THE INSTITUTION OF ENGINEERS, SRI LANKA
IESL ENGINEERING COURSE **PART I EXAMINATION–2010**

104 ELECTROTECHNIQUES

This paper consists of ten questions. Answer **any six (6)** questions.
All questions carry equal marks.
Time allowed : 3 hours

Electric space constant	ε_o	$= 8.854 \times 10^{-12}$ Fm^{-1}
Magnetic space constant	μ_o	$= 4\pi \times 10^{-7}$ Hm^{-1}
Gravitational constant	G	$= 6.672 \times 10^{-11}$ Nm^{2}kg^{-2}
Gravitational acceleration	g	$= 9.81$ ms^{-2}
Electron rest mass	m_e	$= 9.11 \times 10^{-31}$ kg
Electron charge	e	$= 1.602 \times 10^{-19}$ C

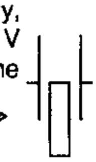
Q1. (i) State Gauss's Law

(ii) A solid conducting sphere carrying charge **q** has radius **a**. It is inside a concentric hollow conducting sphere with inner radius **b** and outer radius **c**. The hollow sphere has no net charge

(a) Derive expressions for the electric-field magnitude in terms of the distance **r** from the centre for the regions **r < a**, **a < r < b**, **b < r < c**, and **r > c**.
(b) Graph the magnitude of the electric field as a function of **r** from r = 0 to **r** = 2**c**.
(c) What is the charge on the inner surface of the hollow sphere?
(d) What is the charge on the outer surface?
(e) Sketch the field lines of the system within a spherical volume of radius 2**c**.

Q2. (i) Describe the **behaviour** of two capacitors connected in series.

(ii) A parallel-plate capacitor with only air between the plates is charged by connecting it to a battery. The capacitor is then disconnected from the battery, without any of the charge leaving the plates. The reading of a voltmeter is 45 V when placed across the capacitor. When a dielectric is inserted between the plates, completely filling the space, the voltmeter reads 11.5 V.



(a) What is the dielectric constant of this material?
(b) What will the voltmeter read if the dielectric is now pulled partway out - parallel to the plates, so it fills only one-third of the space between the plates?

Q3. (i) The potential difference across the terminals of a battery is 8.4 V when there is a current of 1.50 A in the battery from the negative to the positive terminal. When the current is 3.50 A in the reverse direction, the potential difference becomes 9.4 V.
(a) What is the internal resistance of the battery?
(b) What is the emf of the battery?

(ii) A 60 W, 120 V light bulb and a 200 W, 120 V light bulb are connected in series across a 240 V line. Assume that the resistance of each bulb does not vary with current. (A light bulb gives the power it dissipates when connected to the stated potential difference; that is, a 25 W, 120 V light bulb dissipates 25 W when connected to a 120 V line.)

(c) Find the current through the bulbs.
(d) Find the power dissipated in each bulb.
(e) One bulb burns out very quickly. Which one? Why?

Q4. (i) Describe Coulomb's Law.

(ii) Two identical spheres are each attached to silk threads of length L = 0.5 m and hung from a common point. Each sphere has mass m = 8 g. The radius of each sphere is very small compared to the distance between the spheres, so they may be treated as point charges. One sphere is given positive charge $\mathbf{q_1}$, and the other a different positive charge $\mathbf{q_2}$; this causes the spheres to separate so that when the spheres are in equilibrium, each thread makes an angle $\theta = 20°$ with the vertical.

(a) Determine the magnitude of the electrostatic force that acts on each sphere, and determine the tension in each thread.

(b) Based on the information you have been given, what can you say about the magnitudes of $\mathbf{q_1}$ and $\mathbf{q_2}$?

A small wire is now connected between the spheres, allowing charge to be transferred from one sphere to the other until the two spheres have equal charges; the wire is then removed. Each thread now makes an angle of 30° with the vertical.

(c) Determine the values of original charges.

Q5. (i) Describe Faraday's Law.

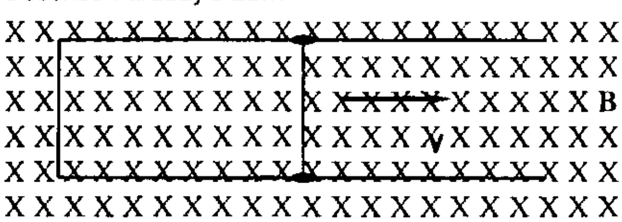


Figure Q5

(ii) A rectangular horizontal loop with width **L** and a slide wire with mass **m** are as shown in Fig. Q5. A uniform magnetic field **B** is directed perpendicular to the plane of the loop into the plane of the figure. The slide wire is given an initial speed of $\mathbf{v_o}$ and then released. There is no friction between the slide wire and the loop, and the resistance of the loop is negligible in comparison to the resistance **R** of the slide wire.

(a) Obtain an expression for current **I** of the circuit while it is moving at speed **v**.

(b) Obtain an expression for **F**, the magnitude of the force exerted on the wire while it is moving at that speed **v**.

(b) What is the distance **x** that the wire moves before coming to rest?

Q6. (i) Describe the condition under which there is maximum power transfer to a load from an electric circuit.

(ii)

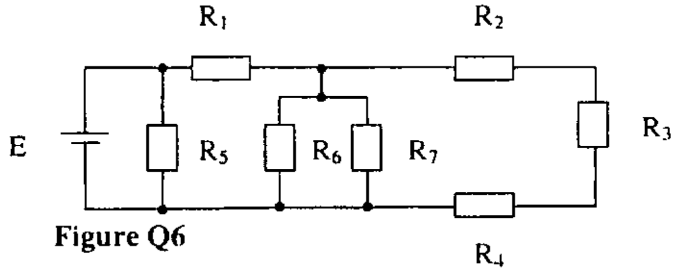


Figure Q6

$R_1 = 5\ \Omega$ $R_2 = 4\ \Omega$
$R_3 = 2\ \Omega$ $R_4 = 8\ \Omega$
$R_5 = 50\ \Omega$ $R_6 = 10\ \Omega$
$R_7 = 10\ \Omega$ $E = 20$ V

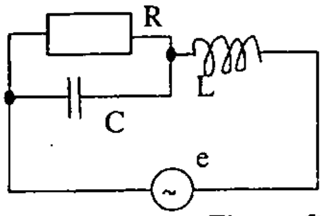
(23)

(a) Calculate, using Thevenin's Theorem, the current flowing through R_3.
(b) The power dissipated from R_3.

You are to replace R_3 with another resistor R_3', so that maximum power can be drawn from it.

(c) What is the suitable value for R_3'?
(d) How much is the power dissipated across R_3'?

Q7. (i) Describe briefly the **behaviour** of
a) a capacitor
b) an inductor in a sinusoidal circuit.

(ii) 

R = 300 Ω
L = 500 mH,
C = 2.5 μF

Figure Q7 (For Q7 and Q8)

(a) Given e = 34 sin 1000t V, calculate the currents through all the components.
(b) Calculate i) the power dissipated from the circuit and
ii) its power factor.
(c) Draw a phasor diagram for the circuit.

Q8. (i) Describe the **characteristic** of a resonant circuit.

(ii) Now the above circuit (Fig. Q7) is set to its resonance situation, where the same components are used, and amplitude may be assumed unchanged at 34 V.

(a) Calculate the currents through all the components.
(b) Draw a phasor diagram for the circuit.

Q9. (i) Describe the phenomenon mutual inductance.

(ii) A solenoidal coil with 25 turns of wire is wound tightly around another coil with 300 turns. The inner solenoid is 25 cm long and has a diameter of 2 cm. At a certain time, the current in the inner solenoid is 0.12 A, and is increasing at a rate of 1.75×10^3 A/s. For this time, calculate;

(a) the average magnetic flux through each turn of the inner solenoid;
(b) the mutual inductance of the two solenoids;
(c) the emf induced in the outer solenoid by the changing current in the inner solenoid.

Q10. (i) Design a 2-input NOR gate, using only the minimum number of 2-input NAND gates.

(ii) A simple Boolean function is described as

$$F = \overline{A}\,\overline{B}\,\overline{C}\,\overline{D} + \overline{A}\,\overline{B}\,C\,\overline{D} + \overline{A}\,B\,\overline{C}\,\overline{D} + \overline{A}\,B\,C\,\overline{D} + A\,\overline{B}\,\overline{C}\,\overline{D} + A\,\overline{B}\,C\,\overline{D} + ABCD$$

(a) Draw a truth table describing the function.

(b) Use a Karnaugh-map to find a simplified logical expression for the above function.