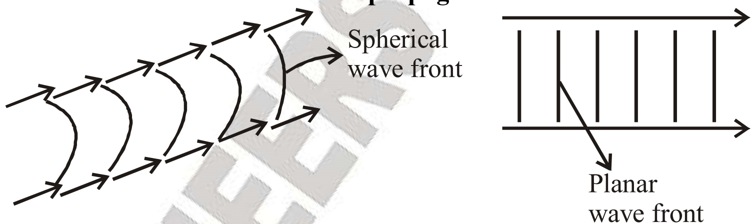
$\alpha = \alpha_c + \alpha_d$ Total loss

6.1.1 Dispersive Wave Nature
1. $E(x, y, z, t)_{(x, y, z)}$

2.$H(x, y, z, t)_{x, y,z})$

3. High frequency wave are practically dispersive spreading out and obeying "Huygen wave principle" that every ray is a source of secondary emission.

4. This is the cause of diffraction or diffusion property of EM wave which is the advantage of broadcast application but serious disadvantage in point-point communication. Hence wave guide are used to confine the wave with in specific bounds.

6.1.2 Nature of wave front and their propagation in media


6.1.3 There are three Guided Wave Structure
1. Parallel plate waveguide

2. Rectangular waveguide

3. Circular waveguide

GATE QUESTIONS

1. A half wavelength dipole is kept in the x-y plane and oriented along 45° from the x-axis. Determine the direction of null in the radiation pattern for $0 \leq \phi \leq \pi$. Here the angle θ ($0 \leq \theta \leq \pi$) is measured from the z-axis, and the angle ϕ($0\leq \phi \leq 2\pi$) is measured from the x-axis in the x-y plane.

[GATE - 2017]

(a) $\theta = 90°, \phi = 45°$
(b) $\theta = 45°, \phi = 90°$
(c) $\theta = 90°, \phi = 135°$
(d) $\theta = 45°, \phi = 135°$

2. A radar operating at 5GHz uses a common antenna for transmission and reception. The antenna has again of 150 and is aligned for maximum directional radiation and reception to a regret 1km away having radar cross-section of $3m^2$. If it transmit 100kW, then the received power (in μW) is ______.

[GATE - 2016]

3. The far-zone power density radiated by a helical antenna is approximated as:

$$\vec{W}_{rad} = \vec{W}_{average} \approx \hat{a}_r C_0 \frac{1}{r^2}\cos^4\theta$$

The radiated power density is symmetrical with respect to ϕ and exists only in the upper hemisphere: $0 \leq \theta \leq \frac{\pi}{2}; 0\leq\phi\leq2\pi; C_0$ is a constant.

The power radiated by the antenna (in watts) and the maximum directivity of the antenna, respectively, are

[GATE - 2016]

(a) $1.5C_0$, 10dB
(b) $1.256C_0$, 10dB
(c) $1.256C_0$, 12dB
(d) $1.5C_0$, 12dB

4. Two lossless X-band horn antennas are separated by a distance of 200λ. The amplitude reflection coefficients at the terminals of the transmitting and receiving antennas are 0.15 and 0.18, respectively. The maximum directivities of the transmitting and receiving antennas (over the isotropic antenna) are 18dB and 22dB, respectively. Assuming that the input power in the lossless transmission line connected to the antenna is 2 W, and that the antennas are perfectly aligned and polarization matched, the power (in mW) delivered to the load at the receiver is ____.

[GATE - 2016]

5. The radiation pattern of an antenna in spherical co-ordinates is given by $F(\theta) = \cos^4\theta$; $0 \leq \theta \leq \pi/2$. The directivity of the antenna is

[GATE - 2012]

(a) 10 dB
(b) 12.6 dB
(c) 11.5 dB
(d) 18 dB

6. A transmission line of character-istic impedance 50 Ω is terminated by a 50 Ω load. When excited by a sinusoidal voltage source at 10 GHz, the phase difference between two points spaced 2 mm apart on the line is found to be π/4 radiance. The phase velocity of the wave along the line is

[GATE - 2011]

(a) 0.8×10^8 m/s
(b) 1.2×10^8 m/s
(c) 1.6×10^8 m/s
(d) 3×10^8 m/s

7. For a Hertz dipole antenna, the half power beam width (HPBW) in the E-plane is

[GATE - 2008]

(a) 360º
(b) 180º
(c) 90º
(d) 45º

8. In the design of a single mode step index optical fiber close to upper cut-off, the signal mode operations is not preserved if

[GATE - 2008]

(a) Radius as well as operating wavelength are halved
(b) Radius as well as operating wavelength are doubled
(c) Radius is halved as operating wavelength is doubled