Problem 1. (10 points)

Consider an op-amp connected in the inverting configuration to achieve a closed-loop gain of 40 dB (this is the absolute value of the voltage gain) using $1\ k\Omega$ and $100\ k\Omega$ resistors. A load resistance R_L is connected from the output to ground. A sine-wave signal of peak amplitude V_P is used as the input signal.

Assume an ideal op-amp with $V_{sat} = \pm 10V$ and $I_{out_{max}} = 20\ mA$, and answer the following questions. Show your work.

a) For $R_L = 400\ \Omega$, what is the maximum possible V_P while an undistorted output sinusoidal signal is obtained?

b) If it is desired to obtain an output sinusoidal signal with a peak amplitude of $10V$, What values of R_L are allowed?

Closed loop gain, of the op-amp = $10^{\frac{40}{20}} = 100$

For inverting amplifier,

$$\frac{V_{out}}{100K} + \frac{V_{out}}{R_L} = I_{out}$$

(a) For maximum possible V_p, with $R_L = 400\Omega$, we can write,

$$\frac{100V_{p,max}}{100k} + \frac{100V_{p,max}}{0.4k} = I_{out,max} = 20m$$

$$\Rightarrow V_{p,max} = \frac{20}{251}V = 79.68\ mV$$

(b) Similarly, for $V_{out} = 10V$, we can write,

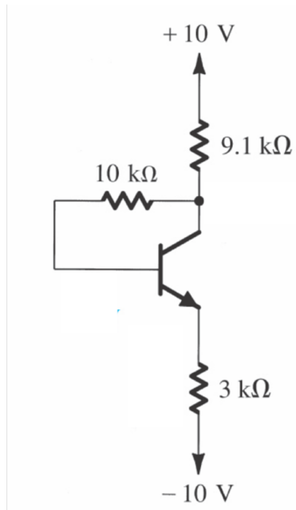
$$\frac{10}{100k} + \frac{10}{R_{L,min}} = I_{out,max} = 20m$$

$$\Rightarrow R_{L,min} = 502.5\ \Omega$$

So R_L > 502.5Ω to obtain output sinusoidal signal with a peak amplitude of 10 V.

Problem 2. (10 points)

In the following circuit, find the values of the collector, base and emitter currents and the collector, base and emitter node voltages. Assume $\beta = 100$, $V_{D0} = 0.7\,V, V_{sat} = 0.2\,V$.



Assuming, BJT is in active mode

$$\Rightarrow I_E = (\beta + 1)I_B \;\; and \; I_C = \beta I_B$$

Now, from CE KVL,

$$10 = 9.1k \times I_E + 10k \times \frac{I_E}{\beta + 1} + V_{D0} + 3k \times I_E - 10$$

$$\Rightarrow I_E = 1.582\,mA$$

$$\Rightarrow I_B = 15.663\,\mu A$$

$$\Rightarrow I_C = 1.5663\,mA$$

$$\Rightarrow V_C = 10 - 9.1 \times 1.582 = -4.3962\,V$$

$$\Rightarrow V_E = -10 + 3 \times 1.582 = -5.254\,V$$

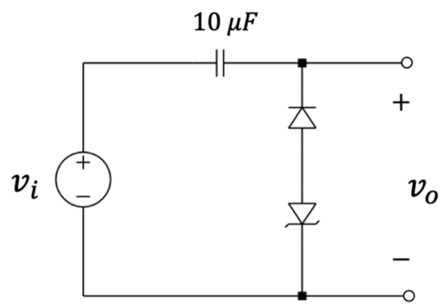
$$\Rightarrow V_B = V_E + 0.7 = -4.554\,V$$

$$\Rightarrow V_{CE} = 0.8578V > V_{D0} \Rightarrow Assumption\ correct$$

Problem 3. (10 points)

In the circuit below, $v_i(t) = 4\,sin\,(\omega t)$ where $\omega = 1000$ rad/s, $v_c(0) = 0$, $v_o(0) = 0$.

Use $V_{D0} = 0.7\,V,\ V_Z = 2.3\,V$.



a) What is the value of $v_o(t)$ at t = 2 ms?

b) What is the value of $v_o(t)$ at t = 6 ms?

$v_i(t) = 4\,sin\,(\omega t)$ where $\omega = 1000$ rad/s, $v_c(0) = 0$, $v_o(0) = 0$, $V_{D0} = 0.7\,V,\ V_Z = 2.3\,V$.

Period of the input, $T = \left(\frac{\omega}{2\pi}\right)^{-1} = 6.2832\,ms$.

(a) @ 2ms, $v_i(t)$ is in first half cycle and diode is OFF. Since diode will not conduct in the first half cycle

$$\Rightarrow v_o(2ms) = v_i(2ms) = 3.6372\,V$$

(b) Diode starts to conduct once $v_i(t)$ goes below -3V or $t \geq 3.98965$ ms and input voltage reaches negative peak at $t = 4.7124\,ms$. After that, circuit will behave as a positive clamp circuit. So,

$$v_o(6ms) = v_i(6ms) + \left(V_{neg_{peak}} - V_z - V_{D0}\right) = -0.11766\,V$$