ELECTRONISC II * Midterm 2 * 90 minutes * closed books and notes * August 13, 2010

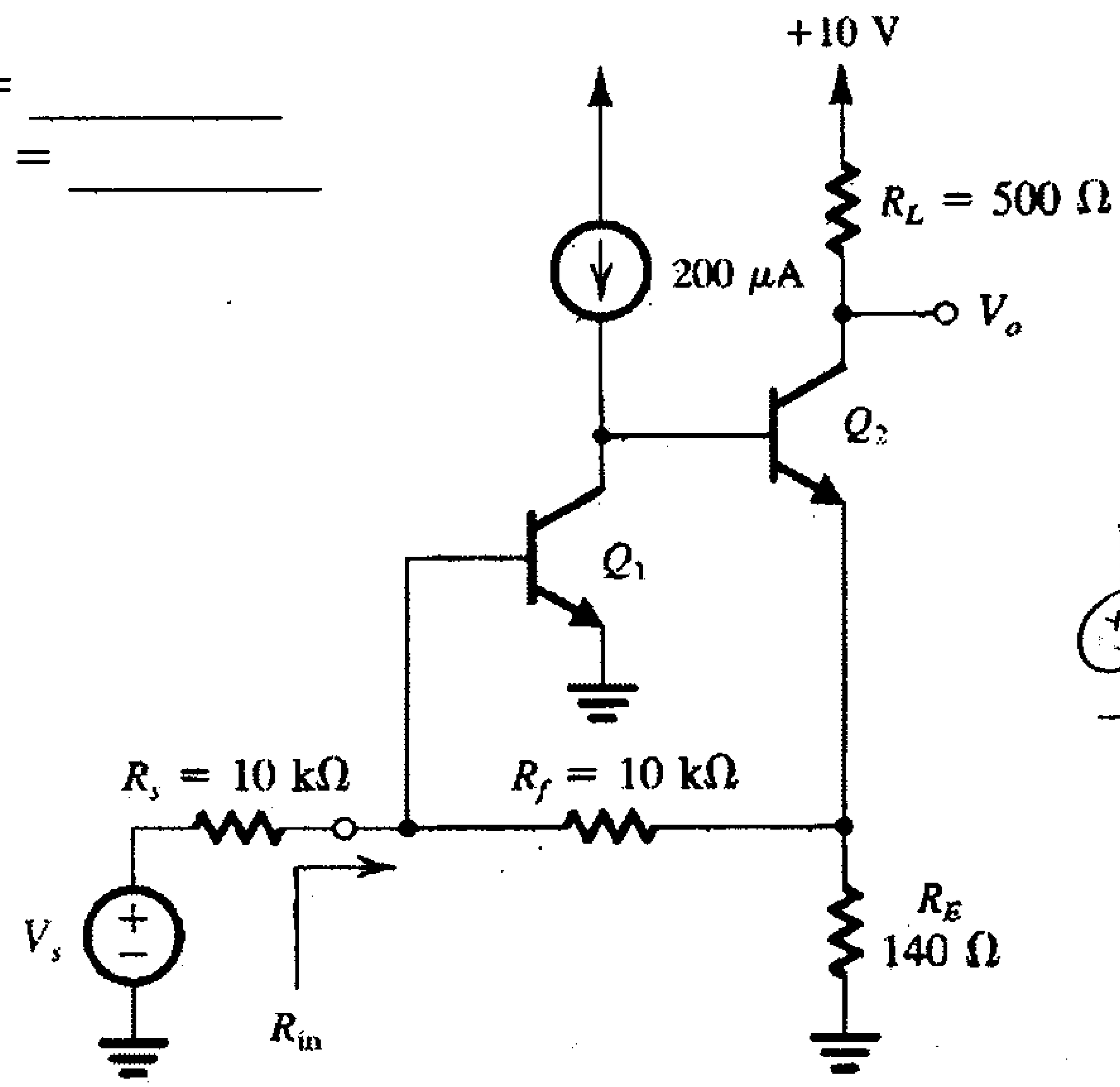
I have neither given nor received unauthorized help with this exam, nor do I have reason that anybody else has.

ID no: ERKAYA *Name:* SOLUTIONS *Signature:* ____________

1) For the amplifier circuit below, assume that V_s has a zero dc component and that I_{B1} is much smaller than the current in R_f. The dc emitter currents of Q_1 and Q_2 can be shown to *be* $I_{E1} = 0.101$ mA and $I_{E2} = 10.1$ mA. Let the BJTs have $\beta = 100$. Find small signal voltage gain v_o/v_s and R_{in}.

R_{in} = ________

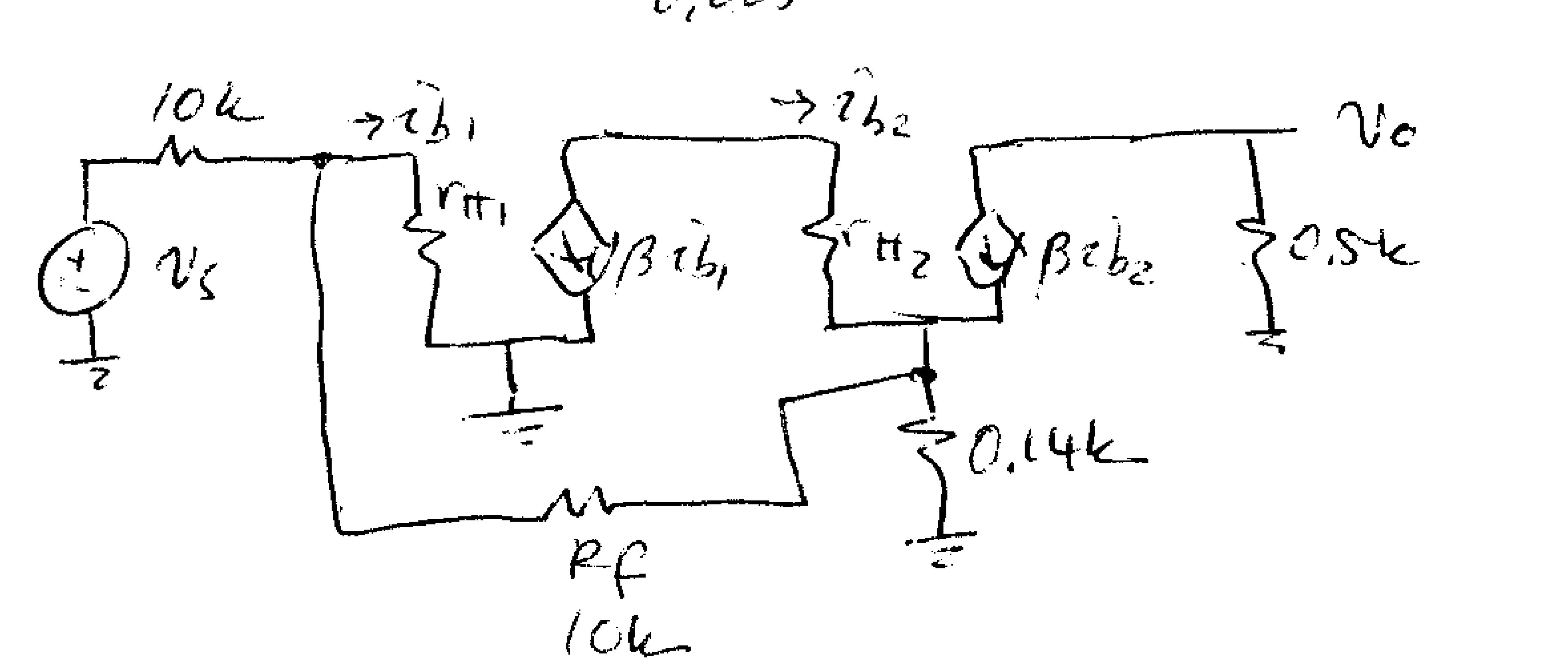
9:04 v_o/v_s = ________



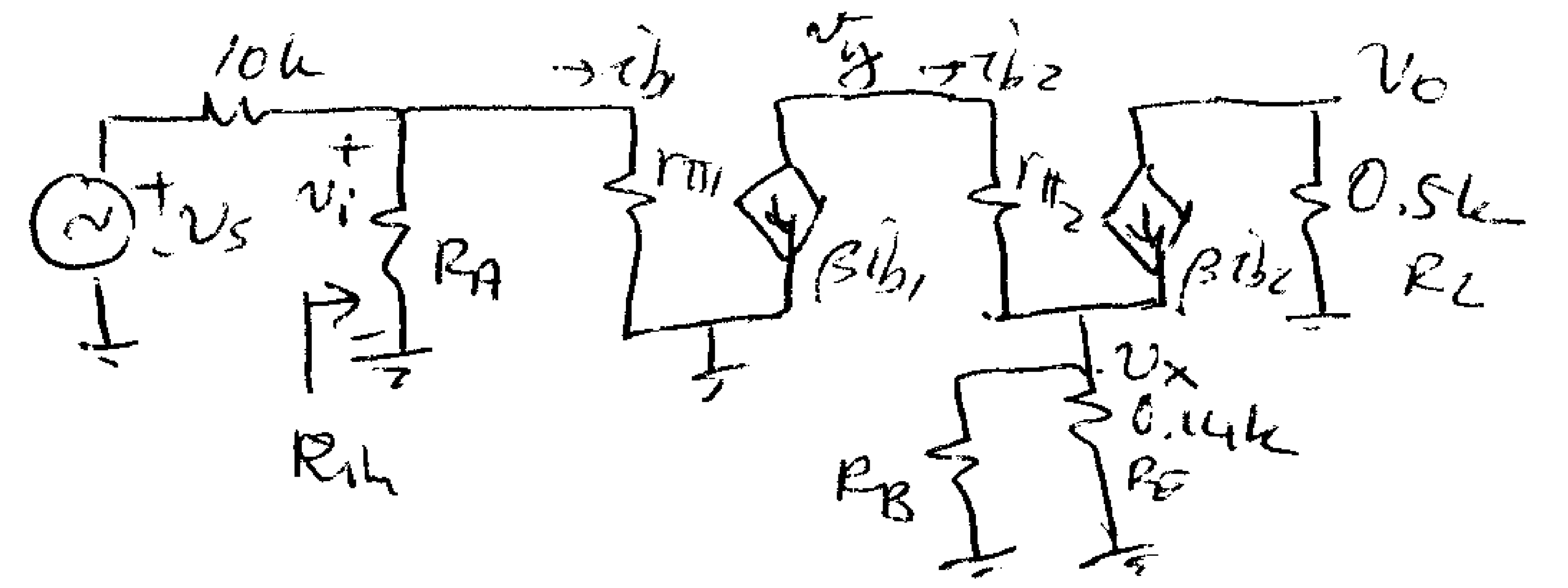
Small Signal Eq Ckt

$$g_{m_1} = \frac{0.1}{0.025} = 4\,mA/V \quad r_{\pi_1} = \frac{100}{4} = 25k$$

$$g_{m_2} = \frac{10}{0.025} = 400\,mA/V, \quad r_{\pi_2} = \frac{100}{400} = 0.25k$$



Apply miller's theorem on Rf



$$R_A = \frac{R_f}{1 - \frac{v_x}{v_i}}, \quad R_B = \frac{R_f}{1 - \frac{v_i}{v_x}} \simeq R_B$$

$$\frac{v_x}{v_i} = \frac{v_x}{v_y} \cdot \frac{v_y}{v_i}, \quad \frac{v_x}{v_y} = \frac{(\beta+1)(R_B \| R_E)}{r_{\pi_2} + (\beta+1)(R_B \| R_E)} \simeq \frac{101 \times 0.14}{0.25 + 101 \times 0.14} = 0.9826$$

$$\frac{v_y}{v_i} = -g_m\left(r_{\pi_2} + (\beta+1)(R_B \| R_E)\right) = -400 \times (0.25 + 101 \times 0.14) = -5756$$

$$R_A = \frac{10k}{1 + 5756} = 1.737\ \Omega$$

$$\frac{v_o}{v_y} = \frac{-\beta R_L}{r_{\pi_2} + (\beta+1)(R_B \| R_E)} = \frac{-50}{14.39} = -3.47$$

$$r_{in} = R_A \| r_{\pi_1} = 1.737 \| 25k \cong 1.737\ \Omega$$

$$\frac{v_i}{v_s} = \frac{r_{in}}{R_s + r_{in}} = \frac{1.737}{10000 + 1.737} \cong 1.737 \times 10^{-4}$$

$$\frac{v_o}{v_s} = \frac{v_o}{v_y} \frac{v_y}{v_i} \frac{v_i}{v_s} = (-3.47)(-5756)(1.737 \times 10^{-4}) = 3.469$$

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2) Find the oscillation frequency and oscillation condition for the circuit given below.

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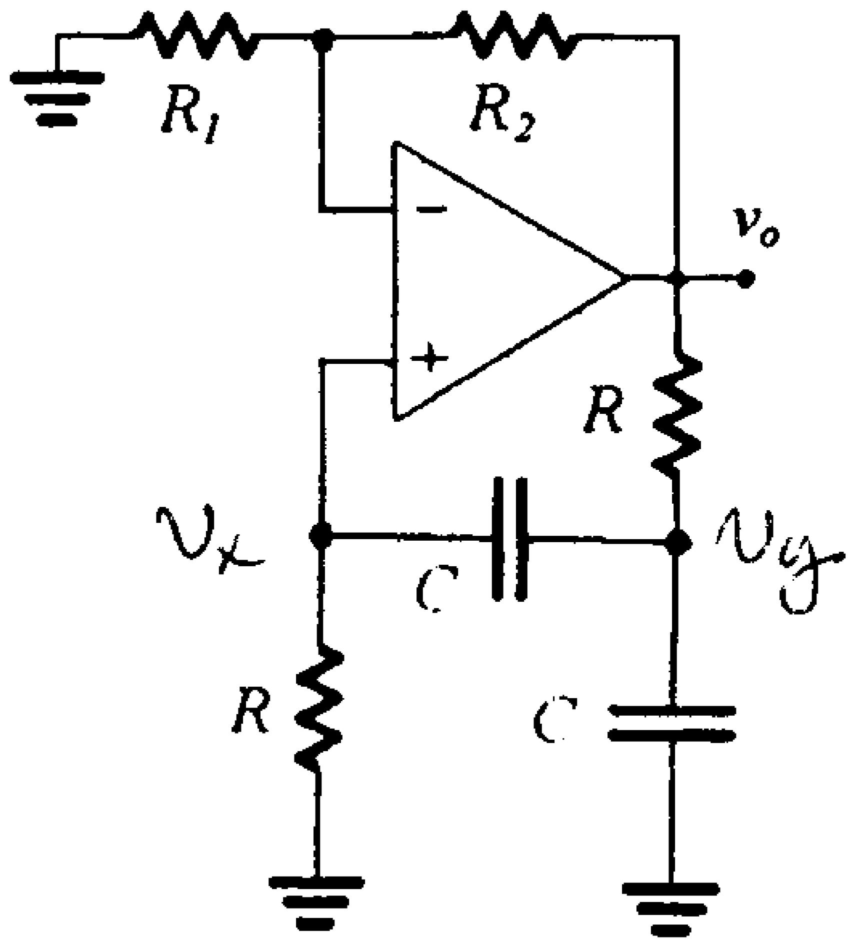

$\omega_o = \dfrac{1}{CR}$

condition : $\dfrac{R_2}{R_1} = 2$

$$v_o = v_x \left(\frac{R_1 + R_2}{R_1} \right)$$

$$\frac{v_x}{R} = \frac{v_y}{R + \frac{1}{j\omega C}}$$

$$\frac{v_o}{R\left(\frac{R_1+R_2}{R_1}\right)} = \frac{v_y}{\left(R + \frac{1}{j\omega C}\right)} \quad , \quad v_o = v_y \frac{R\left(\frac{R_1+R_2}{R_1}\right)}{\left(R + \frac{1}{j\omega C}\right)}$$

$$\frac{v_o - v_y}{R} = j\omega C v_y + v_y \frac{1}{R + \frac{1}{j\omega C}}$$

$$\frac{v_y \left(\frac{R_1+R_2}{R_1}\right)}{R + \frac{1}{j\omega C}} - \frac{v_y}{R} = j\omega C v_y + v_y \frac{1}{R + \frac{1}{j\omega C}}$$

$$\frac{R_1 + R_2}{R_1} - \frac{1}{R}\left(R + \frac{1}{j\omega C}\right) = 1 + j\omega C \left(R + \frac{1}{j\omega C}\right)$$

$$1 + \frac{R_2}{R_1} - 1 - \frac{1}{j\omega CR} = 1 + j\omega CR + 1$$

$$\underbrace{\frac{R_2}{R_1} - 2}_{} = j\omega CR + \frac{1}{j\omega CR}$$

$$\boxed{\frac{R_2}{R_1} = 2}$$

$$j\omega CR - \frac{j}{\omega CR} = 0$$

$$\omega CR = \frac{1}{\omega CR}$$

$$\omega^2 C^2 R^2 = 1$$

$$\boxed{\omega = \frac{1}{CR}}$$

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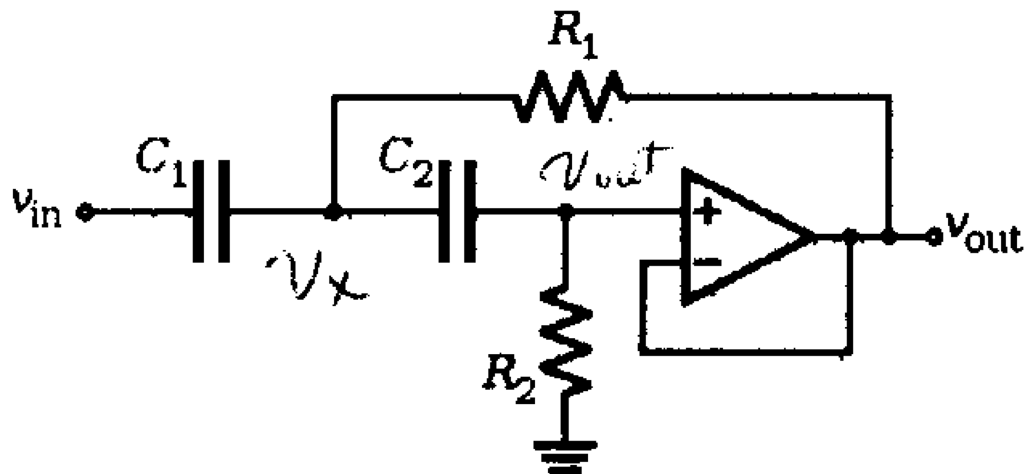
3) Find the transfer function of the circuit given below. Indicate what kind of a filter it is (i.e., high-pass, low-pass, band-pass). Put the transfer function in the form as follows: $(as^2 + bs + c)/(s^2 + s\omega_o/Q + \omega_o^2)$.



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$a =$ 1

$b =$ 0

$c =$ 0

$\omega_o = \sqrt{\frac{1}{C_1 R_2 R_1 C_2}}$

$\omega_o/Q = \frac{1}{R_2}\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$

type = HP

$$\frac{V_{in} - V_x}{\frac{1}{sC_1}} = \frac{V_x - V_{out}}{R_1} + \frac{V_x - V_{out}}{\frac{1}{sC_2}}$$

$$V_x = \left(R_2 + \frac{1}{sC_2}\right)\frac{V_{out}}{R_2}$$

$$\frac{V_x - V_{out}}{\frac{1}{sC_2}} = \frac{V_{out}}{R_2}$$

$$sC_1(V_{in} - V_x) = \frac{V_x - V_{out}}{R_1} + \frac{V_{out}}{R_2}$$

$$sC_1\left(V_{in} - \left(1 + \frac{1}{sC_2R_2}\right)V_{out}\right) = \frac{\left(1 + \frac{1}{sC_2R_2}\right)V_{out} - V_{out}}{R_1} + \frac{V_{out}}{R_2}$$

$$sC_1 V_{in} - sC_1 V_{out} - \frac{C_1}{C_2R_2}V_{out} = \frac{1}{sC_2R_2R_1}V_{out} + \frac{V_{out}}{R_2}$$

$$sC_1 V_{in} = V_{out}\left(sC_1 + \frac{C_1}{C_2}\frac{1}{R_2} + \frac{1}{sC_2R_2R_1} + \frac{1}{R_2}\right)$$

$$\frac{V_{out}}{V_{in}} = \frac{sC_1}{sC_1 + \left(\frac{C_1}{C_2}\frac{1}{R_2} + \frac{1}{R_2}\right) + \frac{1}{sC_2R_2R_1}} = \frac{s^2C_1}{s^2C_1 + s\left(\frac{1}{R_2}\left(1 + \frac{C_1}{C_2}\right)\right) + \frac{1}{R_1}}$$

$$= \frac{s^2}{s^2 + s\frac{1}{R_2}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) + \frac{1}{C_1C_2R_1R_2}}$$

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4) A power transistor is specified to have a maximum junction temperature of 130 °C. When operated at this temperature with a heat sink, the case temperature is found to be 90 °C. The case is attached to a heat sink with a bond having a thermal resistance θ_{CS} = 0.5 °C/W and the thermal resistance of the heat sink θ_{SA} = 0.1 °C/W. If the ambient temperature is 30 °C what is the power being dissipated in the device? What is its thermal resistance θ_{JC} from junction to case?

P_D = 100 W

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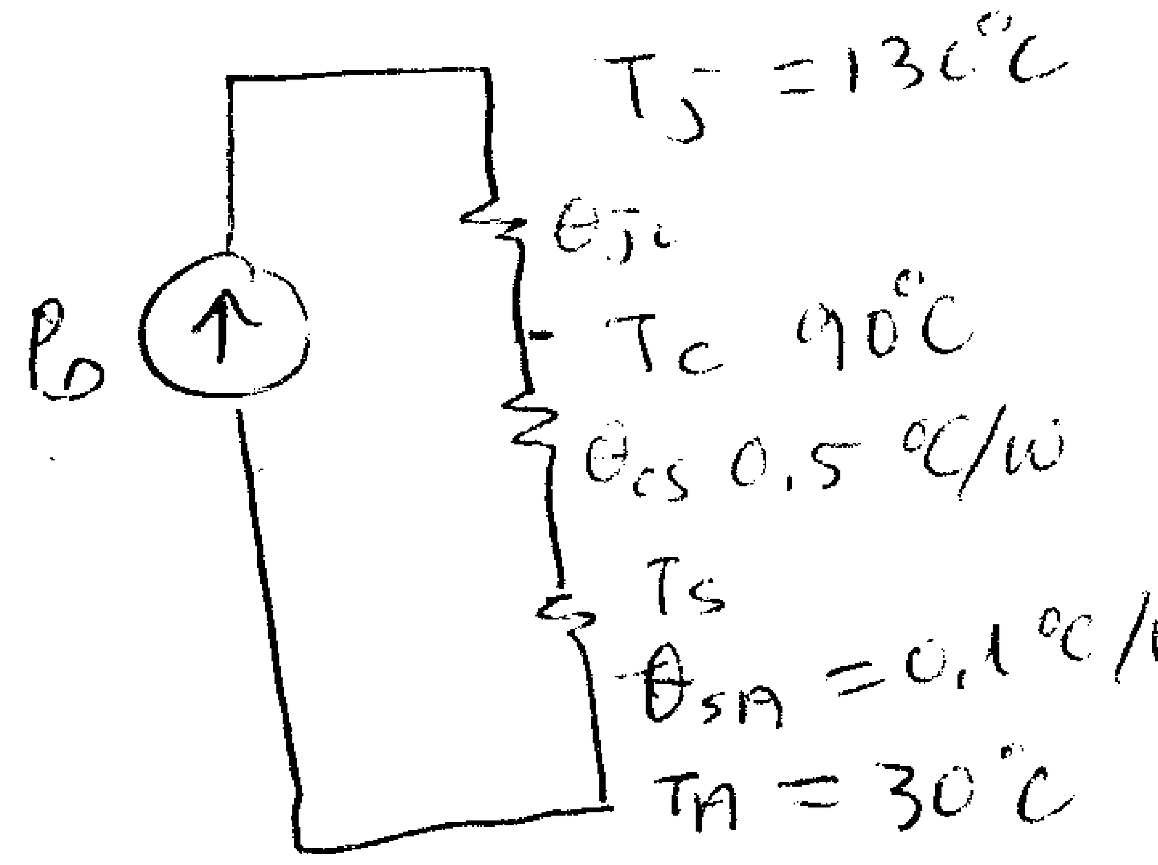
θ_{JC} = 0.4 °C/W



$$T_C - T_A = P_D(\theta_{CS} + \theta_{SA})$$

$$\frac{T_C - T_A}{(\theta_{CS} + \theta_{SA})} = P_D$$

$$\frac{90° - 30°}{0.5 + 0.1} = \frac{60°C}{0.6 °C/W} = 100\ W = P_D$$

$$\theta_{JC} = \frac{T_J - T_C}{P_D} = \frac{130° - 90°}{100\ W} = \frac{40°C}{100W} = 0.4 °C/W$$

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16 + 9 + 10 + 3 = 38 min → 114 min.