The Open University of Sri Lanka
B.Sc. Degree Programme- Level 03
Final Examination 2024/2025
PHU3301 – Basic Electromagnetism
Duration: Two (2) Hours

00417

Date: 16.05.2025 **Time: 9.30 a.m. – 11.30 a.m.**

ANSWER ANY FOUR (04) QUESTIONS ONLY.

$\varepsilon_0 = 8.85\text{x}10^{-12}\ C^2N^{-1}m^{-2}$ $\mu_0 = 4\pi\text{x}10^{-7}\ WbA^{-1}m^{-1}$ $g = 10\ N\,kg^{-1}$

1.

i. State the Coulomb's law used in electrostatics.
ii. Two charges of +5 μC and +20 μC are placed at a distance of 24 cm apart. A third charge Q is placed at the middle point of the line joining them. What would be the magnitude and the nature of the charge Q so that the net force on +5 μC is zero?
iii. Calculate the Electric field intensity and the direction on the charge Q
iv. Write down the relationship between the Electric field intensity and the electrostatic potential
v. Find the Electrostatic potential 5 cm from the charge Q perpendicular to the line joining the +5 μC and +20 μC charges.

2.

i. Using the Biot-Savart law, explain qualitatively how the magnetic field at a point P near a wire carrying a current depends on the distance r from the wire. What happens to the magnetic field if the current is doubled?
ii. A conductor carrying a current is placed in a magnetic field perpendicular to the current. Using Fleming's left-hand rule, explain how to predict the direction of the force on the conductor. Give one practical example where this rule applies.
iii. Calculate the magnitude of the magnetic field at a point 5 cm away from a long straight conducting wire carrying a current of 10 A.
iv. Another long straight conducting wire carrying 5 A is placed to the right side, parallel to the above-mentioned wire at a distance of 5 cm. Calculate the force per unit length and the direction of the force acting on the wire.
v. State Faraday's law of electromagnetic induction. Explain conceptually why the induced electromotive force (EMF) increases when the rate of change of magnetic flux increases.
vi. A circular coil with 50 turns and radius 10 cm is placed in a uniform magnetic field perpendicular to its plane. If the magnetic field changes uniformly from 0.2 T to 0 T in 0.1 s, calculate the magnitude of the induced EMF in the coil.

3.

i. Write down an expression for the resistance of a wire in terms of length and the cross-sectional area of the wire. Describe the symbols in your written expression.

ii. A resistor is made by connecting two wires of the same material in series. The radii of the two wires are 1 mm and 3 mm, while their lengths are 3 cm and 5 cm respectively. a battery of 16 V with negligible internal resistance is connected serially across the resistor. Find the ratio of the resistance of the two wires.

iii. Calculate the potential difference across the short wire

iv. Show that the ratio of the power dissipation of the two wires is the same as the ratio of the resistance of the two wires.

v. Hence show the shorter wire, delivers more power than the other.

4.

i. State the Gauss theorem.

ii. Using the Gauss theorem, derive an expression for the electric field strength for an infinite conducting sheet of charge density σ.

iii. Show that the capacitance (C) of a parallel plate capacitor is $C = \frac{A\varepsilon_o}{d}$ where A, ε_o and d are the area of the plates, permittivity of the air and the separation of the plates respectively.

iv. For the above-mentioned capacitor dielectric medium. of k is inserted into half of the area of the plate as shown in figure 01. Find the new capacitance (C_1) of the capacitor.

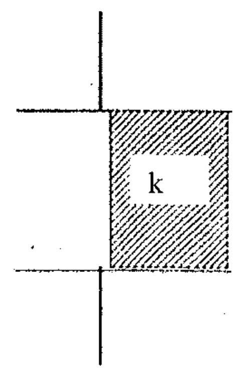


figure 01

v. In the given circuit shown in the figure 02 each of the capacitors C_1,C_2,C_3 and C_4 is equal to 1 μF. Find the effective capacitance across the battery.

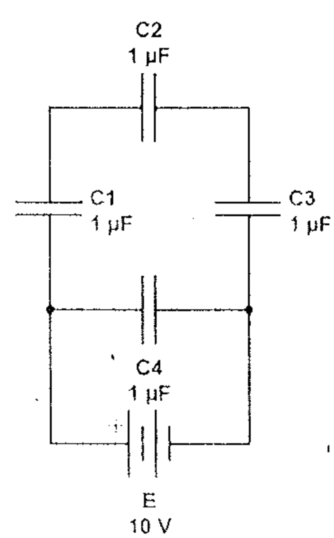


figure 02

5.

Consider the circuit shown in Figure 03, where a battery with an electromotive force (emf) E is connected in series to a resistor R and a capacitor C, through a switch.

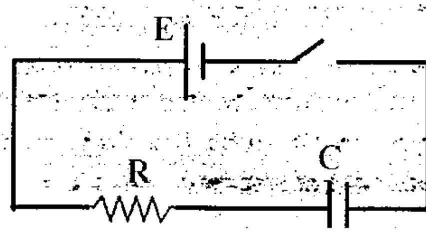


Figure 03

The charge q stored in the capacitor at time t is given by the following equation

$$q = EC\left(1 - e^{-t/CR}\right)$$

i. Determine the maximum (total) charge q that can be stored on the capacitor after a long time.

ii. Derive an expression for the current I(t) flowing in the circuit at time t, using the above expression for q.

iii. Draw a sketch showing how the current [illegible] with time t.

iv. Explain how you can determine the maximum current in the circuit. What is the value of this maximum current?

v. Show that the time taken ($t_{1/2}$) for the current to drop to half of its initial value is given by $t_{1/2} = RC\ln 2$

vi. In the above circuit E, R and C values are 5 V, 2 MΩ and 4 μF respectively. Calculate the Time Constant of the circuit.

6.

i. Write down the expressions for:

a. Capacitive reactance X_C

b. Inductive reactance X_L

Also, clearly define the symbols used in each expression.

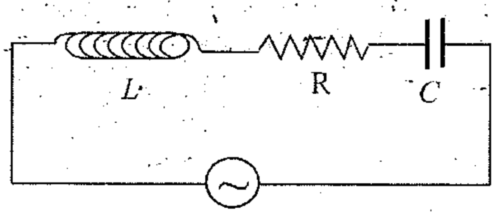
ii. Draw the phasor diagrams for the following components, showing the relationship between voltage and current for:

a. A resistor

b. A pure capacitor

c. A pure inductor

Consider the L C R series circuit with values of 0.2 H, 50 μF and 100 Ω respectively, shown in Figure 04, where the current in the circuit is given by $i = i_o \sin \omega t$



$i = i_0 \sin \omega t$

Figure 04

iii. Draw the phasor diagram for this circuit when $X_L > X_C$.

iv. Derive an expression for the total impedance Z of the circuit, using either the phasor diagram or another suitable method.

v. Determine an expression for the phase angle (ϕ) between the supply voltage and the current.

vi. Show that the resonance frequency f of the circuit is given by $f = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$

vii. Calculate the resonance frequency (f) of the circuit given in figure 4.

****