National Exams December 2019

04-BS-9, Basic Electromagnetics

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of assumptions made;
2. Candidates may use one of two calculators, a Casio or Sharp approved models. This is a **Closed Book** exam. **One** aid sheet written on both sides is permitted.
3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
4. Constants: $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m, $\mu_0 = 4\pi \times 10^{-7}$ H/m, $e = 1.602 \times 10^{-19}$ C

Marking Scheme

Question 1: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 2: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 3: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 4: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 5: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 6: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 7: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 1

A positive 6.40nC point charge, denoted by $\mathbf{q_1}$ is located at (0, 4cm, 0).

a) Calculate the electric field E_1 (magnitude and direction) at point **P** (-4cm, 0, 0) due to $\mathbf{q_1}$.

b) If a 14.23nC point charge, denoted by $\mathbf{q_2}$ is placed at (2cm, -3cm, 0), calculate the electric field E_2 (magnitude and direction) at point **P** due to $\mathbf{q_2}$ only.

c) Calculate the total electric field (magnitude and direction) at **P** due to $\mathbf{q_1}$ and $\mathbf{q_2}$?

d) If a negative 20nC charge **Q** is placed at **P**, calculate the total electrostatic force (magnitude and direction) on **Q**.

Question 2

A positive 40nC point charge is placed inside the conducting spherical shell, 10cm thick, with the outside radius or 1m and the total positive net charge of 10nC.

a) Calculate the total charge distributed on the inner surface of the spherical shell.

b) Calculate the charge density on the outer surface of the spherical shell

c) Calculate the electric field at point P_1, 95cm from the spherical shell centre, and at point P_2, 105cm from the spherical shell centre.

d) Calculate the electric flux through a spherical Gaussian surface of radius 2m surrounding the spherical shell.

Question 3

A cylindrical, infinitely long conductive pipe is located along the *y*-axis and carries 1000A in the positive *y* direction. The current is uniformly distributed through the pipe cross-section. The outer radius of the pipe is R_{outer} = 10mm, while the inner radius of the pipe is R_{inner} = 6mm. Assume that the point P_0 is located at (2mm, 2mm, 2mm) and the point P_1 is located at (40m, 10m, 30m).

a) How is the magnetic field changing along *x*-axis, from x = 0m to x = 100m?

b) What is the value of the magnetic field at point P_0.

c) Calculate the magnitude and the direction of the magnetic field at point P_1.

d) Assume that 10nC charge is located at P_1 and is moving with velocity v = 1m/s in the positive *y* direction. Calculate the force vector on the charged particle.

Question 4

Consider the and 1m wide conducting sheet. The sheet is parallel to y-axis, and is located in xy plane, between $x = 1\text{m}$ and $x = 2\text{m}$. The 1000A current is uniformly distributed throughout the sheet and flows in a positive y direction. Assume that point P_1 is located at (-1m, 0, 0), while point P_2 is located at (-2m, 0, 0). A thin, infinitely long conductor is placed parallel to the y-axis, and is passing through P_2. The current through this conductor is denoted as I_2.

a) For $I_2 = 0$, calculate the magnitude and the direction of the magnetic field at points P_1 and P_2.

b) How does the magnetic field magnitude change from the origin to point P_2 if $I_2 = 0$?

c) For $I_2 = 1\text{A}$ in a positive y direction, Calculate the direction and magnitude of the force per unit length acting on the conductor at P_2.

d) Calculate the required magnitude and the direction of the current I_2 to ensure that the magnetic field at P_1 is zero.

Question 5

Consider the rectangular conductive loop with vertices A (0, 0, 0), B (1m, 0, 0), C (1m, 2m, 0), and D (0, 2m, 0). Assume that the external magnetic field B is in the direction of z-axis.

a) Calculate the induced electromotive force in the loop if external magnetic field is uniform and constant, B = 0.1Tesla, and the loop rotates with the constant speed ($\omega = 1\text{rad/s}$) around x-axis.

b) Calculate the induced electromotive force in the loop if external magnetic field is uniform and constant, B = 0.1Tesla, and the loop rotates with the constant speed ($\omega = 1\text{rad/s}$) around y-axis.

c) Calculate the induced electromotive force in the loop if external magnetic field is uniform and constant, B = 0.1Tesla, and the loop rotates with the constant speed ($\omega = 1\text{rad/s}$) around z-axis.

d) Calculate the induced electromotive force in the loop if it is stationary and the external magnetic field is changing with equation $B = 4 \cdot t + 1$ Tesla (t is in seconds).

Question 6

A parallel-plate capacitor consists of two square metal plates with sides 2m, oriented horizontally, parallel to the x-y plane. The first metal plate is located at $z = 0$, while the other is at $z = 1\text{mm}$. There is a silicon sheet (dielectric constant 12) between the two capacitor plates. The potential difference between the plates is 100V.

a) Calculate the capacitance.

b) Calculate the charge on each plate.

c) Calculate the energy stored in the capacitor.

d) Calculate the force between two capacitor plates.

Question 7

A magnetic core is shown in Figure 1. Relative permeability of the core is $\mu_r = 2000$. Total number of winding turns in the left winding is $N_L = 1000$ and in the right winding is $N_R = 500$. Assume that the core cross section is uniform and the length of air-gaps is much smaller than the dimensions of the core cross-section. Calculate the following:

a) The magnetomotive force in the core if $i = 2$ A.

b) The magnetic flux, ϕ and magnetic flux density B in the 1mm air gap if $i = 2$ A.

c) Self inductance of the left coil from Figure 1.

d) Mutual inductance between the left and the right coil from Figure 1.

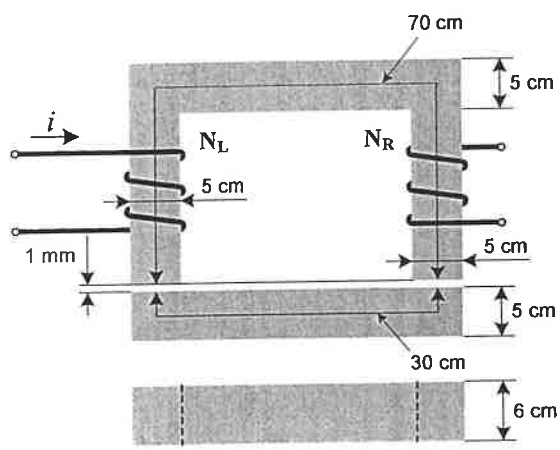

Figure 1: Magnetic core for Question 7