The Open University of Sri Lanka
B.Sc. Degree Programme - Level 04
Final Examination - 2009/2010
Advanced Electromagnetism
PHU 2142 / PHE 4142

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

Date: 20.07.2010 **Time: 01.00 pm *to* 03.30 pm**

Useful Physical Constants

Electronic charge (e)	=	1.602×10^{-19} C
Permittivity of free space, ε_0	=	8.85×10^{-12} F m^{-1}
Permeability of free space, μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}

ANSWER FOUR QUESTIONS ONLY

1. (a) Find expressions for electric potential (i) outside and (ii) inside a charged solid sphere of uniform volume charge density ρ_v and radius R.

   (b) An electric field is given by $\boldsymbol{E} = 2x^2\, \boldsymbol{i} + 3y^2 \boldsymbol{j} + 4z\, \boldsymbol{k}$. Calculate,
   - (i) the divergence of $\boldsymbol{E}$.
   - (ii) the charge density which gives rise to this field at the points (0,0,0) and (1,1,1).
   - (iii) the curl of $\boldsymbol{E}$.
   - (iv) the potential difference $V(1,1,1) - V(0,0,0)$

   (c) The electric field between two co-axial cylinders is 500 Vm^{-1} at the inside surface of the outside cylinder. Find the potential difference between the cylinders, given that the radii are 2 cm and 5 cm.

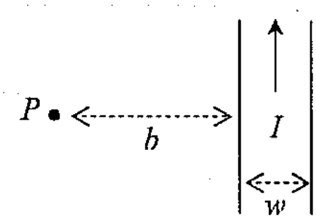
2. (a) A parallel plate capacitor has plates of area A and separation d and stores a charge Q. Write down an expression for the energy stored in it.

   (b) It is isolated and the plates pulled apart so the separation of the plates is now $d + e$. What is now the stored energy and how much work has been done in pulling the plates apart?

(c) Show that the force of attraction between the plates now is $\frac{Q^2}{2\varepsilon_o A}$

(d) The electric field at a radius r, between the inner conductor of radius a and the screen conductor of radius b (i.e. $a < r < b$), in a coaxial cable is $E(r) = \frac{\lambda}{2\pi\varepsilon_o r}$, where λ is the charge per unit length on the inner conductor. The energy density is $\frac{\varepsilon_o E^2}{2}$. Using these two expressions calculate the total energy stored in the electric field.

3. (a) A long thin flat strip of metal is of width w and has a current I flowing along it *(see diagram)*. Find the magnetic induction **B** at a point P in the plane of the strip at a distance b from the nearest edge.



(b) A coaxial line carries a current I upwards through a solid conductor (placed inside, along the axis) of radius a and the same current I downwards through a cylindrical conductor of inner radius b and outer inner radius c. The current density $\boldsymbol{J}$ is uniform within each conductor. Find the magnetic induction as a function of distance r from the axis for,

(i) $r < a$

(ii) $a < r < b$

(iii) $b < r < c$

(iv) $r > c$

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

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

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

(d) A uniformly magnetized bar with a volume of 0.04 m^3 has a magnetic moment of 2000 Am^2. If the flux density in the bar is 0.6 T, find the magnetic field intensity in the bar.

5. A long straight solid cylindrical conducting wire with radius R carries a steady current I.

(a) Calculate the magnetic field energy inside a length l of the wire.

(b) What is the contribution of the interior portion of the conductor to the total self-inductance?

(c) A coil with resistance 0.05 Ω and self-inductance 0.09 H is connected across a 12 V car battery of negligible internal resistance.

(i) How long after the switch is closed will the current reach 95 percent of its final value?

(ii) At that time how much energy (in Joules) is stored in the magnetic field?

(iii) How much energy has been delivered by the battery up to that time?

6. With respect to Maxwell's equations:

(a) Ampere's law in integral form reads $\oint B.dl = \mu_0 I$. Show how to obtain Ampere's law in differential form from the integral form.

(b) Explain how the equation $\nabla \times \boldsymbol{B} = \mu_o \boldsymbol{J}$ is incomplete. Using conservation of electric charge, discuss how Maxwell modified this equation.

(c) Show that the Poynting vector, $S = \frac{1}{\mu_o} E \times B$ satisfies, $\nabla.S + \frac{\partial u}{\partial t} + E.J = 0$,

where $u_E = \varepsilon_0 E^2$ is the electric energy density, $u_B = \frac{1}{2\mu_o} B^2$ is the magnetic energy density, and $u = u_E + u_B$ is the total energy.

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