The Open University of Sri Lanka
B.Sc. Degree Programme - Level 04
Final Examination - 2006/2007
Advanced Electromagnetism
PHU 2142 / PHE 4142

Duration: Two and a Half Hours (2½ Hrs.)

Date: 12.06.2007 **Time: 01.30 pm *to* 04.00 pm**

Useful Physical Constants		
Permittivity of free space, ε_0	=	$8.85 \times 10^{-12}\ Fm^{-1}$
Permeability of free space, μ_0	=	$4\pi \times 10^{-7}\ Hm^{-1}$

ANSWER FOUR QUESTIONS ONLY.

1. (a) Define the Gauss theorem and express it in both the integral and differential forms.

   (b) The electric potential at a perpendicular distance r from the axis of a long straight wire of cross-sectional radius a is given by,

   $$V(r) = -K \ln\left(\frac{r}{a}\right)$$

   where K is a constant. Calculate the electric field as a function of distance. Hence determine the linear charge density q of the wire.

   (c) A second identical wire, having a linear charge density $-q$ is placed parallel to the first at a distance d from it. Calculate the potential difference between the wires, assuming that $d >> a$.

2. (a) A parallel-plate capacitor with plate separation d has a capacitance C. Find its new capacitance when an isolated metal slab of thickness t is placed between the plates.

   (b) A parallel-plate capacitor of plate separation d is charged to a potential difference V_1 and then isolated. Then the plate separation is doubled.

   (i) What is the new potential V_2 between the plates?

(ii) By how much is the energy stored in the capacitor increased?

(iii) Where did this energy come from?

3. (a) State the Biot-Savart law which gives the magnetic field produced by a current element at a distance $\underline{r}$ from the element.

(b) Using Biot-Savart law, find:

(i) the magnetic field at a distance r from a long straight wire carrying a current I.

(ii) the magnetic field at a distance b along the axis of a circular current loop of radius a and carrying a current I.

(c) A circular coil of radius 5 cm has 10 turns and carries a current of 5 A. Find the magnetic field at the center of the coil.

4. (a) Discuss briefly the concepts of real current and virtual current in magnetism.

(b) Describe briefly the three major classes of materials based on their magnetic properties.

(c) Starting from Amperes circuital relation, deduce the relationship that relates the magnetic flux density ($\boldsymbol{B}$), the magnetic field intensity ($\boldsymbol{H}$) and the magnetic moment per unit volume ($\boldsymbol{M}$).

(d) A uniformly magnetized bar with a volume of 0.01 m^3 has a magnetic moment of 500 A m^2. If the flux density in the bar is 0.5 T, find the magnetic field intensity in the bar.

5. (a) Discuss briefly the physical meaning of inductance of an inductor?

(b) Describe briefly the physical phenomena of self inductance and mutual inductance.

(c) Compute the self-inductance of a solenoid with N turns, length l, and radius R with a current I flowing through each turn, as shown in Fig. I.

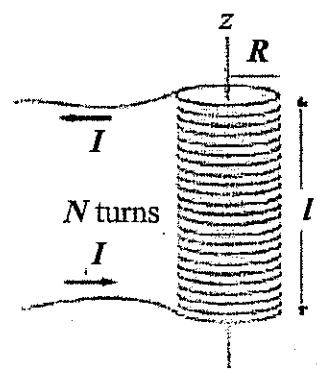

Fig. I

(d) A long solenoid with length l and a cross-sectional area A consists of N_1 turns of wire. An insulated coil of N_2 turns is wrapped around it, as shown in the Fig. II. Calculate the mutual inductance M, assuming that all the flux from the solenoid passes through the outer coil.

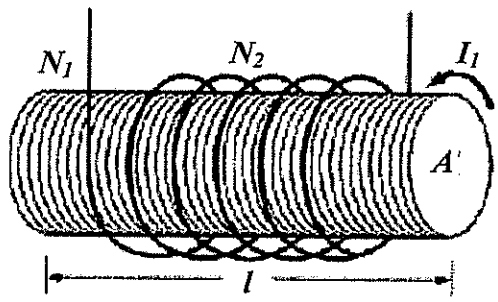

Fig. II

6. (a) Write down Maxwell's equations in electromagnetism.

(b) Show that the equation,

$$\text{div } \mathbf{J} = -\frac{\partial \rho}{\partial t}$$

can be derived from the Maxwell's equations. (Symbols have their usual meanings).

(c) Find the expression for the propagation speed of the field. (State all the assumptions made).

(d) Consider a wave represented by the field vectors,

$$\boldsymbol{E} = \boldsymbol{e} \cos (pt - \boldsymbol{k}z)$$

$$\boldsymbol{H} = \boldsymbol{h} \cos (pt - \boldsymbol{k}z)$$

where $\boldsymbol{e}$ and $\boldsymbol{h}$ are constant vectors and $\boldsymbol{k}$ is a unit vector in z direction. Other symbols have their usual meanings.

Show that $\boldsymbol{e}$, $\boldsymbol{h}$, $\boldsymbol{k}$ form a right-handed set of mutually perpendicular direction.

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