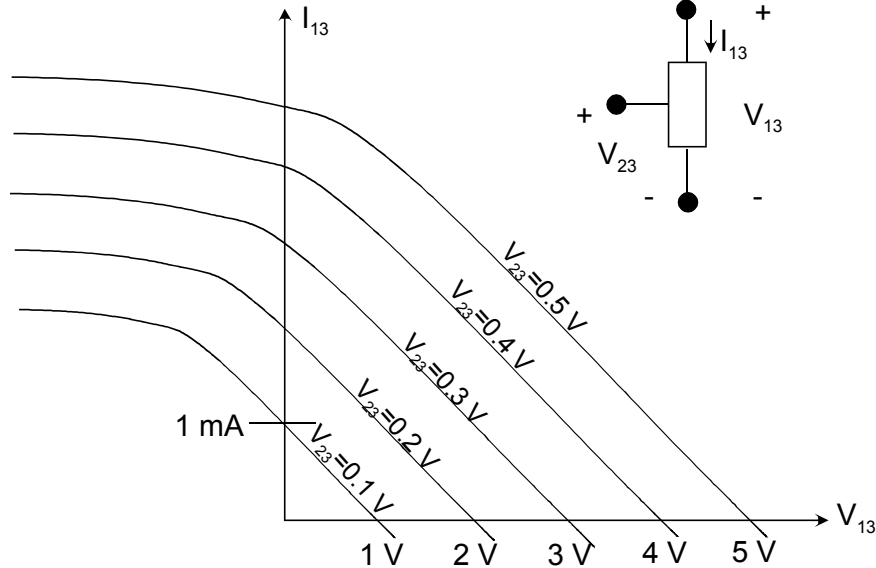


ELEG240- Spring, 2005  
 Homework 11  
 Due 5/17, noon

1. You invent a three terminal device that has the following characteristics:



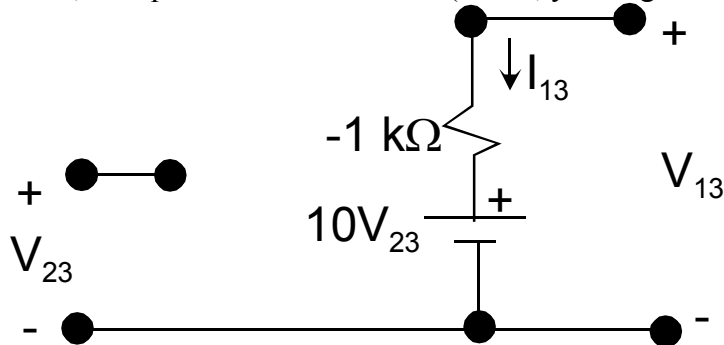
Construct an approximate equivalent circuit model.

ANSWER:

$$I_{13} \cong (V_0 - V_{13}) / 1000 \text{ A, where}$$

$$V_0 = 10V_{23} \text{ volts.}$$

Thus, an equivalent circuit model (that is, yielding the correct equations) is



Note that in an equivalent circuit, resistors can have negative values. That's because they are mathematical elements, not real elements.

2. If a pnp transistor is composed of silicon, and the emitter is heavily doped (meaning the Fermi level in the emitter is essentially at the valence band), while the Fermi level in the base is 90 % of the way up from the valence band, and 99 % of the holes injected from the emitter make it to the collector, calculate the current gain  $I_c / I_b$ .

ANSWER:

For the base emitter junction,

$$\frac{I_{elec}}{I_{hole}} = \frac{e^{-0.9E_{GAP}/k_B T}}{e^{-E_{GAP}/k_B T}} = e^{-0.1E_{GAP}/k_B T} = 0.0135.$$

$$I_c = 0.99I_{hole},$$

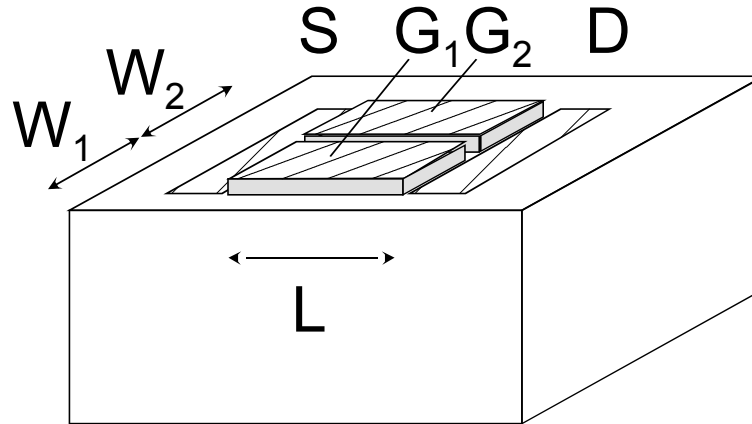
$$I_b = I_{elec} + 0.01I_{hole} = 0.0135I_{hole} + 0.01I_{hole} = 0.0235I_{hole},$$

$$\beta = \frac{I_c}{I_b} = \frac{0.99I_{hole}}{0.0235I_{hole}} = 42.1.$$

3. Describe how to construct an OR gate with a single MOSFET. Draw a picture of it. Write down the drain-source current as a function of the various voltages on this MOSFET. (Problem 10.3 in the textbook may help).

ANSWER:

Construct a MOSFET with two parallel gates, not in series as in 10.3. Then, the channel conducts current if a voltage is applied to either gate, in other words the OR function.



The total current is the sum of the current under each gate:

$$I_{DS} = I_{DS1} + I_{DS2} = G_1 V_{DS} + G_2 V_{DS}.$$

$$G_{1,2} = \frac{W_{1,2} \mu \epsilon_{oxide}}{L h_{oxide}} (V_{G_{1,2}} - V_T), \text{ so}$$

$$\begin{aligned} I_{DS} &= \left[ \frac{W_1 \mu \epsilon_{oxide}}{L h_{oxide}} (V_{G_1} - V_T) + \frac{W_2 \mu \epsilon_{oxide}}{L h_{oxide}} (V_{G_2} - V_T) \right] V_{DS} \\ &= \frac{\mu \epsilon_{oxide}}{L h_{oxide}} [W_1 (V_{G_1} - V_T) + W_2 (V_{G_2} - V_T)] V_{DS} \end{aligned}$$