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EE251 Electromagnetics I EXAM 2 : April 20, 2016

Answer the following questions by ticking the right answer(s) and note that for each question, a wrong answer will cancel the right one.

1. Three point charges 30 nC, -20 nC and 10 nC are located at (-1, 0, 2), (0, 0, 0) and (1, 5, -1) respectively. Then the total electric flux leaving a cube of 6 m side which is centered at the origin is:
   - o -20 nC
   - o 10 nC
   - o 20 nC
   - o 30 nC
   - o None of the above

2. By saying that the electrostatic field is conservative, we do mean:
   - o It is the gradient of a scalar function.
   - o Its circulation is identically zero.
   - o Its curl is identically zero.
   - o The work done in a closed path inside the field is zero.
   - o The potential difference between any two points is zero.

3. A potential field is given by $V(x, y, z) = 3x^2y - yz$ Volts. Which of the following is not true:
   - o At point (1, 0, 1), V and E vanish.
   - o $x^2y = 1$ is an equipotential line on the xy-plane.
   - o The equipotential surface V= -8 Volts passes through the point P(2,-1,4).
   - o The electric field at point P is $12\,\mathbf{a}_x + 8\,\mathbf{a}_y + \mathbf{a}_z$ V/m.
   - o A unit normal to the surface V = -1 V at point (0,-1,1) is $-0.707\mathbf{a}_y$ $-0.707\mathbf{a}_z$.

4. A parallel plate capacitor connected to a battery stores twice as much charge with a given dielectric as it does with air as dielectric, the relative permittivity of this given dielectric is:
   - o 0
   - o 1
   - o 2
   - o 3
   - o 4

5. A potential difference V_o is applied to a mercury column in a cylindrical container. The mercury is now poured into another cylindrical container of half of the radius and the same potential difference V_o applied across the ends. As a result of this change of space, the resistance will be
   - o the same
   - o increased by 8 times
   - o increased by 2 times
   - o increased by 4 times
   - o increased by 16 times

6. Two conducting plates are placed perpendicular to each other with a point charge between them. The number of image charges are:

- o 5
- o 3 → my Answer
- o 4
- o 1
- o 2

7. Which of the following is a source of magneto static fields:

- o A DC current in a long wire
- o A long copper rod.
- o An accelerated charge
- o A static charge
- o A DC current in a rectangular loop.

my Answers

8. The direction along which a DC current I flow in a wire and the resulting magnetic field **H** are:

- o Related to each other according to the left hand rule
- o Parallel to each other
- o No relations between them
- o Related to each other according to the right hand rule
- o None of the above

9. Which of the following statements does characterize the static magnetic field:

- o It is solenoid
- o It is conservative
- o It start from a point and ends at the same point
- o Magnetic flux lines are always closed
- o The total number of magnetic flux lines entering are not equal to the total number of flux lines leaving a region.

10 Two thin parallel wires carry currents along the same direction. The force experienced by one due to the other is

- o Perpendicular to the lines and repulsive
- o Zero
- o Parallel to the lines
- o Perpendicular to the lines and attractive
- o Rotational

11. A 1000 turns coil (good conducting wire) whose radius is 5 mm If the coil carries a current of 15 mA, then the magnetic field at the center of this coil is

- o 1500 A/m
- o 50π mA/m
- o 150 A/m.
- o 15 A/m
- o None of the above

$N = 1000$

$H = \frac{nI}{2}(\cos\theta_2 - \cos\theta_1)$ $r = .005$ m

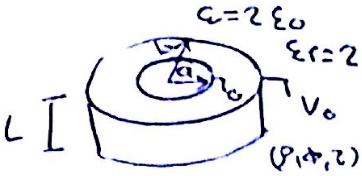
$I = 10$ mA

5000(

I can't determine without the length of the wire

12. A coaxial cable whose specifications are given by: Inner (solid) and outer conductors are made out of good conductor with radii = a and b, respectively. The medium between the two conductors is a composite material whose $\varepsilon = 2\varepsilon_0$ and $\mu = \mu_0$. Then derive :

(i) The capacitance of this cable per unit length **[5 PTS]**.



$C = \frac{Q}{V}$ | assume $V(\rho = a) = 0$, $V(\rho = b) = V_0$ $\quad V \to E \to \int D \cdot ds$

$\nabla^2 V = 0$

$\frac{d^2 V}{d\rho^2} = 0$

$\frac{1}{\rho}\frac{d}{d\rho}\left(\rho \frac{dV}{d\rho}\right) = 0$

$\frac{dV}{d\rho} = \frac{A}{\rho}$

$V = A\ln\rho + B$

$V = A(\ln\rho - \ln a)$

$V(\rho = a) = 0$

$0 = A\ln a + B$

$B = -A\ln a$

$V(\rho = b) = V_0$

$V_0 = A\ln b - A\ln a$

$V_0 = A\ln\left(\frac{b}{a}\right)$

$E = -\nabla V$

$= -\frac{dV}{d\rho}\vec{a}_\rho$

$\vec{E} = -\frac{A}{\rho}\vec{a}_\rho$

$ds = -\rho\, dz\, d\phi\, \vec{a}_\rho$

$Q = \int \varepsilon \vec{E} \cdot ds$

$= \int_0^{2\pi}\int_0^{L} +\frac{2\varepsilon_0 A}{\rho}\vec{a}_\rho \cdot \rho\, dz\, d\phi\, \vec{a}_\rho$

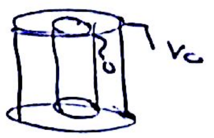
$Q = +4\pi\varepsilon_0 A L$

$C = \frac{Q}{V}$

$= \frac{+4\pi\varepsilon_0 A L}{A\ln\frac{b}{a}}$

$\frac{C}{L} = \frac{4\pi\varepsilon_0}{\ln\frac{b}{a}}$ F/m

(ii) The leakage resistance for this cable per unit length, assuming that the conductivity of the composite material = σ_d Ω^{-1}/m **[5 PTS]**.



$V(\rho = b) = V_0$

$V(\rho = a) = 0$

$\frac{R}{L}$? $R = \frac{V}{I}$

$\nabla^2 V = 0$

$\frac{1}{\rho}\frac{d}{d\rho}\left(\frac{\rho\, dV}{d\rho}\right) = 0$

$V = A\ln\rho + B$

$V = A(\ln\rho - \ln a)$

$V_0 = A\ln\frac{b}{a}$

$E = -\nabla V$

$= -\frac{dV}{d\rho}\vec{a}_\rho$

$\vec{E} = -\frac{A}{\rho}\vec{a}_\rho$

$I = \int_s J \cdot ds$

$J = \sigma_d E$

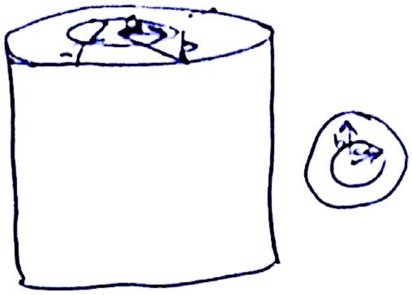
$I = \int_0^{2\pi}\int_0^{L} +\frac{A}{\rho}\sigma_d\, \rho\, dz\, d\phi \quad ds = -\rho\, dz\, d\phi\, \vec{a}_\rho$

$I = 2\pi A \sigma_d L$

$R = \frac{A\ln\frac{b}{a}}{2\pi A\sigma_d L}$

$\frac{R}{L} = \frac{\ln\frac{b}{a}}{2\pi\sigma_d}$ Ω/m

(iii) Find the magnetic flux density, everywhere, for this cable; assuming that the inner conductor current = I A and the outer conductor are carrying the same current in opposite direction. [6 PTS]



$\vec{B} = \mu_0 \vec{H}$ $\qquad \oint H \cdot dl = I_{enc}$

[1] $r < a$

$\oint H \cdot dl = I_{enc} = \int J \cdot ds$

$J = \frac{I}{\pi a^2} \vec{a}_z$, $ds = \rho \, d\rho \, d\phi \, a_z$

$\oint H \cdot dl = \frac{I}{\pi a^2} \int_0^{2\pi} \int_0^{\rho} \rho \, d\rho \, d\phi$

$H_\phi \cdot 2\pi\rho = \frac{2\pi}{2\pi a^2} \cdot \rho^2$

$H_\phi = \frac{\rho}{2\pi a^2} \vec{a}_\phi$

$$\vec{B} = \frac{\mu_0 \rho}{2\pi a^2} \vec{a}_\phi$$

wb/m

[2] $a < r < b$

$\oint H \cdot dl = I_{enc}$

$I_{enc} = I + \int J \cdot ds$

$J = \frac{-I}{\pi(b^2 - a^2)}$

$= I + \int_0^{2\pi} \int_a^{\rho} \frac{-I}{\pi(b^2-a^2)} \rho \, d\rho \, d\phi$

$= I - \frac{2I}{a^2} \int_a^{\rho} \rho \, d\rho$

$I_{enc} = I\left(1 - \frac{(\rho^2 - a^2)}{(b^2 - a^2)}\right)$

$\oint H \cdot dl = I\left(1 - \frac{\rho^2 - a^2}{b^2 - a^2}\right)$

$H \cdot 2\pi\rho \vec{a}_\phi = I\left(1 - \frac{\rho^2 - a^2}{b^2 - a^2}\right)$

$$\vec{B} = \frac{\mu_0 I}{2\pi\rho}\left(1 - \frac{\rho^2 - a^2}{b^2 - a^2}\right) \vec{a}_\phi$$

wb/m

[3] $b < r$

$\oint H \cdot dl = I_{enc}$

$I_{enc} = I - I = 0$

$\vec{H} = 0$

$\vec{B} = \mu_0 H$

$\vec{B} = \text{zero}$

-2

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6 1 ==19 1 ==19 18== 1

1		X				1			x			1		x			
2	X	X	X	X		2	x		x	x		2			x	x	x
3	X			X	X	3	x				x	3	x				x
4			X			4			x			4					x
5					X	5				x		5				x	
6		X				6			x			6					x
7	X				X	7	x	x			x	7	x			x	x
8				x		8			x	x		8		x		x	
9	X		X	x		9		x	x	x		9	x			x	
10				x		10					x	10		x			
11	x					11					x	11			x		

11. A coaxial cable whose specifications are given by: Inner (solid) and outer conductors are made out of good conductor with radii = a and b, respectively. The medium between the two conductors is a composite material whose $\varepsilon = 2\varepsilon_0$ and $\mu = \mu_0$ Then derive: The capacitance of this cable per unit length **[5 PTS]**.

$$Q_{enc} = \oint_S \mathbf{D}\cdot d\mathbf{S} = \varepsilon\oint_S \mathbf{E}\cdot d\mathbf{S} = \varepsilon E_\rho 2\pi\rho L \Rightarrow \mathbf{E} = \frac{Q}{2\pi 2\varepsilon_o \rho L}\mathbf{a}_\rho \text{ V/m}$$

$$V = -\int_l \mathbf{E}\cdot d\mathbf{l} \Rightarrow V = -\int_b^a \frac{Q}{2\pi 2\varepsilon_o \rho L}\mathbf{a}_\rho \cdot d\rho\,\mathbf{a}_\rho = \frac{Q}{2\pi 2\varepsilon_o L}\ln\left(\frac{b}{a}\right)$$

$$C = \frac{Q}{V} = \frac{4\pi\varepsilon_o L}{\ln\left(\frac{b}{a}\right)} \Rightarrow \frac{C}{L} = \frac{Q}{V} = \frac{4\pi\varepsilon_o}{\ln\left(\frac{b}{a}\right)} \text{ F/m}$$

The leakage resistance for this cable per unit length, assuming that the conductivity of the composite material = σ_d Ω^{-1}/m **[5 PTS]**.

R= $\int_a^b \frac{d\rho}{2\pi\, l\, \rho\sigma_d}\ \Omega$ ⇉⇉ and the leakage resistance per unit length $R = \frac{\ln\left(\frac{b}{a}\right)}{2\pi\sigma_d}\ \Omega/\text{m}$

Find the magnetic flux density, everywhere, for this cable; assuming that the inner conductor current = I A and the outer conductor are carrying the same current in opposite direction. **[6 PTS]**

$0 < \rho < a$:

$$\oint_l \mathbf{H}\cdot d\mathbf{l} = I_{enc} = \int_s \mathbf{J}\cdot d\mathbf{S} = \int_0^{2\pi}\int_0^{\rho} \frac{I}{\pi a^2}\rho\, d\rho\, d\phi = \frac{I}{\pi a^2}\pi\rho^2$$

$$H_\phi 2\pi\rho = \frac{I\rho^2}{a^2} \Rightarrow \mathbf{H} = \frac{I\rho}{2\pi a^2}\mathbf{a}_\phi A/m \Rightarrow \mathbf{B} = \frac{\mu_o I\rho}{2\pi a^2}\mathbf{a}_\phi \text{ T}$$

$a < \rho < b$:

$$\oint_l \mathbf{H}\cdot d\mathbf{l} = I_{enc} = I \Rightarrow H_\phi 2\pi\rho = I \Rightarrow \mathbf{H} = \frac{I}{2\pi\rho}\mathbf{a}_\phi A/m \Rightarrow \mathbf{B} = \frac{\mu_o I}{2\pi\rho}\mathbf{a}_\phi \text{ T}$$

$\rho < b$:

$$\oint_l \mathbf{H}\cdot d\mathbf{l} = I_{enc} = I - I = 0 \Rightarrow \mathbf{H} = 0 = \mathbf{B}$$