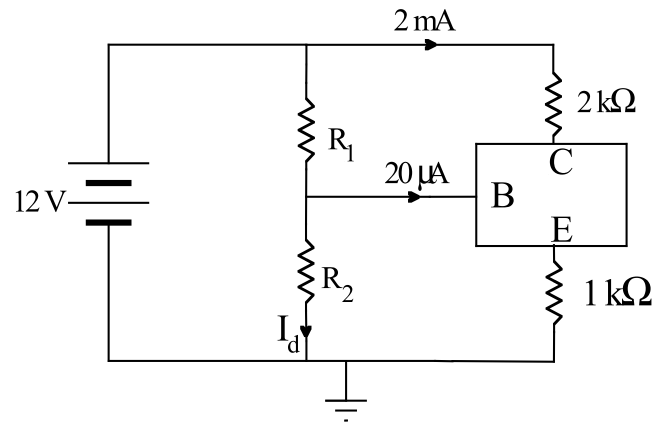
Physics 517/617 Homework 3 (Due July 27th)

1) A "black box" with three terminals labeled E, B, and C is connected in the circuit shown at the right. (a) Calculate V_C and V_E. (b) If terminal "B" is 0.6 V higher in voltage than terminal E, calculate R_1 and R_2 (in terms of I_d), assuming that I_d is very large compared to the $20\ \mu A$ flowing into the B terminal and can be neglected in setting up a voltage divider. (This "black box" is a silicon NPN transistor and C, B, and E will refer to the collector, base and emitter terminals when we study those devices).



The current thru the collector is 2 mA; this is very large compared to the current thru the base and consequently, the emitter current is, by Kirchoff's node law nearly equal to the collector current: $I_E \approx I_C = 2$ mA . Thus (a) measured relative to the ground of the circuit $V_E = 2\ mA \times 1\ k\Omega = 2\ V$ and $V_C = 12\ V - 2\ mA \times 2\ k\Omega = 8\ V$. The base voltage is $V_B = V_E + 0.6 = 2.6\ V$. (b) The two resistors for a voltage divider that provides 2.6 V at the base. This means the voltage drop across R_2 is 2.6 V and the voltage drop across R_1 is $12 - 2.6 = 9.4V$. Thus $R_1 = \frac{9.4}{I_d}$, $R_2 = \frac{2.6}{I_d}$.

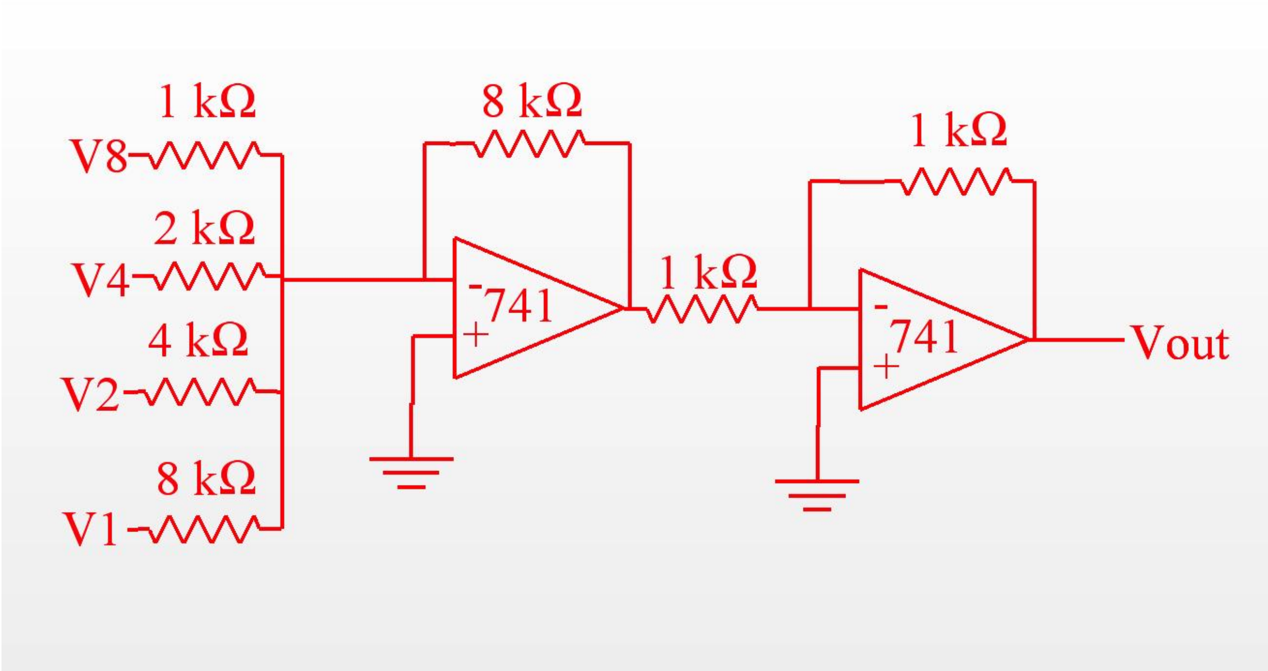
2) Use the diode equation, $I_D = I_0\left(e^{\frac{qV_D}{kT}} - 1\right)$, for what follows. Note, q = the electronic charge, $1.6\times10^{-19}\ C$. Consider a forward biased diode with a "bias" current and voltage, I_{bias} and V_{bias}. (these are related by the diode equation). Consider now adding a small *additional "signal"* voltage, δv, across the diode which will in turn drive a small additional current δi. Show (use differential calculus) that the "differential resistance" relating these, i.e. $r \equiv \frac{\delta v}{\delta i}$ is given by: $r = \frac{1}{38.9 \cdot I_{bias}(A)}$ --- or --- if the bias current is measured in mA $r = \frac{25.7}{I_{bias}(mA)}$.

We ignore the -1 in the diode equation expression.

$$I_{bias} + \delta i = I_{bias} + \left.\frac{dI_D}{dV_D}\right|_{V_D} \delta v \Rightarrow \frac{\delta v}{\delta i} = \left[\left.\frac{dI_D}{dV_D}\right|_{V_D}\right]^{-1} = \left[\frac{q}{kT} \bullet I_0 \bullet e^{\frac{qV_{Bias}}{kt}}\right]^{-1} = \frac{1}{38.9 \bullet I_{Bias}}$$

3) Using one or more op-amps, design a summing amplifier that given inputs v_a, v_b, v_c, and v_d produces the sum: $v_{out} = 8v_a + 4v_b + 2v_c + v_d$.

A standard summing amplifier will give the negative of the desired result. Following this by a times 1 inverting amplifier will give exactly the desired result.


1 kΩ
V8
2 kΩ
V4
4 kΩ
V2
8 kΩ
V1
8 kΩ
-
741
+
1 kΩ
1 kΩ
-
741
+
Vout