10.56 An n-channel MOSFET has the following parameters:

$\mu_n = 400 \text{ cm}^2/\text{V-s}$ $t_{ox} = 500 \text{ Å}$

$L = 2\ \mu\text{m}$ $W = 20\ \mu\text{m}$

$V_T = +0.75 \text{ V}$

Assume the transistor is biased in the saturation region at $V_{GS} = 4$ V. (*a*) Calculate the ideal cutoff frequency. (*b*) Assume that the gate oxide overlaps both the source and drain contacts by 0.75 μm. If a load resistance of $R_L = 10$ kΩ is connected to the output, calculate the cutoff frequency.

a) Per (10.96), $f_T = \dfrac{\mu_n (V_{GS} - V_T)}{2\pi L^2}$

Using MKS units

$$f_T = \frac{400 \times 10^{-4} (4 - 0.75)}{2\pi (2 \times 10^{-6})^2}$$

$$f_T = 5.172536 \times 10^{9} \text{ Hz} = 5.1725 \text{ GHz}$$

b) Per Table B.6, $\epsilon_r = 3.9$ for SiO_2 @ 300K

Per (10.35), $C_{ox} = \dfrac{\epsilon_{ox}}{t_{ox}} = \dfrac{3.9(8.8541878 \times 10^{-12})}{500 \times 10^{-10}}$

$= 6.906266 \times 10^{-4} \text{ F/m}^2$

Overlap area $A_{overlap} = W(\text{overlap})$

$= 20 \times 10^{-6} (0.75 \times 10^{-6})$

$= 1.5 \times 10^{-11} \text{ m}^2$

Parasitic capacitances

$C_{gdp} = C_{gsp} = C_{ox} A_{overlap} = 6.906 \times 10^{-4} (1.5 \times 10^{-11})$

$= 1.03594 \times 10^{-14} \text{ F}$

b) cont. With transistor in saturation, per page 426 of text,

$$C_{gs} = C_{ox} WL = 6.906\times10^{-4}(20\times10^{-6})(2\times10^{-6})$$

$$= 2.76251\times10^{-14}\,F$$

$$C_{gd} = 0$$

$$C_{gdT} = C_{gd} + C_{gdp} = 0 + 1.03594\times10^{-14}\,F$$

$$C_{gsT} = C_{gs} + C_{gsp} = 2.76251\times10^{-14} + 1.03594\times10^{-14}$$

$$= 3.79845\times10^{-14}\,F$$

Per (10.77), $g_{ms} = \dfrac{W\mu_n C_{ox}}{L}(V_{GS} - V_T)$

$$= \frac{20\times10^{-6}(400\times10^{-4})6.906\times10^{-4}}{2\times10^{-6}}(4-0.75)$$

$$= 8.97815\times10^{-4}\,S$$

Per (10.91), $C_m = C_{gdT}(1 + g_{ms}R_L)$

$$= 1.03594\times10^{-14}(1 + 8.978\times10^{-4}(10\times10^{3}))$$

$$= 1.033676\times10^{-13}\,F$$

Per (10.95), $f_T = \dfrac{g_{ms}}{2\pi(C_{gsT} + C_m)}$

$$= \frac{8.97815\times10^{-4}}{2\pi(3.79845\times10^{-14} + 1.033676\times10^{-13})}$$

$$\underline{\underline{f_T = 1.0109\times10^{9}\,Hz = 1.0109\,GHz}}$$