ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE
FACULTY OF ENGINEERING
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FIRST SEMESTER EXAMINATION, 2019/2020 ACADEMIC SESSION

COURSE TITLE: ELECTRIC CIRCUIT THEORY

COURSE CODE: EEE 317

EXAMINATION DATE: 14TH FEBRUARY, 2020

COURSE LECTURER: DR R. O. Alli-Oke

HOD's SIGNATURE

TIME ALLOWED: 3 HRS

INSTRUCTIONS:

1. ANSWER **QUESTION 1** AND ANY OTHER FOUR QUESTIONS **(TOTAL OF 5 QUESTIONS)**
2. SEVERE PENALTIES APPLY FOR MISCONDUCT, CHEATING, POSSESSION OF UNAUTHORIZED MATERIALS DURING EXAM.
3. YOU ARE **NOT** ALLOWED TO BORROW CALCULATORS AND ANY OTHER WRITING MATERIALS DURING THE EXAMINATION.

QUESTION #1 [20 Marks]

a) Figure Q1a shows a relay driver circuit in which the relay is modelled as a series connection of $R_R = 200\Omega$ and $L_R = 400\mu H$. To protect the switch driving the relay, a resistor $R_F = 100\Omega$ is placed across the relay as shown.

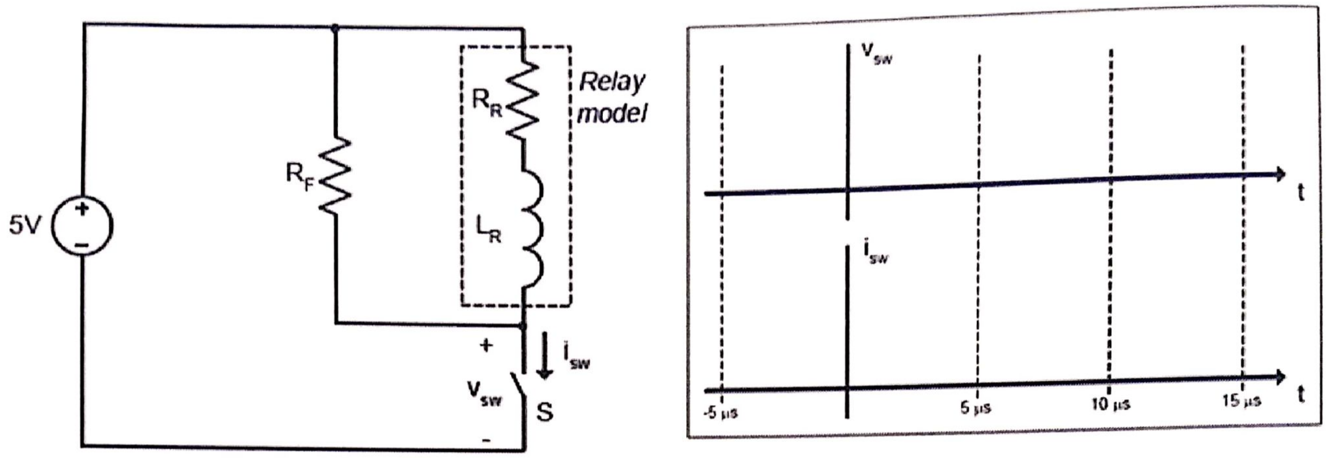

Figure Q1a: Relay Driver Circuit

After being open for a long time, the switch is closed at $t = 0$, then opened at $t = 10\ \mu s$. On the axes provided, sketch the switch voltage v_{sw} and switch current i_{sw} from $t = -5\ \mu s$ to $15\ \mu s$. Clearly label all the time constants, initial values, and steady-state values. *Hint: There are three regions, and therefore three sub-circuits to be drawn and analyzed for their time constants, initial values, and steady-state values.* **[10 marks]**

b) Consider the schematic of the Sallen-Key Low-Pass Filter shown in Figure Q1b. **[10 marks]**

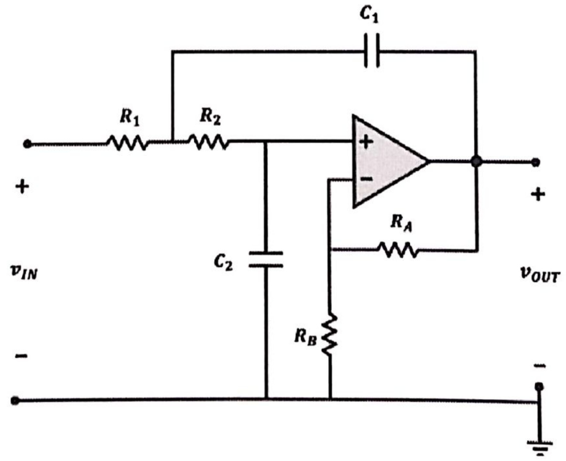

Figure Q1b: Sallen-Key Low-Pass Filter

i) Determine the DC gain. *Hint: at DC the capacitors are open-circuits, and you can then use ideal op-amp analysis.*

ii) Suppose the initial conditions on the capacitors are zero, R_A=0 and R_B=∞. Let R_1=R_2=R and C_1=C_2=C. Show that the voltage transfer function $H(s) = \frac{V_{OUT}}{V_{IN}} = \frac{1}{s^2R^2C^2+2\,sRC+1}$ *Hint: Use the Laplace-domain circuit.*

iii) Obtain the DC gain from the expression obtained in (ii). Is it consistent with the result obtained in (i)?

iv) The cut-off frequency is given by $f_c = 1/(2\pi RC)$. Choose R ≥ 5 $k\Omega$ and C such that it has a unity DC gain, and a cutoff frequency at 1 kHz.

QUESTION #2 [10 Marks]

a) Consider the op-amp circuit shown in the Figure Q2a. Using only KCL, determine v_{out}. **[4 marks]**

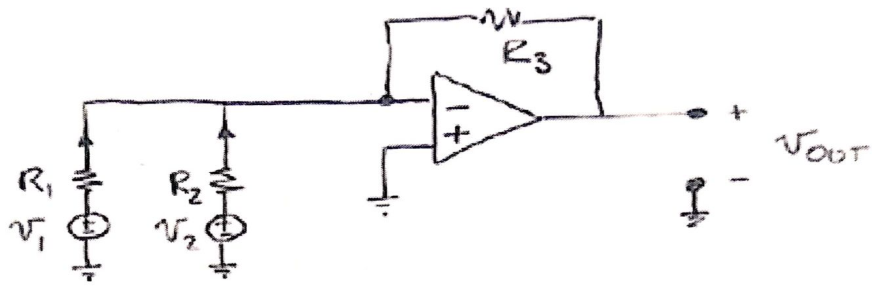

Figure Q2a: Op-Amp Circuit

b) Assume $v_o(0) = 5$ and use Laplace-domain analysis to determine $v_o(t)$ in Figure Q2b *Hint:* $\mathcal{L}\{e^{-t}\,u(t)\} = \frac{1}{s+1}$ *and* $\mathcal{L}\{\partial t\} = 1$. **[6 marks]**

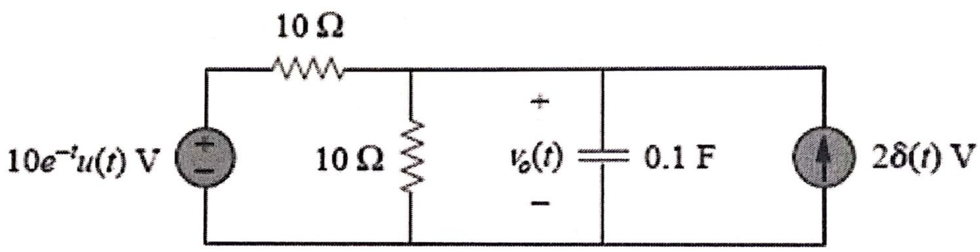

Figure Q2b: Source-Driven RC Circuit

QUESTION #3 [10 Marks]

a) Use time-domain analysis to obtain the inductor current $i_L(t)$ for all times for the circuit in Figure Q3a. **[4 marks]**

b) Compute the voltage v_o at the output port in Figure 3b, and the power absorbed by the voltage–dependent source. **[6 marks]**

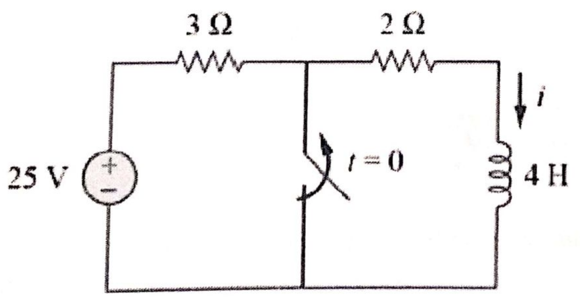

Figure Q3a: Resistive Network

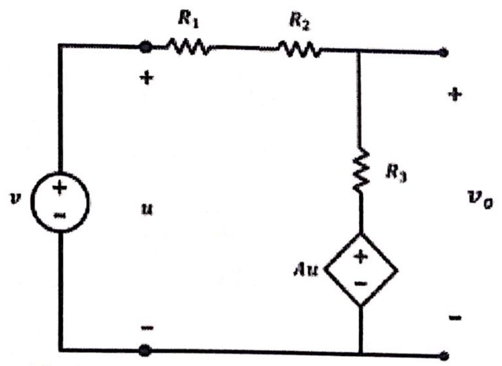

Figure Q3b: Voltage-Dependent Source Circuit

QUESTION #4 [10 Marks]

a) Using phasor-domain analysis, determine the steady-state current $i(t)$ shown in Figure Q4a. **[4 marks]**

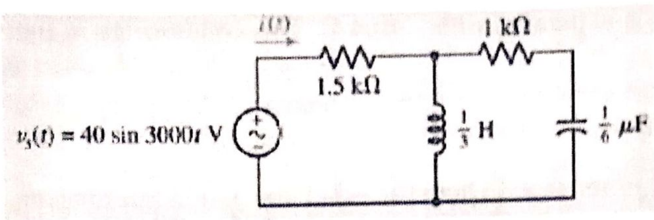

Figure Q4a: A Sinusoidal-Excited Circuit

b) Consider the schematic diagram of 2-bit op-amp-based R-2R ladder logic shown in Figure Q4b. Use superposition with Thevenin's theorem to determine V_o. **[6 marks]**

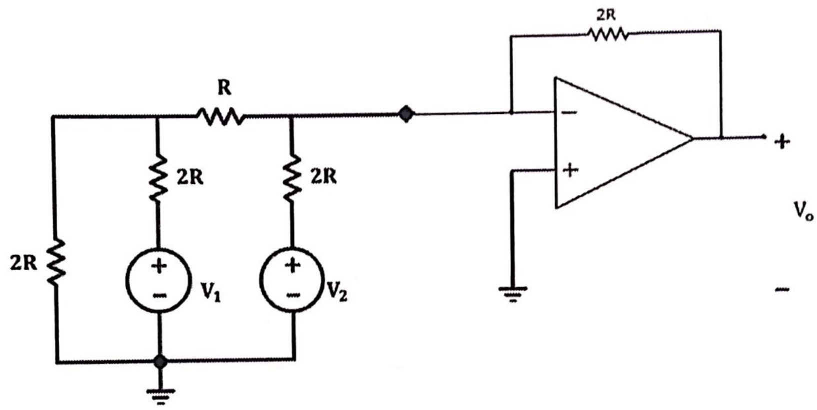

Figure Q4b: Op-Amp Based R-2R ladder DAC Circuit

QUESTION #5 [10 Marks]

a) Differentiate between Laplace–Domain circuits and Phasor–Domain circuits. With the aid of well-labelled diagrams, differentiate between Thevenin's theorem and Norton's theorem. **[4 marks]**

b) Let $V(s)$ be the Laplace-transform of $v(t)$ shown in Figure Q5b. Derive the expression for $V(s)$. **[6 marks]**

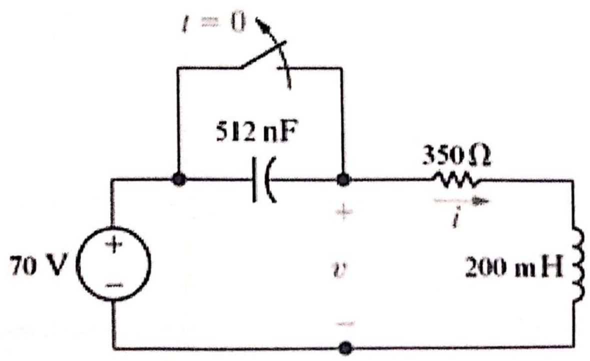

Figure Q5b: Source-Driven RLC Circuit

QUESTION #6 [10 Marks]

a) An ultrasonic device transmits signals which bounces off a moving object, and are turned back to voltages by an ultrasonic receiver. The received signal is tiny and needs to be amplified before further processing. Show that the voltage gain of this receiver amplifier (Figure Q6a) is given by $v_{OUT} = 2.5 - \frac{R5}{R4} v_{IN}$. Choose resistor values (10 $k\Omega$ - 100 $k\Omega$ range) for R4 and R5 such that the amplifier gain is eight. **[5 marks]**

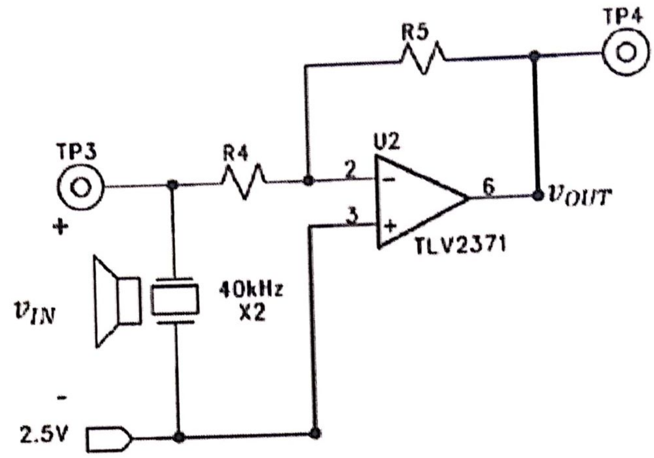

Figure Q6a: Ultrasonic Receiver Amplifier

b) Consider the single node-pair circuit shown in Figure Q6b. Determine the current in the 3kΩ resistor using Thevenin's theorem. **[5 marks]**

i. Find the Thevenin's network of network A.

ii. Find the Thevenin's network of network B.

iii. Draw the diagram of the reduced circuit diagram of Figure 6b by replacing network A & B with their respective Thevenin's network.

iv. Use KVL to compute the current through the 3kΩ resistor.

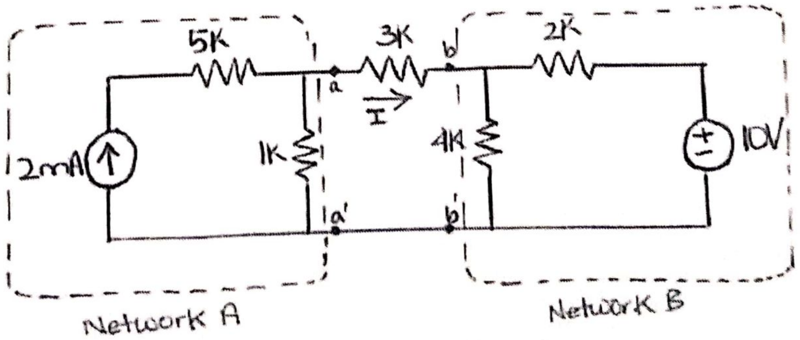

Figure Q6b: Resistive Network

QUESTION #7 [10 Marks]

a) Consider the network shown in Figure Q7a. When $V = 10\ V$ and $I = 0\ A$, it is observed that $i = -1\ A$ and $v = 5\ V$. Additionally, when $I = 2\ A$ and $V = 0$, it is observed that $v = 20\ V$. With this information, determine R_1, R_2 and R_3.

[3 marks]

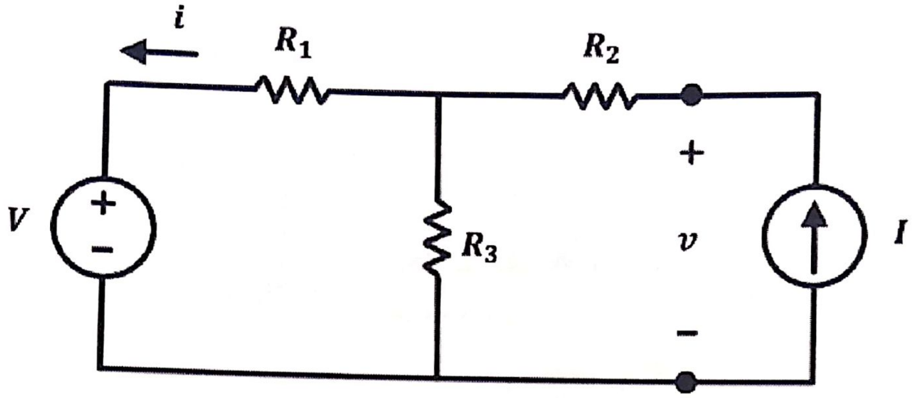

Figure Q7a: Resistive Network

b) Consider the source-driven RC circuit shown in Figure Q7b.

[7 marks]

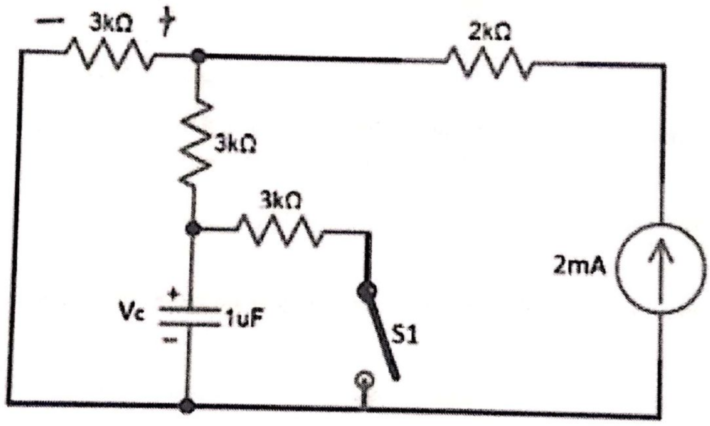

Figure Q7b: Source-Free RC Circuit

i) The switch S1 closes at $t \geq 0^+$. At $t \geq 0^+$ (i. e. switch S1 is closed), determine the effective resistance R_{eff} seen by the capacitor, and the characteristic time-constant τ by which the capacitor voltage V_c evolves.

ii) Using time-domain analysis, derive an expression for $V_c(t)$ for $t \geq 0^+$.