FIJI NATIONAL UNIVERSITY

COLLEGE OF ENGINEERING, SCIENCE AND TECHNOLOGY

SCHOOL OF ELECTRICAL & ELECTRONIC ENGINEERING

BACHELOR IN ENGINEERING (HONS) (ELECTRICAL & ELECTRONICS)

EEB601 – CIRCUIT THEORY

SEMESTER 1 - 2019. Total [100marks]

DAY/DATE: As per timetable TIME: As per timetable ROOM: As per timetable.

INSTRUCTIONS TO STUDENTS

1. *Candidates are reminded that they should have no books, notes, paper or other material in their procession unless their use is specifically permitted by "instructions to Candidates" set out below.*
2. *Reading time is 10 minutes duration.*
3. *Examination time is of 3 hours duration*
4. *This paper consist of 6 questions, with parts, printed on 8 pages.*
5. *Attempt all 6 questions. Each question may carry a different mark.*
6. *A set of Laplace Transforms Table is attached*
7. *A formula sheet is also attached*
8. *The MatLab software is available on the PC provided.*
9. *Use of the Internet, Google and any other application is strictly prohibited.*
10. *Write your candidate number at the top of each attached sheet*
11. *Start each question on a new page*
12. *Non- programmable Calculators may be used*
13. *Mobile phones are not allowed inside the examination venue.*

FORMULA SHEET

1. $\int u dv = uv - \int v du$

2. Integrating Factor $R = e^{\int P(t)dt}$; $Rf(t) = \int RQ(t)dt$

3. $s = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

4. $CLTF = \dfrac{G(s)}{1 + G(s)H(s)}$

5. $f(t) = a_0 + \sum_{n=1}^{\infty}\left(a_n \cos\frac{n\pi}{L}t + b_n \sin\frac{n\pi}{L}t\right)$; $a_0 = \frac{1}{T}\int_0^T f(t)dt = \frac{1}{2L}\int_0^{2L} f(t)dt$;

   $a_n = \frac{2}{T}\int_0^T f(t)\cos n\omega t\, dt = \frac{1}{L}\int_0^{2L} f(t)\cos\frac{n\pi}{L}t\, dt$;

   $b_n = \frac{2}{T}\int_0^T f(t)\sin n\omega t\, dt = \frac{1}{L}\int_0^{2L} f(t)\sin\frac{n\pi}{L}t\, dt$

6. $q = CV$; $i(t) = \frac{dq}{dt}$; $i(t) = C\frac{dv}{dt}$ $i(t) = \frac{v(t)}{R}$ $w_C = \frac{1}{2}CV^2$

7. $v(t) = L\frac{di}{dt}$; $v(t) = \frac{1}{C}\int i(t)\, dt$; $v(t) = Ri(t)$; $w_L = \frac{1}{2}LI^2$

QUESTION 1: THEVENIN THEOREM & NORTON THEOREM

[TOTAL: 20]

Q 1 - 1: Thevenin Theorem

Refer to Figure 1. The circuit load is $R_L = 8\Omega$

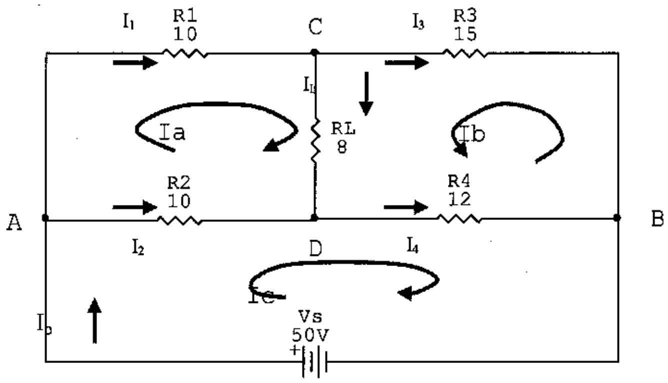

Figure 1: Bridge Network

(a) Determine the Thevenin equivalent circuit. **[8 marks]**

(b) Calculate the current through the load, $R_L = 8\Omega$. **[2 marks]**

(c) Solve for the power absorbed by the load. **[2 marks]**

Q1 - 2: Norton Theorem

Refer to Figure 1.

(a) Derive the Norton equivalent circuit. **[6 marks]**

(b) Confirm the current through the load, $R_L = 8\Omega$. **[2 marks]**

QUESTION 2: LOOP ANALYSIS & NODAL ANALYSIS

[TOTAL: 16 MARKS]

Q2 - 1: Loop Analysis

Refer to
Figure 2.

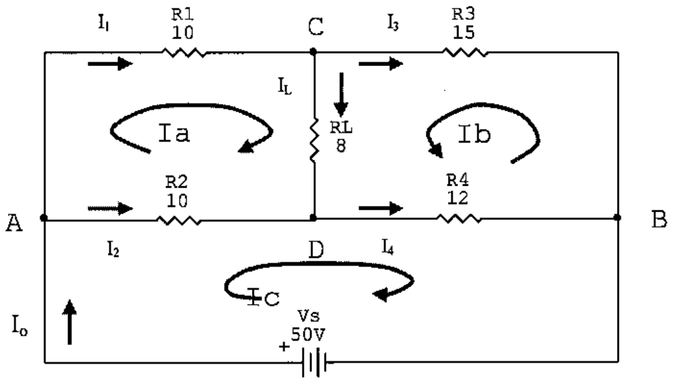

Figure 2: Bridge Network

(a) Solve for the currents I_a, $I_{b,}$ and I_c. **[6 marks]**

(b) Work out the current through the load, $R_L = 8\Omega$. **[2 marks]**

Q2 - 2: Nodal Analysis

(a) Use Nodal Analysis to determine V_C and V_D **[6 marks]**

(b) Determine the load current, I_L. **[2 marks]**

QUESTION 3: SUPERPOSITION THEOREM & LOOP ANALYSIS WITH DEPENDENT SOURCE **[TOTAL: 12 MARKS]**

Q3-1: Superposition Theorem

Utilize the Superposition Theorem to determine the four unknown currents in Figure 3. Then determine the voltage drop across the 6Ω load. **[8 marks]**

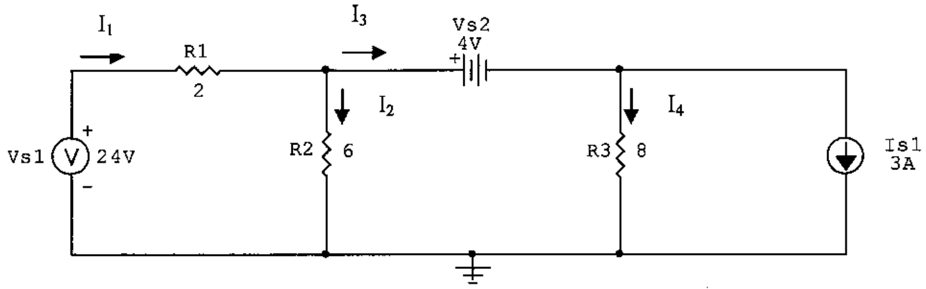

Figure 3

Q3 - 2: Loop Analysis With Dependent Source

Consider Figure 4, shown. Use Loop (Mesh) analysis to determine currents $I_1, I_2, I_3,$ and I_0. **[4 marks]**

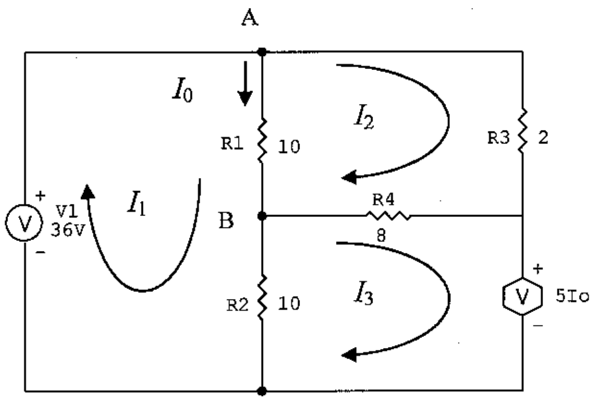

Figure 4

QUESTION 4: SECOND ODER *RLC* NETWORKS & TRANSIENTS
[TOTAL = 22 MARKS]

Q4 - 1: Analyze the *RLC* Series circuit shown in **Figure 5**. The output is taken across the resistor, *R*. Assume zero initial conditions.

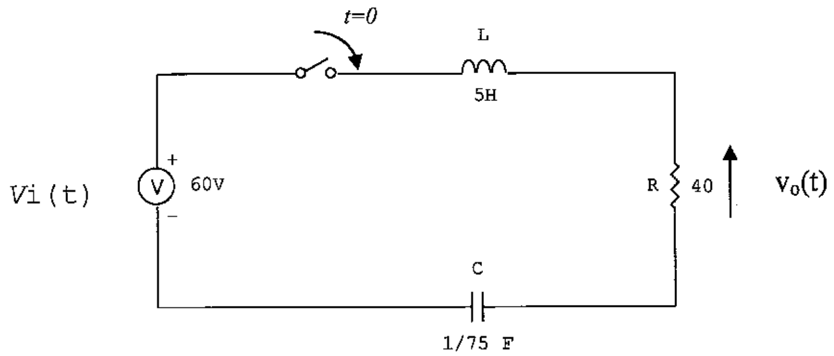

Figure 5: Series *RLC* circuit

(a) Derive the Second Order Differential Equation model of the system using Kirchhoff's Voltage Law (KVL). **[4 marks]**

(b) Transform the Differential Equation from time to s-domain using Laplace Transforms, to obtain $Q(s)$

[5 marks]

(c) Determine the Particular Solution *q(t)*.from the *Q(s)*obtained in (b).

[3 marks]

[Total: 12 marks]

Q4 - 2: Process the information regarding the Series *RLC* Critically damped circuit shown in Figure 6. The initial conditions are $v(0) = 2$ V and $i(0) = 1$ A. Derive the step response *i(t)* and *v(t)* for the *RLC* circuit.

[Total: 10 marks]

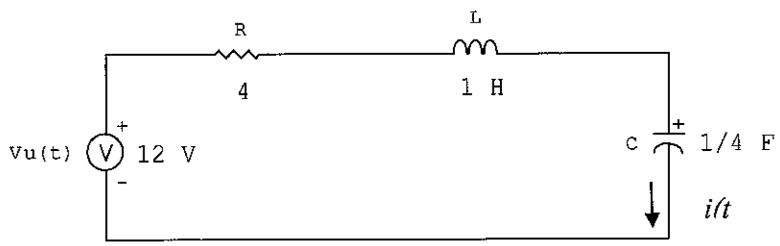

Figure 6: Series *RLC* circuit – Critically damped

QUESTION 5: AC NETWORKS **[TOTAL = 20 MARKS]**

Q5-1: A 60 Ω resistor, a 0.5 H inductor, and an 8 uF capacitor are connected in series with a 240 V, 60 Hz ac source.

(a) Determine the magnitude of the Impedance of the circuit. **[3 marks]**

(b) Calculate the effective (rms) current and the phase angle. **[3 marks]**

(c) Resolve for the Resonance Frequency. **[3 marks]**

(d) Derive the Average Power. **[3 marks]**

(e) Analyse for the Power Factor. **[2 marks]**

Q5 - 2: A balanced Δ-connected load having an impedance 20-j15 Ω is connected to a Δ-connected positive-sequence generator having $V_{ab} = 330\angle 0° \text{ V}$ Calculate the phase currents of the load and the line currents. **[6 marks]**

QUESTION 6: TWO-PORT NETWORKS [TOTAL: 10 MARKS]

Q6 - 1: Determine the Z-parameters of the circuit in Figure 7 given the relationships stated. **[6 marks]**

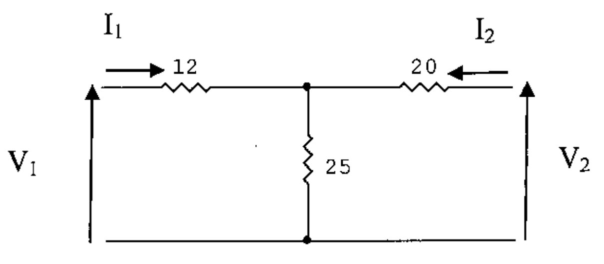

Figure 7

$$z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0} \qquad z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0}$$

$$z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0} \qquad z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0}$$

Q6 – 2: Analyse for the Z-parameters for the circuit of Figure 8. **[4 marks]**

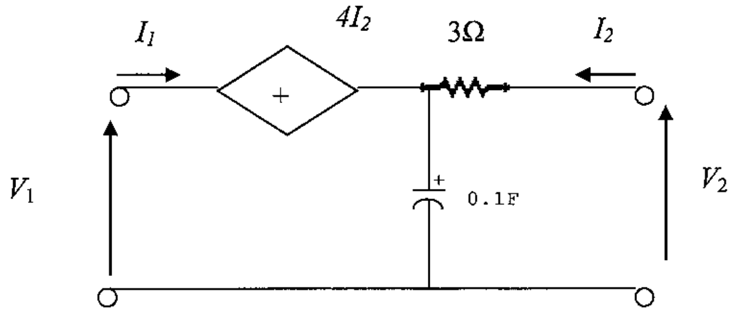

Figure 8

[END OF EXAMINATION]

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TABLE OF LAPLACE TRANSFORMS

$F(s)=L[f(t)]$	$f(t),\ t\geq 0$
1. 1	$\delta(t_0)$, Unit Impulse at $t=t_0$
2. $\frac{1}{s}$	1, Unit Step
3. $\frac{n!}{s^{n+1}}$	t^n
4. $\frac{1}{s+a}$	e^{-at}
5. $\frac{1}{(s+a)^n}$	$\frac{1}{(n-1)!}t^{n-1}e^{-at}$
6. $\frac{a}{s(s+a)}$	$1-e^{-at}$
7. $\frac{1}{(s+a)(s+b)}$	$\frac{1}{(b-a)}\left(e^{-at}-e^{-bt}\right)$
8. $\frac{s+\alpha}{(s+a)(s+b)}$	$\frac{1}{(b-a)}\left[(\alpha-a)e^{-at}-(\alpha-b)e^{-bt}\right]$
9. $\frac{ab}{s(s+a)(s+b)}$	$1-\frac{b}{(b-a)}e^{-at}+\frac{a}{(b-a)}e^{-bt}$
10. $\frac{1}{(s+a)(s+b)(s+c)}$	$\frac{e^{-at}}{(b-a)(c-a)}+\frac{e^{-bt}}{(c-a)(a-b)}+\frac{e^{-ct}}{(a-c)(b-c)}$
11. $\frac{s+\alpha}{(s+a)(s+b)(s+c)}$	$\frac{(\alpha-a)e^{-at}}{(b-a)(c-a)}+\frac{(\alpha-b)e^{-bt}}{(c-b)(a-b)}+\frac{(\alpha-c)e^{-ct}}{(a-c)(b-c)}$
12. $\frac{ab(s+\alpha)}{s(s+a)(s+b)}$	$\alpha-\frac{b(\alpha-a)}{(b-a)}e^{-at}+\frac{a(\alpha-a)}{(b-a)}e^{-bt}$
13. $\frac{\omega}{s^2+\omega^2}$	$\sin\omega t$
14. $\frac{s}{s^2+\omega^2}$	$\cos\omega t$
15. $\frac{s+a}{s^2+\omega^2}$	$\frac{\sqrt{\alpha^2+\omega^2}}{\omega}\sin(\omega t+\phi)$, $\phi=\tan^{-1}\left(\frac{\omega}{\alpha}\right)$
16. $\frac{\omega}{(s+a)^2+\omega^2}$	$e^{-at}\sin\omega t$

$F(s) = L[f(t)]$	$f(t),\ t \geq 0$
17. $\dfrac{(s+a)}{(s+a)^2+\omega^2}$	$e^{-at}\cos\omega t$
18. $\dfrac{s+\alpha}{(s+a)^2+\omega^2}$	$\dfrac{1}{\omega}\left[(\alpha-a)^2+\omega^2\right]^{\frac{1}{2}} e^{-at}\sin(\omega t+\phi),$ $\phi=\tan^{-1}\left(\dfrac{\omega}{\alpha-a}\right)$
19. $\dfrac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$	$\dfrac{\omega_n}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}\,t,\ \zeta<1$
20. $\dfrac{1}{s\left[(s+a)^2+\omega^2\right]}$	$\dfrac{1}{a^2+\omega^2}+\dfrac{1}{\omega\sqrt{a^2+\omega^2}} e^{-at}\sin(\omega t-\phi),$ $\phi=\tan^{-1}\left(\dfrac{\omega}{-a}\right)$
21. $\dfrac{\omega_n^2}{s\left(s^2+2\zeta\omega_n s+\omega_n^2\right)}$	$1-\dfrac{1}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t}\sin\left(\omega_n\sqrt{1-\zeta^2}\,t+\phi\right),$ $\phi=\cos^{-1}\zeta, \zeta<1$
22. $\dfrac{(s+\alpha)}{s\left[(s+a)^2+\omega^2\right]}$	$\dfrac{\alpha}{a^2+\omega^2}+\dfrac{1}{\omega}\left[\dfrac{(\alpha-a)^2+\omega^2}{a^2+\omega^2}\right]^{\frac{1}{2}} e^{-at}\sin(\omega t+\phi),$ $\phi=\tan^{-1}\left(\dfrac{\omega}{\alpha-a}\right)-\tan^{-1}\left(\dfrac{\omega}{-a}\right)$
23. $\dfrac{1}{(s+c)\left[(s+a)^2+\omega^2\right]}$	$\dfrac{e^{-ct}}{(c-a)^2+\omega^2}+\dfrac{e^{-at}\sin(\omega t+\phi)}{\omega\left[(c-a)^2+\omega^2\right]^{\frac{1}{2}}},$ $\phi=\tan^{-1}\left(\dfrac{\omega}{c-a}\right)$

24. $\frac{a}{s^2 - a^2}$	$\sinh at$
25. $\frac{s}{s^2 - a^2}$	$\cosh at$
26. $\frac{\omega^2}{s(s^2 + \omega^2)}$	$1 - \cos \omega t$
27. $\frac{\omega^3}{s^2(s^2 + \omega^2)}$	$\omega t - \sin \omega t$
28. $\frac{2\omega^3}{(s^2 + \omega^2)^2}$	$\sin \omega t - \omega t \cos \omega t$

$F(s) = L[f(t)]$	$f(t), \quad t \geq 0$
29. $\dfrac{s}{(s^2+\omega^2)^2}$	$\dfrac{t}{2\omega}\sin\omega t$
30. $\dfrac{s^2}{(s^2+\omega^2)^2}$	$\dfrac{1}{2\omega}(\sin\omega t + \omega t\cos\omega t)$
31. $\dfrac{s}{(s^2+a^2)(s^2+b^2)} \quad (a^2 \neq b^2)$	$\dfrac{1}{b^2-a^2}(\cos at - \cos bt)$

LAPLACE TRANSFORM OF DERIVATIVES

32. $sF(s) - f(0)$	$f'(t)$, First Derivative
33. $s^2F(s) - sf(0) - f'(0)$	$f''(t)$, Second Derivative

GENERAL PROPERTIES OF LAPLACE TRANSFORMS

1. Linearity $\quad L[af_1(t) + bf_2(t)] = aF_1(s) + bF_2(s)$

2. Scaling $\quad L[f(at)] = \dfrac{1}{a}F\left(\dfrac{s}{a}\right)$

3. Transform of a Derivative
$$L[f^{(n)}(t)] = s^nF(s) - s^{n-1}f(0) - s^{n-2}f'(0) - \ldots - sf^{(n-2)}(0) - f^{(n-1)}(0)$$

4. First Shifting Theorem $\quad L[e^{at}f(t)] = F(s-a)$
(Complex Translation; s-shifting)

5. Second Shifting Theorem $\quad L[u(t-a)f(t-a)] = e^{-as}F(s)$
(Real Translation; t—shifting)

6. Integration $\quad L\left[\int_0^t f(\tau)d\tau\right] = \dfrac{1}{s}F(s)$

7. Complex Differentiation $\quad L[t\,f(t)] = -\dfrac{dF(s)}{ds}$

8. Final Value Theorem $\quad f(\infty) = \lim_{s \to 0} sF(s)$

9. Initial Value Theorem $\quad f(0+) = \lim_{s \to \infty} sF(s)$