Homework 7:

a) Under DC conditions: (Capacitors are open circuit)

The mosfet is used as an Amplifier, so it is biased to operate in the saturation region.

$I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS}-V_t)^2 (1 + \lambda V_{DS})$

$\Rightarrow 0.25 \times 10^{-3} = \frac{1}{2} \times 10^{-3} V_{ov}^2 (1 + 0.025 \times 2.5)$

$\Rightarrow 0.5 = V_{ov}^2 (1.0625) \Rightarrow V_{ov} = 0.686V$

$- r_o = \frac{V_{DS} + \frac{1}{\lambda}}{I_D} = \frac{2.5 + \frac{1}{0.025}}{0.25 \times 10^{-3}} = \frac{42.5}{0.25 \times 10^{-3}} = 170 K\Omega$

$- A_v = - \frac{2 I_D}{V_{ov}} (R_D // R_L // r_o)$

$-9 = - \frac{0.5 \times 10^{-3}}{0.686} (R_D // R_L // r_o) \Rightarrow R_D // R_L // r_o = 9 \times 0.686 \times 2 \ K\Omega = 12.348 K\Omega$

$\Rightarrow \frac{1}{R_D} + \frac{1}{R_L} + \frac{1}{r_o} = \frac{1}{12.348K} \Rightarrow \frac{1}{R_D} = \frac{1}{12.348K} - \frac{1}{170k} - \frac{1}{33K}.$

$\Rightarrow R_D = 22.32 K\Omega$

$- V_{DD} = R_D I_D + V_{DS} + R_S I_D \Rightarrow 9 = 0.25 \times 22.32 + 2.5 + R_S \times 0.25 \times 10^{-3}$

$\Rightarrow R_S = 3.68 K\Omega$

$- V_{GS} - V_t = 0.686 \Rightarrow V_G - V_S - V_t = 0.686 \Rightarrow V_G = 0.686 + 0.9 + R_S I_D = 2.505V$

$R_{in} = R_1 // R_2 = \frac{R_1 R_2}{R_1 + R_2} = 1 M\Omega$

$V_G = V_{DD} \cdot \frac{R_2}{R_1 + R_2} \Rightarrow \frac{R_2}{R_1 + R_2} = 0.2784$

$\therefore R_1 (0.2784) = 1 M\Omega \Rightarrow R_1 = 3.6 M\Omega$

$\frac{R_2}{3.6 + R_2} = 0.2784 \Rightarrow R_2 = 1.385 M\Omega$

Design: C: very large

$R_D = 22.32 k\Omega$

$R_S = 3.68 K\Omega$

$R_1 = 3.6 M\Omega$

$R_2 = 1.385 M\Omega.$

b)

1) Under AC or high frequency conditions : Capacitors act as short circuit.

$v_{GS} = V_{GS} + v_{gs}$

Mosfet in cutoff if $v_{GS} \leq V_t$ $\Rightarrow V_{GS} + v_{gs} \leq V_t$

$\Rightarrow v_{gs} \leq -V_{ov}$ $\Rightarrow v_{gs} \leq -0.686$

but C_S is short circuit $\Rightarrow V_S = 0$ $\Rightarrow v_{gs} = v_i$

Mosfet in cutoff if $v_i \leq -0.686$.

$\Rightarrow$ if $v_{i\,peak} \geq 0.686V$ $\Rightarrow$ MOSFET will enter cutoff.

$\Rightarrow$ $|v_i| \leq 0.686V$ $\Rightarrow$ MOSFET will not enter cutoff.

For largest value of v_i so that MOSFET enters cut off v_i is 0.686 V.

2) As long as $V_{DS} \geq V_{GS} - V_t$ $\Rightarrow$ mosfet in saturation.

$\Rightarrow V_{DS} + v_{ds} \geq V_{GS} + v_{gs} - V_t$ $\Rightarrow 2.5 + v_{ds} \geq v_{gs} + V_{ov}$

$v_{gs} = v_i$; $v_{ds} = v_o$ $(v_s = 0)$

$\Rightarrow 2.5 + v_o \geq v_i + V_{ov}$.

but $v_o = A_v v_i$

$\Rightarrow 2.5 + A_v v_i \geq v_i + V_{ov}$

$\Rightarrow v_i(1-A_v) \leq -V_{ov} + 2.5.$ $\Rightarrow v_i \leq \frac{2.5 - V_{ov}}{1-(-9)}$ $\Rightarrow v_i \leq \frac{2.5 - V_{ov}}{10}$

$\Rightarrow v_i \leq 0.1814V$.

The largest possible input that results in MOSFET entering linear region is 0.1814V

3) $v_{gs\,peak} = v_{i\,peak}$

$v_{i\,peak} \leq 0.05 V_{ov}$ $\Rightarrow$ largest value of v_i that results in distortion is 0.0343V.

$|v_i| \leq 0.686V$ $\Rightarrow$ avoid cutoff

$|v_i| \leq 0.1814V$ $\Rightarrow$ avoid linear region

$|v_i| \leq 0.0343V$ $\Rightarrow$ avoid distortion

$\Rightarrow$ $|v_i| \leq 0.0343V$ to avoid all above conditions