II Year / IV Semester
Department of Electronics and communication Engineering
Sub. Code /Sub. Name: EC8451 / ELECTROMAGNETIC FIELDS

EC8451 ELECTROMAGNETIC FIELDS L T P C 3 1 0 4
UNIT I INTRODUCTION 12
Electromagnetic model, Units and constants, Review of vector algebra, Rectangular, cylindrical and spherical coordinate systems, Line, surface and volume integrals, Gradient of a scalar field, Divergence of a vector field, Divergence theorem, Curl of a vector field, Stoke's theorem, Null identities, Helmholtz's theorem
UNIT II ELECTROSTATICS 12
Electric field, Coulomb's law, Gauss's law and applications, Electric potential, Conductors in static electric field, Dielectrics in static electric field, Electric flux density and dielectric constant, Boundary conditions, Capacitance, Parallel, cylindrical and spherical capacitors, Electrostatic energy, Poisson's and Laplace's equations, Uniqueness of electrostatic solutions, Current density and Ohm's law, Electromotive force and Kirchhoff's voltage law, Equation of continuity and Kirchhoff's current law
UNIT III MAGNETOSTATICS 12
Lorentz force equation, Law of no magnetic monopoles, Ampere's law, Vector magnetic potential, Biot-Savart law and applications, Magnetic field intensity and idea of relative permeability, Magnetic circuits, Behaviour of magnetic materials, Boundary conditions, Inductance and inductors, Magnetic energy, Magnetic forces and torques
UNIT IV TIME-VARYING FIELDS AND MAXWELL's EQUATIONS 12
Faraday's law, Displacement current and Maxwell-Ampere law, Maxwell's equations, Potential functions, Electromagnetic boundary conditions, Wave equations and solutions, Time-harmonic fields
UNIT V PLANE ELECTROMAGNETIC WAVES 12
Plane waves in lossless media, Plane waves in lossy media (low-loss dielectrics and good conductors), Group velocity, Electromagnetic power flow and Poynting vector, Normal incidence at a plane conducting boundary, Normal incidence at a plane dielectric boundary
TOTAL (L:45+T:15): 60 PERIODS
TEXT BOOKS:
1. William H Hayt and Jr John A Buck, "Engineering Electromagnetics" , Tata Mc Graw-Hill Publishing Company Ltd, New Delhi, 2008
2. Sadiku MH, "Principles of Electromagnetics", Oxford University Press Inc, New Delhi, 2009
REFERENCES:
1. David K Cheng, "Field and Wave Electromagnetics", Pearson Education Inc, Delhi, 2004
2. John D Kraus and Daniel A Fleisch, "Electromagnetics with Applications", Mc Graw Hill Book Co, 2005
3. Karl E Longman and Sava V Savov, "Fundamentals of Electromagnetics", Prentice Hall of India, New Delhi, 2006
4. Ashutosh Pramanic, "Electromagnetism", Prentice Hall of India , New Delhi, 2006

UNIT-1

1. How is the unit vectors defined in cylindrical co-ordinate systems?

A unit vector is a dimensionless quantity of unit magnitude. In cylindrical co-ordinate systems $\bar{r}, \bar{\theta}, \varphi$ are unit vectors.

2. Define scalar and vector?

A quantity that is characterized by both magnitude and direction is called as vector. A quantity that is characterized by only magnitude is called as scalar.

3. Define the vector differential operator?

The vector differential operator, denoted as del (∇) is defined as

$$\nabla = \frac{\partial}{\partial x}\bar{a}_x + \frac{\partial}{\partial y}\bar{a}_y + \frac{\partial}{\partial z}\overline{a_z}$$

4. Define Gradient.

Gradient of any scalar function is defined as the maximum space rate of change of that function. If scalar V represents electric potential; then ∇.V represents potential gradient

I.e.; $\nabla.\text{V}=\frac{\partial V}{\partial x}\hat{a}_x + \frac{\partial V}{\partial y}\hat{a}_y + \frac{\partial V}{\partial z}\hat{a}_z$ Gradient of a scalar is a vector. ∇.V=grad.V

5. Define Divergence.

The Divergence of a vector A at any point is defined as the limit of its surface integrated per unit volume as the volume enclosed by the surface shrinks to zero.

$$\nabla.A = \underset{v\to 0}{Lt}\frac{1}{v}\oiint A.\hat{n}ds$$

$$\nabla.\text{A}= \left(\frac{\partial}{\partial x}\hat{a}_x + \frac{\partial}{\partial y}\hat{a}_y + \frac{\partial}{\partial z}\hat{a}_z\right).\left(\hat{a}_x.A_x + \hat{a}_y.A_y + \hat{a}_z.A_z\right)$$

$$= \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z} \qquad \nabla.\text{A} = \text{div A}$$

6. Define curl.

The curl of a vector A at any point is defined as the limit of its surface integrated of its cross product with normal over a closed surface per unit volume as the volume shrinks to zero.

$$|curlA| = \underset{v\to 0}{Lt}\frac{1}{v}\oiint \hat{n}\times Ads$$

$$\nabla\times A = \left(\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z}\right)\hat{a}_x + \left(\frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x}\right)\hat{a}_y + \left(\frac{\partial A_y}{\partial x} - \frac{\partial Ax}{\partial y}\right)\hat{a}_z$$

7. State Divergence theorem?

The volume integral of the divergence of a vector field over a volume is equal to the surface integral of the normal component of this vector over the surface bounding the volume

$$\iiint_v \nabla.Adv = \oiint_s A.ds$$

8. State Stokes's theorem?

The line integral of a vector around a closed path is equal to the surface integral of the normal component of its curl over any closed surface.

$$\oint H.dl = \iint_s \nabla \times H.ds$$

9. State coulomb's law?

Coulomb's law states that the force between two very small objects separated by a distance which is large compared to their size is proportional to the charge of each and inversely proportional to the square of the distance between them.

10. Define electric field intensity?

The electric field or electric field intensity is defined as the electric force per unit charge is given by $E=\frac{F}{q}$

11. What is a point charge?

Point charge is one whose maximum dimension is very small in comparison with any other length.

12. What do you understand by the term line, surface and volume charge distributions?

Line charge density:

It is defined as the total charge distributed over a line or curve

$$\ell_l = \underset{\Delta l \to 0}{Lt}\left(\frac{\Delta Q}{\Delta l}\right)$$

$$= \frac{Q}{l} c/m$$

Surface charge density:

$$\ell_s = \underset{\Delta s \to 0}{Lt}\left(\frac{\Delta Q}{\Delta s}\right)$$

$$= \frac{Q}{s} = \frac{Q}{A} c/m^2$$

Volume charge density:

$$\ell_v = \underset{\Delta v \to 0}{Lt}\left(\frac{\Delta Q}{\Delta v}\right)$$

$$= \frac{Q}{v} c/m^3$$

13. What is electric flux density?

Electric flux density is defined as the electric flux per unit area.

$$D = \frac{Q}{A}$$

14. What is Electric flux?

If the test charge is moved towards the charge Q, the test charge will experience a force due to the main charge, that force is called electric flux which is equal to the charge itself. It is denoted as χ

15. State Gauss's law?

The electric flux passing through any closed surface is equal to the total charge enclosed by the surface. χ =Q.

16. Mention the applications of Gauss's law?

1. Electric field determination of shell
2. Electric field determination of cylinder
3. Electric field determination of concentric shells.

17. State Gauss's divergence theorem?

The divergence of electric flux density is equal to the volume charge density $\nabla . D = \ell_v$

18. What is electric dipole?

An electric dipole is defined as two equal and opposite charges separated by a small distance is equal to the product of charge and spacing is called electric dipole moment.

19. What is electrostatic energy?

Electrostatic energy is defined as the work done to build up the charge

$$W = \frac{1}{2} CV^2$$

20. What is meant by energy density?

Energy density is defined as the work done per unit volume.

$$\frac{\Delta W}{\Delta v} = \frac{1}{2} \varepsilon E^2 = \frac{1}{2} DE$$

****

UNIT-2

1. State Poisson's equation

The Poisson's equation is stated as $\nabla^2 v = \frac{\ell_v}{\varepsilon}$

2. State the applications of Poisson's equation and Laplace's equation

1. To obtain potential distribution over the region
2. To obtain E in the region
3. To check whether given region is free of charge or not
4. To obtain the charge induced on the surface of that region.

3. Define current density (J)

The current density is defined as the current passing through the unit surface area when the surface is held normal to the direction of the current and it is measured in A/m^2

4. Express the continuity equation in integral form and differential form

Integral form:

$$\oint J.ds = -\frac{dQ}{dt}$$

Differential form:

$$\nabla.J = -\partial\ell_v/\partial t$$

5. Write the equation of point form of ohm's law

J= σ E

6. State boundary conditions?

1. The tangential component of electric field E is continuous at the surface
2. The normal component of electric flux density is continuous if there is no surface charge density.

7. What is meant by method of images or an electric image?

When a point charge Q at a distance d from grounded conducting plane induces another charge - Q in opposite direction is called as electric image.

8. A point charge of 10μc is located at (1, 2, 3) and another point charge -3μc is located at (3, 0, 2) in vacuum. Find the force between them.

Q1=10 μc, Q2=-3 μc, r1= $\vec{a}_x + 2\vec{a}_y + 3\vec{a}_z$, r2= $3\vec{a}_x + 2\vec{a}_z$

r = r2-r1

$= 2\vec{a}_x - 2\vec{a}_y - \vec{a}_z$

$$|r| = \sqrt{2^2 + 2^2 + 1^2} = 3$$

$$\vec{a} = \frac{r}{|r|} = \frac{2\vec{a}_x - 2\vec{a}_y - \vec{a}_z}{3}$$

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}\vec{a}$$

$= 4.44 \times 10^{-3}(-2\vec{a}_x + 2\vec{a}_y + \vec{a}_z)$ Newton

9. What are dielectrics?

Dielectrics are materials that may not conduct electrically through it but on applying electric field induced charges are produced on its faces.

10. Write the expression for capacitance of a parallel plate capacitor having two dielectric media.

$$C=\frac{A\varepsilon_0\varepsilon_r}{d_1\varepsilon_r+(d-d_1)}$$

11. Define polarization

Polarization is defined as the dipole moment per unit volume.

$$P=\underset{\Delta v\to 0}{Lt}\frac{1}{\Delta v}\sum_{i=1}^{n\Delta v}P_i \quad c/m^2$$

12. What is susceptibility?

$$\chi=\varepsilon_R-1$$

13. Write the Poisson's equation of Cartesian co-ordinate system

$$\nabla^2 v=\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}=-\frac{\ell_v}{\varepsilon}$$

14. State Laplace's equation

If the volume charge density (ℓ_v) is zero then, $\nabla^2 v=0$

15. What is meant by boundary conditions?

The conditions existing at the boundary of the two media when field passes from one medium to other are called boundary conditions.

16. Write the expression of spherical capacitance

$$C=\frac{4\pi\varepsilon}{(\frac{1}{a}-\frac{1}{b})F}$$

17. What is meant by displacement current?

Displacement current is nothing but the current flows through the capacitor.

18. Write the expression for isolated spherical conductor coated with dielectric?

$$\ell=\frac{4\pi}{(\frac{1}{\varepsilon_1}(\frac{1}{a}-\frac{1}{r_1})+\frac{1}{\varepsilon_0 r_1})F}$$

19. Write the expression for capacitance of single isolated sphere

$$\ell=4\pi\varepsilon a \text{ F}$$

20. Write the expression for capacitance of co-axial cable

$$\ell=(2\pi\varepsilon L)\ln(\frac{b}{a}) \text{ F}$$

****

UNIT-3

1. State Biot-Savart's law

The magnetic flux density produced by a current element at any point in a magnetic field is proportional to the current element and inversely proportional to square of the distance between them.

2. Defined magnetic flux density

Magnetic flux density is defined as the magnetic flux passing per unit area. Its unit is Weber/metre^2 (or) Tesla.

$$B=\frac{\phi}{A}(or)B=\mu H$$

3. Define magnetic flux (ϕ)

Magnetic flux is defined as the flux passing through any area

$$\phi=\int_s B.ds$$

4. What is Lorentz force?

The force on a moving particle due to combined electric and magnetic field is called as Lorentz force.

5. State Ampere's circuital law

Ampere's circuital law states that the line integral of magnetic flux intensity H about any closed path is exactly equal to the direct current enclosed by that path.

$$\oint H.dl=I$$

6. Express Ampere's circuital law in point form

$$\nabla\times H=J\ .$$

7. State Stoke's theorem

The line integral of a vector A around a closed path L is equal to the integral of curl A over the open surface S enclosed by the path L.

8. Give the applications of Stoke's theorem

Stoke's theorem is applicable for the open surface enclosed by the given closed path. Any volume is a closed.

9. Write the expression for magnetic field intensity due to infinite conductor

$$H = \frac{I}{2\pi d} \quad \text{A/m}$$

10. Write the expression for magnetic field intensity of circular conductor

$$H = \frac{I}{2a}$$

11. Write the expression of scalar magnetic potential

$$V_m = -\int H.dl$$

12. Write the expression of vector magnetic potential

$$A = \frac{\phi}{4\pi}\iiint \frac{J}{r}dr$$

13. Define Magnetization (M)

Magnetization is defined as the net dipole moment per unit volume and it is represented as vector

Where M= $\underset{\Delta v \to 0}{Lt} \frac{m}{\Delta v}$ A/m

14. Define Magnetic Susceptibility

Magnetic Susceptibility is defined as the ratio of magnetization to the magnetic field intensity

$$\chi_m = \frac{M}{H}$$

15. Two wires carrying a current in the same direction of 500A and 800A are placed with the area 5cm apart. Calculate the force between them.

$$I_1 = 500A, I_2 = 800A, r = 5\times 10^{-2} m$$

$$F = \frac{\mu_0 I_1 I_2}{4\pi r}$$

= 0.8 Newton's

16. A circular coil of radius 10cm is made up of 100 turns. It carries a current of 5A, calculate the magnetic field intensity at the centre of the coil.

a = 10cm N=100 I=5A

$$H = \frac{NI}{2a}$$

$$= \frac{100\times 5}{2\times 0.1}$$

= 2500 AT/m

17. A single phase circuit comprises of two parallel conductors A and B. 1cm diameter and spaced 1 metre apart,the conductors carrying a current of 10A and -10A respectively. Determine the field intensity at the surface of each conductor and also in the middle of A and B.

$$H = \frac{I}{2\pi} + \frac{I}{2\pi \times 0.5 \times 10^{-2}}$$

$$= \frac{10}{2\pi}\left[1 + \frac{10^2}{0.5}\right]$$

= 318.3 A/m

$$H = \frac{I}{2\pi(0.5)} + \frac{I}{2\pi(0.5)} = \frac{2I}{2\pi(0.5)} = 6.366 A/m$$

18. Determine the force between two parallel conductors of length 1m separated by 50cm and carrying currents of 30 A (a) in the same direction (b) in the opposite direction

I= 30A l=1m d= 0.5m

Force of attraction

F= $\frac{\mu_0 I_1 I_2 l}{2\pi d} = 0.36 \times 10^{-3} N.$

Force of repulsion

F= $\frac{\mu_0 I^2 l}{2\pi d} = 0.36 \times 10^{-3} N.$

19. What is the relation between magnetic flux density and magnetic field intensity?

B= μH

$\mu = \mu_0 \mu_r$

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

****

UNIT-4

1. **Write the expression for self inductance**

$$L = \frac{N\phi}{i}$$

2. **Write the expression for self inductance**

$$M = N_1 \frac{\phi_{21}}{i_2} (or) N_2 \frac{\phi_{12}}{i_1}$$

3. **Write the expression for inductance of toroid**

$$L = \frac{\mu_0 N^2 r^2}{2R}$$

4. **Write the expression for inductance of solenoid**

$$L = \frac{NBA}{I}$$

5. **Write the expression for inductance of solenoid**

$$L = \frac{\mu_0}{2\pi} \ln\left(\frac{b}{a}\right)$$

6. Write the expression for inductance of two transmission line.

$$L = \frac{\mu_0}{4\pi}\left[\mu_r + 2\ln\frac{d^2}{ab}\right] \text{ H/m}$$

7. Write the expression for energy store in a magnitude field

$$W = \frac{1}{2} L I^2$$

8. What is reluctance?

The reluctance is defined as the ratio of total mmf (magnetic motive force) of magnetic circuit to the flux through it.

$$= \frac{mmf}{magneticflux}$$

$$R = \frac{\oint Hdl}{BA}$$

9. On Evaluate the inductance of a solenoid of 2500 turns wound uniformly over a length of 0.5m on a cylindrical paper tube 4cm in diameter,the medium is air.

N=2500; l=0.5m; d=4cm

$$A = \frac{\pi d^2}{4} = \frac{\pi \times 4 \times 4 \times 10^{-4}}{4} = 12.566 \times 10^{-4} m^2$$

Inductance of solenoid

$$L = \frac{\mu_0 N^2 A}{l} = 19.7386 mH$$

10. Two coils are wound on a common magnetic circuit of 50 cm^2 in section and mean length of 100cm. One coil has 80 turns and other 700 turns. Calculate the mutual inductance if μ_r of the iron path is 1500.

N1=80; N2=700; l=1m; A=$50\times10^{-4} m$; μ_r =1500

$$M = \frac{N_1 N_2 \mu_0 \mu_r}{l} = 0.528H$$

11. Define coupling co-efficient

The fraction of the total flux produced by one coil linking the second coil is called the coefficient of coupling (k).

$$k = \frac{\phi_2}{\phi_1} = \frac{\phi_{21}}{\phi 2}$$

ϕ1=The flux produced by coil1 ϕ2=flux linking with coil2

12. Distinguish between solenoid and toroid?

Solenoid is cylindrically shaped coil consisting of a large number of closely spaced turns of insulated wire wound on a non-magnetic frame.

If a long solenoid is bent into the form of a ring and there by closed on itself, it becomes toroid.

13. What are major classifications of magnetic materials?

1. Diamagnetic 2. Paramagnetic 3. Ferromagnetic

14. Give the force on a current element.

The force on a current element is Idl is given by

$$dF = I \times Bdl$$

$$= BIdl \sin\theta \text{ Newton}$$

15. Write down the magnetic boundary conditions.

1. The normal components of flux density B is continuous across the boundary.
2. The tangential component of field intensity H is continuous across the boundary.

16. Distinguish between diamagnetic, paramagnetic and Ferro magnetic materials.

Diamagnetic: In diamagnetic materials magnetization is opposed to the applied. It has weak magnetic field.

Paramagnetic: The magnetization is in the same direction of field. It has weak magnetic field.

Ferromagnetic: The magnetization is in the same direction of field. It has strong magnetic field.

17. What is Permeability?

In Magnetostatics the B and H are related to each other through the property of the region in which current carrying a conductor is placed .It is called permeability denoted as μ. It is the ability in which the current carrying conductor forces the magnetic flux through the region around it.

$$B=\mu H$$

18. What is magnetization?

The field produced due to the movement of bound charges is called magnetization represented by M.

19. Write the expression for force between two parallel conductor

$$F = \frac{\mu_0 I_1 I_2 l}{2\pi d} N$$

20. What is the total magnetic flux passing any closed surface?

The total magnetic flux passing any closed surface is equal to zero.

****

<u>UNIT-5</u>

1. State Faradays law?

Faradays' law state that the electromagnetic force (emf) induced in a circuit is equal to the rate of decrease of the magnetic flux linkage in the circuit.

2. Write the Maxwell's equations in integral form

$$\oint H.dl = \iint (J + \frac{\partial D}{\partial t})ds = \iint (\sigma E + \varepsilon \frac{\partial E}{\partial t})ds$$

$$\oint E.dl = -\iint \frac{\partial B}{\partial t}ds = -\mu \iint \frac{\partial H}{\partial t}ds$$

$$\oiint D.ds = \iiint \rho dv$$

$$\oiint B.ds = 0$$

3. **Write the Maxwell's equation in point /Differtial form?**

$$\nabla \times H = J + \frac{\partial D}{\partial t} = \sigma E + \varepsilon \frac{\partial D}{\partial t}$$

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

$$\nabla . D = \rho$$

$$\nabla . B = 0$$

4. **State pointing theorem?**

The vector product of electric field intensity and magnetic field intensity at any point is a measure of the rate of energy flow per unit area at that point

$$\vec{P} = \vec{E} \times \vec{H}$$

5. **Write the Maxwell's equation in point form for free space.**

$$\nabla \times H = \frac{\partial D}{\partial t} = \varepsilon \frac{\partial E}{\partial t}$$

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

$$\nabla . D = 0$$

$$\nabla . B = 0$$

6. **Write the Integral for Maxwell's equation in free space.**

$$\oint H.dl = \iint \frac{\partial D}{\partial t}ds = \varepsilon \iint \frac{\partial E}{\partial t}ds$$

$$\oint E.dl = -\iint \frac{\partial B}{\partial t}ds = -\mu \iint \frac{\partial H}{\partial t}ds$$

$$\oiint D.ds = 0$$

$$\oiint B.ds = 0$$

7. **Write the point form of Maxwell's equation in phasor form.**

$$\nabla \times H = (\sigma + jw\varepsilon)E$$
$$\nabla \times E = -jw\mu H$$
$$\nabla . D = \rho$$
$$\nabla . B = 0$$

8. Write the Integral form of Maxwell's equation in phasor form

$$\oint H.dl = \iint (\sigma + jw\varepsilon)Eds$$

$$\oint E.dl = -\mu \iint jwH.ds$$

$$\oint D.ds = \iiint \rho dv$$

$$\oint B.ds = 0$$

9. Define skin depth

It is defined as that depth in which the wave has been attenuated to 1/e or approximately 37% of its original value.

10. Define Pointing vector.

The Pointing vector is defined as rate of flow of energy of a wave as it propagates.

P =E X H

11. What is the fundamental difference between static electric and magnetic field lines?

There is a fundamental difference between static electric and magnetic field lines. The tubes of electric flux originate and terminate on charges, whereas magnetic flux tubes are continuous.

12. State Snell's law.

When a wave is travelling from one medium to another medium, the angle of incidence is related to angle of reflection.

$$\frac{\sin \theta_i}{\sin \theta t} = \sqrt{\frac{\eta_1}{\eta_2}} = \sqrt{\frac{\varepsilon_2}{\varepsilon_1}} (\mu_1 = \mu_2 = \mu_0)$$

13. In a time varying situation how do you define a good conductor and lossy dielectric?

$$\frac{\sigma}{w\varepsilon} >> 1$$

For good conductor
$$\alpha = \beta = \sqrt{\frac{w\mu\sigma}{2}}$$
$$= \sqrt{\pi f \mu\sigma}$$

Alpha and beta are large i.e. the a wave is attenuated greatly as its progress through the conductor.

14. Write down the expression for average power flow in electromagnetic field and average Pointing vector.

Average power

$$W_{av} = \frac{|V||I|}{2}\cos\theta$$

Average Pointing vector $P_{av} = \frac{1}{2}\operatorname{Re} alpartof\left[E \times H^*\right]$

15. What is Magneto statics?

The study of steady magnetic field, existing in a given space, produced due to the flow of direct current through a conductor is called Magneto statics.

16. Brief about complex Pointing vector.

The complex Pointing vector is given by

P =1/2 E X H

Product of E and H is a vector product. Mutually perpendicular components of E and H contribute to the power flow. This power flow is directed along the normal to the plane containing E and H

17. What do you mean by Depth of penetration?

The distance δ through which the amplitude of a travelling plane wave decreases by a factor of e^{-1} (or) 0.368 is called skin depth or the depth of penetration of a conductor.

18. Write down Maxwell's equations derived from Faraday's law.

$$\oint E.dl = -\iint \frac{\partial B}{\partial t}.ds \quad \text{(Integral form)}$$

$$\nabla \times E = -\frac{\partial B}{\partial t} \quad \text{(Point form)}$$

19. State Faraday's law of electromagnetic induction.

Faraday's law states that electromagnetic force induced in a circuit is equal to the rate of change of magnetic flux linking the circuit.

$$\text{emf}= \frac{d\phi}{dt}$$

20. Define electromagnetic spectrum.

The electromagnetic spectrum is the range of all possible frequencies of electromagnetic radiation. The "electromagnetic spectrum" of an object has a different meaning, and is instead the characteristic distribution of electromagnetic radiation emitted or absorbed by that particular object.

QUESTION BANK

ELECTROMAGNETIC FIELDS

UNIT 1

PART-B

1. Find the electric field intensity at a point P located at $(0,0,h)$m due to charge of surface charge density σ C/m^2 uniformly distributed over the circular disc $r \leq a, z = 0$ m. (10)
2. Determine the divergence and curl of the given field F= 30 $_{ax}$ + 2 xy $_{ay}$ + 5 x^{z2} $_{az}$ at (1, 1,-0.2) and hence state the nature of the field. (6)
3. Point charges Q and –Q are located at (0, 0, d/2) and (0, 0,-d/2). Show that the potential at a point $(r, \theta, \emptyset)$ is inversely proportional to r^2 noting that r >> d (8)
4. Given a field E= $\frac{-6y}{x^2}$ a_x + $\frac{6}{x}$ a_y+ 5 a_z V/m find the potential difference V_{AB} between A(-7, 2, 1) and B(4, 1, 2). (8)
5. Assume a straight line charge extending along the z-axis in a cylindrical coordinate system from $-\infty$ *to* ∞. Determine the electric field intensity $\bar{E}$ at every point resulting from a uniform line charge density ρ_L C/m. (8)
6. Consider an infinite uniform line charge at 5 nC/m parallel to z-axis at $x = 4, y = 6.$ Find the electric field intensity at the point P (0, 0, 5) in free space. (8)
7. The flux density within the cylindrical volume bounded by r=2m,z=0 and z=5 m is given by $\bar{D} = 30e^{-r}\, \bar{a}_r - 2z\, \bar{a}_z$ C/^{m2}. What is the total outward flux crossing the surface of the cylinder. (8)
8. State and prove Gauss's law for the electric field. Also give the differential form of Gauss law. (8)
9. Find the total electric field at the origin due to 10^{-8} charge located at P(0,4,4)m and -0.5 x 10^{-8} C charge at P(4,0,2)m. (8)
10. Derive an expression for the electric field intensity at any point due to a uniformly charged sheet with density ρ_s C/m^2. (8)
11. Derive expression for potential due to an electric dipole at any point P. Also find electric field intensity at the same point. (10)
12. Two point charges $1.5\ nC\ \ at(0,0,0.1) - 1.5\ nC\ at\ (0,0,0.1)$ are in free space. Treat the two charges as a dipole at the origin and find potential at P (0.3, 0, 0.4). (6)
13. Given two points A$(x = 2, y = 3, z = -1)$ & B$(r = 4, \theta = 25°, \emptyset = 120°)$ Find the spherical co-ordinates of A and Cartesian co-ordinates B. (8)
14. Find curl$\bar{H}$, if $\bar{H}$=$(2\rho cos\emptyset\, \bar{a}_\rho - 4\rho sin\emptyset \bar{a}_\phi + 3\bar{a}_z)$. (8)
15. A circular disc of radius $'a'$m is charged uniformly with a charge of σ C/m^2. Find the electric field intensity at a point $'h'$m from the disc along its axis. (8)

16. If V= $\left[2x^2y + 20z - \frac{4}{x^2+y^2}\right]$ volts, find $\bar{E}$ and $\bar{D}$ at P (6, -2.5, 3). (8)

UNIT-2
PART-B

1. Derive Laplace and Poisson's equation.
2. Explain in detail the behavior of a dielectric medium in electric field.
3. Explain the polarization of the dielectric material
4. Give and derive the expression for the capacitance of co-axial cables with single and two dielectrics.
5. Apply Gauss's law to an (i0 Infinite line charge (ii) Infinite sheet of charge
6. Derive the boundary conditions at the interface of two dielectrics
7. Solve one dimensional Laplace equation to obtain the field inside a parallel plate capacitor and also find the expression for the surface charge density at two plates.
8. Derive an expression for electric field intensity E due to a uniformly charged infinitely long straight line with constant charge density in C/m.
9. Distinguish between a conductor and a dielectric. The electric field E in air above a block of paraffin (ρ_r =2.1) is at an angle of 45 with respect to plane surface of the block. Find the angle between E and the surface in the paraffin.
10. Obtain the expression for energy density in an electrostatic field.

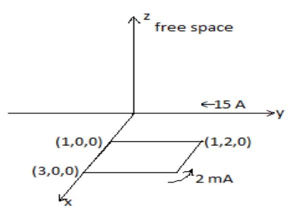
UNIT 3

PART-B

1. Derive an expression for magnetic field intensity due to a linear conductor of infinite length carrying current I at a distance point P. Assume R to be the distance between conductor and point P. Use Biot-Savart's law. (8)
2. Derive an expression for magnetic field intensity on the axis of a circular loop of radius $'a'$ carrying current I. (8)
3. Obtain the expressions for scalar and vector magnetic potential. (8)
4. At a point P(x, y, z) the components of vector magnetic potential $\bar{A}$ are given as A_x=4x+3y+2z, A_y=5x+6y+3z and A_z=2x+3y+5z. Determine the magnetic flux density $\bar{B}$ at the point P.

(4)

5. Given the magnetic flux density $\bar{B} = 2.5[\sin\frac{\pi x}{2}]e^{-2y}\,\bar{a}_z$ Wb/m^2, find the total magnetic flux crossing the strip defined by $z = 0, y \geq 0, 0 \leq x \leq 2m.$ (4)
6. Find the magnetic field intensity due to a finite wire of carrying a current I and hence deduce an expression for magnetic field intensity at the centre of a square loop. (8)
7. A circular loop located on $x^2 + y^2 = 4, z = 0$ carries a direct current of 7A along $\hat{a}_\phi$. Find the magnetic field intensity at (0, 0,-5). (4)
8. Using Ampere's circuital law determine the magnetic field intensity due to a infinite long wire carrying a current I. (4)
9. Find the force on a wire carrying a current of 2mA placed in the xy plane bounded by $x = 1, x = 3, y = 0$ and $y = 2$ as in the figure. The magnetic field is due to a long conductor, located in y-axis, carrying a current of 15A as shown. (8)



10. A differential current $Idz\,\hat{a}_z$ is located at the origin in free space. Obtain the expression for vector magnetic potential due to the current element and hence find the magnetic field intensity at the point $(\rho, \emptyset, z)$. (8)
11. Using Biot-Savart's law, derive the magnetic field intensity due to a co-axial cable carrying a steady current I. (8)
12. Derive an expression for a torque on a closed rectangular loop carrying current. (8)
13. In cylindrical co-ordinates $\bar{A} = 50\rho^2\bar{a}^2 Wb/m$ is a vector magnetic potential in a certain region of free space. Find the magnetic field intensity (H), magnetic flux density (B) and current density (J). (8)
14. The vector magnetic potential $\bar{A} = (3y - 3)\vec{a}_x + 2xy\vec{a}_y\, Wb/m$ in a certain region of free space.
    (1) Show that $\nabla.\vec{A} = 0$ (3)
    (2) Find the magnetic flux density $\vec{B}$ and the magnetic field intensity $\vec{H}$ at P (2,-1,3). (5)

15. State and explain Ampere's circuital law. (8)
16. Find an expression for $\overline{H}$ at any point due to a long straight conductor carrying I amperes. (8)
17. Find the maximum torque on an 85 turns rectangular coil with dimension (0.2 × 0.3) m carrying a current of 5 Amps in a field B=6.5T. (8)
18. Derive an expression for Magnetic vector potential. (8)

UNIT 4

1. Determine whether or not the following potential fields satisfy the Laplace's equation.
   (1) $V = x^2 - y^2 + z^2$ (2)
   (2) $V = rcos\emptyset + z$ (3)
   (3) $V = rcos\theta + \emptyset$ (3)
2. Solve the Laplace's equation for the potential field in the homogeneous region between the two concentric conducting spheres with radius $'a'$ and $'b'$ where $b > a$, V=0 and r=b and V=V_0 at $r = a$. Find the capacitance between the two concentric spheres. (8)
3. Derive the expression for the inductance of a toroid coil with N turns, carrying current I and the radius of the toroid R. (8)
4. Considering a toroidal coil, derive an expression for energy density. (8)
5. A metallic sphere of radius 10 cm has a surface charge density of 10 nC/m^2. Calculate the energy stored in the system. (4)
6. State and explain the electric boundary conditions between two dielectrics with permittivity's ε1 and ε_2. (8)
7. Derive the expression for continuity equation of current in differential form. (4)
8. Derive an expression for inductance of a solenoid with N turns and l metre length carrying a current of I amperes. (6)
9. An iron ring of relative permeability 100 is wound uniformly with two coils of 100 and 400 turns of wire. The cross section of the ring is 4cm^2. The mean of circumference is 50cm. Calculate
   (1) The self inductance of each of the two coils
   (2) The mutual inductance
   (3) Total inductance when the coils are connected in series with flux in the same sense
   (4) Total inductance when the coils are connected in series with flux in the opposite sense. (10)
10. Find the permeability of the material whose magnetic susceptibility is 49. (4)
11. The inner and outer conductors of a co-axial cable are having radii $'a'$ and $'b'$ respectively. If the inner conductor is carrying current 'I' and outer conductor is carrying the return current 'I' in

the opposite direction. Derive the expressions for (1) the internal inductance and (2) the external inductance. (12)

12. Write down the Poisson's and Laplace's equations. State their significance in electrostatic problems. (4)
13. Two parallel conducting plates are separated by distance'd' apart and filled with dielectric medium having 'ε_r' as relative permittivity. Using Laplace's equation, derive an expression for capacitance per unit length of parallel plate capacitor, if it is connected to a DC source supplying 'V' volts. (12)
14. A solenoid is 50cm long, 2cm in diameter and contains 1500 turns. The cylindrical core has a diameter of 2cm and a relative permeability of 75. This coil is co-axial with a second solenoid, also 50cm long, but 3cm diameter and 1200 turns. Calculate L for the inner solenoid and L for the outer solenoid. (8)
15. A parallel plate capacitor has an area of 0.8 m^2, separation of 0.1 mm with a dielectric for which ε_r=1000 and a field of 10^6 V/m. calculate C and V. (8)
16. Derive the boundary conditions at an interface between two magnetic medias. (8)

UVIT 5

PART-B

1. Electric flux density in a charge free region is given by $\bar{D} = 10X\,\hat{a}_x + 5y\hat{a}_y + kz^2\,\hat{a}_z\,\frac{\mu C}{m^2}$, find the constant k. (6)
2. If electric field intensity in free space is given by $\bar{E} = \frac{50}{\rho}\cos(10^8 - 10z)\hat{a}_\rho$ V/m. Find the magnetic field intensity $\bar{H}$. (10)
3. State and prove Poynting theorem. (8)
4. Derive the expression for total power flow in co-axial cable. (8)
5. Derive an expression for displacement current density J_d.. (6)
6. A rectangular loop of length $a = 1m$ and width b=80cm is placed in a uniform magnetic field. Calculate the maximum value of induced emf if the magnetic flux density B=0.1 Wb/m^2 is constant and the loop rotates with a frequency of 50Hz. (6)
7. Give the physical interpretation of Maxwell's First and Second equation. (4)
8. In free space, $\bar{E} = 50\cos(\omega t - \beta z)\,\bar{a}_z$ V/m. Find the average power crossing a circular area of radius 2.5m in the plane z=0. Assume $E_m = H_m\eta_0$ and $\eta_0 = 120\mp\pi\Omega$. (6)
9. Generalize Ampere's law for time varying fields. (8)
10. List the Maxwell's equations in integral and point form for free space conditions. (8)
11. Explain the following Poynting vector, average power and instantaneous power. (8)

12. In free space, H=0.2cos $(\omega t - \beta x) a_z$ A/m. Find the total power passing through a circular disc of radius 5cm. (8)
13. Derive modified form of Ampere's circuital law in Integral and Differential forms.(8)
14. Derive Maxwell's equation derived from Faraday's law both in Integral and Point forms. (8)
15. Find the amplitude of displacement current density inside a capacitor where ε_r=600 and $\bar{D} = 3 \times 10^{-6} \sin(6\times10^{6}t - 0.346x)\bar{a}_z$ **C/m²**. **(8)**

Reg. No. :

Question Paper Code : 80120

B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2019

Fourth Semester

Electronics and Communication Engineering

EC 8451 – ELECTROMAGNETIC FIELDS

(Common to Electronics and Telecommunication Engineering)

(Regulation 2017)

Time : Three hours Maximum : 100 marks

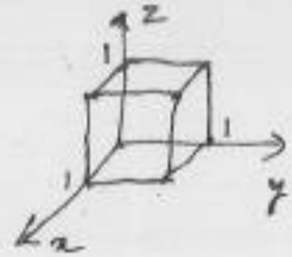
Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Write Stoke's theorem in integral form.
2. Define infinitesimal volume element in spherical polar coordinates.
3. Write coulomb's law.
4. Find the energy of a uniformly charged spherical shell of total charge q with a radius R.
5. Write Lorentz force equation.
6. Find the magnetic field a distance s from a long straight wire carrying a steady current I.
7. What is meant by displacement current?
8. Write electromagnetic boundary conditions.
9. What is meant by Brewster's angle?
10. Define phase velocity and group velocity.

PART B — (5 × 13 = 65 marks)

11. (a) Check the divergence theorem using the function $V = y^2\hat{i} + (2xy + z^2)\hat{j} + (2yz)\hat{k}$ and the unit cube situated at the origin.



Or

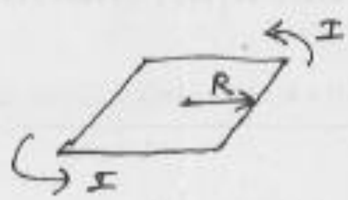
(b) Write the infinite simal displacement, surface and volume elements is spherical and cylindrical coordinates.

12. (a) Find the electric field a distance Z above the center of a square loop of side 'a' carrying uniform line charge λ.

Or

(b) Derive the expressions for the energy of a (i) point charge distribution (ii) continuous charge distributions.

13. (a) Find the magnetic field at the center of a square loop, which carries a steady current I. Let 'R' be the distance from center to side (fig.). Find the field at the center of an n-sided polygon, carrying a steady current I. Again, let R be the distance from the center to any side. Find the formula in the limit n (number of sides) tends to infinity.



Or

(b) Define (i) the mutual inductance between two circuits, and (ii) self inductance of a single coil. Also explain how the self inductance of a wire-wound inductor depends on its number of turns.

2 80120

14. (a) Write Maxwell's equations in differential form and integral form. Examine them and give its physical interpretation.

Or

(b) Derive wave equations for electric and magnetic fields.

15. (a) Derive Poynting theorem.

Or

(b) Analyse the wave reflection and transmission at normal incidence at the boundary between two linear media.

PART C — ($1 \times 15 = 15$ marks)

16. (a) A 1.8 KHz wave propagates in a medium characterized by $\mu_r = 1.6$, $\epsilon r = 25$ and conductivity $\sigma = 2.5$ s/m. The electric field intensity in the region is given by $\bar{E} = 0.1e^{-\alpha z}\cos(2\pi f t - \beta z)\,\hat{i}$ V/m. Determine the attenuation constant, propagation constant, intrinsic impedance, phase velocity, skin depth, and wave length of the wave.

Or

(b) Two grounded conducting planes $(y = 0$ and $x = 0)$ are intersecting at 90°. A charge of 100 nC is placed at (3, 4, 0). Find the electric potential and electric field intensity at (3, 5, 0).

Question Paper Code: 11285

B.E./B.Tech.Degree Examinations, April/May 2011
Regulations 2008

Fourth Semester

Electronics and Communication Engineering

EC 2253 Electromagnetic Fields

Time: Three Hours Maximum: 100 marks

Answer ALL Questions

Part A - (10 x 2 = 20 marks)

1. State Divergence theorem.
2. A point charge +2 nC is located at the origin. What is the value of potential at P (1, 0, 0) m?
3. State Ampere's circuital law.
4. A loop with magnetic dipole moment $8 \times 10^{-3}\, \hat{a}_z\ A.m^2$, lies in a uniform magnetic field $\overline{B} = 0.2\, \hat{a}_x + 0.4\, \hat{a}_z\ Wb/m^2$. Calculate the torque.
5. What do you understand from current continuity equation?
6. Draw the B-H curve for classifying Magnetic materials.
7. Give the situations, when the rate of change of flux results in a non-zero value.
8. Define complex poynting vector.
9. What is meant by skin effect? Mention its significance.
10. What is meant by polarization of a uniform plane wave?

Part B - (5 x 16 = 80 marks)

11. (a) (i) Find the total electric field at the origin due to 10^{-8} C charge located at P (0, 4, 4) m and a -0.5×10^{-8} C charge at P(4, 0, 2) m. (8)

(ii) Derive an expression for the electric field intensity at any point due to a uniformly charged sheet with density ρ_S C/m^2. (8)

OR

11. (b) (i) Point charges Q and $-Q$ are located at (0, 0, $d/2$) and (0, 0, $-d/2$). Show that the potential at a point (r, θ, ϕ) is inversely proportional to r^2, noting that $r \gg d$. (8)

(ii) Given a field $E = \frac{-6y}{x^2}a_x + \frac{6}{x}a_y + 5a_z$ V/m, find the potential difference V_{AB} between $A(-7, 2, 1)$ and $B(4, 1, 2)$. (8)

12. (a) (i) Using Biot-Savart's law, derive the magnetic field intensity on the axis of a circular loop carrying a steady current I. (8)

(ii) Using Ampere's circuital law, derive the magnetic field intensity due to a co-axial cable carrying a steady current I. (8)

OR

12. (b) (i) Derive an expression for a torque on a closed rectangular loop carrying current. (8)

(ii) In cylindrical co-ordinates, $\overline{A} = 50\rho^2\, \overline{a}_z$ Wb/m is a vector magnetic potential in a certain region of free space. Find the magnetic field intensity (H), magnetic flux density (B) and current density (J). (8)

13. (a) (i) Determine whether or not the following potential fields satisfy the Laplace's equation.

(1) $V = x^2 - y^2 + z^2$ (2)

(2) $V = r\cos\varphi + z$ (3)

(3) $V = r\cos\theta + \varphi$ (3)

(ii) Solve the Laplace's equation for the potential field in the homogenous region between the two concentric conducting spheres with radius 'a' and 'b' where $b > a$, $V = 0$ at $r = b$ and $V = V_0$ at $r = a$. Find the capacitance between the two concentric spheres. (8)

OR

13. (b) (i) Find the permeability of the material whose magnetic susceptibility is 49. (4)

(ii) The inner and outer conductors of a co-axial cable are having radii 'a' and 'b' respectively. If the inner conductor is carrying current 'I' and outer conductor is carrying the return current 'I' in the opposite direction. Derive the expressions for (1) the internal inductance and (2) the external inductance. (12)

14. (a) (i) Electric flux density in a charge free region is given by $\overline{D} = 10x\ \widehat{a}_x + 5y\ \widehat{a}_y + kz^2\ \widehat{a}_z\ \mu C/m^2$, find the constant k. (6)

(ii) If electric field intensity in free space is given by $\overline{E} = \frac{50}{\rho}\cos(10^8 t - 10z)\ \widehat{a}_\rho\ V/m$. Find the magnetic field intensity $\overline{H}$. (10)

OR

14. (b) (i) State and prove Poynting theorem. (8)

(ii) Derive the expression for total power flow in co-axial cable. (8)

15. (a) (i) From the Maxwell's equation, derive the electromagnetic wave equation in conducting medium for E and H fields. (10)

(ii) Calculate the attenuation constant and phase constant for the uniform plane wave with the frequency of 100 GHz in a conducting medium for which $\mu_r = 1$ and $\sigma = 58 \times 10^6$ S/m. (6)

OR

15. (b) (i) Explain different types of polarizations of uniform plane waves. (8)

(ii) $\overrightarrow{E}$ and $\overrightarrow{H}$ waves, traveling in free space, are normally incident on the interface with perfect dielectric with $\varepsilon_r = 3$. Compute the magnitudes of incident, reflected and transmitted $\overrightarrow{E}$ and $\overrightarrow{H}$ waves at the surface. (8)

B.E./B.Tech.Degree Examinations,Novomber/December 2010
Regulations 2008

Fourth Semester

Electronics and Communication Engineering

EC 2253 Electromagnetic Fields

Time: Three Hours Maximum: 100 Marks

Answer ALL Questions

Part A - (10 x 2 = 20 Marks)

1. Convert the given rectangular coordinate $A(x = 2, y = 3, z = 1)$ into the corresponding cylindrical coordinate.
2. What is an electric dipole? Write down the potential due to an electric dipole.
3. Write Lorentz's force equation for a moving charge.
4. Find the magnetic field intensity at a point $P(0.01, 0, 0)$ m, if the current through a co-axial cable is 6A, which is along the z axis and $a = 3$ mm, $b = 9$ mm and $c = 11$ mm.
5. State the difference between Poisson's equation and Laplace's equation.
6. Draw the B-H curve for classifying Magnetic materials.
7. Write down the Maxwell's equation derived from Faraday's law.
8. Write down instantaneous, average and complex poynting vectors.
9. Write the point form of four Maxwell's equations in the Phasor form.
10. What is meant by polarization of a uniform plane wave?

Part B - (5 x 16 = 80 Marks)

11. (a) (i) Find the electric field intensity at a point P located at $(0, 0, h)$ m due to charge of surface charge density σ C/m^2 uniformly distributed over the circular disc $r \leq a, z = 0$ m. (10)

(ii) Determine the divergence and curl of the given field $F = 30a_x + 2xya_y + 5xz^2a_z$ at $(1, 1, -0.2)$ and hence state the nature of the field. (6)

OR

11. (b) (i) Derive the expression for potential due to an electric dipole at any point P. Also find electric field intensity at the same point. (10)

(ii) Two point charges, 1.5 nC at (0, 0, 0.1) and −1.5 nC at (0, 0, −0.1), are in free space. Treat the two charges as a dipole at the origin and find potential at $P(0.3, 0, 0.4)$. (6)

12. (a) (i) Derive an expression for magnetic field intensity due to a linear conductor of infinite length carrying current I at a distant point P. Assume R to be the distance between conductor and point P. Use Biot Savart's law. (8)

(ii) Derive an expression for magnetic field intensity on the axis of a circular loop of radius 'a' carrying current I. (8)

OR

12. (b) (i) Obtain the expressions for scalar and vector magnetic potential. (8)

(ii) The vector magnetic potential $\overrightarrow{A} = (3y - 3)\overrightarrow{a}_x + 2xy\overrightarrow{a}_y$ Wb/m in a certain region of free space.

(1) Show that $\nabla \cdot \overrightarrow{A} = 0$ (3)

(2) Find the magnetic flux density $\overrightarrow{B}$ and the magnetic field intensity $\overrightarrow{H}$ at $P(2, -1, 3)$. (5)

13. (a) (i) Write down the Poisson's and Laplace's equations. State their significance in electrostatic problems. (4)

(ii) Two parallel conducting plates are separated by distance 'd' apart and filled with dielectric medium having 'ε_r' as relative permittivity. Using Laplace's equation, derive an expression for capacitance per unit length of parallel plate capacitor, if it is connected to a DC source supplying 'V' volts. (12)

OR

13. (b) (i) Derive the expression for inductance of a toroidal coil carrying current. (8)

(ii) A solenoid is 50 cm long, 2 cm in diameter and contains 1500 turns. The cylindrical core has a diameter of 2 cm and a relative permeability of 75. This coil is co-axial with a second solenoid, also 50 cm long, but 3 cm diameter and 1200 turns. Calculate L for the inner solenoid; and L for the outer solenoid. (8)

14. (a) (i) Generalise Ampere's law for time varying fields. (8)

(ii) List the Maxwell's equations in integral and point form for free space conditions. (8)

OR

14. (b) (i) Explain the following: Poynting vector, average power and instantaneous power. (8)

(ii) In free space, $H = 0.2\cos(\omega t - \beta x)a_z$ A/m. Find the total power passing through a circular disc of radius 5 cm. (8)

15. (a) (i) From the Maxwell's equation, derive the electromagnetic wave equation in conducting medium for E and H fields. (10)

(ii) The Electric fields associated with a plane wave traveling in a perfect dielectric medium is given by $E_x(z,t) = 10\cos[2\pi \times 10^7\ t - \ 0.1\pi\ x]$ V/m. Find the velocity of propagation, and intrinsic impedance. Assume $\mu = \mu_0$. (6)

OR