Example 7.1 Calculate the drain current of a silicon nMOSFET with V_T = 1 V, W = 10 µm, L = 1 µm and t_{ox} = 20 nm. The device is biased with V_{GS} = 3 V and V_{DS} = 5 V. Use the quadratic model, a surface mobility of 300 cm^2/V-s and set V_{BS} = 0 V.
Also calculate the transconductance at V_{GS} = 3 V and V_{DS} = 5 V and compare it to the output conductance at V_{GS} = 3 V and V_{DS} = 0 V.

Solution The MOSFET is biased in saturation since $V_{DS} > V_{GS} - V_T$.
Therefore the drain current equals:

$$I_D = \mu_n C_{ox} \frac{W}{L} \frac{(V_{GS} - V_T)^2}{2}$$

$$= 300 \times \frac{3.9 \times 8.85 \times 10^{-14}}{20 \times 10^{-7}} \frac{10}{1} \times \frac{(3-1)^2}{2} = 1.04 \text{ mA}$$

The transconductance equals:

$$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)$$

$$= 300 \times \frac{3.9 \times 8.85 \times 10^{-14}}{20 \times 10^{-7}} \frac{10}{1} \times (3-1) = 1.04 \text{ mS}$$

and the output conductance equals:

$$g_d = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T - V_{DS})$$

$$= 300 \times \frac{3.9 \times 8.85 \times 10^{-14}}{20 \times 10^{-7}} \frac{10}{1} \times (3-1-0) = 1.04 \text{ mS}$$