Library copy

University of Ruhuna- Faculty of Technology

Bachelor of Engineering Technology Honours Degree

Level 1 (Semester II) Examination, Nov.-Dec. 2025

Academic Year 2023/2024

Course Unit: **TMS1222/ENT1242 Electromagnetics/E&M** . Duration: **2 hours**

Instructions and details:

- Answer **All parts of Five (05)** questions.
- This question paper is composed of 4 pages.
- The paper carries a total of 100 marks, and each question carries 20 marks.
- Calculators are allowed for calculations.
- When relevant, answers should be expressed in terms of the given (relevant) variables and simplified.
- All symbols have their usual meanings.
- The solution of the differential equation $\frac{dy}{dt} + by = 0$ can be written as $y = ae^{-bt}$, where a and b are constants.
- $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$.
- $\varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$.
- $\mu_0 = 4\pi \times 10^{-7} \text{ T.m/A}$.

1.

(i) In Figure 1, an electric dipole is located along the x-axis and it is centered at the origin O. It is made of two charges of equal magnitude q and opposite signs that are separated by a distance $2a$. Let k denote the Coulomb's constant.

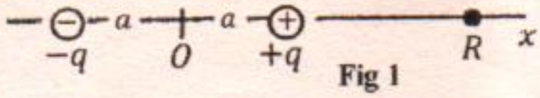


Fig 1

(a) Find the electrostatic force (magnitude) between the two charges of the dipole. (2 marks)

(b) Find the electric potential (V) at point $R(x, 0)$ on the x-axis as shown in the Figure. (5 marks)

(c) If the point R is located far away (such that $x \gg a$) then, find the approximate potential at point R. (1 mark)

(ii) A charged air-filled parallel-plate capacitor is made of plates of area A and plate separation d.

(a) When the surface charge density of each plate is σ (i.e., magnitude), the potential difference between the plates is given by $|\Delta V| = \sigma d/\varepsilon_0$. Thus, find the capacitance of the capacitor in terms of ε_0, A and d. (3 marks) [*Hint: Consider the definition of capacitance using charge Q.]

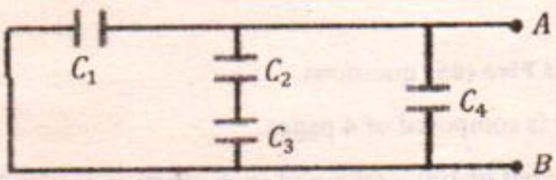
If $A = 50\ \text{cm}^2$, $d = 0.50$ mm and $|\Delta V| = 500$ V then,

(b) Calculate the capacitance of the capacitor. (2 marks)

(c) Calculate the electric field (magnitude) between the plates of the capacitor. (2 marks)

(iii) In a capacitor network four capacitors of capacitance each of 10.0 μF are connected as shown in Figure 2.

Fig 2



A potential difference of 10.0 V is applied between the points A and B. Then,

(a) Calculate the equivalent capacitance (C_{eq}), between the points A and B. (3 marks)

(b) Calculate the total electrical energy stored in the capacitor network. (2 marks)

2.

(i) The initial charge of the capacitor C of the RC circuit shown in Figure 3 is Q_0. The switch S is switched ON at time $t = 0$, and the capacitor discharges through the resistor.

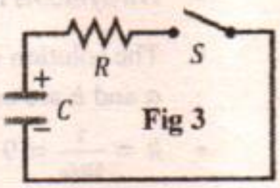


Fig 3

(a) Find an expression for the charge q of the capacitor at time t. (7 marks)

[*Hints: Current $i = -\frac{dq}{dt}$. See the instructions given for the solution of differential equations.]

(b) Find the current (i) flowing through the circuit at time t. (4 marks)

(ii) Figure 4 shows a straight conducting electrical wire segment of length l.

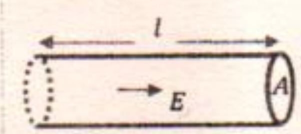


Fig 4

(a) When ΔV is the potential difference between the two end-points of the wire segment then, show that the electric field inside it can be written as $E = \frac{|\Delta V|}{l}$. (4 marks) [i.e., magnitude. *Hint: Integration along x-axis.]

(b) If the resistivity of the ohmic wire material is ρ and the circular cross-sectional area of the wire is A then, find the resistance (R) of the wire segment in terms of ρ, l, and A. (5 marks) [*Hints: part-(a). Consider the current density J.]

3. In Figure 5, the resistances of the resistors are $R_1 = 50.0\ \Omega$, $R_2 = R_5 = 25.0\ \Omega$, and $R_3 = R_4 = 100\ \Omega$ and the (ideal) batteries have emfs, $\varepsilon_1 = 6.00$ V and $\varepsilon_2 = 12.0$ V.

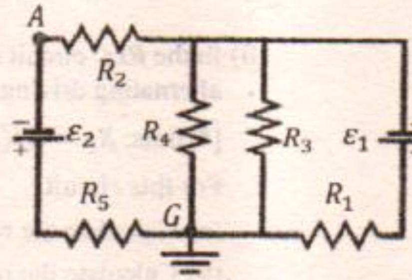


Fig 5

(a) Calculate the currents flowing in each resistor R_1, R_2, and R_3. (12 marks) [*Hints: You may want to simplify and redraw the circuit first.]

(b) Is the battery ε_2 is being charged or discharged? Briefly explain why. (2 marks)

(c) Calculate the power transfer in battery ε_2. (2 marks)

(d) Calculate the combined power dissipated by both resistors R_3 and R_4. (2 marks)

(e) If the point G of the circuit is grounded then, calculate the electric potential at point A. (2 marks)

4.

(i) Figure 6 shows the cross-section of a long ideal solenoid coil (i.e., inductor) that carries a current i and has n turns per unit length.

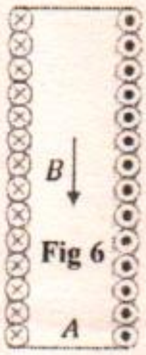


Fig 6

(a) Using Ampere's law, show that the uniform magnetic field generated inside the solenoid coil can be written as $B = \mu_0\, i\, n$. (6 marks)

(b) If the solenoid coil has a circular cross-sectional area A and a length l then, find the inductance (L) of it. (4 marks)

(c) A straight wire carrying a current i and of length L_0 is placed at the midpoint of the solenoid coil perpendicular to its central axis. Find the magnetic force (F) acting on the wire. (3 marks) [i.e., the magnitude]

(ii) A wire of resistance 1.0 mΩ forms a circular loop of diameter 5.0 cm. A uniform magnetic field $\vec{B}$ is perpendicular to the plane of the wire loop. To induce a 5.0 A current in the loop, find the required rate of change of the magnitude of $\vec{B}$. (7 marks) [i.e., time rate. *Hint: Faraday's law.]

5.

(i) In the circuit shown in Figure 7, initially the switch S is in its ON position, and thus the inductors with inductances L_1 and L_2 are charged. Next, the switch S is switched OFF at time $t = 0$ and just then the current flowing in the circuit is i_0. As the inductors discharge through the resistor with resistance R, find the current (i) flowing in the circuit at time t. (7 marks) [*Hints: first, you may want to replace both inductors with one. Self-induction ε_L. See the instructions given for the solution of differential equations.]

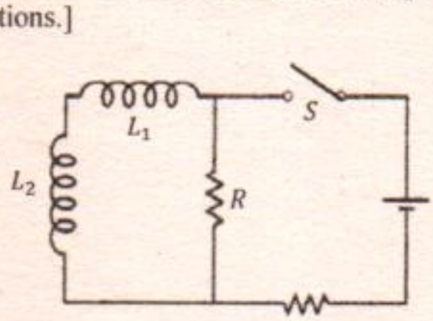
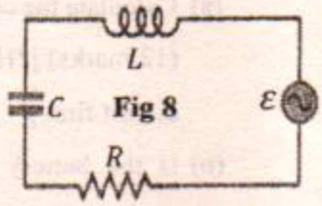


Fig 7

(ii) In the RLC circuit shown in Figure 8. $R = 200\ \Omega$, $C = 100\ \mu F$. $L = 200$ mH. the amplitude of the alternating driving emf ε is $\varepsilon_m = 40.0$ V, with a AC frequency of $f_d = 60.0$ Hz.

[*Hints: $X_C = 1/(\omega_d C)$, $X_L = \omega_d L$]

For this circuit,



(a) Calculate the reactance of the inductor L. (2 marks)

(b) Calculate the reactance of the capacitor C. (2 marks)

(c) Calculate the impedance (Z) of the circuit. (2 marks)

(d) Calculate the power factor (PF) of the circuit. (1 mark)

(e) Calculate the root mean square (RMS) current flowing in the circuit. (2 marks)

(f) Calculate the combined RMS voltage across the R and C together. (2 marks)

(g) Calculate the average power that is dissipated by the circuit. (2 marks)

@@@@@@@@@@@@@@@@@@@