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University of Ruhuna- Faculty of Technology

Bachelor of Engineering Technology Honours Degree

Level 1 (Semester II) Examination, November 2022

Academic Year 2020/2021

Course Unit: **ENT1242 Electricity and Magnetism** Duration: **2 hours**

Instructions:

- Answer all **Five (05)** questions.
- 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.
- $k = k_e = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ Nm^2/C^2.
- $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/Nm^2.
- $\mu_0 = 4\pi \times 10^{-7}$ T. m/A.

1. Figure -1 shows an electric dipole with charges of $+q$ and $-q$ separated by a distance d. The dipole is along the y-axis and it is centered at the origin of the xy plane.

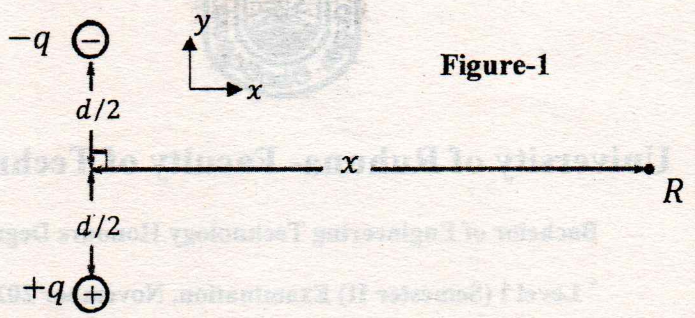


Figure-1

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

(b) Find the electric potential at point $R(x, 0)$.

(c) Find the electric field $\vec{E}$ of the dipole at point $R(x, 0)$ on the $+x$-axis, in unit-vector notation. (*Hint: May draw the fields. The field due to a point charge: $\vec{E} = k\frac{|q|}{r^2}\hat{r}$)

If the point R is located far away from the dipole such that $x >> d$ then, in unit-vector notation,

(d) Find the approximate electric field $\vec{E}$ of the dipole at point $R(x, 0)$.

(e) Find the electrostatic force on a charge Q that is placed at point R.

2.

(i) Figure -2 shows a non-conducting rod of length L and uniform positive linear charge density λ. The rod is along the x-axis and it is centered at the origin. (*Note: $V = 0$ at infinity.)

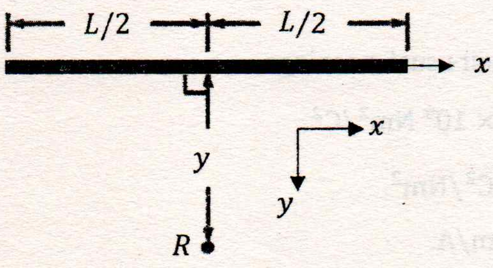


Figure-2

(a) Show that the electric potential at point $R(0, y)$ is given by,

$$V = 2k\lambda \ln\left(\frac{L/2 + \sqrt{(L/2)^2 + y^2}}{y}\right).$$

[*Hint: You may consider two symmetric charge segments on each rod half. *Note: $\int dx/\sqrt{x^2 + y^2} = \ln\left[x + \sqrt{(x^2 + y^2)}\right]$, and $\ln A - \ln B = \ln(A/B)$.]

(b) Show that the electric potential at point R, located at distance $y << L$, can be written as,

$$V = 2k\lambda \ln\left(\frac{L}{y}\right).$$

(c) Using the result from part-(b), find the electric field at point R in the $+y$-direction due to the rod. [*Note: $\frac{d}{dy}(\ln y) = \frac{1}{y}$]

(ii) In the Figure - 3, $C_1 = C_2 = 20\ \mu\text{F}$, and $C_3 = 10\ \mu\text{F}$.

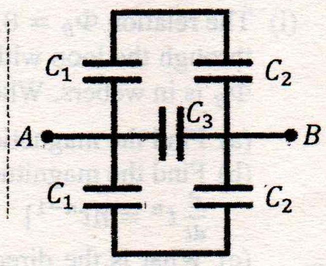
(a) Calculate the equivalent capacitance (C_{eq}) between the points A and B of the capacitor network.

If the potential difference between points A and B is 30 V, then

(b) Calculate the charge stored by C_{eq}.

(c) Calculate the energy stored in C_{eq}.

Figure-3



3. In the Figure - 4, the ideal batteries have emfs, $\varepsilon_1 = 100$ V and $\varepsilon_2 = 50$ V, and the resistances are $R_1 = 40\ \Omega$, $R_2 = R_5 = 20\ \Omega$, and $R_3 = R_4 = 80\ \Omega$. One point of the circuit is grounded.

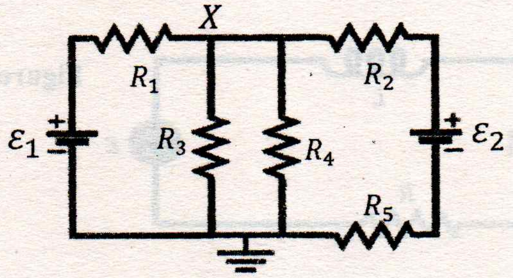


Figure-4

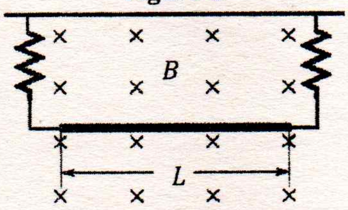
(a) Calculate the current in R_2.
(b) Calculate the current in R_1.
(c) Calculate the current in R_3.
(d) Calculate the potential difference of R_1.
(e) Calculate the power dissipated by R_1.
(f) Calculate the electric potential at point X.
(g) Is the battery ε_1 being charged or discharged? Briefly explain why.

4.

(i) Derive an expression for the magnetic field (B) produced by a long straight wire carrying a current i at a radial distance r. [*Hint: Use Ampere's law]

(ii) A wire of mass m and length L placed in a uniform magnetic field of magnitude B is suspended by two springs as shown in Figure - 5. If there is no tension in the springs then, find the current (i) in the wire. (*Note: denote acceleration due to gravity by g)

Figure-5



(iii) In the circuit shown in Figure - 6 the switch S is turned on at time $t = 0$. R, L, and ε represent a resistance, inductance, and ideal-battery emf, ~~receptively~~. At time t, find the current i in the circuit. (*Hint/s: Use Kirchhoff's rule/s. The solution of the equation $\frac{dI}{dt} + bI = 0$ can be written as $I = ae^{-bt}$)

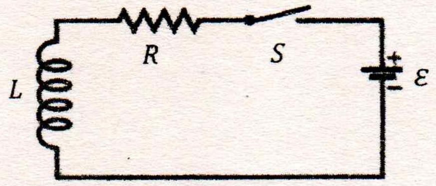


Figure-6

5.

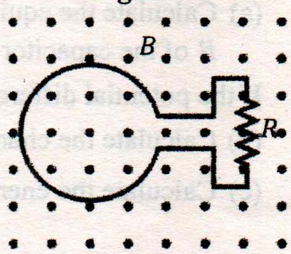
(i) The relation $\Phi_B = 8.0t^3 + 5.0t^2$ gives an increasing magnetic flux through the loop with time in Figure - 7, where t is in seconds and Φ_B is in webers. When $t = 1.5$ s,

(a) Find the magnetic flux through the loop.

(b) Find the magnitude of the induced emf in the loop. [*Note: $\frac{d}{dt}t^n = nt^{n-1}$]

(c) What is the direction of the current through *R* (i.e., up or down)?

Figure-7



(ii) In the Figure - 8, the amplitude of the driving emf ε is $\varepsilon_m = 38.0$ V (i.e., of the generator) and the frequency of it is $f_d = 55.0$ Hz. Further, $R = 210\ \Omega$, $L = 220$ mH, and $C = 80.0\ \mu$F. [*Hints: $X_C = 1/(\omega C)$, $X_L = \omega L$]

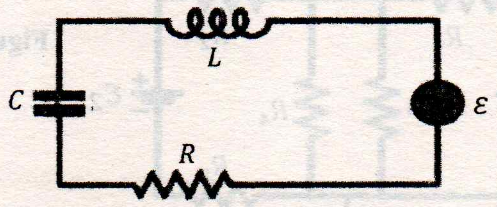


Figure-8

For the circuit,

(a) Find the reactance (*X*) of the inductor *L*.

(b) Find the reactance (*X*) of the capacitor *C*.

(c) Find the impedance *Z*.

(d) Find the current amplitude *I* and the RMS current I_{rms} in the circuit.

(e) Find the voltage amplitude *V* and the RMS voltage V_{rms} of the inductor.

(f) Find the average power that is supplied to the circuit by the generator.

(g) Find the power factor and the phase constant (ϕ) of the circuit.

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