

Name \_\_\_\_\_

**Electromagnetic Fields**  
**Ph.D. Qualifying Examination**  
**Sample Test Paper**

**Time - 3 hours**

**August xx,xxxx**  
**Maximum Points - 160**

1. (a) (i) Are unit vectors  $\bar{a}_r, \bar{a}_\theta$  and  $\bar{a}_\phi$  constants?  
(ii) Write the vector component of vector  $\bar{A}$  in the direction of vector  $\bar{B}$ .  
(iii) Are flux lines normal to  $\bar{E}$  field?  
(iv) What is the value of  $\bar{E}$  at a point in between two infinite charge sheets with uniform charge density  $+\rho_s C/m^2$  on each of them?  
(v) What is the direction of  $\bar{E}$  field due to an infinite line charge?  
(10 pts)
- (b) An electric field intensity is given as:  
$$\bar{E} = \frac{100 \cos \theta}{r^3} \bar{a}_r + \frac{50 \sin \theta}{r^3} \bar{a}_\theta$$
  
At the point whose spherical coordinates are  $r = 2, \theta = 60^\circ, \phi = 20^\circ$ , find a unit vector in rectangular coordinates in the direction of  $\bar{E}$ .  
(10 pts)
2. (a) (i) What is the difference between flux density  $\bar{D}$  and charge density  $\rho_s$  on a surface?  
(ii) What is the differential form of Gauss's law?  
(iii) What is difference between electric flux lines and magnetic flux lines?  
(iv) Is divergence theorem true for any vector?  
(v) What is the difference between Gauss's law and Faraday's experiment?  
(10 pts)
- (b) Inside the sphere  $r \leq 5m$ , the electric flux density is given by  $\bar{D} = 4r^2 \bar{a}_r C/m^2$ .  
What is the volume charge density at  $r = 2$  and how much electric flux leaves the sphere  $r = 2$ ?  
(10 pts)
3. (a) (i) Can energy be exchanged from a point charge to an electric field?  
(ii) Is  $\bar{E}$  a conservative field when  $\oint \bar{E} \cdot d\bar{L} \neq 0$ ?  
(iii) How much energy is required to bring two point charges from infinity to the empty universe?  
(iv) What is the work done in carrying a positive charge Q about a circular path from  $a$  to  $b$  in the field of an infinite line charge normal to the path?  
(v) Where is the reference point for potential in a coaxial cable?  
(10 pts)
- (b) A circular disk,  $\rho \leq 1 \text{ cm}, z = 0$  carries a surface charge density  $\rho_s = \frac{1}{\rho} nC/m^2$ . Find V at P(0,0,z) if V = 0 at infinity.  
(10 pts)

4. (a) (i) What is  $(\epsilon_0 \bar{E} + \bar{P})$  equal to in a dielectric?  
(ii) What is the value of  $\int \bar{E} \cdot d\bar{L}$  for two points on the surface of a conductor?  
(iii) What boundary state between two dielectric results in  $D_{n_1} - D_{n_2} \neq 0$ ?  
(iv) What is the value of  $\bar{E}$  inside a conductor?  
(v) What is the important assumption made in the analysis of a capacitor using the concept of uniform charge distribution on the plates?  
(10 pts)
- (b) Two conducting spherical shells have radii  $a = 2\text{cm}$  and  $b = 5\text{cm}$ . The interior is a perfect dielectric for which  $\epsilon_R = 10$ . Find C and E at a point between them if  $V_0$  is the potential differential between them.  
(10 pts)
5. (a) (i) What law in steady magnetic fields is parallel to Coulomb's law in electrostatic?  
(ii) What condition must be imposed for  $V_m$  to be a single valued function of position?  
(iii) What is the direction of vector magnetic potential  $\bar{A}$  with respect to current flow?  
(iv) What is the value of  $\bar{H}$  at any point in the region between two current sheets with  $\bar{K} = K_y \bar{a}_y$  on each?  
(v) Why is  $\oint_s \bar{B} \cdot d\bar{s} = 0$ ?  
(10 pts)
- (b) Find  $\bar{H}$  at  $z = 3.11\text{m}$  due to 10 current sheets at  $z = -4.5, -3.5, \dots, 3.5, 4.5$  and each sheet carrying a current  $\bar{K} = 100\bar{a}_y \text{ A/m}$ .  
(10 pts)
6. (a) (i) What is the boundary condition for tangential components of magnetic fields at the boundary of two different media?  
(ii) What is the force on a filamentary closed loop carrying current  $I$  and placed in a uniform magnetic field  $\bar{B}$ ?  
(iii) What is the effect of the torque produced when a current loop is placed in a magnetic field?  
(iv) Modify the relationship  $\bar{B} = \mu_0 \bar{H}$  for a magnetic material.  
(v) How do we define a magnetic dipole?  
(10 pts)
- (b) A current filament carrying 8A in the  $\bar{a}_z$  direction lies along the entire z-axis in free space. A rectangular loop connecting A (0, 0.2, 0) to B(0,0.2,0.3) to C(0, 0.7, 0.3) to D(0, 0.7, 0) to A lies in the  $X = 0$  plane. The loop current is 3 mA and it flows in the  $\bar{a}_z$  direction in the AB segment. Find  $\bar{F}$  on side DA.  
(10 pts)
7. (a) (i) What is Ampere's circuital law for time varying magnetic fields?  
(ii) What are different ways to create a time varying magnetic field?  
(iii) How does displacement current differ from conduction current?  
(iv) Can a time varying electric field produce magnetic field?

- (v) What is the angle between **E** and **H** fields in the plane wave propagation? (10 pts)
- (b) A voltage source  $V_0 \sin \omega t$  is connected between two concentric conducting spheres,  $r = a$  and  $r = b$ ,  $b > a$ , where the region between them is a material for which  $\epsilon = \epsilon_0 \epsilon_R$ ,  $\mu = \mu_0$  and  $\sigma = 0$ . Find the total displacement current through the dielectric. (10 pts)
8. (a) (i) What is the meaning of characteristic impedance of a line?  
(ii) How do you compare the resonant circuits with open and short transmission lines?  
(iii) What is the actual mode of propagation in a microstrip line and why?  
(iv) What is the meaning of subscripts m, n for  $TE_{m,n}$  mode in a rectangular waveguide?  
(v) Where do you read VSWR on a Smith Chart? (10 pts)
- (b) A 50 MHz uniform plane wave is normally incident from air onto the surface of a calm ocean. For seawater  $\sigma = 4 \text{ S/m}$  and  $\epsilon_r = 78$ . Determine the fractions of incident power that are transmitted and reflected. (10 pts)