Permeability of free space \( \mu_0 = 4 \pi \times 10^{-7} \text{ H/m} \)

Permittivity of free space \( \varepsilon_0 = 8.854 \times 10^{-12} \text{ F/m} \)

1. (a) Sketch the circuit diagram of a residual current circuit breaker showing the basic principle of its operation. [2 marks]
(b) For the circuit shown in figure Q1, determine the currents in all the branches. [6 marks]
(c) Sketch the phasor diagram showing the branch currents and supply voltage. [2 marks]

2. (a) Figure Q2 shows a mutually coupled circuit supplied from a variable frequency source. Determine an expression for the effective impedance of the circuit. [4 marks]
(b) Determine the frequency at which resonance occurs, the Q factor at resonance, and the current at resonance. [4 marks]
(c) Determine also the voltage drop across the inductor \( L_1 \) at resonance. [2 marks]

3. (a) Determine the Thevenin’s equivalent circuit across the terminals AB, of the circuit shown in figure Q3. [6 marks]
(b) Using the above result or otherwise determine the value of R for which maximum power will be transferred and the value of this maximum power. [4 marks]

4. (a) Convert the two voltage sources shown in figure Q4 to equivalent current sources. [2 marks]
(b) Hence draw the circuit for nodal analysis. Determine the nodal admittance matrix and the nodal injected current source. [3 marks]
(c) Using matrix nodal analysis, determine the currents in all the branches [5 marks]
(a) A 3 phase, 400 V, 50 Hz supply feeds a balanced star connected load, each arm consisting of an inductance of 200 mH and a resistance of 100 Ω in series. Determine the line current, the power factor of the load and the total active power supplied to the load. [3 marks]

(b) Determine the value of the 3 capacitors that must be connected across the load in delta in order to increase the overall power factor to 0.95 lag. [4 marks]

(c) Determine the Symmetrical Components of the phase “A” voltage, given that

\[ V_{AN} = 200 \angle 0^\circ \text{ V}, \quad V_{BN} = 100 \angle -90^\circ \text{ V} \text{ and } V_{CN} = 200 \angle 150^\circ \text{ V}. \] [3 marks]

(a) Determine the first 3 significant terms of the Fourier Series of the periodic rectangular voltage waveform \( e(t) \) shown in figure Q6a. [5 marks]

(b) Determine the peak value, average value, mean value, rms value and form factor of the waveform \( e(t) \). [2 marks]

(c) If the waveform \( e(t) \) is applied across the series L R circuit shown in figure Q6b, determine the Fourier Series of the resulting voltage \( v(t) \) across the resistor R. [3 marks]

(a) Determine the Laplace transform of the causal waveform \( e(t) \) shown in figure Q7a. [4 marks]

(b) Determine the Laplace transform of the causal waveform \( A e^{-at} \). [2 marks]

(c) If a constant d.c. voltage \( E = 100 \text{ V} \), is switched on to the circuit shown in figure Q7b, at \( t = 0 \), determine and sketch the voltage \( v(t) \). [4 marks]