Student Name : answer Key

Student I.D

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Course Name	Electromagnetic Fields and Waves II	**Course Code**	: PHYS 380
Exam	: Exam-2	**Sections**	: A
Date	: 14/12/2017	**Time**	: 11:00 – 12:15
Semester	:Fall	**Year**	: 2017-2018
Instructor	:Diana Kaeen	**Exam Weight**	:25%
Auditorium	:	**Campus**	: Saida

Instructions

- Time allowed: **75 minutes**
- Cheating in any way will result in **F** grade
- Read each question carefully before answering
- Answer questions that you are confident about it first
- This exam consists of **7pages** including this page

Problem #	Grade
Problem 1	/25
Problem 2	/20
Problem 3	/25
Problem 4	/30
Total	

Problem - 1 (25 points) **Magnetic Materials**

(a) How can we distinguish between paramagnetic, diamagnetic and ferromagnetic materials?

(b) Define magnetic domains and hysteresis loop.

Problem-2 (20 points) **Magnetized Sphere**

A sphere of radius R carries a uniform magnetization $\vec{M}$ parallel to its axis.

(a) Determine the bound currents and magnetic field $\vec{B_0}$ due to $\vec{M}$ inside the sphere.

(b)A small spherical cavity is hollowed out of the material. Knowing that $H_0 = \frac{1}{\mu_0} B_0 - M$, find:

(i) The field at center of cavity in terms of B_0 and M.

(ii)The auxiliary field $\vec{H}$ at the center of cavity in terms of H_0 and M.

(a) $\vec{J_b} = \vec{\nabla} \times \vec{M} = 0$ 3

$\vec{K_b} = \vec{M} \times \vec{n} = M \sin\theta \, \hat{\phi}$ 4

$\vec{K} = \sigma \vec{v} = \sigma \vec{\omega} \times \vec{r}$

$= \sigma \omega \hat{z} \times \vec{r} \Rightarrow K = \sigma \omega r \hat{\phi}$

$= \sigma \omega R \sin\theta \, \hat{\phi}$

$\sigma \omega = \frac{M}{R}$

(b)(i) $\vec{B} = \frac{2}{3} \mu_0 \vec{M}$

$\vec{M}_{cut} = \vec{M} = M \hat{z}$

$\vec{K} = \vec{M}_{cut} \times \hat{n}$

$= M \hat{z} \times \hat{n} = M \frac{\vec{z} \times \vec{r}}{R}$ 4

$\rightarrow B = \frac{2}{3} \mu_0 \sigma R \omega \hat{z}$

$= \frac{2}{3} \mu_0 R \left(\frac{M}{R} \right) \hat{z}$

$= \frac{2}{3} \mu_0 M \hat{z}$

$\rightarrow \vec{B}_{after\ cut} = \vec{B_0} - \vec{B}_{cut}$ 4

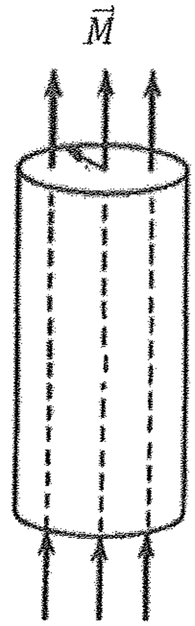
$= \vec{B_0} - \frac{2}{3} \mu_0 \vec{M}$

(ii) $\vec{H}_{a.c} = \frac{\vec{B}_{a.c}}{\mu_0} = \frac{\vec{B_0}}{\mu_0} - \frac{2}{3} M \hat{z}$ 5

$= \frac{\vec{B_0}}{\mu_0} - \vec{M} + \frac{1}{3} \vec{M} \hat{z} = \vec{H_0} + \frac{\vec{M}}{3}$

Problem-3(25 points) **Magnetized Infinite Cylinder**

Consider a uniformly magnetized infinite circular cylinder, of radius R, with its axis coinciding with the z-axis. The magnetization inside the cylinder is $\vec{M} = M_0\hat{z}$.
There is no free current anywhere.
(a)Determine the bound currents $\vec{J_b}$ and $\vec{K_b}$.
(b)Determine the auxiliary field $\vec{H}$ inside and outside the cylinder.
(c)Determine the magnetic field $\vec{B}$ inside and outside the cylinder.



(a) $\vec{J_b} = \vec{\nabla} \times \vec{M} = \vec{\nabla} \times M_0 \hat{z} = 0$ (4)

$\vec{K_b} = \vec{M} \times \hat{s} = M_0 \hat{z} \times \hat{s}$
$= M_0 \hat{\phi}$ (4)

(b) $\oint \vec{H} \cdot d\vec{l} = I_{f,\,enclosed} = 0$ (4)

$\longrightarrow H = 0$ (2)

(c) $\vec{H}(\vec{r}) = \dfrac{\vec{B}(\vec{r})}{\mu_0} - \vec{M}(\vec{r}) = 0$ (2)

$\vec{B} = \mu_0 \vec{M} = \mu_0 M_0 \hat{z}$ for $r < R$ (5)

$B = 0$ for $r > R$ since $M = 0$ (4)

Problem-4(30 points) **Magnetized Cylindrical wire with permeability μ**

A cylindrical wire of radius R, made of a linear magnetic material of permeability μ . A current I is uniformly distributed over its cross section flowing along the positive z- direction.

(a) Determine the free currents inside and outside the wire as a function of I.

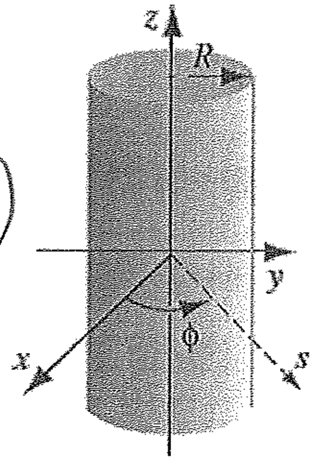
(b)Use Ampere's Law to find the auxiliary field $\vec{H}$ inside and outside the rod.

Deduce the magnetic field $\vec{B}$ inside and outside the rod.

(c)Prove that the magnetization $\vec{M}$ inside the wire is given by:

$$\vec{M} = (\frac{\mu - \mu_0}{\mu_0}) \frac{I.r}{2\pi R^2} \hat{\phi}$$

(d)Determine the net bound current.



(a) $I_{free} = I$ (for $r > R$) 2

For $r < R$: Take an AL

2 $I_f = I \left(\frac{\pi r^2}{\pi R^2}\right) = I \left(\frac{r}{R}\right)^2$ 2

(b) For $r \geq R$

$\oint \vec{H} \cdot d\vec{l} = I_{f, enclosed}$ 2

$H(2\pi r) = I$ 2 $\Rightarrow \vec{H} = \frac{I}{2\pi r} \hat{\phi}$ 2

$\Rightarrow \vec{B} = \mu_0 \cdot \vec{H} = \frac{\mu_0 I}{2\pi r} \hat{\phi}$ 2

For $r < R$

$H \cdot 2\pi r = I \left(\frac{r}{R}\right)^2$ 2

$\vec{H} = \frac{I \cdot r}{2\pi R^2} \hat{\phi}$ 1 $\longrightarrow \vec{B} = \frac{\mu \cdot I \cdot r}{2\pi R^2} \hat{\phi}$ 2

(c) $\vec{M} = \frac{\vec{B}}{\mu_0} - \vec{H}$

For $r > R \rightarrow M = 0$ 1

Extra Sheet

$$I_{encl} = I_f + I_{J_b} + I_{K_b}$$

$$I_{J_b} = \int J_b \cdot dA$$
$$= \left(\frac{\mu - \mu_0}{\mu_0}\right)\frac{I}{\pi R^2} \cdot \pi R^2$$
$$= \frac{\mu - \mu_0}{\mu_0} \cdot I$$

$$I_{K_b} = \int K_b \cdot dl = -\left(\frac{\mu - \mu_0}{\mu_0}\right) \frac{I}{2\pi R} (2\pi R)$$
$$= -\frac{(\mu - \mu_0)}{\mu_0} \cdot I$$

$$\Rightarrow I_{net} = 0$$

Extra Sheet