National Exams May 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.
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

Two positive 2nC point charges, denoted by $\mathbf{q_1}$ and $\mathbf{q_2}$, are located at (0, 4cm, 0) and (0, -4cm, 0), respectively.

a) Calculate the electric field E (magnitude and direction) at point P_1 (-4cm, 0, 0).

b) Which point charge **Q** would have to be placed at point P_2 (4cm, 0, 0) such that its electric field at point P_1 cancels the electric field due to $\mathbf{q_1}$ and $\mathbf{q_2}$?

c) Calculate the electrostatic force on **Q**.

d) If charge **Q** is to be moved from P_2 to P_1, calculate the work done by an external force?

Question 2

Four positive point charges, 10nC each, are placed at corners of the pyramid square base, while one negative, 30nC, charge is placed at the top of the pyramid. Each pyramid edge is 10cm long. Pyramid is fully enclosed by 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 10m surrounding the spherical shell.

Question 3

A cylindrical, infinitely long conductor is located along the y-axis and carries 1000A in the positive y direction. The current is uniformly distributed through the conductor cross-section. The radius of the conductor is R = 10mm. Assume that point P_1 is located at (40m, 10m, 30m).

e) Where in the x-z plane is the magnetic field the greatest? Consider the area inside and outside the conductor. What is the maximum value of the magnetic field?

f) What is the minimum value of the magnetic field inside the conductor and where does this occur.

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

h) 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 thin, infinitely long conductor, bent at right angle at the origin (0, 0, 0), so that it is aligned with positive x and y-axis. The 1000A current flows in a positive y direction. Assume that point P_1 is located at (0, -1m, 0), point P_2 is located at (0, 1m, 0).

a) 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?

c) Calculate the direction and magnitude of the force per unit length acting on the conductor at P_2.

d) Calculate the total force magnitude acting on the conductor segment from the origin to P_2.

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 (ω = 1rad/s) around y-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 (ω = 1rad/s) around z-axis.

c) Calculate the induced electromotive force in the loop if it is stationary and the external magnetic field is changing with equation $B = 4 \cdot t^2 + 2 \cdot t + 3$ Tesla (t is in seconds).

d) Calculate the induced electromotive force in the loop if it is stationary and the external magnetic field is changing with equation $B = 4 \cdot t^2 \cdot x^2$ Tesla (t is in seconds and x is in meters).

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 $z = 1$cm. The potential difference between the plates is 100V.

e) Calculate the capacitance.

f) Calculate the charge on each plate.

g) Calculate the energy stored in the capacitor.

h) A small, non-conducting sphere with a mass of 1 g and carrying a negative charge Q, is placed between the plates at $z = 0.5$cm where it remains in equilibrium. Determine the magnitude of the charge Q. Assume that the electric field between the plates is uniform.

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 $\mathbf{N_L} = 100$ and in the right winding is $\mathbf{N_R} = 10$. Assume that the core cross section is uniform and the combined length of all air-gaps is much smaller than the dimensions of the core cross-section. Calculate the following:

a) The magnetomotive force in the core if $\boldsymbol{i} = 2$ A.

b) The magnetic flux, $\boldsymbol{\phi}$ and magnetic flux density $\boldsymbol{B}$ in the 1mm air gap if $\boldsymbol{i} = 2$ A.

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

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

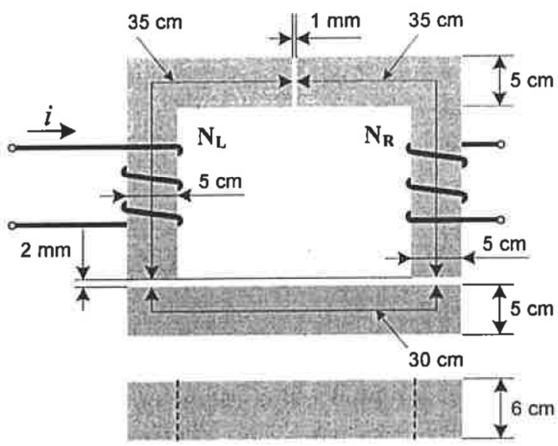

Figure 1: Magnetic core for Question 7