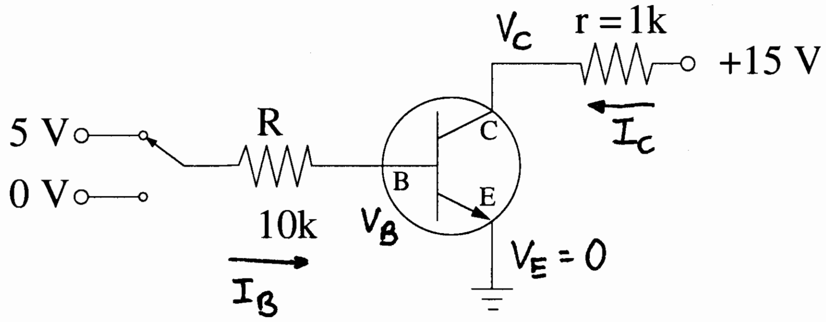
Name: ______________________________

1. Calculate the current through the resistor r in the transistor switch shown below when the input is set to 5 V.



Since we are considering switches it is reasonable to assume that the transistor is saturated. If saturated $V_c \simeq 0.2V$ and, therefore,

$$I_c = \frac{15V - 0.2V}{r} = \frac{14.8V}{1 \cdot 10^3 \Omega} = 14.8\,mA \quad \left(= I_c^{max}\right)$$

We now have to check our assumption:

We know that $V_B \simeq 0.6V$

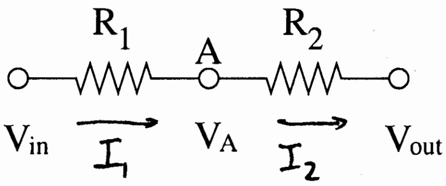
$$\hookrightarrow I_B = \frac{5V - 0.6V}{R} = \frac{4.4V}{10 \cdot 10^3 \Omega} = 0.44\,mA$$

Thus, for $\beta \geq 100$ $\quad \beta I_B > I_c^{max} \approx 15mA$

↳ Our assumption is correct, the transistor is in the saturated regime.

$$\boxed{I_c = 14.8\,mA}$$

2.



For the voltage divider shown on the left, **prove** that the voltage V_A at point A is given by

$$V_A = \frac{V_{in}\,R_2 + V_{out}R_1}{R_1 + R_2}.$$

Kirchhoff's current law: $I_1 = I_2$

Ohm's law: $I_1 R_1 = V_{in} - V_A$; $I_2 R_2 = V_A - V_{out}$

$$\hookrightarrow V_A\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{V_{in}}{R_1} + \frac{V_{out}}{R_2} \quad \Big| \cdot \frac{R_1 R_2}{R_1 + R_2}$$

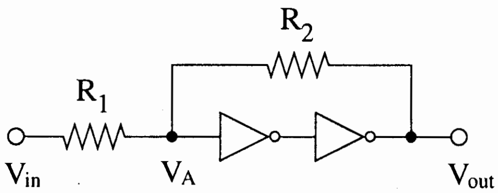
$$\boxed{V_A = \frac{V_{in}\,R_2 + V_{out} \cdot R_1}{R_1 + R_2}}$$

When incorporated into a Schmitt Trigger, V_{out} can only take on two possible values: 0 ("low") and V_{DD} ("high"). A change in the output can only occur when the voltage V_A crosses through a threshold voltage V_T. **Show** that if the output is low, the input voltage required to switch to the high state is

$$V_{\text{low-to-high}} = \frac{(R_1 + R_2)\,V_T}{R_2}$$

while, if the output is high, the input voltage required to switch to the low state is

$$V_{\text{high-to-low}} = -\frac{R_1\,V_{DD}}{R_2} + \frac{(R_1 + R_2)\,V_T}{R_2}.$$



Schmitt trigger circuit

Thus, the hysteresis of a Schmitt Trigger is given by

$$\Delta V = V_{\text{low-to-high}} - V_{\text{high-to-low}} = \frac{R_1\,V_{DD}}{R_2}$$

low-to-high : ($V_{in} := V_{L\to H}$)

$V_A := V_T$ and $V_{out} = 0$ (start low)

$$V_T = \frac{V_{L\to H} \cdot R_2 + 0 \cdot R_1}{R_1 + R_2}$$

$$\hookrightarrow \boxed{V_{L\to H} = \frac{R_1 + R_2}{R_2} V_T}$$

high-to-low : ($V_{in} := V_{H\to L}$)

$V_A := V_T$ and now $V_{out} = V_{DD}$ (start high)

$$V_T = \frac{V_{H\to L} \cdot R_2 + V_{DD} \cdot R_1}{R_1 + R_2}$$

$$\hookrightarrow \boxed{V_{H\to L} = -\frac{R_1}{R_2} V_{DD} + \frac{R_1 + R_2}{R_2} V_T}$$

$$\boxed{\Delta V = V_{L\to H} - V_{H\to L} = \frac{R_1}{R_2} V_{DD}}$$