Second Semester Examination
2022/2023 Academic Session

July/August 2023

EEU 104- ELECTRICAL TECHNOLOGY

Duration : 3 hours

Please check that this examination paper consists of **TWELVE (12)** pages of printed material including appendix before you begin the examination.

Instructions : This paper consists of **THREE (3)** questions. Answer **ALL** questions.

1. a) Find the equivalent resistance at terminal a-b for the following network in Figure 1(a) and 1(b):

(i).

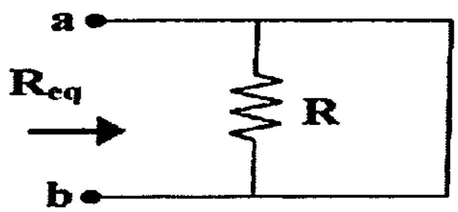

Figure 1(a)

(10 marks)

(ii).

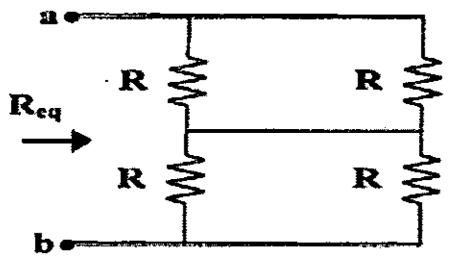

Figure 1(b)

(10 marks)

b) By using Thevenin Theorem, solve the current, *i* in Figure 1(c).

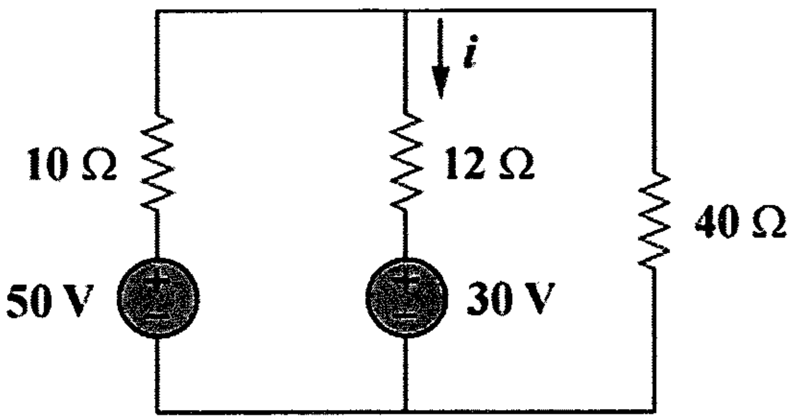

Figure 1(c)

(30 marks)

c) Find the Norton equivalent circuit for network in Figure 1(d).

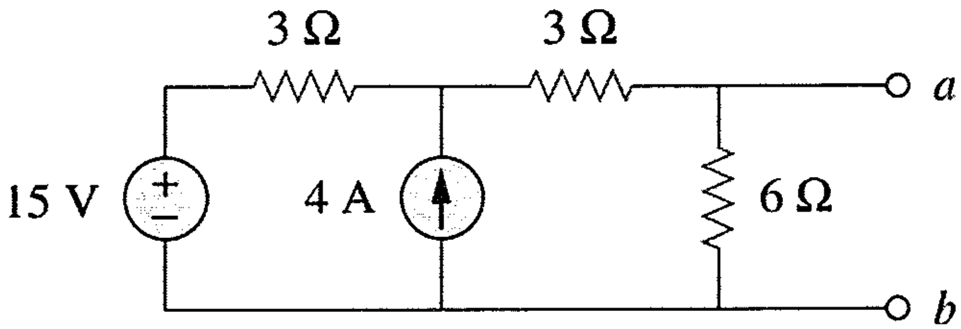

Figure 1(d)

(30 marks)

d) Use nodal analysis to obtain v_o in the circuit in Figure 1(e).

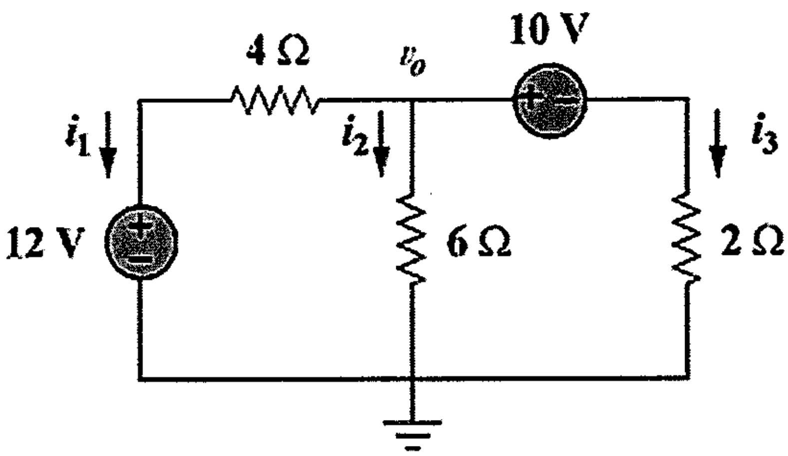

Figure 1(e)

(20 marks)

2. a) For the circuit in Figure 2(a), $i(t) = 4(2 - e^{-10t})$ mA. If $i_2(0) = -1$ mA,

Find:

(i). $i_1(0)$

(ii). $v_1(t)$ and $v_2(t)$

(iii). $i_1(t)$ and $i_2(t)$

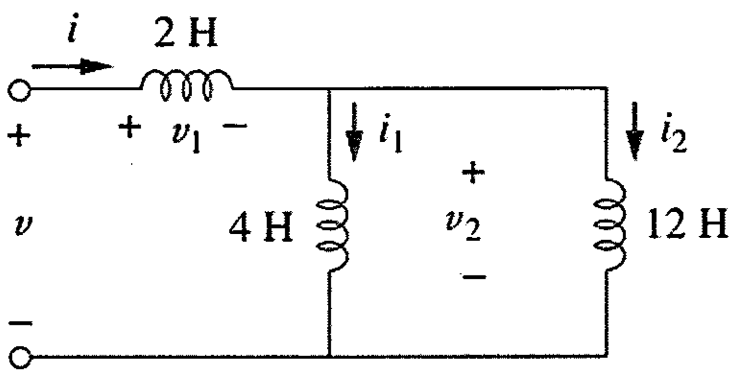

Figure 2(a)

(30 marks)

b) The initial voltages on capacitors in the circuit shown in Figure 2(b) have been established by sources not shown. The switch is closed at $t = 0$. Find:

(i). $v(t)$ for $t >= 0$

(ii). $i(t)$ for $t >= 0$

(iii). $v_1(t)$ for $t >= 0$.

(iv). $v_2(t)$ for $t >= 0$

(v). Calculate the initial energy stored in the Capacitors C1 and C2.

(vi). Determine how much energy is stored in the capacitors at $t \rightarrow \infty$.

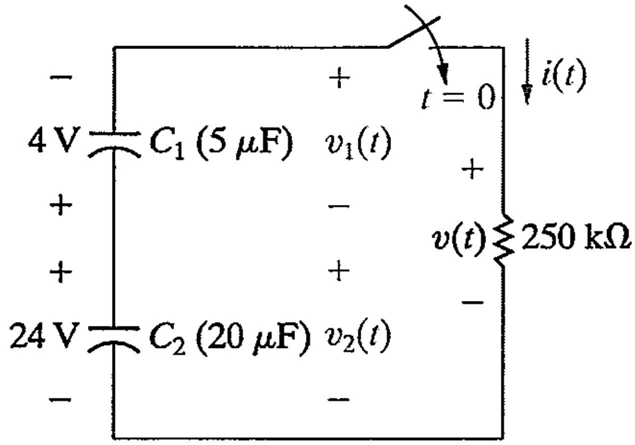

Figure 2(b)

(50 marks)

c) The switch in the circuit shown in Figure 2(c) has been open for a long time. The initial charge on the capacitor is zero. At t = 0, the switch is closed. Find the expression for:

(i). *i(t)* for *t*>=0

(ii). *v(t)* when *t* >=0

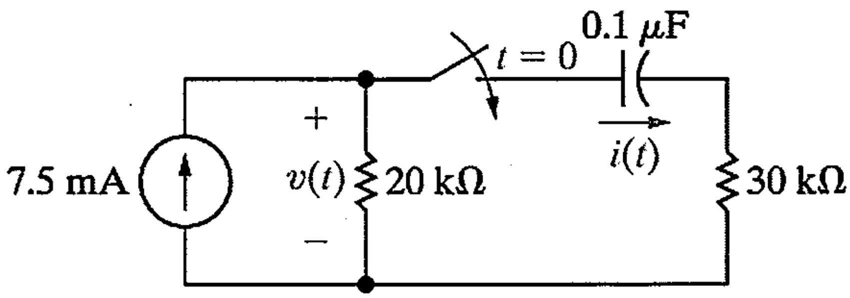

Figure 2(c)

(20 marks)

3. a) Briefly explain the comparison between AC voltage and DC voltage. May add related figure/s in your answers.

(20 marks)

b) Determine the total current in the circuit of Figure 3(a). Also, find the power consumed and the power factor.

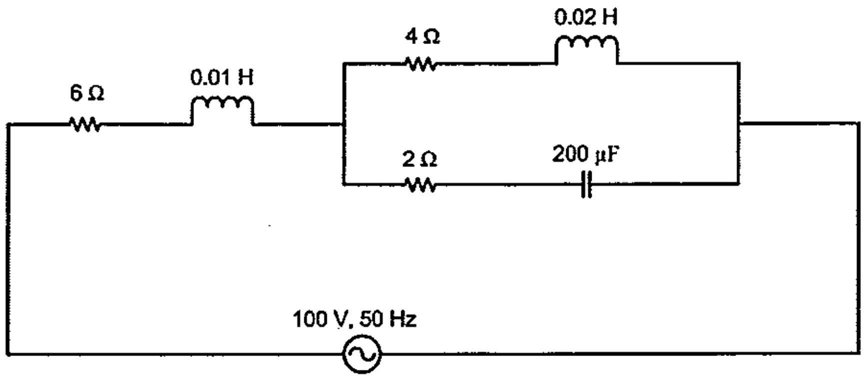

Figure 3(a)

(40 marks)

c) A three-phase network, 200kW, 50Hz, delta-connected induction motor is supplied from a three-phase, 440V, 50Hz supply system. The efficiency and power factor of the three-phase induction motor is 91% and 0.86 respectively. Calculate:

(i). Line currents

(ii). Currents in each phase of the motor

(iii). Active and reactive components of phase current

(40 marks)

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APPENDIX

Question	Course Outcome (CO)	Programme Outcome (PO)
1	2	PO2
2	2	PO3
3	3	PO4

Mathematical Formulas

This appendix – by no means exhaustive – serves as a handy reference. It does contain all the formulas needed to solve circuit problems in this examination book.

Quadratic Formula

The roots of the quadratic equation $ax^2 + bx + c = 0$ are

$$x_1, x_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Trigonometric Identities

$$\sin(-x) = -\sin x$$

$$\cos(-x) = \cos x$$

$$\sec x = \frac{1}{\cos x}, \csc x = \frac{1}{\sin x}$$

$$\tan x = \frac{\sin x}{\cos x}, \cot x = \frac{1}{\tan x}$$

$$\sin(x \pm 90°) = \pm \cos x$$

$$\cos(x \pm 90°) = \mp \sin x$$

$$\sin(x \pm 180°) = -\sin x$$

$$\cos(x \pm 180°) = -\cos x$$

$$\cos^2 x + \sin^2 x = 1$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \quad \text{(law of sines)}$$

$$a^2 = b^2 + c^2 - 2bc \cos A \quad \text{(law of cosines)}$$

$$\frac{\tan\frac{1}{2}(A - B)}{\tan\frac{1}{2}(A + B)} = \frac{a - b}{a + b} \quad \text{(law of tangents)}$$

$$\sin(x \pm y) = \sin x \cos y \pm \cos x \sin y$$

$$\cos(x \pm y) = \cos x \cos y \mp \sin x \sin y$$

$$\tan(x \pm y) = \frac{\tan x \pm \tan y}{1 \mp \tan x \tan y}$$

$$2 \sin x \sin y = \cos(x - y) - \cos(x + y)$$

$$2 \sin x \cos y = \sin(x + y) + \sin(x - y)$$

$$2 \cos x \cos y = \cos(x + y) + \cos(x - y)$$

$$\sin 2x = 2 \sin x \cos x$$

$$\cos 2x = \cos^2 x - \sin^2 x = 2\cos^2 x - 1 = 1 - 2\sin^2 x$$

$$\tan 2x = \frac{2\tan x}{1 - \tan^2 x}$$

$$\sin^2 x = \frac{1}{2}(1 - \cos 2x)$$

$$\cos^2 x = \frac{1}{2}(1 + \cos 2x)$$

$$K_1 \cos x + K_2 \sin x = \sqrt{K_1^2 + K_2^2}\cos\left(x + \tan^{-1} - \frac{K_2}{K_1}\right)$$

$$e^{\pm jx} = \cos x \pm j \sin x \quad \text{(Euler's identity)}$$

$$\cos x = \frac{e^{jx} + e^{-jx}}{2}$$

$$\sin x = \frac{e^{jx} - e^{-jx}}{2j}$$

$$1 \text{ rad} = 57.296°$$

Hyperbolic Functions

$$\sinh x = \frac{1}{2}(e^x - e^{-x})$$

$$\cosh x = \frac{1}{2}(e^x + e^{-x})$$

$$\tanh x = \frac{\sinh x}{\cosh x}$$

$$\coth x = \frac{1}{\tanh x}$$

$$\operatorname{csch} x = \frac{1}{\sinh x}$$

$$\operatorname{sech} x = \frac{1}{\cosh x}$$

$$\sinh(x \pm y) = \sinh x \cosh y \pm \cosh x \sinh y$$

$$\cosh(x \pm y) = \cosh x \cosh y \pm \sinh x \sinh y$$

Derivatives

If $U = U(x)$, $V = V(x)$, and $a =$ constant,

$$\frac{d}{dx}(aU) = a\frac{dU}{dx}$$

$$\frac{d}{dx}(UV) = U\frac{dV}{dx} + V\frac{dU}{dx}$$

$$\frac{d}{dx}\left(\frac{U}{V}\right) = \frac{\left(V\frac{dU}{dx} - U\frac{dV}{dx}\right)}{V^2}$$

$$\frac{d}{dx}(aU^n) = naU^{n-1}$$

$$\frac{d}{dx}(a^U) = a^U \ln a \frac{dU}{dx}$$

$$\frac{d}{dx}(e^U) = e^U \frac{dU}{dx}$$

$$\frac{d}{dx}(\sin U) = \cos U \frac{dU}{dx}$$

$$\frac{d}{dx}(\cos U) = -\sin U \frac{dU}{dx}$$

Indefinite Integrals

If $U = U(x)$, $V = V(x)$, and $a =$ constant,

$$\int a\,dx = ax + C$$

$$\int U\,dV = UV - \int V\,dU \quad \text{(integration by parts)}$$

$$\int U^n\,dU = \frac{U^{n+1}}{n+1} + C, \quad n \neq 1$$

$$\int \frac{dU}{U} = \ln U + C$$

$$\int a^U\,dU = \frac{a^U}{\ln a} + C, \quad a > 0, a \neq 1$$

$$\int e^{ax}\,dx = \frac{1}{a}e^{ax} + C$$

$$\int xe^{ax}\,dx = \frac{e^{ax}}{a^2}(ax - 1) + C$$

$$\int x^2e^{ax}\,dx = \frac{e^{ax}}{a^3}(a^2x^2 - 2ax + 2) + C$$

$$\int \ln x\,dx = x\ln x - x + C$$

$$\int \sin ax\,dx = -\frac{1}{a}\cos ax + C$$

$$\int \cos ax\,dx = \frac{1}{a}\sin ax + C$$

$$\int \sin^2 ax\,dx = \frac{x}{2} - \frac{\sin 2ax}{4a} + C$$

$$\int \cos^2 ax\,dx = \frac{x}{2} + \frac{\sin 2ax}{4a} + C$$

$$\int x\sin ax\,dx = \frac{1}{a^2}(\sin ax - ax\cos ax) + C$$

$$\int x \cos ax\, dx = \frac{1}{a^2}(\cos ax + ax \sin ax) + C$$

$$\int x^2 \sin ax\, dx = \frac{1}{a^3}(2ax \sin ax + 2\cos ax - a^2x^2 \cos ax) + C$$

$$\int x^2 \cos ax\, dx = \frac{1}{a^3}(2ax \cos ax - 2\sin ax + a^2x^2 \sin ax) + C$$

$$\int e^{ax} \sin bx\, dx = \frac{e^{ax}}{a^2 + b^2}(a \sin bx - b \cos bx) + C$$

$$\int e^{ax} \cos bx\, dx = \frac{e^{ax}}{a^2 + b^2}(a \cos bx + b \sin bx) + C$$

$$\int \sin ax \sin bx\, dx = \frac{\sin(a-b)x}{2(a-b)} - \frac{\sin(a+b)x}{2(a+b)} + C, \quad a^2 \neq b^2$$

$$\int \sin ax \cos bx\, dx = -\frac{\cos(a-b)x}{2(a-b)} - \frac{\cos(a+b)x}{2(a+b)} + C, \quad a^2 \neq b^2$$

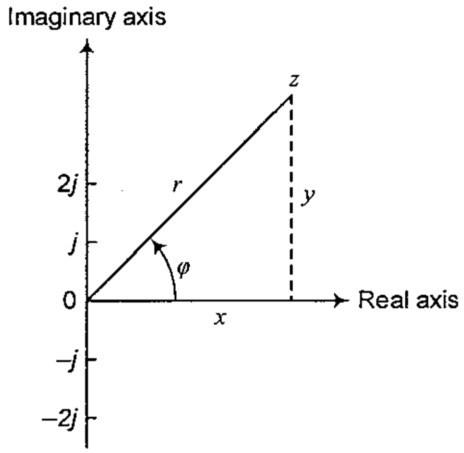
$$\int \cos ax \cos bx\, dx = \frac{\sin(a-b)x}{2(a-b)} + \frac{\sin(a+b)x}{2(a+b)} + C, \quad a^2 \neq b^2$$

$$\int \frac{dx}{a^2 + x^2} = \frac{1}{a}\tan^{-1}\frac{x}{a} + C$$

$$\int \frac{x^2 dx}{a^2 + x^2} = x - a\tan^{-1}\frac{x}{a} + C$$

$$\int \frac{dx}{(a^2 + x^2)^2} = \frac{1}{2a^2}\left(\frac{x}{x^2 + a^2} + \frac{1}{a}\tan^{-1}\frac{x}{a}\right) + C$$

Phasor & Complex Number



Complex number in rectangular form:

$$z = x + jy$$

$$r = \sqrt{x^2 + y^2}$$

$$\varphi = \tan^{-1}\frac{y}{x}$$

$$z = r(\cos\varphi + j\sin\varphi)$$

$$\frac{1}{j} = -j \text{ and } j = 1\angle 90°$$

Complex number in polar form:

$$z = r\angle\varphi$$

Complex number in exponential form:

$$z = re^{j\varphi}$$

Sinusoid ↔ phasor transformation:

$$V_m\cos(\omega t + \varphi) \leftrightarrow V_m\angle\varphi$$

$$V_m\sin(\omega t + \varphi) \leftrightarrow V_m\angle(\varphi - 90°)$$

$$I_m\cos(\omega t + \theta) \leftrightarrow I_m\angle\theta$$

$$I_m\sin(\omega t + \theta) \leftrightarrow I_m\angle(\theta - 90°)$$

Mathematic operation of complex number:

Addition $z_1 + z_2 = (x_1 + x_2) + j(y_1 + y_2)$

Subtraction $z_1 - z_2 = (x_1 - x_2) + j(y_1 - y_2)$

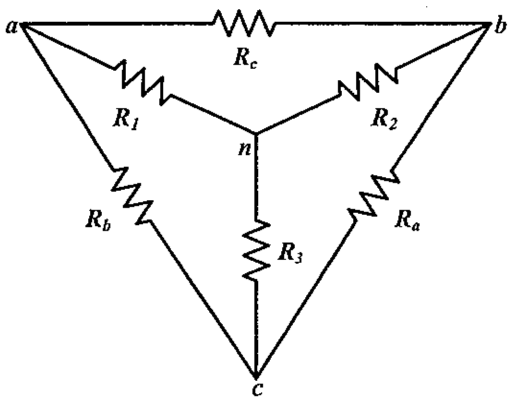
Multiplication $z_1 z_2 = r_1 r_2\angle(\varphi_1 + \varphi_2)$

Division $\frac{z_1}{z_2} = \frac{r_1}{r_2}\angle(\varphi_1 - \varphi_2)$

Reciprocal $\frac{1}{z} = \frac{1}{r}\angle - \varphi$

Square-root $\sqrt{z} = \sqrt{r}\angle(\varphi/2)$

Complex conjugate $z^* = x - jy = r\angle - \varphi = re^{-j\varphi}$



$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} \qquad R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

$$R_2 = \frac{R_c R_a}{R_a + R_b + R_c} \qquad R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c} \qquad R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$