UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE	**:**	**EEB2063/EFB2053 - MICROELECTRONIC CIRCUITS**
DATE	**:**	**7 AUGUST 2024 (WEDNESDAY)**
TIME	**:**	**9.00 AM - 12.00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **SIX (6)** pages in this Question Booklet including the cover page and appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. Consider a typical BJT amplifier connected to an active load as shown in **FIGURE Q1**. Assume that the circuit has a supply of $V^+ = 5$ V and has the following transistor parameters: $I_{S0} = I_{S1} = I_{S2} = 1.5 \times 10^{-12}$ A and $V_{AN} = V_{AP} = 120$ V.

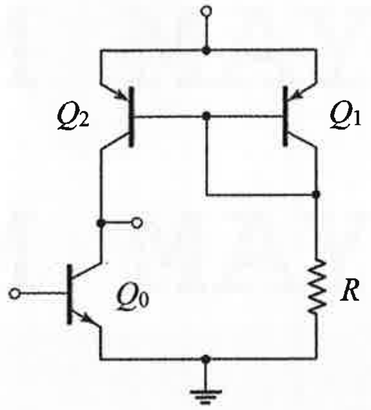

FIGURE Q1

a. Redraw the circuit in **FIGURE Q1** and label all components, input v_I, output v_O, current I_{REF}, and all other voltages and currents. Show clearly the current directions and terminal polarities.

[6 marks]

b. Referring to the sketch in **part (a)**, identify the elements that form the active load circuit, the transistor which is the active load driver and the transistor which functions as amplifier.

[5 marks]

c. Let $I_{REF} = I_S \exp\left(\frac{v_{EB2}}{V_T}\right)$. Determine the value of v_{EB2} and R such that $I_{REF} = 0.6$ mA.

[6 marks]

d. Assuming the following equation for the BJT amplifier with active load, evaluate the value of the input voltage, v_I, to produce $v_{CE0} = v_{EC2}$.

$$I_{S0}\left[\exp\left(\frac{v_I}{V_T}\right)\right]\left(1+\frac{v_{CE0}}{V_{AN}}\right) = I_{REF} \times \frac{\left(1+\frac{v_{EC2}}{V_{AP}}\right)}{\left(1+\frac{v_{EB2}}{V_{AP}}\right)}$$

[7 marks]

2. A differential amplifier is a fundamental building block of analog circuits commonly used as the input stage of an op-amp. **FIGURE Q2** shows a differential amplifier with the following transistor parameters: $\beta = 90$, $V_{BE}(on) = 0.75$ V, and $V_A = \infty$.

a. For $v_1 = v_2 = 0$, find I_{C1}, I_{C2}, I_E, V_{CE1} and V_{CE2}.

[10 marks]

b. Determine the maximum and minimum values of the common-mode input voltage, v_{cm}.

[6 marks]

c. Calculate the differential-mode gain, A_d, for a one-sided output at the collector of Q_2.

[8 marks]

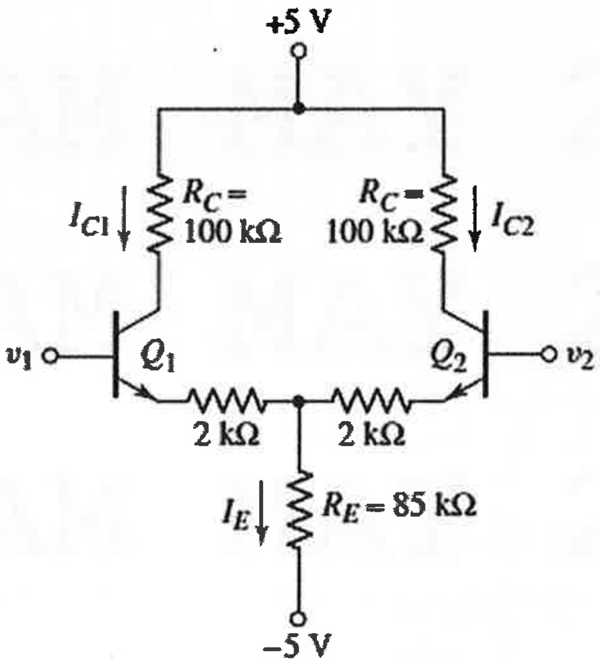

FIGURE Q2

3. **FIGURE Q3** shows an example of a shunt–series feedback circuit. A signal proportional to the output current is fed back to the shunt connection at the base of Q_1. However, the circuit may be used as a voltage amplifier. Assume transistor parameters of h_{FE} = 110, $V_{BE}(\text{on})$ = 0.65 V, and $V_A = \infty$.

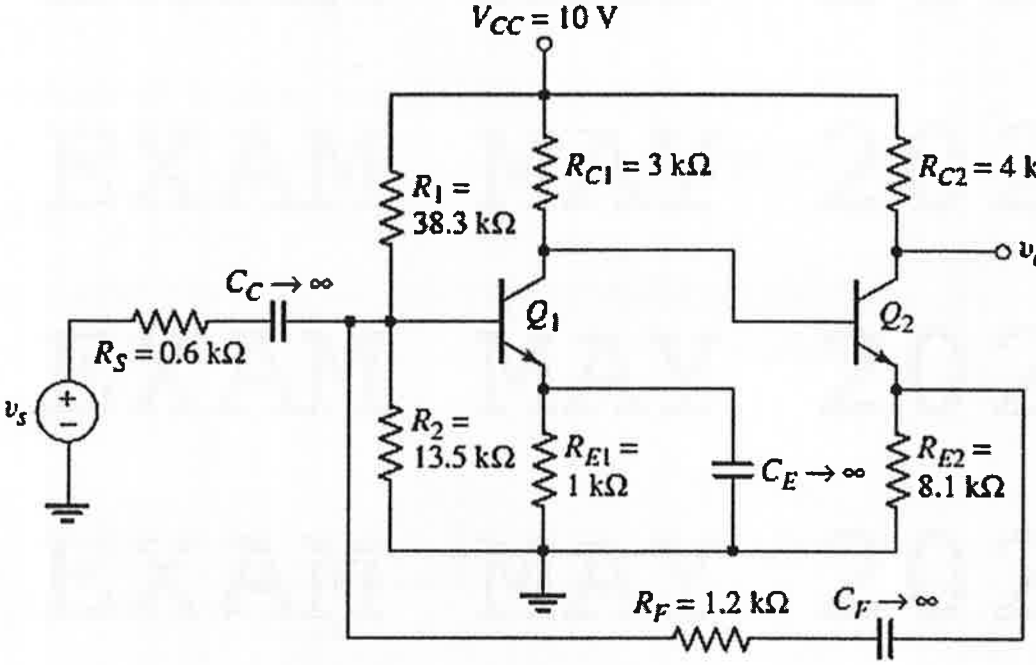

FIGURE Q3

a. Construct a small-signal equivalent circuit of the shunt-series feedback circuit.

[10 marks]

b. For the input of transistor Q_1, analyze the Thevenin equivalent resistance, R_{TH}, and Thevenin equivalent voltage, V_{TH}.

[6 marks]

c. If R_{TH} = 9.98 kΩ and V_{TH} = 2.606 V, determine the parameters I_{C1}, V_{C1}, $r_{\pi 1}$ and g_{m1} for transistor Q_1.

[10 marks]

4. a. Construct a Wien-bridge oscillator circuit and label completely the components. Identify in the sketch, the components for parallel and series impedances, Z_p and Z_s . Explain the functions of the different sub-systems in the Wien-bridge circuit.

[10 marks]

b. State the equation for the loop gain $T(s)$ and define the amplifier gain A and feedback transfer function $\beta(s)$. Derive the equations for the impedances Z_p and Z_s .

[8 marks]

c. The loop gain is given by:

$$T(j\omega_o) = \left(1 + \frac{R_2}{R_1}\right)\left[\frac{1}{3 + j\omega_o RC + (1/j\omega_o RC)}\right]$$

Show how the oscillation frequency ω_o is derived from the above equation and the condition for sustained oscillations. Derive the frequency ω_o .

[4 marks]

d. Show how the relationship between resistors R_1 and R_2 is derived from the equation in **part (c)** for loop gain and the Barkhausen condition and state the relationship.

[4 marks]

- END OF PAPER -

APPENDIX I

KEY FORMULAE

Bipolar Junction Transistor (BJT)

DC current gain	$I_C = \beta I_B$
Transistor currents	$I_E = I_B + I_C$
Transistor emitter current	$I_E = (\beta + 1) I_B$
Internal emitter resistance	$r_e = \dfrac{26mV}{I_E}$
DC Current Ratio	$\alpha = \dfrac{I_C}{I_E}$
	$\beta = \dfrac{I_C}{I_B}$
	$\beta = \dfrac{\alpha}{1-\alpha}$; $\alpha = \dfrac{\beta}{\beta+1}$
Transconductance	$g_m = \dfrac{I_C}{V_T}$; V_T = 26 mV
Small-signal Input Resistance between Base and Emitter	$r_\pi = \dfrac{\beta}{g_m}$
Early-Effect Resistance	$r_0 = \dfrac{V_A}{I_C}$
Small-Signal Voltage Gain	$A_V = \dfrac{v_o}{v_i}$; $G_V = \dfrac{v_o}{v_{sig}}$
Small-Signal Current Gain	$A_i = \dfrac{i_o}{i_i}$
Small-Signal Input and Output Impedances	$Z_i = \dfrac{V_i}{I_i}$; $Z_o = \dfrac{V_o}{I_o}$
BJT Capacitances	$C_\mu = \dfrac{C_{\mu 0}}{\left(1 + \dfrac{V_{CB}}{V_{0c}}\right)^{m_{CBJ}}}$; $C_{je} = 2C_{je0}$; $C_{de} = \tau_F g_m$ $C_\pi = C_{je} + C_{de}$