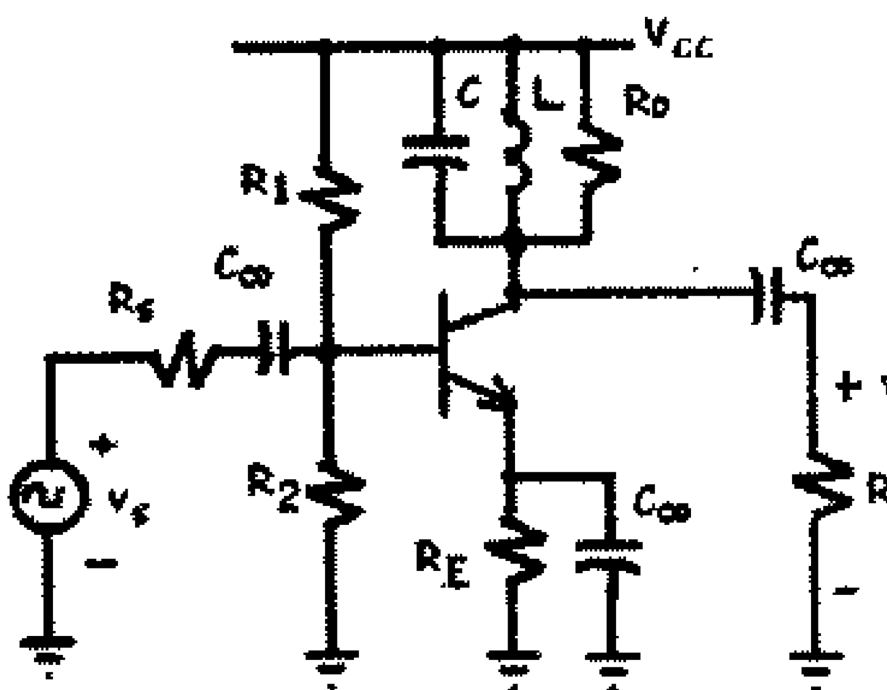
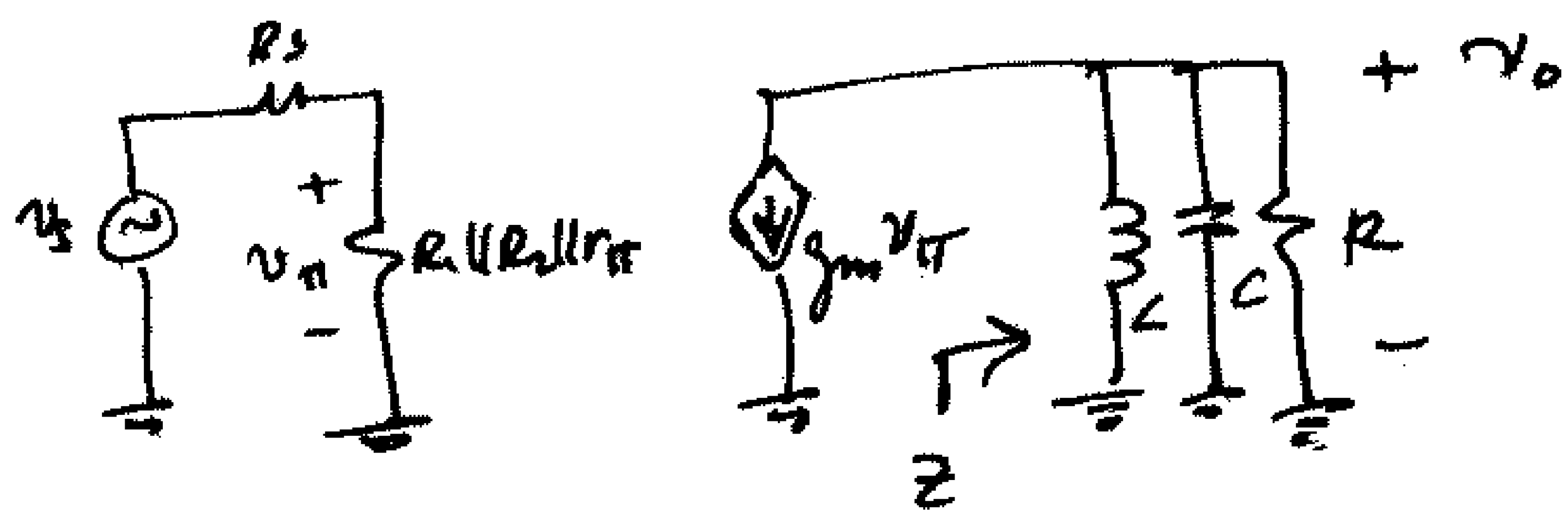
Electronics II * Exam II * April 30, 2009 * 90 minutes * (33+33+34 points)

ID number: ERKAYA Name: SOLUTIONS Signature:______________

1) Find the small signal 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: $V_o/V_s = (as^2 + bs + c)/(s^2 + s\omega_o/Q + \omega_o^2)$. Ignore internal capacitances and Early effect.



S.S. eq. ckt:



$a =$ 0

$b = -g_m \frac{K}{C}$

$c =$ 0

$\omega_o = \frac{1}{\sqrt{LC}}$

$\omega_o/Q = \frac{1}{RC}$

type = Band pass

$R = R_o \| R_L$

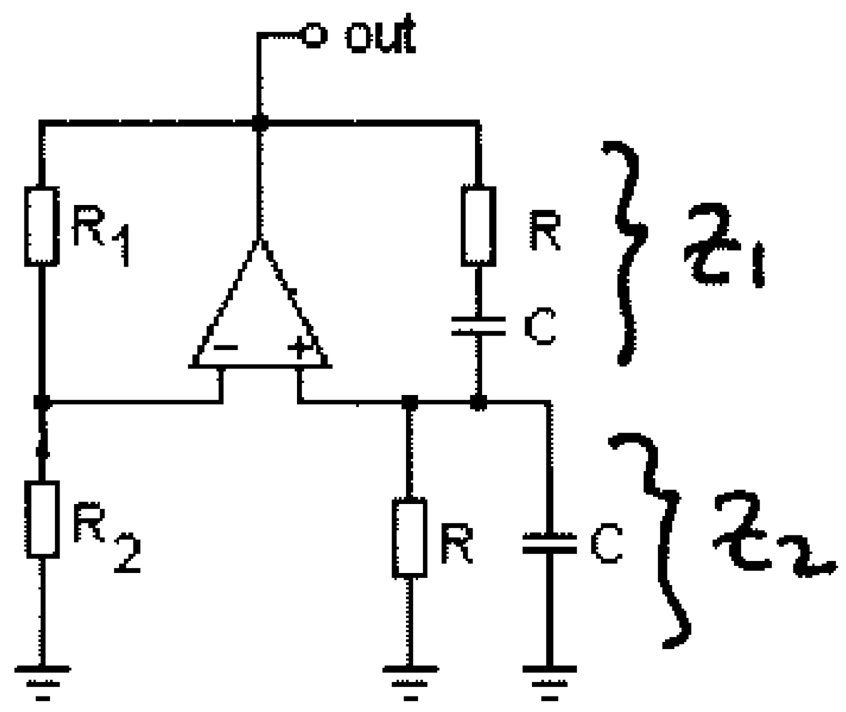
$$Z = \frac{1}{\frac{1}{sL} + \frac{1}{R} + sC} = \frac{\frac{s}{C}}{\frac{1}{CL} + \frac{s}{RC} + s^2}$$

$$Z = \frac{\frac{s}{C}}{s^2 + s\frac{1}{RC} + \frac{1}{LC}}$$

$$\frac{V_o}{V_s} = -g_m Z \underbrace{\frac{R_1 \| R_2 \| r_\pi}{R_s + R_1 \| R_2 \| r_\pi}}_{\equiv K} = \frac{-g_m \frac{s}{C} K}{s^2 + s\frac{1}{RC} + \frac{1}{LC}}$$

(Loading effect at the input)

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



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

condition : $R_1 = 2R_2$

$$\frac{R_2}{R_1+R_2} = \frac{Z_2}{Z_1+Z_2}$$

$$Z_1 = R + \frac{1}{j\omega C} = \frac{1+j\omega CR}{j\omega C}$$

$$Z_2 = \frac{R\,\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}} = \frac{R}{1+j\omega CR}$$

$$\frac{R_2}{R_1+R_2} = \frac{\frac{R}{1+j\omega CR}}{\frac{1+j\omega CR}{j\omega C}+\frac{R}{1+j\omega CR}} = \frac{R}{\frac{(1+j\omega CR)^2}{j\omega C}+R} = \frac{j\omega CR}{(1+j\omega CR)^2+j\omega CR}$$

$$\frac{R_2}{R_1+R_2} = \frac{j\omega CR}{1-\omega^2C^2R^2+2j\omega CR+j\omega CR} = \frac{j\omega CR}{(1-\omega^2C^2R^2)+3j\omega CR}$$

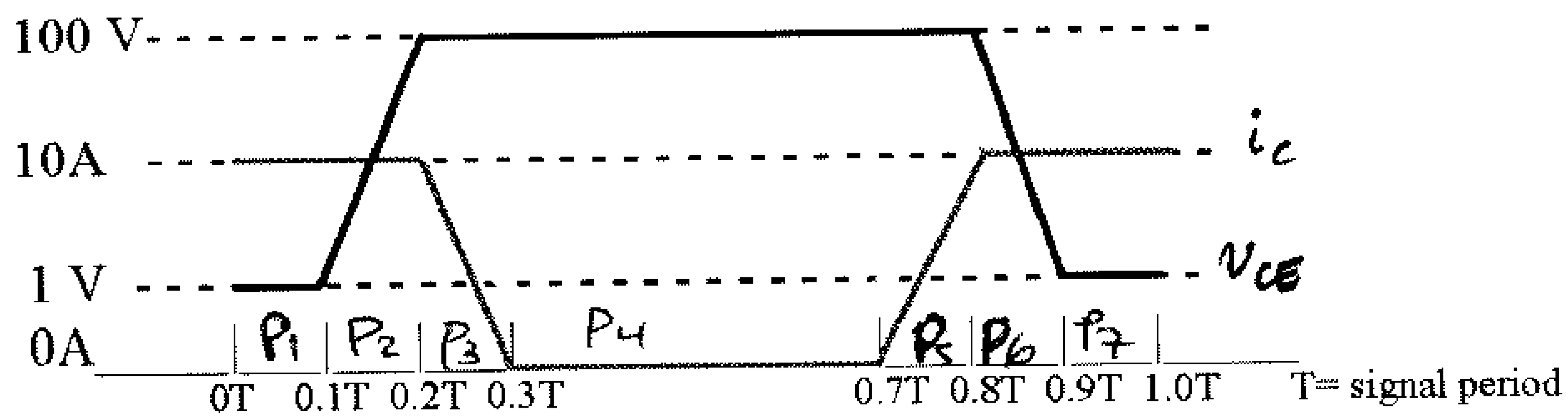
Real part $= \frac{R_2}{R_1+R_2}$

Im part $= 0 \longrightarrow 1-\omega^2c^2R^2 = 0 \rightarrow \boxed{\omega = \frac{1}{CR}}$ oscill. freq.

Real part $\quad \frac{R_2}{R_1+R_2} = \frac{j\omega CR}{3j\omega CR} = \frac{1}{3}$

$$\frac{1}{\frac{R_1}{R_2}+1} = \frac{1}{3} \rightarrow \boxed{R_1 = 2R_2}$$ osc. cond.

) A switching bipolar transistor is mounted on a heat sink. Its total thermal resistance $\theta_{ja} = 0.1$ °C/W. The thermal resistance between the junction and the case $\theta_{jc} = 0.03$ °C/W while the thermal resistance between the case and the heat sink $\theta_{cs} = 0.05$°C/W. The transistor has the following collector current and collector-emitter voltage in time:



a) Find the average power dissipation in the transistor.
b) Find the temperature of the heat sink if the ambient room temperature is 20°C.
c) If the max allowed junction temperature is 145°C, what would be the max room temperature the transistor can be operated safely?

$P_D =$ 203W
$T_s =$ 24.06 °C
$T_{max} =$ 124.7°C

a) $$P_D = \frac{P_1 + P_2 + P_3 + 4P_4 + P_5 + P_6 + P_7}{10}$$

$P_1 = 10 \times 1 = 10\,W$
$P_2 = 10 \times \left(\frac{1+100}{2}\right) = 505\,W$
$P_3 = 100 \times \left(\frac{10+0}{2}\right) = 500\,W$
$P_4 = 0$
$P_5 = P_3 = 500\,W$
$P_6 = P_2 = 505\,W$
$P_7 = P_1 = 10\,W$

$$P_D = \frac{10 + 505 + 500 + 0 + 500 + 505 + 10}{10} = \frac{2030}{10} = 203\,W$$

b) $\theta_{ja} = \theta_{jc} + \theta_{cs} + \theta_{sa}$, $\theta_{sa} = \theta_{ja} - \theta_{cs} - \theta_{jc}$
$= 0{,}1 - 0{,}03 - 0{,}05 = 0{,}02$ °C/W

$$T_s = T_a + P_D \theta_{sa} = 20°C + 203 \times 0{,}02 = 24.06\ °C$$

c) $T_{Amax} + \theta_{ja} P_D = T_{jmax}$

$$T_{Amax} = T_{jmax} - \theta_{ja} P_D = 145°C - 203 \times 0{,}1 = 124{,}7°C$$