**UNIT-IV**

**ELECTRODYNAMIC FIELDS**

**PART-A**

**1. Find the emf induced in a conductor of length 1m moving with a velocity of 100 m/s perpendicular to a field of 1 Tesla. (May 2017)**

The magnitude induced e.m.f is given by e = Bℓv sinθ

As the field and direction of motion are perpendicular to each other, θ = 90°, sin 90° = 1

e = 1 × 1 × 100 = 100 V

**2. Differentiate transformer and motional emf. (May 2017)(May 2015)**

**Transformer e.m.f:** It is generated when stationary path is placed in time varying field .



**Motional e.m.f**: It is generated when a closed path is moved or revolved in a constant and time variant field 



**3. Moist soil has conductivity of 10-3 s/m and εr = 2.5, determine the displacement current density if  (Dec 2016)**

The conduction current density is given by

Jc = σ = 10-3 (6 × 10-6 sin 9 × 109 t) = 6 × 10-9 sin 9 × 109 t A/m2

The displacement current density is given by



= 

= 1.3281 × 10-19 × 9 × 109 cos 9 × 109 t A/m2

= 1.1953 × 10-9 cos 9 × 109 t A/m2

**4. State Faradays law. (Dec 2016) (May 2016)**

The electromotive force (e.m.f) induced in a closed path (or circuit) is proportional to rate of change of magnetic flux enclosed by the closed path (or linked with the circuit).

Faradays law can be stated as,



**5. What is meant by displacement current? (May 2016)**

The current that flows through dielectric is called displacement current. The displacement current is associated with the time varying electric fields. If always exists in all imperfect conductors which carry time varying conduction current.



**6. A parallel plate capacitor with plate area of 5 cm2 and plate separation of 3 mm has a voltage 50 sin 103t V applied to its plates. Calculate the displacement current assuming ε = 2ε0  (Dec 2016)**

The displacement current of a parallel plate capacitor is given by



= 2.9513 × 10-12 × 50 × 103 cos 103 t

= 0.1476 cos 103 t μA

**7. Compare equi-potential plots of uniform and non – uniform fields (May 2015)**

A uniform electric field is one whose magnitude and direction is same at all points in space and it will exert the same force on a charge regardless of the position of charge in space. It is represented by parallel and evenly spaced lines.

**8. Give two important equations that provide a connection between field and circuit theory. (Dec 2014)**

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The equations which connect field theory and circuit theory:

**f**

**9. State Neumann’s law**

When a magnetic field linked with a coil or circuit is changed in any manner, the emf induced in the circuit is proportional to the rate of change of flux linkage with the circuit.

**10. Static Lenz’s law.**

Lenz’s law states that the direction of the induced emf is such that it will oppose the change of flux producing it.

Note: Neumann’s law + Lenz’s law=Faradays law

**11. State Electro magnetic potential.**

It is well known from Maxwell’s eqn 



From vector identity 

 is the potential gradient for time varying fields.

**12. State Maxwell’s equation in integral and differential form.**

Integral form Differential form Name



**13. How does displacement current differ from conventional current? (May 2015)**

In electromagnetism, displacement current is a quantity appearing in Maxwell's equations that is defined in terms of the rate of change of electric displacement field. Displacement current has the units of electric current density, and it has an associated magnetic field just as actual currents do. On the other hand conduction current is the current in conductors due to flow of electron under applied electric potential.

**14. What is displacement current density?**

The term is known as displacement current density.

Based on the displacement current density, we define the displacement current as

**15. Define Electric Gauss law.**

It states that electric flux through any closed surface is equal to the charge enclosed by the surface.

**16. Define Magnetic Gauss law.**

According to the Gauss's law for the magneto-static field, the magnetic flux cannot reside in a closed surface due to the non existence of single magnetic pole. It states that the total magnetic flux through any closed surface is equal to zero.

**17. Explain why ?**

There are no isolated magnetic poles hence the net magnetic flux emerging through any closed surface is zero.

**18. Explain why ?**

In a free space there is no charge enclosed by the medium .The volume charge density is zero.

**19. Write down the Maxwell’s Equations for free space in point form and integral form.**

Free space is a non conducting medium in which volume charge density is zero and conductivity is also zero.

Maxwell’s Equations for free space in integral form

**20. Write Maxwell's equations for good conductors in point form and integral form.**

A good conductor will not have any charge and the conduction current is greater than displacement current

Maxwell's equations for good conductors in point form are:

Maxwell's equations for good conductors in integral form are:

**21. Write down the Maxwell’s Equations in point phasor form and integral phasor form.**

Maxwell’s Equations in point phasor form

Maxwell’s Equations in integral phasor form.

**22. Write the expression for the e.m.f. induced in the moving loop in static field.**

The e.m.f induced in the moving loop in a static field is given by

**23. Write the expression for the transformer e.m.f.**

This emf is induced in a stationary conducting loop in a time varying magnetic field.

**24. Write the emf equation a moving conducting loop is in a time varying field.**

In this case the magnetic field is changing as well as the conduction loop is moving. Then by applying superposition for transformer and motional emf,

**25. State Ohm’s law for magnetic circuits. (Dec 2014)**

Ohm’s law for magnetic circuit is defined as J = σ E. states that the conduction current density is equal to the product of conductivity and Electric field intensity.

**PART-B**

**1. Derive the expressions for induced Emf for time varying fields. (or) Give the expressions for transformer and motional emf.**

According to Faraday’s law, Emf can be induced in either of the three ways.

1. Stationary loop in time varying magnetic field  (Transformer emf)



Further, 

Equating (a) and (b) Faraday’s law in integral form

Applying stokes’s theorem to left part of above equation.



If the circuit is stationary and is time varying then the above equation is



Faraday’s law in differential form in time varying fields 

(b) Moving loop is stationary magnetic field  (Motional EMF)

Force on a moving charge in stationary magnetic field is 

Therefore motional emf 



Applying stokes’s theorem on both sides 



1. Moving loop in time varying field  (transformer + motional emf).



**2. Explain about displacement current (or) inconsistency in Ampere’s law for time varying field (α) Modified Ampere’s law.**

According to Ampere’s critical law in differential form 

Taking divergence 

But the divergence of curl = 0 (vector identity)



However, according to equation of continuity of current we have



Therefore we can see that Ampere’s law is not consistent for time varying fields. Therefore the modification is done as given below

Let  where  is to be determined and defined.

 (From Gauss’s law for time varying  and 



‘Jd’ know as displacement current density, ‘J’ is conduction current density.



This is the modified Ampere’s law in point form.

 is the modified Ampere’s law in integral form.

**3. Derive Maxwell’s equation for time varying fields. (or) Derive the Maxwell’s equation in both point and integral forms from Ampere’s law and Faraday’s law of electro magnetic induction (May 2017) (Dec 2016, 2014) (May 2016, 2015)**

**I. Maxwell’s equation from Modified Ampere’s law**

It is well known from ampere’s law 



 is the conduction current density and is the displacement current density.

To derive Jc: It is well known that V=IR (ohm’s law in circuit theory)

 where σ is conductivity.





This is the ohm’s law for field theory in point form.

Similarly, to derive Jd: Let

 



Also Displacement current density 



Maxwell’s (I) equation integral form

Applying Stoke’s theorem 

Maxwell’s (I) equation in Differential or point form.

**(II) – Maxwell’s equation from Farday’s law**

According to faraday’s law 

also Maxwell’s (II) equation integral form.

Applying Stoke’s theorem 

Maxwell’s (II) equation in differential or point form.

**(III) Maxwell’s equation from Gauss’s law**

Gauss’s law states that the total electric flux flowing out of a closed surface enclosing a volume is equal to the total charge within the volume

 Maxwell’s III equation in integral form.

Applying divergence theorem

 Maxwell’s III equation in Differential or point form.

**(IV) Maxwell’s equation from Gauss’s law for magnetostatics**

It is well known that, 

If the surface is enclosed then There is no existence of magnetic monopole.

 Maxwell’s IV equation in integral form

Applying divergence theorem  Maxwell’s IV equation inn differential or point form.

To summarize

Integral form Differential form Name



**4. Give the Maxwell’s equation for time Harmonic fields.**

To transform the instantaneous Maxwell’s equation into time harmonic forms, we replace all sources and field quantities by their phasor equivalents and replace all time-derivatives of quantities with ‘jω’time the phasor equivalent . i.e

Time harmonic fields are those fields that vary sinusoidally with time



Harmonic equation for time harmonic fields.

Integral form Differential form Name



**5. An infinite straight wire carries a current ‘I’ is placed to the left of a rectangular loop of wire with width ‘ω’ and length ‘l’ as shown in fig.**

**(a) Determine the magnetic flux through the rectangular loop due to the current I.**

**D:\EMT\Unit4\Link\Fig4.1.eps(b) Suppose that the current in a function of time with I(t) = a+bt, where ‘a’ and ‘b’ are positive constants. What is the induced emf in the loop and the direction of the induced current.**

(a) using Ampere’s law 



By lenz’s law, the induced current in the loop must be flowing counter clockwise in order to produce a magnetic field out of the page to counter act the increase in inward flux.

**6. The circular loop conductor having radius of 0.15m is placed in the xy plane. The loop consists of a resistence of 20Ω as shown in fig. If the magnetic flux density . Find the current flowing through the loop.**

D:\EMT\Unit4\Link\Fig4.2.epsIt is well known that





**D:\EMT\Unit4\Link\Fig4.3.eps7. Derive the expression for voltage developed in a faraday’s disc generator.**

A faraday’s disc generator is a homopolar DC electrical generator which consists of an electrically conductive disc made of magnetic material (flywheel) rotating in a uniform magnetic field with one electrical contact near the axis and the other near the periphery.

Let ω → angular velocity of the disc (rod/s)



→ uniform Magnetic field (T), a→radius of the disc (m)

At a distance ‘ρ’ m in the disc, consider a radial element, which has a velocity



**8. A copper disc, 0.5m in diameter, is rotated at a constant speed of 2000rpm on a horizontal axis perpendicular to and through the center of the disc, the axis lying in the magnetic meridian. Two brushes make contact with the disc, one at the edge and other at the center. If the horizontal component of the earth’s field B is 0.2 gauss (0.02mT), Calculate the emf induced between the brushes.**



**9. A conductor of length100cm moves at right angles to a a uniform field of strength 10,000 lines/m2 with a velocity of 50m/s. Calculate the emf induced in it. Find also the value of induced emf when the conductor moves at an angle of 30° to the direction of the field.**

Length of the conductor =100x10-2m, 1ωb/m2 = 104 times/m2 or gauss

Velocity v = 50m/s.

B=10,000 lines/m2 = 1ωb/m2=1(T)



**10. A circular cross section of radius 2mm carries a current ic=2.5 s in (5x108)t μA. What is the amplitude of the displacement current density if σ= 35 MS /in and εr=1 ?**

It is well known that,



If 

Amplitude of 



Also it is known,



**11. The conduction current flowing through a wire with conductivity σ=3x107 s/m and relative permittivity εr=1 is given by Ic=3 sinωt(mA) . If ω=108 rad/s, find the displacement current.**

It is well known that







**12. A poor conductor is characterized by a conductivity σ=100(s/m) and permittivity ε=4ε0. At what angular frequency ‘ω’ is the amplitude of the conduction current density Jc­ equal to the amplitude of displacement current density Jd.**

It is well known,



**13. State and prove the boundary condition using Maxwell’s equation.**

Boundary conditions

1. D:\EMT\Unit4\Link\Fig4.4a.epsE1t = E2t → tangential component of electric field is continuous.
2. H1t = E2t → tangential component of Magnetic field is continuous.
3. D1n = D2n → Normal component of Electric flux density is continuous.
4. B1n = B2n → Normal component of Magnetic flux density is continuous.

Using Maxwell’s II equation in fig (a) i.e. 

at the interface Δh =0 

Using Maxwell’s I equation in fig. (a)

i.e., 

For abcda,

D:\EMT\Unit4\Link\Fig4.4b.eps

Using Maxwell’s III equation in fig (b), i.e.



Using Maxwell’s IV equation in fig (b)



**14. An AC voltage source  is connected across a parallel plate capacitor C. Verify that the displacement current in the capacitor is same as the conduction current in the wires.**

Let the conduction current,



**15. A parallel plate capacitor with plate area of 5cm2 and plate seperation of 3mm has a voltage of 50 sin 103t V applied to its plates. Calculate the displacement current assuming ε = 2 ε0 (Dec 2014)**

The displacement current density is given by







**16. The magnetic circuit of an iron ring with mean radius of 10cm has a uniform cross section of 10-3m2. The ring is wand with two coils. If the circuit is energized by a current G(t) = 3 sin 100πt A in the first coil with 200 turns, find the induced emf in the second coil with 100 turns. Assume that µ = 500 µ0. (Dec 2014)**

For toroid 1:





Assuming K =1



Here emf induced in Coil 2 is



**17. Explain law the circuit equation for a given RLC circuit is derived from the field relation. (Dec 2014) (May 2016) (May 2017)**

In general, total electric field related to the emfs. (Ee) and the electric field due to charge and currents ()



Now the total electric field is the ratio of current density of the conductivity ie.,



Also, we can write, using general field relation for the varying fields



Substituting equation (2) and (3) in equation (1) we get



Let us consider as circuit consisting relation inductive and capacitor driven by a generator Vg as shown in fig its equivalent representation is an shown in fig.

E:\new\Question bank odd sem\EMT\Fig.4.1.eps

Integrating all the term in equation around circuit in clockwise direction we get.



Now the integration of LHS terms is generated voltage Vg, so we can write



Now consider the last term,



Hence equation becomes



Now,



**18. Compare in detail conduction and displacement currents. (Dec 2015) (May 2015)**

For the static electromagnetic field according to Amperes circuit law, we can write



Taking divergence on both the sides



But according to vector identity, divergence of the curl of any vector field is zero, Hence we write,



But equation of conductivity is given by



For equation it is clear that when, , then only equation becomes true. Thus equation (1) and (2) are not compatible for time varying fields. We must modify equation by adding one unknown term say Jd.



Again taking divergence on both sides



 To get correct conditions we must write



Burt according to Gauss law



Thus the replacing ev by 



Comparing two sides of equation



Now we write Amperes circuit law is point terms as



The first term in equation is conduction current density denoted by Jc. The current is due to the moving charges. The second term in equation represents current density expressed in ampere per square meter. As this quantity is obtained from the varying electric flux density, this is also called Displacement density. The displacement current density is denoted by JD.



**19. A circular loop of wire is placed in a uniform magnetic field of flux density 0.5 wb/m2. The wire has 200 turn and frequency of rotation of 1000 rev/min. If the radius of the coil of 0.2m, determine (1) the induced emf, when the plane of the coil is 60° to the flux lines and 2) the induced emf, when the plane of the coil is perpendicular to the field.**

The velocity of circular loop is given by



i) Now the angle made by plane of coil to the flux line is 60° ie., θ = 60. Hence induced emf is given by



ii) When plane of coil is perpendicular to flux they θ = 90.



**20. In a material for which σ= 5.0 S/m and εr = 1 with E = 250 sin 1010t V/m. Find the JC and JD and also the frequency at which they are equal in magnitude. (Dec 2016)**

The conduction current density is given by



The displacement current density is given by



For the two densities, the condition for magnitudes to be equal is,



But ω = 2πf



**21. A circular loop conductor having a radius of 0.15m is placed in x – y plane. This loop consists of a resistance of 20Ω, If the magnetic flux density is B = 0.5 sin 103t az Tesla. Find the current through the loop.**

Given: r = 0.15m, 

A conducting loop is in z = 0 plane and  is in z – direction which is perpendicular the loop. Hence  is perpendicular to the loop.



Now the emf induced is given by



The current through the loop

