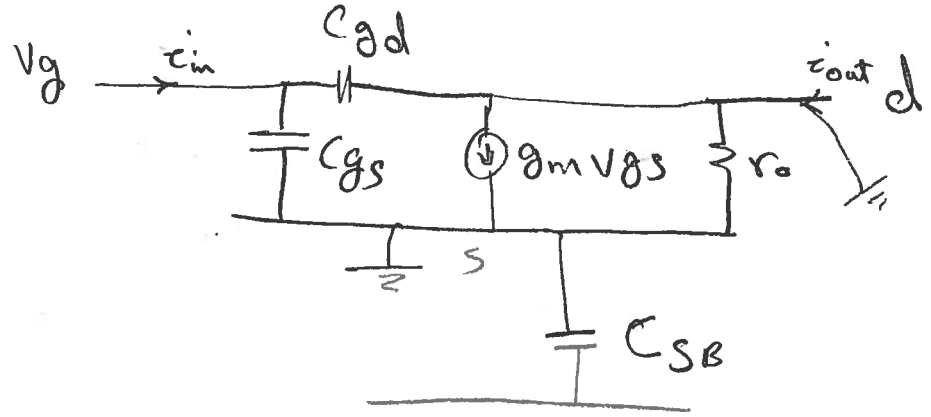
1)



$$\begin{cases} i_{in} = \dfrac{V_g}{\frac{1}{C_{gds}} + \frac{1}{C_{gs}S}} = V_g(C_{gd}+C_{gs})S \\ i_{out} = g_m V_{gs} \end{cases}$$

$$\Rightarrow A = \frac{i_{out}}{i_{in}} = \frac{g_m}{(C_{gd}+C_{gs})S}$$

$$A(f_T)=1 \Rightarrow f_T = \frac{g_m}{2\pi(C_{gd}+C_{gs})}$$

in sub threshold:

$$I_d = I_o e^{\frac{V_{GS}}{\eta V_T}}$$

$$g_m = \frac{\partial I_d}{\partial V_{GS}} = \frac{I_o}{\eta V_T} e^{\frac{V_{GS}}{\eta V_T}} = \frac{I_d}{\eta V_T}$$

$$\rightarrow f_T = \frac{I_d}{2\pi \eta V_T (C_{gd}+C_{gs})} \overset{C_{Gd} \simeq C_{gs} \simeq C_{ov}}{=} \frac{I_d}{4\pi V_T C_{ov}}$$

in Active:

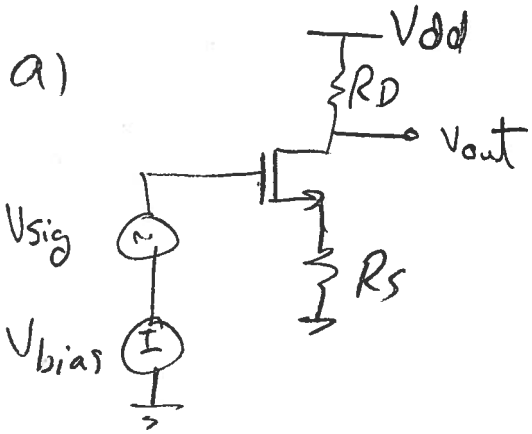
$$f_T = \frac{g_m}{2\pi(C_{gd}+C_{gs})} \simeq \frac{\mu_n C_{ox}(\frac{W}{L})(V_{GS}-V_{th})}{2\pi(C_{gd}+C_{gs})}$$

$$\simeq \frac{\mu_n C_{ox}(W/L)(V_{GS}-V_{th})}{2\pi\left(C_{ov}+C_{ov}+\frac{2}{3}WLC_{ox}\right)}$$

$$\simeq \frac{3I_d}{2\pi(WLC_{ox})(V_{GS}-V_{th})}$$

2)

a)



$$V_{dc_out} = V_{dd} - I_d R_D$$

$$1.44 = 1.8 - I_D \times \left(\frac{1}{2}\,k\Omega\right)$$

$$\rightarrow I_d = (1.8 - 1.44)2\ mA$$

$$= 0.36 \times 2 = \boxed{0.72\ mA}$$

$$I_d = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_{th})^2 \quad \rightarrow V_{eff} = 0.3V$$

$$V_{th} = V_{tho} + \gamma\left(\sqrt{2\phi_f + V_{BS}} - \sqrt{2\phi_f}\right) = 0.6V$$

$$V_{GS} = V_{Bias} - R_S I_d \rightarrow$$

$$= V_{Bias} - 0.36 \rightarrow \cancel{V_{eff} = 0.3V}$$

$V_{Bias} = 1.26\ V$

$$\rightarrow 0.72 \times 10^{-3} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{Bias} - 0.36 - V_{th})^2$$

$$\rightarrow V_{Bias} = \boxed{1.26}$$

b) $V_{GD} < V_{th}$?? $\rightarrow V_{GD} = {}^{1.26-1.44} \rightarrow V_{GD} < V_{th}$ ✓

c) $A_s \; G_M R_{out} \simeq \left(\frac{g_m}{1 + g_m R_S}\right)(R_D \| r_o) \simeq -0.53$