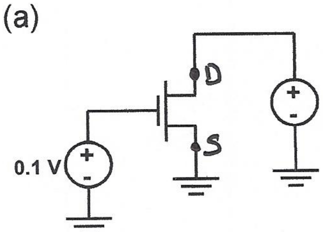
HW 3 Solutions   ECE 520

1. In each circuit configuration below:

1) Identify Drain and Source terminals assuming the device is an NMOS
2) Identify operating region of each transistor (cutoff, linear, saturation, or velocity saturation)
3) Determine the drain current

Assume V_{DSat} = 1 V, V_{Tn} = 0.5 V, and $K'_n(W/L)=1mA/V^2$. Ignore the body effect.

(a)

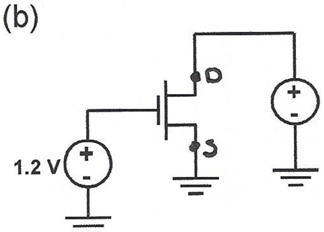


$V_{min} = min(V_{GS}-V_t, V_{DS}, V_{Dsat})$

$V_{min} = ((0.1-0.5), 2.5, 1)$

$V_{GT} \leq 0 \Rightarrow$ $I_{DS}=0$ $\Rightarrow$ Cutoff

(b)

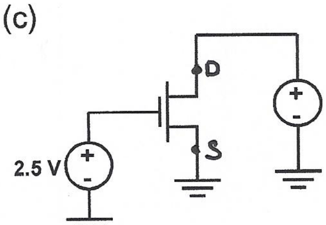


$V_{min} = ((0.7), 2.5, 1) \Rightarrow$ Saturation

$I_{DS} = \frac{k'n}{2}(W/L)(V_{gs}-V_t)^2 =$ 245 uA

= 0.245mA

(c)

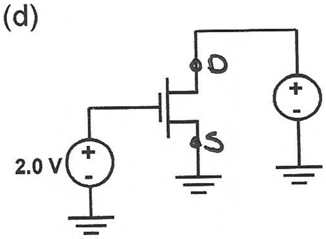


$V_{min} = (2, (0.8), 1) \Rightarrow$ linear

$I_{DS} = k'n(W/L)((V_{gs}-V_t)V_{DS} - V_{DS}^2/2)$

I_{DS} = 1.28mA

(d)

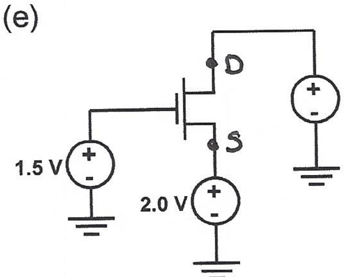


$V_{min} = (1.5, 2.5, \textcircled{1}) \Rightarrow$ **Vel sat**

$I_{DS} = k'_n((1.5)(1) - 1^2/2) =$ **1mA**

$k'_n = 1 mA/V^2$

(e)

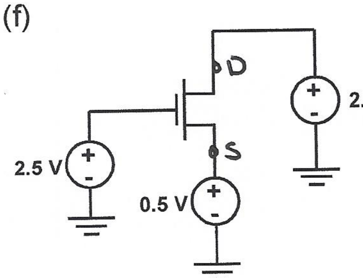


$V_{min} = (1.5 - 2 - 0.5,\ 2.5 - 2,\ 1)$

$= (-1, 0.5, 1)$

$V_{GT} \leq 0 \Rightarrow$ **$I_{DS} = 0$** $\Rightarrow$ **Cutoff**

(f)

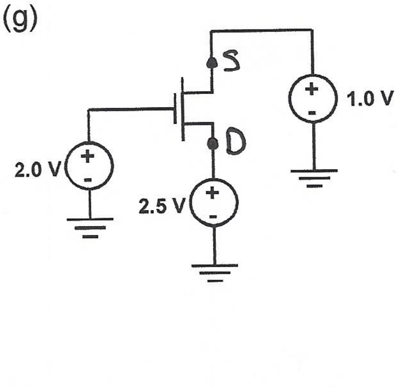


$V_{min} = (1.5, 2, \textcircled{1}) \Rightarrow$ **Vel sat**

$I_{DS} = k'_n((1.5)(1) - 1^2/2) =$ **1mA**

$k'_n = 1 mA/V^2$

(g)



$V_{min} = (\textcircled{0.5}, 1.5, 1) \Rightarrow$ **Saturation**

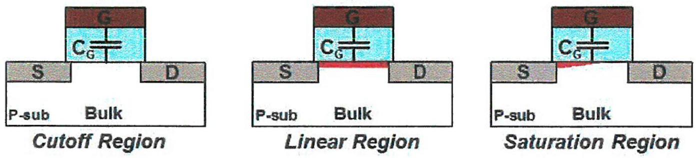
$I_{DS} = \frac{k'_n}{2}(W/L)(V_{GS} - V_t)^2$

$I_{DS} =$ **125 uA** or **0.125 mA**

2. We discussed in class how the channel capacitance can be modeled in different region of operations in MOSFETs. For your reference, the slide is shown below. Explain how you think the model would look like if a transistor is in velocity saturation region?

Channel Capacitances

- **Channel capacitance is a voltage dependent and non-linear capacitance**



Operation Region	C_{GBCH}	C_{GSCH}	C_{GDCH}
Cutoff	$C_{OX}WL_{eff}$	0	0
Linear	0	$\frac{1}{2}C_{OX}WL_{eff}$	$\frac{1}{2}C_{OX}WL_{eff}$
Saturation	0	$\frac{2}{3}C_{OX}WL_{eff}$	0

In velocity saturation two conditions may happen:

1) The channel is complete, where the channel capacitances would look like the linear region:

$C_{GDCH} = C_{GSCH} = \frac{1}{2} C_{ox} W L_{eff}$, $C_{GBCH} \approx 0$

when $V_{DS} < V_{GS} - V_T$, but $V_{DS} > V_{DSAT}$

2) The channel is pinched off, where the channel capacitances would look like the saturation region:

$C_{GSCH} = \frac{2}{3} C_{ox} W L_{eff}$, $C_{GBCH} \approx C_{GDCH} \approx 0$

when $V_{DS} > V_{GS} - V_T$, but $V_{GS} - V_T > V_{DSAT}$