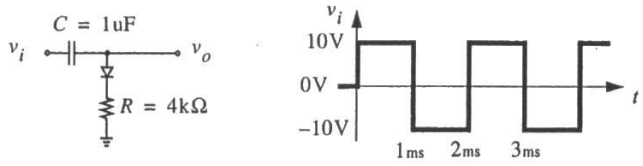
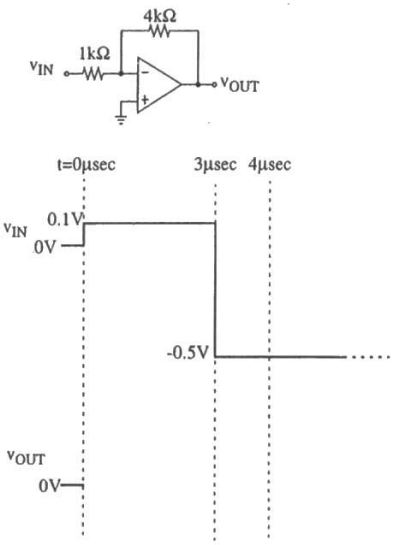
[5] Question 1: Consider the circuit below. Assuming the diode is ideal and the capacitor is initially discharged, find the output voltage at time $t = 3\text{ms}$. (Hint, make a sketch of the output waveform).



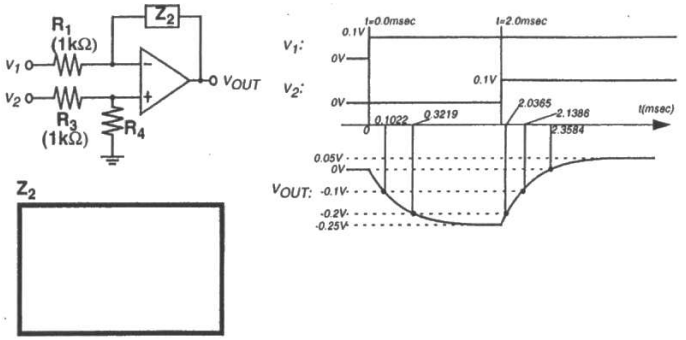
[5] Question 2: Assuming the opamp has infinite gain at DC but a unity-gain bandwidth of $\omega_t = 1 \times 10^7$ rad/sec, and a slew rate of $SR = 1\text{V}/\mu\text{sec}$, sketch the output waveform from t=0 to t=4μsec and determine roughly the value of v_{OUT} at t=3μsec and t=4μsec as shown.



$v_{OUT}(3\mu\text{sec}) =$ _____ V

$v_{OUT}(4\mu\text{sec}) =$ _____ V

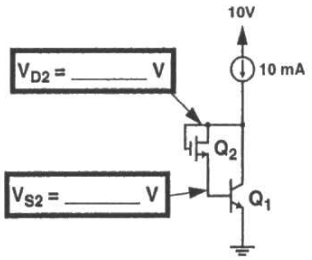
[5] Question 3: Determine the impedance Z_2 given the input signals $v_1(t)$ and $v_2(t)$ and the output signal $v_{OUT}(t)$ shown below. Assume the op amp is ideal and that Z_2 is made up of a resistor and a capacitor. In your answer for Z_2, give the schematic and component values.



Z_2

Question 3: (cont'd) BONUS MARK: Find the value of R_4

[5] Question 4: Assuming {β = 40 for Q_1} and {$\mu_n C_{ox} = 30\mu A/V^2$, $V_{tn} = 0.9V$, and $W/L = 20$ for Q_2}, determine the indicated voltages and current, and indicate the mode of operation for each transistor in the circuit below. Assume room temperature, and ignore the Early effect for both devices.



$V_{D2} =$ _____ V

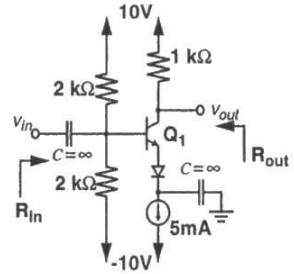
$V_{S2} =$ _____ V

$I_{D2} =$ _____ mA

Indicate the mode of operation:

Q_1: Cut-off / Saturation / Active
Q_2: Cut-off / Triode / Saturation

[5] Question 5: Given that {β = 40, $I_s = 6.9 \times 10^{-16}$A, and the Early voltage is infinite for the BJT} and {$n = 2$ and $I_s = 6.9 \times 10^{-16}$A for the diode}, determine the small-signal gain as well as the input and output resistance of the amplifier shown below. Assume the thermal voltage $V_T = 25mV$.

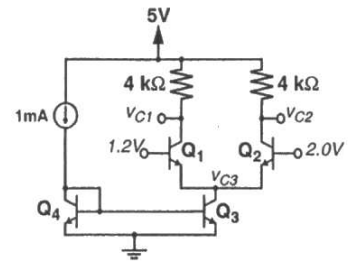


gain =

R_{in} =

R_{out} =

[5] Question 6: Given that all BJT's have $I_s = 6.9 \times 10^{-16}$A, and effectively infinite β and Early voltages, determine the requested voltages, and indicate the mode of operation for each device (hint: transistors Q_3 and Q_4 form a current mirror. If both devices are in the active region, their drain currents will be equal.).



$V_{C1} =$ _____ V

$V_{C2} =$ _____ V

$V_{C3} =$ _____ V

Indicate the mode of operation:

Q_1: Cut-off / Saturation / Active
Q_2: Cut-off / Saturation / Active
Q_3: Cut-off / Saturation / Active
Q_4: Cut-off / Saturation / Active

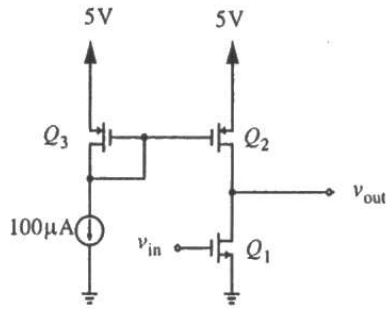
[5] Question 7: An NMOS transistor with $W = 10\mu m$ and $L = 0.5\mu m$ in a technology with $\mu_n C_{ox} = 100\mu A/V^2$ and $V_t = 1V$ is to be operated at very low values of v_{DS} as a linear resistor. For v_{GS} varying from 1.2V to 5V, what range of resistor values can be obtained?

$R_{max} =$ $R_{min} =$

[5] Question 8: A CMOS logic inverter with a 3V power supply must drive a 10pF load. Given that the output signal is always low except for 3 high pulses as shown below, how much energy (in joules) is dissipated in the inverter?

$E_{diss} =$

[5] Question 9: Consider the circuit below. The small-signal gain changes as the bias voltage at v_{in} changes. Find the maximum small-signal gain, A_v, when the bias voltage at v_{in} is in the range from 0 to 5V.



$\mu_n C_{ox} = 3\mu_p C_{ox} = 100\mu A/V^2$

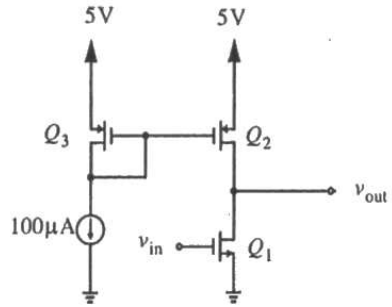
$V_{tn} = |V_{tp}| = 1V$

$\left(\frac{W}{L}\right)_1 = 10 \quad \left(\frac{W}{L}\right)_2 = 10 \quad \left(\frac{W}{L}\right)_3 = 20$

$V_{A1} = 10V \quad V_{A2} = 20V$

$A_v|_{max} =$

[5] Question 10: Consider the circuit below. Given that the output voltage is equal to $v_{out} = 4.6V$, find the value of the input voltage, v_{in}. Ignore the finite-output impedance of the transistors.



$\mu_n C_{ox} = 3\mu_p C_{ox} = 100\mu A/V^2$

$V_{tn} = |V_{tp}| = 1V$

$\left(\frac{W}{L}\right)_1 = 10 \quad \left(\frac{W}{L}\right)_2 = 10 \quad \left(\frac{W}{L}\right)_3 = 20$

$v_{in} =$