Physics 261
Homework # 10
Remember to show your work.

1. For questions a & b, select the appropriate answer(s) from among the four given possibilities. In the fish tank comparator example, which quality or qualities of the comparator makes it possible to...

	High input impedance
(a) Power the pump?	Low input impedance
(b) Not electrocute the fish?	High output impedance
	Low output impedance

   (c) The input resistor I used for the water sensor was $1\,\mathrm{M}\Omega$. If this value is chosen wisely, what other resistance should it be *greater* than? What other resistance should it be *less* than?

2. Consider the inverting Schmitt trigger (the same type as in lecture, and in Faissler figure 34-5). Given $V_L = 0\,\mathrm{V}$, $V_H = 3\,\mathrm{V}$, and $R_2 = 2\,\mathrm{k}\Omega$, choose V_b and R_1 so that the thresholds are at $1\,\mathrm{V}$ and $2\,\mathrm{V}$.

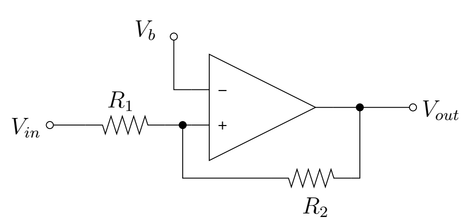
3. The illustration below shows a *non-inverting* variant of the Schmitt trigger. Assume that the op amp is ideal.

   (a) Find V_+ in terms of V_{in}, V_{out}, and the resistors.

   (b) Assuming $V_+ > V_b$, find V_{out} and the corresponding range of V_{in} in terms of V_H, V_L, V_b, and the resistors.

   (c) Assuming $V_+ < V_b$, find V_{out} and the corresponding range of V_{in} in terms of V_H, V_L, V_b, and the resistors.

   (d) Sketch the relationship between V_{out} and V_{in}, including arrows on the vertical parts of the hysteresis loop.



1. (a) THE COMPARATOR CAN POWER THE WATER PUMP BECAUSE IT HAS LOW OUTPUT IMPEDANCE.

   (b) THE FISH ARE NOT ELECTROCUTED BECAUSE THE CIRCUIT HAS HIGH INPUT IMPEDANCE.

   (c) RESISTANCE OF WATER < $1\,M\Omega$ < OP AMP INPUT IMPEDANCE

2. GIVEN $V_L = 0V$, $V_H = 3V$, $R_2 = 2k\Omega$

THE THRESHOLDS FOR THE INVERTING SCHMITT TRIGGER ARE

$$V_{+H} = 2V = \frac{R_1 V_b + R_2 V_H}{R_1 + R_2} = \frac{R_1 V_b}{R_1 + R_2} + \frac{R_2 \cdot 3V}{R_1 + R_2} \qquad (i)$$

$$V_{+L} = 1V = \frac{R_1 V_b + R_2 V_L}{R_1 + R_2} = \frac{R_1 V_b}{R_1 + R_2} \qquad (ii)$$

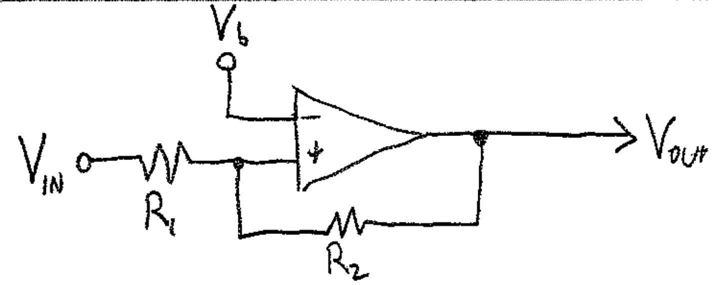
SUBSTITUTING (ii) INTO (i),

$$2V = 1V + \frac{R_2}{R_1 + R_2} 3V \Rightarrow R_1 = 2R_2 = 4k\Omega$$

THEN (ii) BECOMES

$$\frac{2}{3} V_b = 1V \Rightarrow V_b = 1.5V$$

3



(a) CONSIDERING THE NODE AT V_+, KCL IS

$$\frac{V_{IN}-V_+}{R_1}+\frac{V_{OUT}-V_+}{R_2}=0 \Rightarrow R_2(V_{IN}-V_+)+R_1(V_{OUT}-V_+)=0$$

$$\Rightarrow (R_1+R_2)V_+ = R_2V_{IN}+R_1V_{OUT} \Rightarrow \boxed{V_+ = \frac{R_2V_{IN}+R_1V_{OUT}}{R_1+R_2}}$$

(b) $V_+ > V_b$: $\boxed{V_{OUT}=V_H}$

$$V_+ = \frac{R_2V_{IN}+R_1V_H}{R_1+R_2} > V_b \Rightarrow R_2V_{IN}+R_1V_H > V_b(R_1+R_2)$$

$$\Rightarrow \boxed{V_{IN} > V_b\left(1+\frac{R_1}{R_2}\right)-\frac{R_1}{R_2}V_H} \quad (i)$$

(c) $V_+ < V_b$: $\boxed{V_{OUT}=V_L}$

$$V_+ = \frac{R_2V_{IN}+R_1V_L}{R_1+R_2} < V_b \Rightarrow R_2V_{IN}+R_1V_L < V_b(R_1+R_2)$$

$$\Rightarrow \boxed{V_{IN} < V_b\left(1+\frac{R_1}{R_2}\right)-\frac{R_1}{R_2}V_L} \quad (ii)$$

(d) WE HAVE: $V_{OUT}=V_H$ ON $V_{IN}>V_1$, V_1 GIVEN BY (i),
$V_{OUT}=V_L$ ON $V_{IN}<V_2$, V_2 GIVEN BY (ii).

SINCE $V_L<V_H$, $\underline{\underline{V_2>V_1}}$.