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.

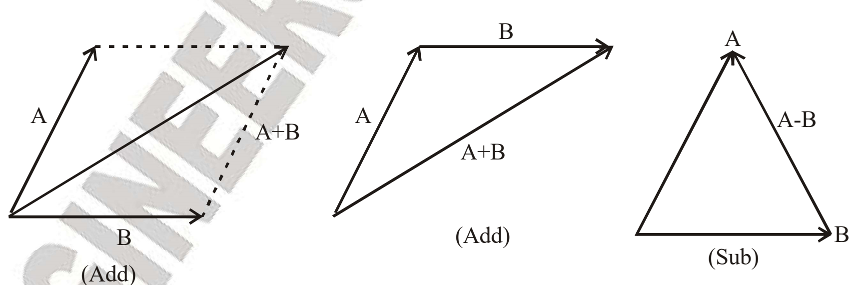
$$\longrightarrow \vec{A}$$

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) $\in_0, \mu_0$

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

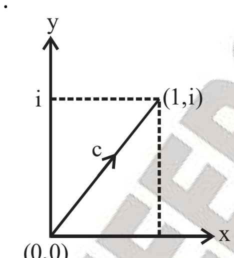
2. The smaller angle (in degrees) between the planes $x + y + z = 1$ and $2x - y + 2z = 0$ is ___.

[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:

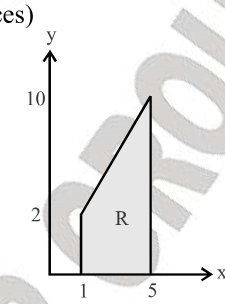


The value of I is

[GATE - 2017]

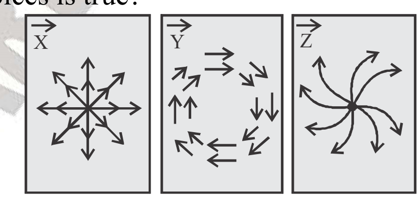
(a) $\frac{1}{2}i$ (b) $\frac{2}{3}i$
(c) $\frac{3}{4}i$ (d) $\frac{4}{5}i$

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

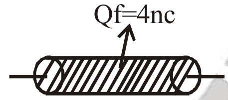
2.1 CONTINUITY EQUATION

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

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

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

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

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 'v' 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

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

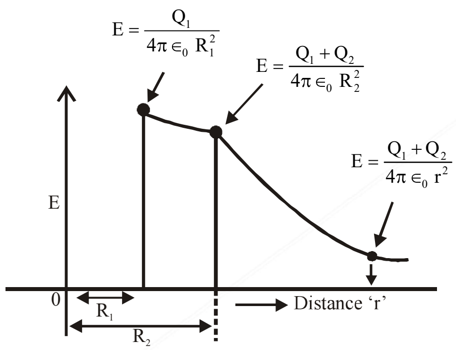
From equation (i) and (ii)

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

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

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) $\sigma = 0, \epsilon = 1, \mu = 1, \vec{p} \neq 0, \vec{j} \neq 0$

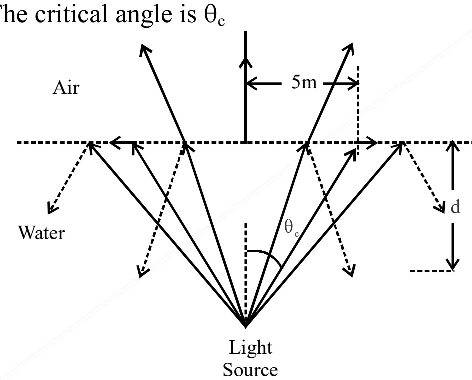
7. Assertion (A): Net charge within a conductor is always zero.
Reason (R): The conductor has a very large number office electrons
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are trite but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is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

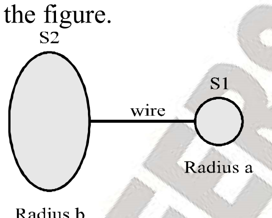
1. The permittivity of water at optical frequencies is 1.75 ε_0. It is found that an isotropic light source at a distance d under water forms an illuminated circular area of radius 5m, as shown in the figure.
The critical angle is θ_c



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.

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

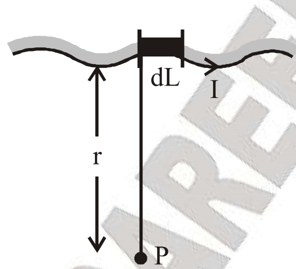
$\vec{H} = \frac{I\overrightarrow{dL} \times \hat{a}_r}{4\pi r^2} A/m$

Above is the equation of magnetic field

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

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

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

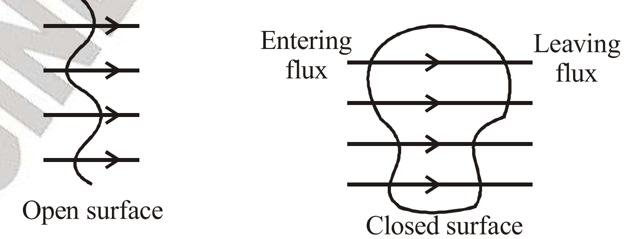


Magnetic force is weakest force.

3.1.1 Basic Current Element
$I\overrightarrow{dL} = J_s\overrightarrow{ds} = J_v\overrightarrow{dv}$

1. Magnetic field lines are always closed in nature.

2. They are always around the current.



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

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) $\nabla \bullet \vec{D} = \rho_v$

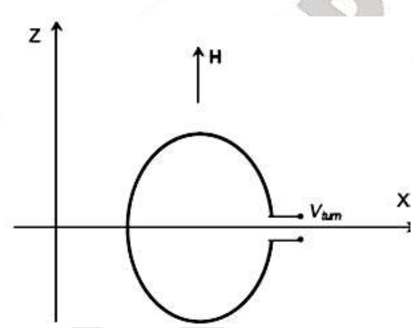
(c) $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ (d) $\nabla \times \vec{H} = \sigma \vec{E} + \frac{\partial \vec{D}}{\partial t}$

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]

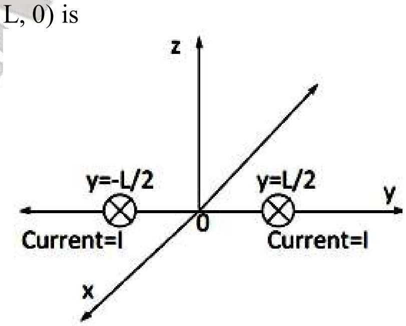
(a) Helical motion in the $\hat{z}$ direction
(b) Circular motion in the xy plane
(c) Linear motion in the $\hat{z}$ direction
(d) Linear motion in the $\hat{x}$ direction

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 $y = \pm \frac{L}{2}$ 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) $-\frac{4\mu_0 I}{3\pi L}\hat{Z}$ (b) $+\frac{4\mu_0 I}{3\pi L}\hat{Z}$

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

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.

$$\nabla \times \vec{E} = -\frac{\partial B}{\partial t} \quad \text{…(i)}$$

$$\nabla \times \vec{H} = \sigma \vec{E} + \frac{\partial \vec{D}}{\partial t} \quad \text{…(ii)}$$

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

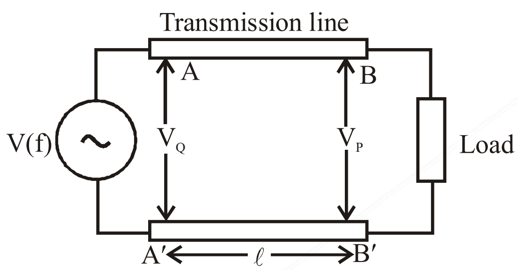
6. The electric field intensity of a plane wave traveling in free space is give by the following expression $E(x, t) = a_y 24\pi\cos(\omega t - k_0 x)$ (V/m)
In this field, consider a square area 10cm x 10 cm on a plane x + y = 1. The total time-averaged power (in mW) passing through the square area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

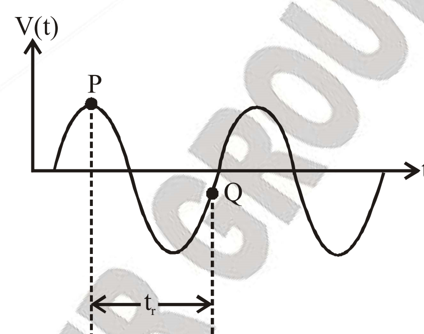
[GATE - 2015]

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

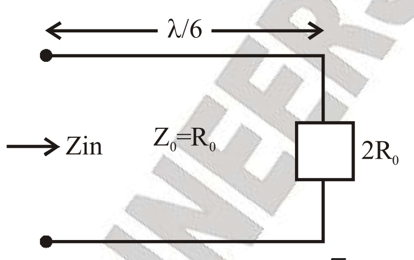
1. When $Z_1>Z_0$, the VSWR on a line is its
(a) Normalized load impedance
(b) Normalized input impedance
(c) Characteristic impedance
(d) Load impedance

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 $\epsilon_R=4$ 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) $\frac{R_0(2+j\sqrt{3})}{(1+j2\sqrt{3})}$
(c) $\frac{R_0}{2}$ (d) $R_0\left(\frac{1+j}{1-j}\right)$

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) $\frac{Z_0^2(Z_{OC}+Z_L)}{Z_0^2+Z_LZ_{OC}}$ (b) $\frac{Z_0^2(Z_L-Z_{OC})}{Z_0^2-Z_LZ_{OC}}$
(c) $\frac{Z_{OC}^2}{Z_0^2+Z_LZ_{OC}}$ (d) $\frac{Z_0^2+Z_LZ_{OC}}{Z_L+Z_{OC}}$

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 ______.

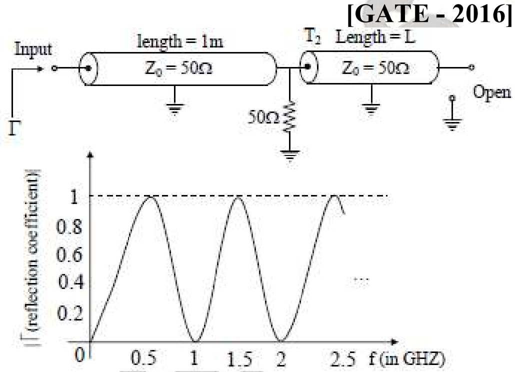
[GATE - 2017]

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.

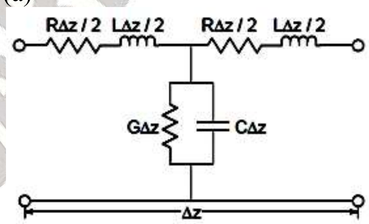
[GATE - 2016]

(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

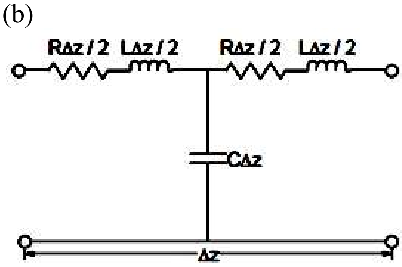
5. A coaxial cable is made of two brass conductors. The spacing between the conductors is filled with Teflon (ε_r = 2.1, tan δ=0). Which one of the following circuits can represent the lumped element model of a small piece of this cable having length Δz?

[GATE - 2015]

(a)



(b)

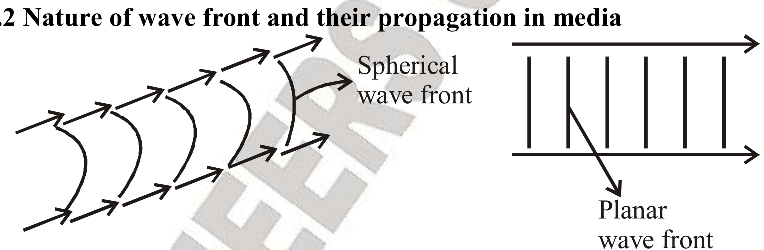


(c)

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 $0 \le \phi \le \pi$. Here the angle θ ($0 \le \theta \le \pi$) is measured from the z-axis, and the angle ϕ($0\le \phi \le 2\pi$) 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:

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

The radiated power density is symmetrical with respect to ϕ and exists only in the upper hemisphere: $0 \le \theta \le \frac{\pi}{2}; 0\le\phi\le 2\pi; C_0$ 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 $F(\theta) = \cos^4\theta$; $0 \le \theta \le \pi/2$. 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

GATE

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CONTENTS

CHAPTER - 1
DEVICES

1.1. INTRODUCTION
Power electronics is an established technology that bridges the power industry with its need for fast controllers, and the semiconductor industry with its attempt to produce devices with greater power handling capabilities. In essence, what power electronics does is to condition the power from a supply to suit the needs of the load. The main element of power electronics is the semiconductor switch.

1.2 DC SUPPLIES TO A LOAD
Table 1.1 indicates that there are at least three possibilities (types 1, 2 and 3) to obtain an adjustable dc voltage by power electronics. In practice there are many complex circuits. The reader needs only view the different dc power supplies on the market to confirm this. However, the principles are not so different from those generic forms that follow.

TABLE 1.1 Power conditioning

	Type	Description
1.	ac) to) dc	Integral-cycle control
2.	ac) to) dc	Point-on-wave switching
3.	dc) to) dc	Chopper control
4.	ac) to) ac	Integral-cycle control
5.	ac) to) ac	Point-on-wave switching
6.	ac) to) ac	Cycloconverter
7.	dc) to) ac	Inverter

1.3 AVERAGE VALUES
Determination of the average value of the voltage across a dc load is important. If the instantaneous value of the voltage v(t) is periodic with a period T, then the average voltage is given by

$$V_{av} = \frac{1}{T}\int_0^T v(t)dt$$

It can be convenient to transform time t to radian θ measure, so that

$$V_{av} = \frac{1}{2\pi}\int_0^{2\pi} v(\theta)\,d\theta$$

where $\theta = \omega t$, $\omega = 2\pi f$ and $f = 1/T$.

1.4 RMS VALUES
The rms (root mean square) value of a current that varies periodically with time is the effective value that is equivalent to a constant dc current in terms of heating. That is, the periodic current and direct current produce the same average power in an element. If the instantaneous value of the current i (t) is periodic with a period T, then the rms current is given by

$$I_{rms} = \left[\frac{1}{T}\int_0^T i^2(t)dt\right]^{1/2}$$

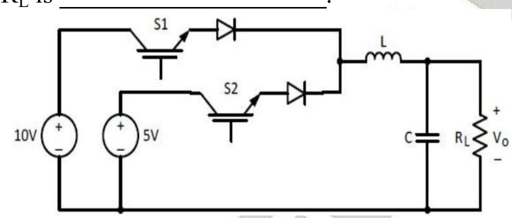
GATE QUESTIONS

1. For the power semiconductor devices IGBT, MOSFET. Diode and Thyristor, which one of the following statements is TRUE?

[GATE - 2017]

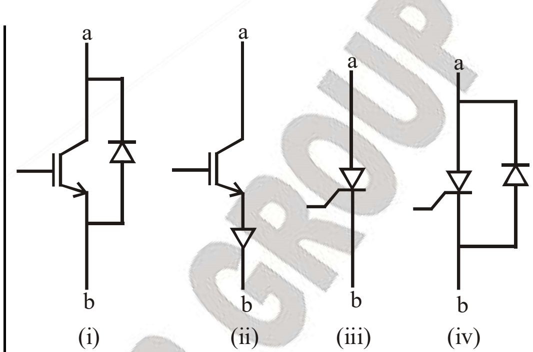
(a)All the four are majority carrier devices
(b)All the four are minority carrier devices
(c)IGBT and MOSFET are majority carrier devices, whereas Diode and Thyristor are minority carrier devices.
(d)MSOFET is majority carrier device, whereas IGBT, Diode, Thyristor are minority carrier devices.

2. The circuit shown in meant to supply a resistive load R_L from two separate DC voltage sources. The switch S1 and S2 are controlled so that only one of them is ON at any instant. S1 is turned on for 0.2 ms and S2 is turned on for 0.3ms in a 0.5ms switching cycle time period. Assume continuous conduction of the inductor current and negligible ripple on the capacitor voltage, the output voltage V_0 (in Volt) across R_L is ____________________.



[GATE - 2015]

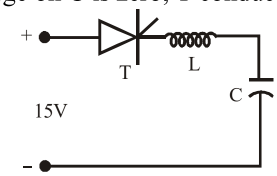
3. Figure shows four electronic switches (i), (ii), (iii) and (iv). Which of the switches can block voltages of either polarity (applied between terminals 'a' and 'b') when the active device is in OFF state?



[GATE - 2014]

(a) (i), (ii) and (iii)
(b) (ii), (iii) and (iv)
(c) (ii) and (iii)
(d) (i) and (iv)

4. Thyristor T in the figure below is initially off and is triggered with a single pulse of width 10µs. It is given that $L = \left(\frac{100}{\pi}\right)\mu H$ and $C = \left(\frac{100}{\pi}\right)\mu F$. Assuming latching and holding currents of the thyristor are both zero and the initial charge on C is zero, T conducts for



[GATE - 2013]

(a) 10µs
(b) 50µs
(c) 100µs
(d) 200µs

5. The typical ratio of latching current to holding current in a 20A thyristor is

[GATE - 2012]

(a) 5.0
(b) 2.0
(c) 1.0
(d) 0.5

6. Circuit turn-off time of an SCR is defined as the time

[GATE - 2011]

(a)Taken by the SCR turn to be off

CHAPTER - 2
DIODE CIRCUITS AND RECTIFIERS

2.1 DIODE CIRCUITS WITH DC SOURCE

In this section, the effect of switching a dc source to a circuit consisting of diode and different circuit parameter is examined. The conclusions arrived at can then be applied to similar situations encountered later in power-electronic circuits.

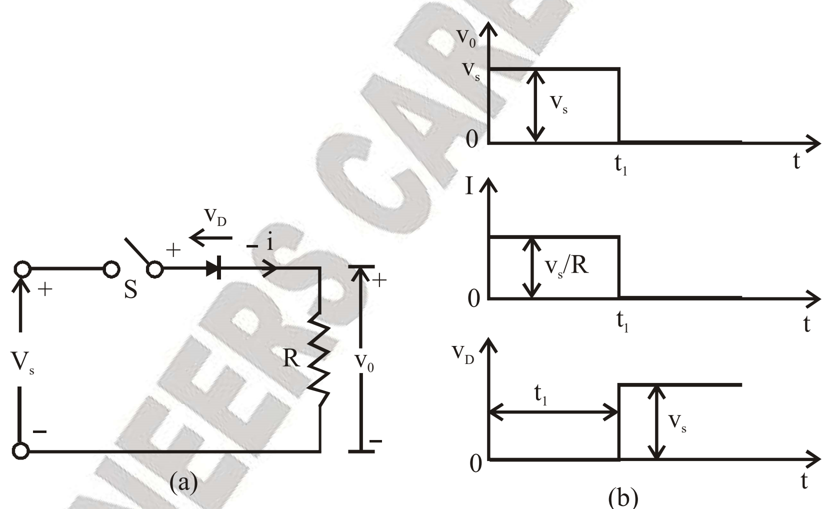
1. Resistive Load

In the circuit of figure, when switch S is closed, the current rises instantaneously to V_s/R as show in figure. Here V_s is the dc source voltage and R is the load resistance. When switch S is opened at t_1, the current at once falls to zero, figure voltage v_D across diode is zero during the time diode conducts and is equal to $+V_s$ after diode stops conducting.

2. RC Load

A circuit with dc source, diode and RC load is shown in figure. When switch S is closed at t = 0, KVL gives

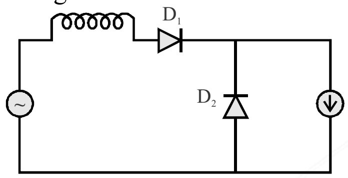
$$Ri + \frac{1}{C}\int i\,dt = V_s$$



Diode Circuit with R Load (a) Circuit Diagram and (b) Waveforms

GATE QUESTIONS

1. In the circuit shown, the diodes are ideal, the inductance is small, and $I_0 \neq 0$. Which one of the following statements is true?



[GATE - 2017]

(a) D_1 conducts for greater than 180° and D_2 conducts for greater than 180°

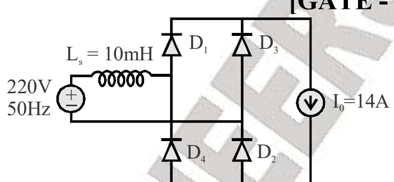
(b) D_2 conducts for more than 180° and D_1 conducts for 180°

(c) D_1 conducts for 180° and D_2 conducts for 180°

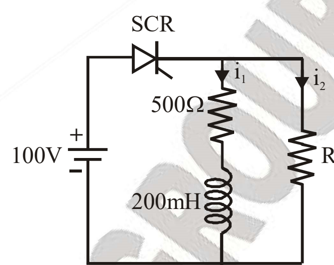
(d) D_1 conducts for more than 180° and D_2 conducts for 180°

2. The figure below shows an uncontrolled diode bridge rectifier supplied from a 220V, 50Hz, 1-phase ac source. The load draws a constant I_0 = 14A. The conduction angle of the diode D_1 in degrees (rounded off to two decimal places) is ____.

[GATE - 2017]

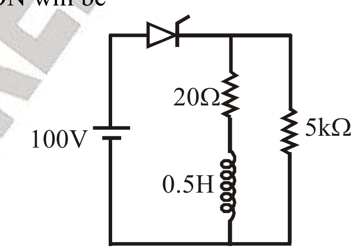


3. The SCR in the circuit shown has a latching current of 40mA. A gate pulse of 50μs is applied to the SCR. The maximum value of R in Ω to ensure successful firing of the SCR is__________.



[GATE - 2014]

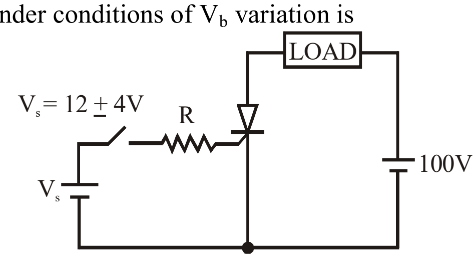
4. An SCR having a turn ON time of 5μsec, latching current of 50A and holding current of 40mA is triggered by a short duration pulse and is used in the circuit shown in figure. The minimum pulse width required to turn the SCR ON will be



[GATE - 2006]

(a) 251 μsec (b) 150 μsec
(c) 100 μsec (d) 5 μ sec

5. The triggering circuit of a thyristor is shown in figure. The thyrisotr requires a gate current of 10mA, for guaranteed turn-on. The value of R required for the thyristor to turn on reliably under conditions of V_b variation is



[GATE- 2004]

(a) 1000 Ω (b) 1600Ω
(c) 1200 Ω (d) 800Ω

CHAPTER - 3
PHASE CONTROLLED CONVERTERS

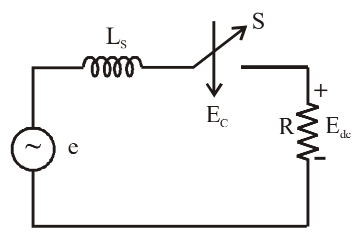
3.1 INTRODUCTION

Rectification is a process of converting an alternating current of voltage into a direction current or voltage. This conversion can be achieved by a variety of circuits based on an and using switching devices. The widely used switching devices are diodes, thyristors, power-transistors, power MOS, etc. The rectifier circuits can be classified broadly into three classes: uncontrolled, fully-controlled and half-controlled. An uncontrolled rectifier uses only diodes and the d.c. output voltage is fixed in amplitude by the amplitude of the a.c. supply. The fully-controlled rectifier uses thyristors as the rectifying elements and the d.c. output voltage is a function of the amplitude of the a.c. supply voltage and the point-on-wave at which the thyristors are triggered (called firing-angle α). The half-controlled rectifier contains a mixture of diodes and thyristors, allowing a more limited control over the d.c. output voltage-level than the fully-controlled rectifier. The half-controlled rectifier is cheaper than a fully-controlled rectifier of the same rating but has operational limitations.

Uncontrolled and half-controlled rectifiers will permit power to flow only from the a.c. system to the d.c. load and are, therefore, referred to as unidirectional converters. However, with a fully-controlled rectifier it is possible, by control of the point-on-wave at which switching takes place, to allow power to be transferred from the d.c. side of the rectifier back into the a.c. system. When this occurs, operation is said to be in the inverting mode. The fully controlled converter may therefore be referred to as a bidirectional converter.

3.2 PASTE ANGLE-CONTROLLED [FIRING ANGLE CONTROL]

In a.c. circuits, the SCR can be turned “on” by the gate at any angle, with respect to the applied voltage. This firing angle is measured with respect to a given reference, at which the firing pulses are applied to the thyristors gates. The reference point is the point at which the application of the gate pulses results in the maximum mean positive d.c.-terminal voltage of which the converter is capable. In other words, a firing-angle of 0° corresponds to the conditions when each thyristor in the circuit is fired at the instant its anode voltage-first becomes positive in each cycle, under this condition, therefore, the converter operates in exactly the same manner as if it was an an uncontrolled rectifier circuit. The ‘α’ is the symbol for the firing-angle. Hence, the most efficient method to control the turning “on” of a thyristor is achieved by varying the firing-angle of thyristor. Such a method of control is called as phase-angle control. The phase-angle control is a highly efficient means of controlling the verage-power to loads such as lamps, heaters, motors, d.c. suppliers, etc.



Half-wave controlled converter using unidirectional switch

CHAPTER - 4
THREE PHASE CONTROLLED CONVERTERS

4.1 INTRODUCTION

The converter operating from a single-phase supply produces a relatively high proportion of a.c. rippile-voltage at its d.c. terminals. This ripple is generally undersirable because of its heat producing effect. Therefore, a large outlay of smoothing reactor is necessary to smoothen the output voltage as well as to reduce the possibility of discontinuous operation. The need for smoothing can be minimised by increasing the number of pulses. A three phase a.c. supply with a suitable transformer connection permits an increase in the pulse number. When the number of pulses of the converter is increased, the number of segments that fabricate the output voltage also increases and consequently the ripple content decreases. Higher the pulse number, smoother is the output voltage.

Three-phase rectifier circuits are used for large power applications. Generation of the three-phase a.c. power is now universal and in some countries, only generation frequencies may be different. Now-a days, 11kV, 33kV, 66kV three-phase a.c. supply is available to the industries. The voltage are suitably stepped down using transformers. These transformers are generally delta-connected on primary side and star-connected on the primary side and star-connected on the secondary side.

Three-phase controlled converter circuits can be studied under following categories

1. Three-pulse converters
2. Six-pulse converters
3. Twelve-pulse converters

4.1.1 Three-pulse Converters (M_3 Connection)

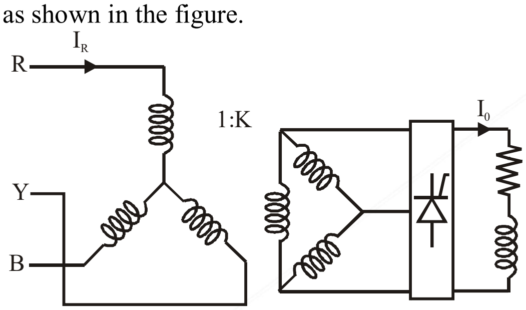
Three pulse converters are also known as the three-phase half wave controlled rectifier. The simplest type of phase- controlled converter operating from a three-phase supply is the three-pulse midpoint converter.

4.1.1.1 Three-Phase Half-Wave Controlled Rectifier with Resistive Load

Figure shows are power – diagram of a three-phase half-wave controlled rectifier with resistive load. This configuration is called as the mid-point configuration because all the phase emfs can have a common terminal which may be considered as the neutral point or the midpoint. As shown in figure, the primary is connected in a delta fashion and secondary in star. The load is connected to the neutral point. For the analysis of the circuit, the leakage inductance and on state SCR drops are assumed to be zero. The vector diagram of the three-phase voltage is shown in figure.

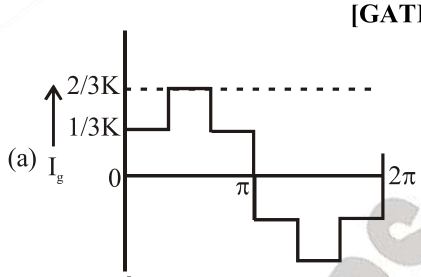
GATE QUESTIONS

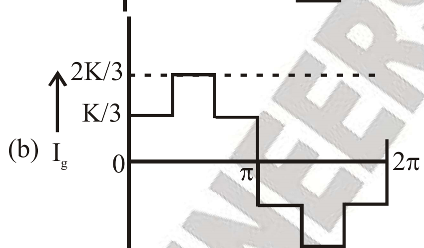
1. A three-phase fully controlled bridge converter is fed through star-delta transformer as shown in the figure.

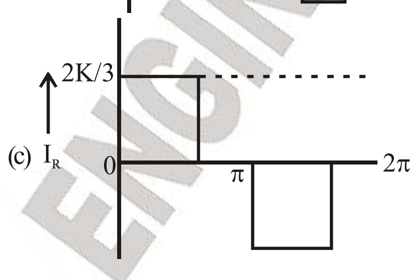


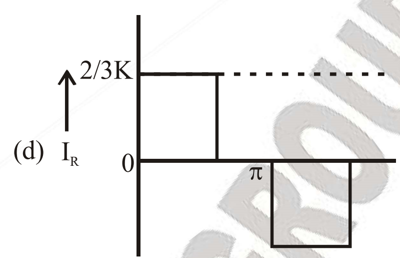
The converter is operated at firing angle of 30°. Assuming the load current (I_0) to be virtually constant at 1p.u. and transformer to be an ideal one, the input phase current waveform is

[GATE - 2014]



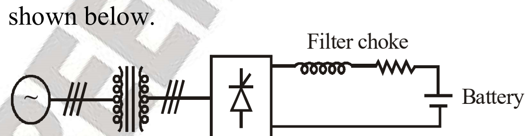






Statement linked for Q. 2 & Q.3

A solar energy installation utilize a three-phase bridge converter to feed energy into power system through a transformer of 400V/400V, as shown below.



The energy is collected in a bank of 400V battery and is connected to converter through a large filter choke of resistance 10Ω.

2. The maximum current through the battery will be

[GATE - 2011]

(a) 14A (b) 40A
(c) 80A (d) 94A

3. The kVA rating of the input transformer is

[GATE - 2011]

(a) 53.2kVA (b) 46.0kVA
(c) 22.6kVA (d) 7.5kVA

4. A three phase fully controlled bridge converter is feeding a load drawing a constant and ripple free load current of 10A at a firing angle of 30°. The approximate Total harmonic Distortion (% THD) and the rms value of fundamental component of input current will respectively be

[GATE - 2008]

(a) 31% and 6.8 A (b) 31% and 7.8 A
(c) 66% and 6.8A (d) 66% and 7.8A

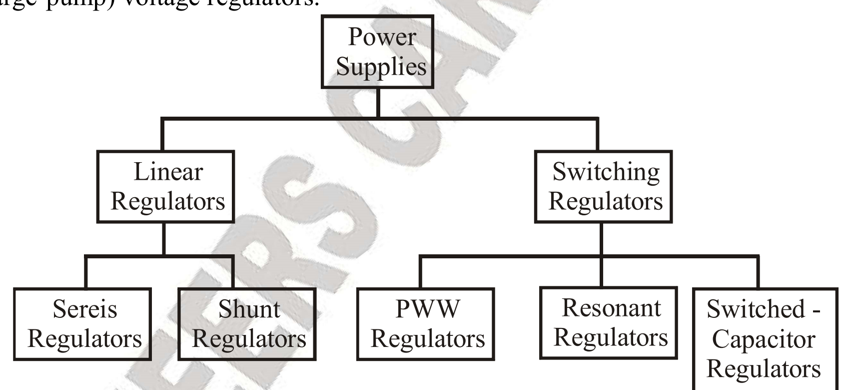
CHAPTER - 5
CHOPPER

5.1 INTRODUCTION

Many electronic system require several dc supply voltages. Power supplies are widely used in computers, telecommunications, instrumentation equipment aerospace, medical, and defense electronics. A dc supply voltage is usually derived from a battery or an ac utility line using a transformer, rectifier, and filter the resultant raw dc voltage not constant enough and contains a high ac ripple that is not appropriate for most applications. Voltage regulators are used to make the dc voltage more constant and to attenuate the ac ripple.

A power supply is constant voltage source with a maximum current capability. There are two general classes of power supplies: regulated and unregulated. The output voltage of a regulated power supply is automatically maintained within a narrow range, 1-2% of the desired nominal value, in spite of line voltage, load current, and temperature variations. Regulated dc power supplies are called dc voltage regulators. There are also dc current regulators, such as battery charges.

Shown a figure classification of regulated power supply technologies. Two of the most popular categories of voltage regulators are linear regulators and switching-mode power supplies. There are two basic linear regulator topologies: the series voltage regulator and the shunt voltage regulator. The switching-mode voltage regulators are divided into three categories: pulse-width modulated (PWM) dc-dc converters, resonant dc-dc converters, and switched-capacitor (also called charge-pump) voltage regulators.



Classification of power supply technologies

5.1.1 Basic Function of Voltage Regulator

The basic functions of a dc-dc converter are as follows:

1.To provide conversion of a dc input voltage V_1 to the desired dc output voltage within a tolerance range (e.g., $V_0 = 1.2V \pm 1\%$);

2.To regulate the output voltage V_0 against variations in the input voltage V_1, the load current I_0 (or the load resistance R_L), and the temperature;

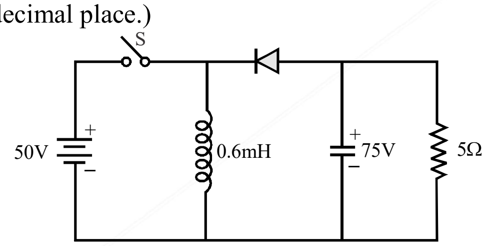
3.To reduce the output ripple voltage below the specified level;

4.To ensure fast response to rapid changes in the input voltage and load current (or load resistance);

5.To provide dc isolation;

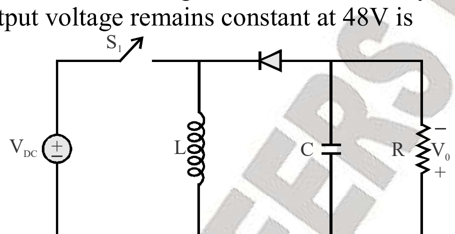
GATE QUESTIONS

1. In the circuit shown all elements are ideal and the switch S is operated at 10 kHz and 60% duty ratio. The capacitor is large enough so that the ripple across it is negligible and at steady state acquires a voltage as shown. The peak current in amperes drawn from the 50V DC source is _____. (Given the answer up to one decimal place.)



[GATE - 2017]

2. The input voltage V_{DC} of the buck-boost converter shown below varies from 32V to 72V. Assume that all components are ideal, inductor current is continuous, and output voltae is ripple free. The range of duty ratio D of the converter for which the magnitude of the steady-state output voltage remains constant at 48V is

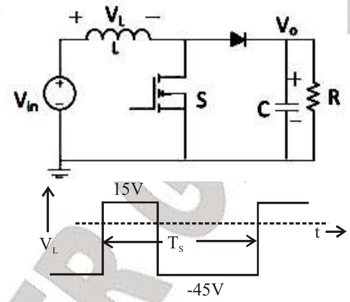


[GATE - 2017]

(a) $\frac{2}{5} \le D \le \frac{3}{5}$ (b) $\frac{2}{5} \le D \le \frac{3}{4}$

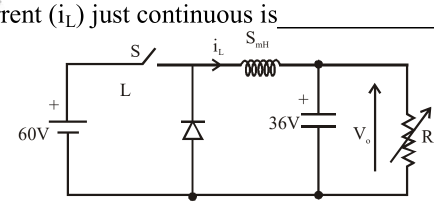
(c) $0 \le D \le 1$ (d) $\frac{1}{3} \le D \le \frac{2}{3}$

3. For the switching converter shown in the following figure, assume steady-state operation. Also assume that the components are ideal, the inductor current is always positive and continuous at switching period is T_s. If the voltage V_L is as shown, the duty cycle of the switch S is _______.



[GATE - 2015]

4. A buck converter feeding a variable resistive load is shown in the figure. The switching frequency of the switch S is 100 kHz and the duty ratio is 0.6. The output voltage V_0 is 36 V. Assume that all the components are ideal, and that the output voltage is ripple-free. The value of R (in Ohm) that will make the inductor current (i_L) just continuous is_______________.



[GATE - 2015]

5. In the following chopper, the duty ratio of switch S is 0.4. If the inductor and capacitor are sufficiently large to ensure continuous inductor current and ripple free capacitor voltage, the charging current (in Ampere) of the 5V battery, under steady-state, is_______.

[GATE - 2015]

6. A self commutating switch SW, operated at duty cycle δ is used to control the load voltage as shown in the figure

CHAPTER - 6
INVERTOR

6.1 INTRODUCTION

The D.C. to A.C. power converters are known as inverters. In other words, an inverter is a circuit which converter a D.C. power into an a.c. power at desired output voltage and frequency. The A.C. output voltage could be fixed at a fixed or variable frequency. This conversion can be achieved either by controlled turn-on and turn-off devices (e.g. BJTs, MOSFETs, IGBTs, MCTs, SITs, GTOs, and SITHs) or by forced commutated thyristors, depending on applications.
The D.C. power input to the inverter may be battery, fuel cell, solar cells or other D.C. source. But in most industrial applications, it is fed by a rectifier. This configuration of A.C. to D.C. to A.C. inverter is called a D.C. link converter because it is a two-stage static frequency converter in which A.C. power at network frequency is rectified and then filtered in the D.C. link before being inverted to A.C. at an adjustable frequency. Rectification is achieved by standard diode or thyristor converter circuits, and inversion is achieved by the circuit techniques described in this chapter.
1. Variable speed A.C. motor drives
2. Induction heating
3. Aircraft power supplies
4. Uninterruptible power supplies (UPS)
5. High voltage D.C. transmission lines
6. Battery-vehicle drives
7. Regulated voltage and frequency power supplies, etc.

6.1.1 Classification of Inverters

Inverters can be classified on the basis of a number of factors:

6.1.1.1 Classification According to the Nature of Input Source

Based on the nature of input power source, inverters are classified as
1. Voltage source inverters (VSI)
2. Current source inverters (CSI)
In case of VSI, the input to the inverter is provided by a ripple free dc voltage source and then used to supply the power to the inverter.

6.1.1.2 Classification According to the Waveshape of the Output Voltage

The inverters can be classified according to the natural of output voltage waveform as:
1. Square-wave inverter
2. Quasi-square wave inverter
3. Pulse-width modulated (PWM) inverters
A square-wave inverter produces a square-wave ac voltage of a constant magnitude. The output voltage of this type of inverter can only be varied by controlling the input dc voltage. Square-wave ac-output voltage of an inverter is adequate for low and medium power applications. However, the sine-wave output voltage is the ideal waveform for many high-power applications. Two methods can be used to make the output closer to a sinusoid.
The second method, pulse-width modulation (PWM) uses a switching scheme within the inveter to modify the shape of the output voltage waveform.

ESE OBJ QUESTIONS

1. Current source inverters are suitable for supplying power to
(a) R-L loads (b) Inductive loads
(c) All loads (d) Capacitive loads

2. The main application of multilevel inverter is in
(a) Reactive power compensation
(b) D.C. motor drive
(c) Synchronous buck-converter
(d) Voltage regulator

3. In a 3-phase inverter with 180° conduction mode the number of witches that is on at any instant of time is
(a) 1 (b) 2
(c) 3 (d) 4

4. In the sinusoidal pulse-width modulation scheme, if the zero of the triangular wave coincides with the zero of the refence sinusoidal, then the number of pulses per half cycle is
(a) $\frac{f_c}{2f}$ (b) $\frac{f_c}{2f}+1$
(c) $\frac{2f_c}{f}$ (d) $\frac{f_c}{2f}-1$

5. Modified McMurray full-bridge inverter works on
[ESE - 2015]
(a) Voltage commutation
(b) Current commutation
(c) Load commutation
(d) Complementary commutation

6. What is the region of operation of a 3-phase inverter employing sinusoidal PWM when the peak-to-peak values of both the carrier and the modulating waves are made equal?
[ESE - 2015]
(a)Linear modulation
(b)Over modulation
(c)Boundary of linear modulation and over modulation
(d)Six-step operation

7. In a single-phase full bridge inverter what is the advantage of a unipolar switching over the bipolar switching?
[ESE - 2015]
(a)Increase of the fundamental component by a factor of 115 for the same DC-input voltage
(b)Elimination of 5^{th} and 7^{th} harmonics
(c)Apparent doubling of the switching frequency
(d)None of the above

8. In a McMurray inverter, diodes are connected in inverse parallel to thyristors to
1. Protect the thyristor
2. Make the turn off of the thyristor successful
3. Make the turn on of the thyristor successful
4. Provide path to the reactive component of the load current
Which of the above statements are correct?
[ESE - 2015]
(a) 1 and 3 (b) 1 and 4
(c) 2 and 4 (d) 2 and 3

9. A voltage source inverter is used when source and load inductances are respectively
[ESE - 2015]
(a) Small and large (b) Large and small
(c) Large and large (d) Small and small

10. For a 1-phase full-bridge inverter fed from 48 V dc and connected to load resistance of 2.4 Ω„ the rms value of fundamental component of output voltage is
[ESE - 2015]
(a) 20V (b) 21.6V
(c) 34.4V (d) 43.2V

CHAPTER - 7
DRIVES

7.1 INTRODUCTION
An electric motor together with its control equipment and energy transmitting device forms an electric drive. And an electric drive together with its working machine constitutes an electric drive system.

1. Electric Drive
A ceiling fan motor with its speed regulator but without blades.

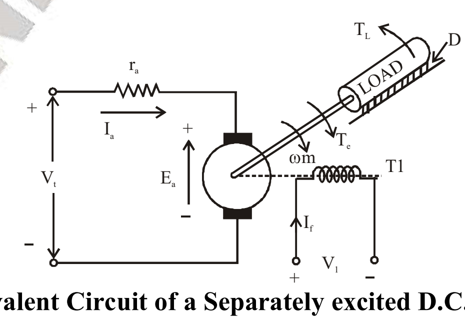
2. Electric drive system
A ceiling fan motor with regulator and also with of blades, a food mixture/mixer with food to be processed.

Electric Drives	
–1–ϕ DC drives –3–ϕ DC drives –Chopper drives	–1–ϕ induction motor drives –3–ϕ induction motor drives –Synchronous motor drives

7.1.1 D.C. Drives
DC motors are used extensively in adjustable speed drives and position control applications. Where, speed control below base speed ⇒ Armature voltage control
Speed control above base speed ⇒ filed flux control.
DC motor drives are preferred where wide-speed control range is required.
Depending upon the type of AC source or the method of voltage control, D.C. drives are classified as:-
1. 1–ϕ D.C. drive
2. 3–ϕ D.C. drive
3. Chopper drive

7.1.2 Basic Performance Equation of DC Motor

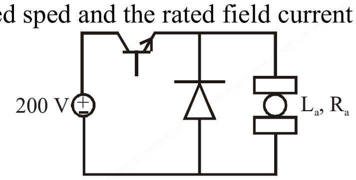
1. Separately-excited D.C. Motor
The equivalent circuit for a separately excited D.C. motor coupled with a load is shown in figure below as:



Equivalent Circuit of a Separately excited D.C. Motor

GATE QUESTIONS

1. The separately excited dc motor in the figure below has a rated armature current of 20A and a rated armature voltage of 150V. An ideal chopper switching at 5 kHz is used to control the armature voltage. If L_a = 0.1mH, R_a = 1Ω, neglecting armature reaction, the duty ratio of the chopper to obtain 50% of the rated torque at the rated sped and the rated field current is



[GATE - 2013]

(a) 0.4 (b) 0.5
(c) 0.6 (d) 0.7

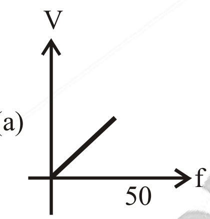
2. A three-phase, 440V, 50 Hz ac mains feed thyristor bridge is feeding a 440V dc, 15kW, 1500 rpm separately excited dc motor with a ripple free continuous current in the dc link under all operating conditions, Neglecting the losses, the power factor of the ac mains at half the rated speed is

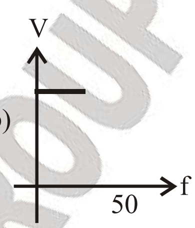
[GATE - 2007]

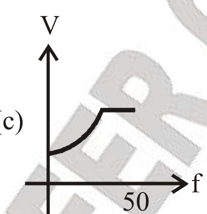
(a) 0.354 (b) 0.372
(c) 0.90 (d) 0.955

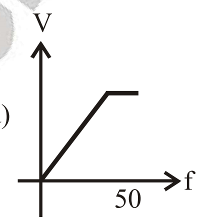
3. The speed of a 3-phase, 440V and 50Hz induction motor is to be controlled over a wide range from zero speed to 1.5 times the rated speed using 3-phase voltage source inverter. It is desired to keep the flux in the machine constant in the constant torque region by controlling the terminal voltage as the frequency changes. The inverter output voltage vs frequency characteristic should be

[GATE - 2006]

(a)


(b)


(c)


(d)


4. An electric motor, developing a starting torque of 15Nm, starts with a load torque of 7Nm on its shaft. If the acceleration at start is 2 rad/sec^2, the moment of inertia of the system must be (neglecting viscous and coulomb friction)

[GATE - 2005]

(a) 0.25 kg–m^2 (b) 0.25 Nm^2
(c) 4 kg–m^2 (d) 4Nm^2

5. A single-phase half-controlled rectifier is deriving a separately excited dc motor. The dc motor has a back emf constant of 0.5V/rpm. The armature current is 5A without any ripple. The armature resistance is 2Ω. The converter is working from a 230V, single-phase ac source with a firing angle of 30°. Under this operating condition, the speed of the motor will be

[GATE - 2004]

(a) 339 rpm (b) 359 rpm
(c) 366 rpm (d) 386 rpm

6. A variable speed drive rated for 1500 rpm, 40 Nm is reversing under no load. Figure shws the reversing torque and the speed during the transient. The moment of inertia of the drive is

ESE OBJ QUESTIONS

1. It is required to control the speed and braking operation of a dc shunt motor in both the directions of rotation. The most suitable power electronic circuit will be

[ESE - 2015]

(a) A half-controlled converter
(b) A fully-controlled converter
(c) A diode-bridge converter
(d) A dual converter

2. In a single-phase to 1-phase cyclo-converter, the magnitudes of harmonic components are quite large. How can they be reduced?

[ESE - 2015]

(a) By using a chopper circuit
(b) By using a RC oscillator
(c) By using a three phase input supply
(d) By adding an alternator to the input

3. Statement (I): A switched-mode dc power supply has high efficiency and light weight.
Statement (II): A switched-mode dc power supply uses a dc to dc switching converter switched at high frequency.

[ESE - 2015]

(a)Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b)Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c)Statement (I) is true but Statement (II) is false.
(d)Statement (I) is false but Statement (II) is true.

4. How can the 3rd harmonic current be filtered in Thyristor-controlled reactor?

[ESE - 2015]

(a) By connecting in delta
(b) By connecting in star
(c) By connecting in star-delta
(d) None of the above

5. The device used for switching in a switched Mode Power supply is

[ESE - 2014]

(a) Diode (b) Thyristor
(c) GTO (d) MOSFET

6. In a forward converter, a tertiary winding is used. What is the reason?

[ESE - 2014]

(a)To provide di/dt protection to the switching device.
(b)To provide dv/dt protection to the switching device.
(c)To provide electrical isolation between the input and output.
(d)To demagnetize the core before the application of the next switching pulse.

7. Consider the following statements:
Switched mode power supplies are preferred over the continuous types, because they are
1.Suitable for use in both ac and dc
2.More efficient
3.Suitable for low-power circuits
4.Suitable for high-power circuits Which of these statements are correct?

[ESE - 2013]

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 3 and 4

8. A single-phase ac regulator fed from 50 Hz supply feeds a load having 4 Ω resistance and 12.73 mH inductance. The control range of firing angle will be

[ESE - 2012]

(a) 0° to 180° (b) 45° to 180°
(c) 90° to 180° (d) 0°to 45°

9. An integral cycle a.c. voltage controller is feeding a purely resistive circuit from a single-phase a.c. voltage source. The current waveform consists alternately burst of N-complete cycle of conduction followed by M-complete of