RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree in Applied Sciences
First Year – Semester II Examination – September / October 2020

PHY 1203 - FUNDAMENTALS OF ELECTROMAGNETISM

Time: Two (02) hours

Answer all **four** questions
Use of a non-programmable calculator is permitted.

Some fundamental constants and physical data;

Electron mass, $m_e = 9.1 \times 10^{-31}$ kg,
Electron charge, $e = 1.6 \times 10^{-19}$ C,
Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ N A^{-2},
Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2 N^{-1} m^{-2}.
Speed of light in vacuum, $c = 3.0 \times 10^8$ m s^{-1},
Electron volt, eV $= 1.6 \times 10^{-19}$ J,
$\frac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9$ N m^2 C^{-2},

1. a) State Ampere's Circuital Law. (05 marks)

   b) Using the Ampere's Circuital Law, show that the magnetic field B inside an ideal solenoid which carries a current I can be given by $B = \mu_0 nI$; where n is the number of turns per unit length. (06 marks)

   c) A superconducting solenoid is to be designed to generate a magnetic field of 10 T.

      i. If the solenoid winding has 2000 turns/meter, what is the required current? (05 marks)

      ii. What is the force exerted per unit length on the solenoid windings by this magnetic field? (04 marks)

   d) Can the path of integration around which we apply Ampere's law pass through a conductor? Explain. (05 marks)

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2. a) State Faraday's Law of induction. (06 marks)

b) A rectangular loop of area A is placed in a region where the magnetic field is perpendicular to the plane of the loop. The magnitude of the field is allowed to vary with time according to $B = B_0 e^{-t/\tau}$, where B_0 and τ are constants. The field has a value of B_0 at $t = 0$.

i. Use Faraday's law to show that the emf induced in the loop is given by

$$\varepsilon = \frac{AB_0}{\tau} e^{-t/\tau}.$$

(06 marks)

ii. Obtain the numerical value for ε at $t = 4$ s when $A = 0.16\ \mathrm{m}^2$, $B_0 = 0.35$ T and $\tau = 2$ s.

(04 marks)

iii. For the values of A, B_0, τ given in part ii, what is the maximum value of ε?

(04 marks)

c) A magnet is dropped down a long vertical copper tube. Show that, even neglecting air resistance, the magnet will reach a constant terminal velocity.

(05 marks)

3. a) State Gauss's Law. (05 marks)

b) i. A thin spherical shell of radius r has a total charge Q distributed uniformly over its surface. Find the electric field at points inside and outside the shell. (06 marks)

ii. An inflated balloon in the shape of a sphere of radius 12 cm has a total charge of 7 μC uniformly distributed on its surface. Calculate the electric field intensity at 10 cm, 30 cm distances from the center of the balloon. (04 marks)

c) A student measures the electric flux through a closed spherical surface of volume V to be X. She then removes the charge from inside the spherical surface and place it in a closed cylindrical surface of volume $V/2$. She then claims that the flux through the cylindrical surface is $2X$. Explain why the student is wrong. (05 marks)

d) Is Gauss's law useful in calculating the field due to three equal charges located at the corners of an equilateral triangle? Explain. (05 marks)

4. a) State Coloumb's law. (05 marks)

b) A cube of edge a carries a point charge q at each corner.

i. Show that the magnitude of the resultant force on any one of the charges is

$$F = \frac{0.261q^2}{\varepsilon_0 a^2}.$$

(10 marks)

ii. What is the direction of the resultant force relative to the cube edges? (05 marks)

c) When is it valid to approximate a charge distribution by a "point charge"? (05 marks)

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