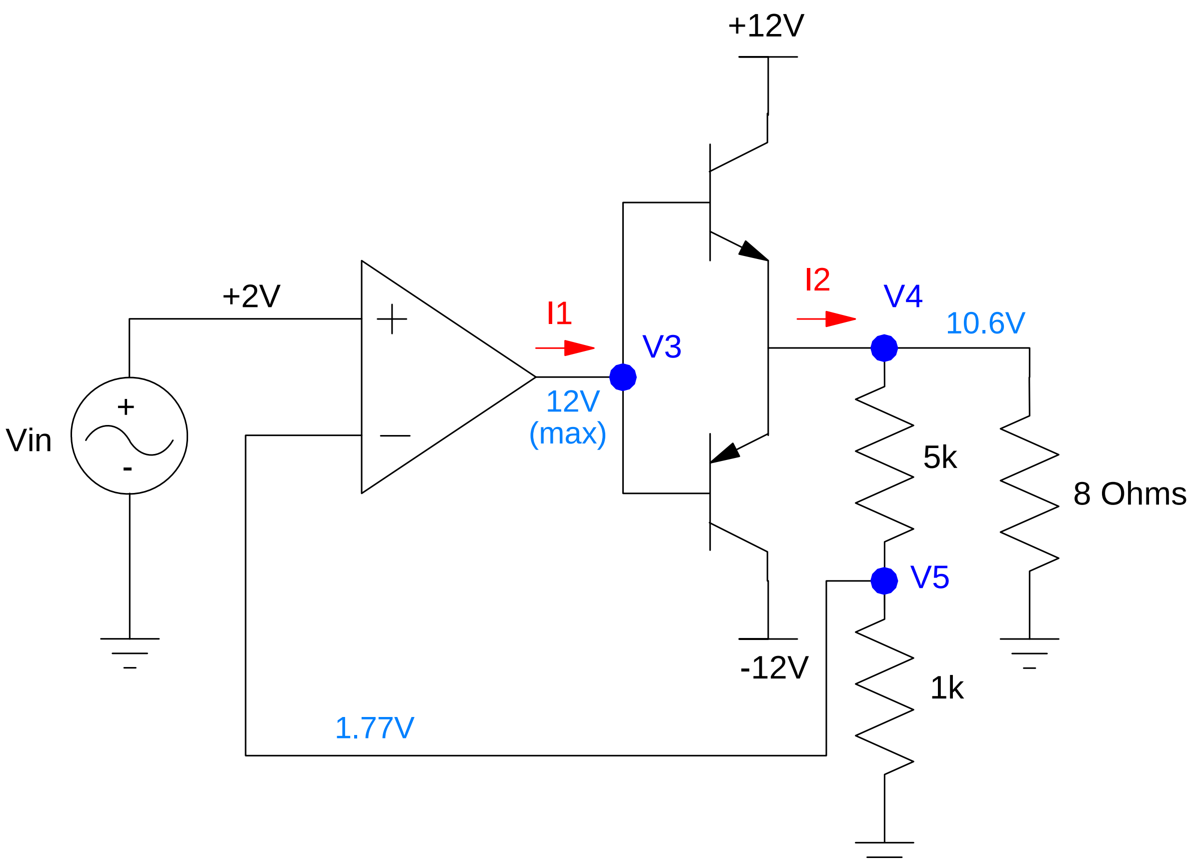
ECE 321 Final - Name ________________________

Closed-Book, Closed Notes, Calculators Permitted. - Spring 2019

1) Push Pull AmplifiersDetermine the voltages and currents for the following push-pull amplifier. Assume TIP transistors:

- $\beta = 1000$
- $|V_{be}| = 1.4V$
- $\min(|V_{ce}|) = 0.9V$

I1	I2	V3	V4	V5
1.32 mA	**1.32 A**	**12V** *saturated at +Vcc*	**10.6V**	**1.77V**



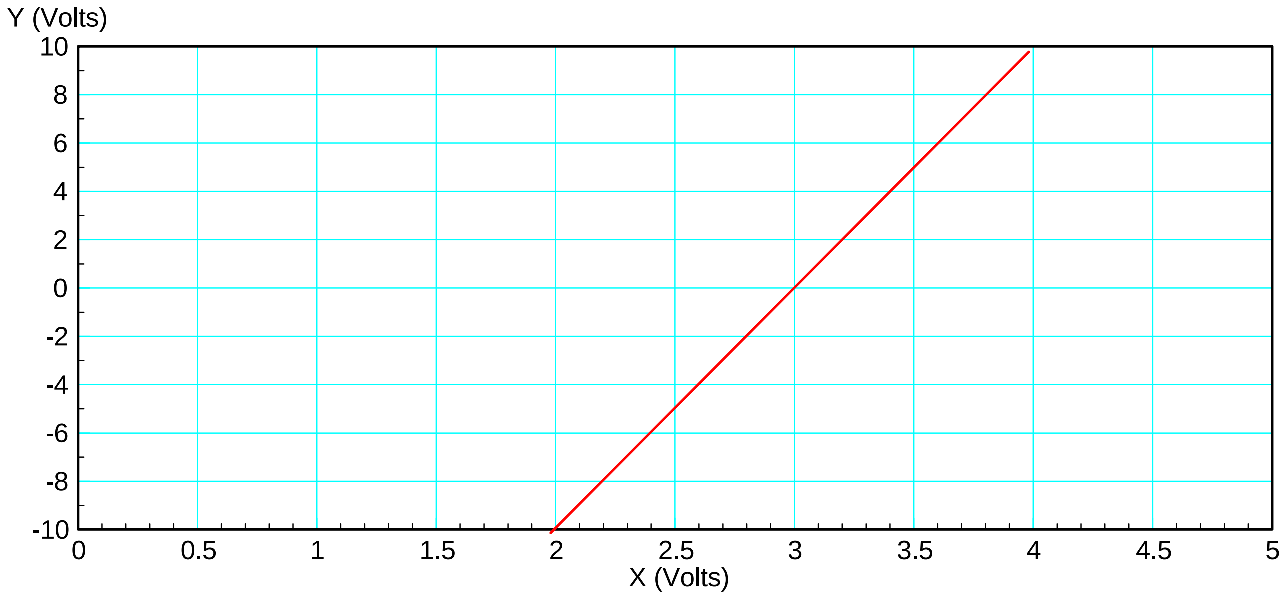
Assume Vp = Vm.

- V5 = 2V
- V4 = 12V (can't happen with a 12V supply)

Assume the op-amp is maxed out at Vcc (+12V)

- V3 = 12V
- V4 = V3 - 1.4V = 10.6V
- V5 = V4 / 6 = 1.77V

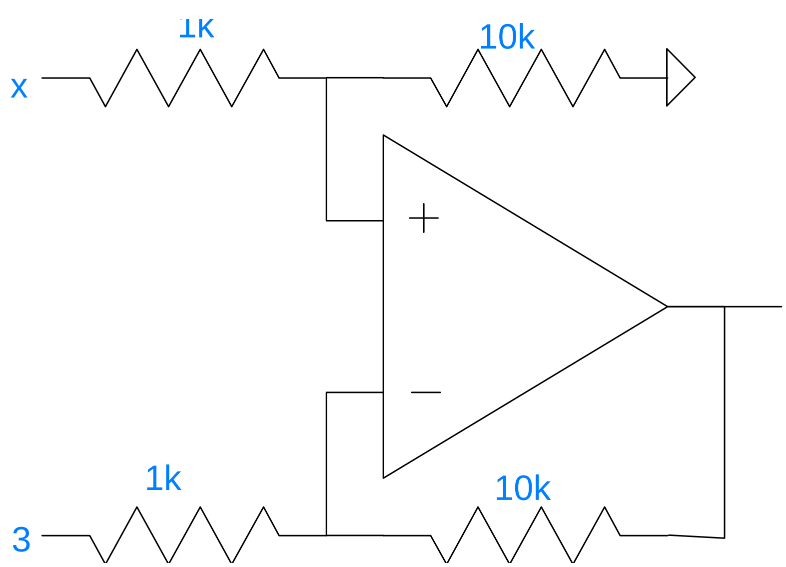
2a) Determine the relationship between X and Y from the following graph.



$$y = 10x - 30$$

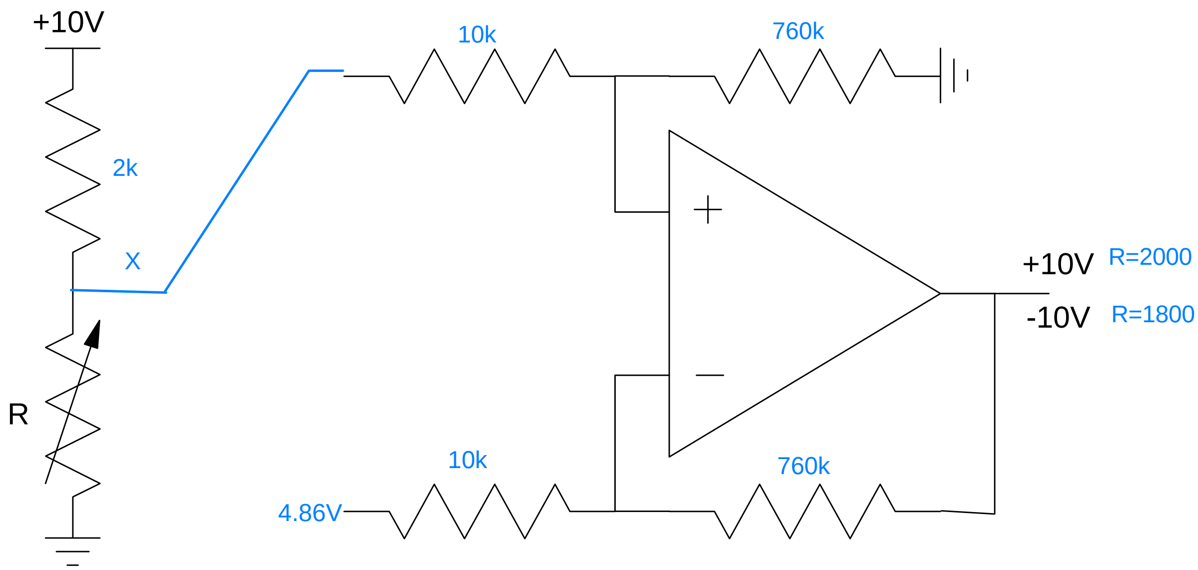
2b) Design an op-amp circuit to match the following relationship between X and Y:

$$y = 10(x - 3)$$



3) Design a circuit which outputs

- -10V when R = 1800 Ohms
- +10V when R = 2000 Ohms



Assume a 2k resistor

When R = 1800

$$X = \left(\frac{1800}{1800+2000}\right)10V = 4.7368V$$

When R = 2000

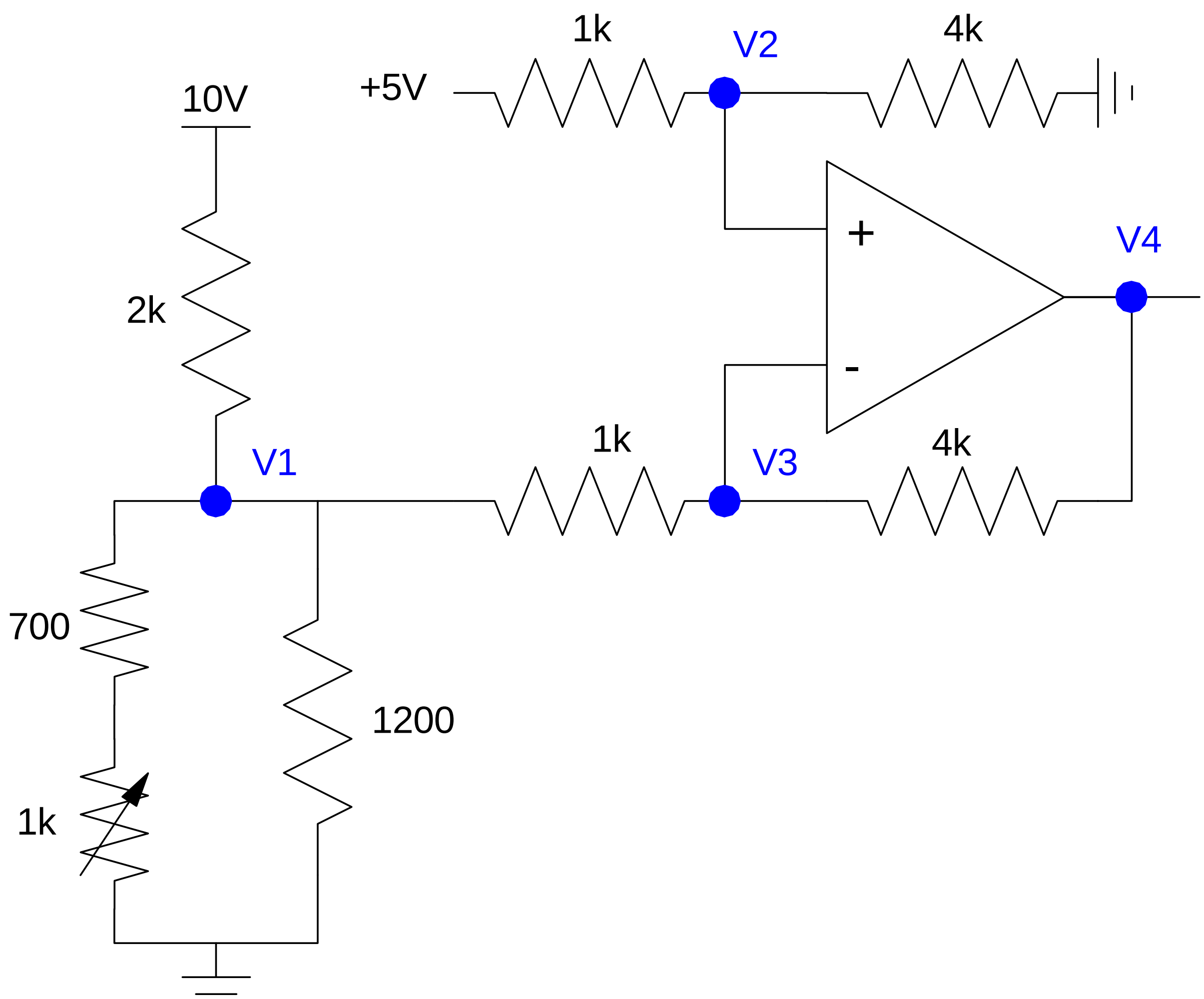
$$X = \left(\frac{2000}{2000+2000}\right)10V = 5.00V$$

$$gain = \left(\frac{20V}{5.00V-4.7368V}\right) = 76.0$$

$$offset = \left(\frac{5.00V+4.7368V}{2}\right) = 4.86V$$

4) The following circuit uses a linearizing circuit with an instrumentation amplifier. Determine the voltages at V1..V4

V1	V2	V3	V4
3.0805 V	**4 V**	**4 V**	**7.68 V**



$$V_2 = \left(\frac{4k}{4k+1k}\right)5V = 4V$$

$$V_3 = V_2 = 4V$$

$$\left(\frac{V_1}{1700}\right) + \left(\frac{V_1}{1200}\right) + \left(\frac{V_1 - 10}{2000}\right) + \left(\frac{V_1 - 4}{1000}\right) = 0 \qquad \Rightarrow V_1 = 3.08V$$

$$V_4 = \left(\frac{4k}{1k}\right)(5 - V_1) = 7.68V$$

5) X and Y are related by the following filter

$$Y = \left(\frac{2s+7}{s^2+2s+17}\right) X = \left(\frac{2s+7}{(s+1+j4)(s+1-j4)}\right) X$$

a) What is the differential equation relating X and Y?

cross multiply

$$(s^2 + 2s + 17)Y = (2s + 7)X$$

'sY' means 'the deriative of Y'

$$y'' + 2y' + 17y = 2x' + 7x$$

b) Find y(t) assuming

$$x(t) = 5 + 6\sin(10t)$$

Use superposition

x(t) = 5

X = 5

s = 0

$$Y = \left(\frac{2s+7}{s^2+2s+17}\right) X$$

$$Y = \left(\frac{2s+7}{s^2+2s+17}\right)_{s=0} \cdot (5)$$

$$Y = \left(\frac{7}{17}\right) \cdot 5$$

$$Y = 2.0588$$

x(t) = 6 sin(10t)

X = 0 - j6

s = j10

$$Y = \left(\frac{2s+7}{s^2+2s+17}\right) X$$

$$Y = \left(\frac{2s+7}{s^2+2s+17}\right)_{s=j10} \cdot (0 - j6)$$

$$Y = -1.48 + j0.15$$

real means cosine, -imag means sine

$$y(t) = -1.48\cos(10t) - 0.15\sin(10t)$$

$$y(t) = 2.0588 - 1.48\cos(10t) - 0.15\sin(10t)$$

6) The transfer function for a 4th-order Butterworth low-pass filter with a corner at 100 rad/sec is

$$Y = \left(\frac{100^4}{(s+100\angle 22.5^0)(s+100\angle -22.5^0)(s+100\angle 67.5^0)(s+100\angle 67.5^0)} \right) X$$

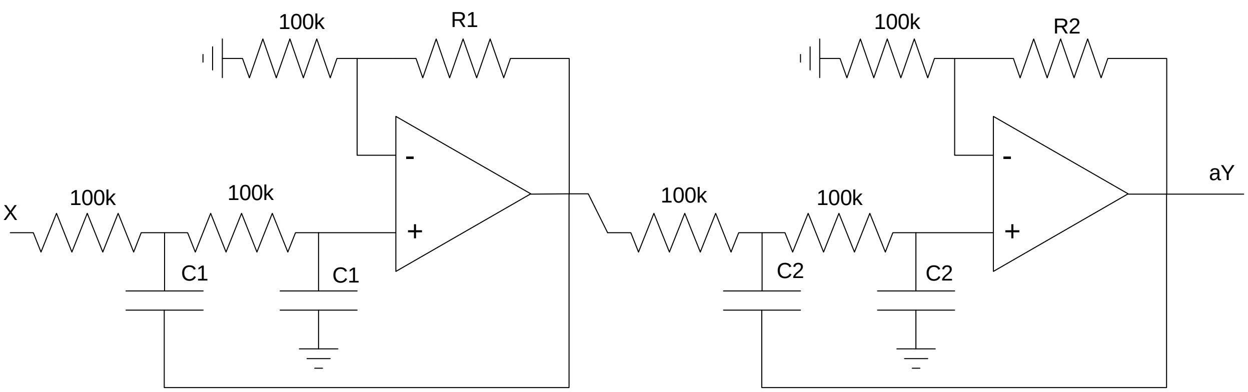
Find R and C to implement this filter

C1	R1	C2	R2
0.1 uF	**15k**	**0.1 uF**	**123k**

Note: The transfer function for the first stage is

$$\left(\frac{k\left(\frac{1}{RC}\right)^2}{s^2 + \left(\frac{3-k}{RC}\right)s + \left(\frac{1}{RC}\right)^2} \right) \qquad k = 1 + \frac{R_1}{100{,}000}$$

$$3 - k = 2\cos\theta$$



$$\left(\frac{1}{RC}\right) = 100 \qquad\qquad \left(\frac{1}{RC}\right) = 100$$

R = 100k | R = 100k

C1 = 0.1uF | C2 = 0.1uF

$$3 - k = 2\cos\theta \qquad\qquad 3 - k = 2\cos\theta$$

$$\theta = 22.5^0 \qquad\qquad \theta = 67.5^0$$

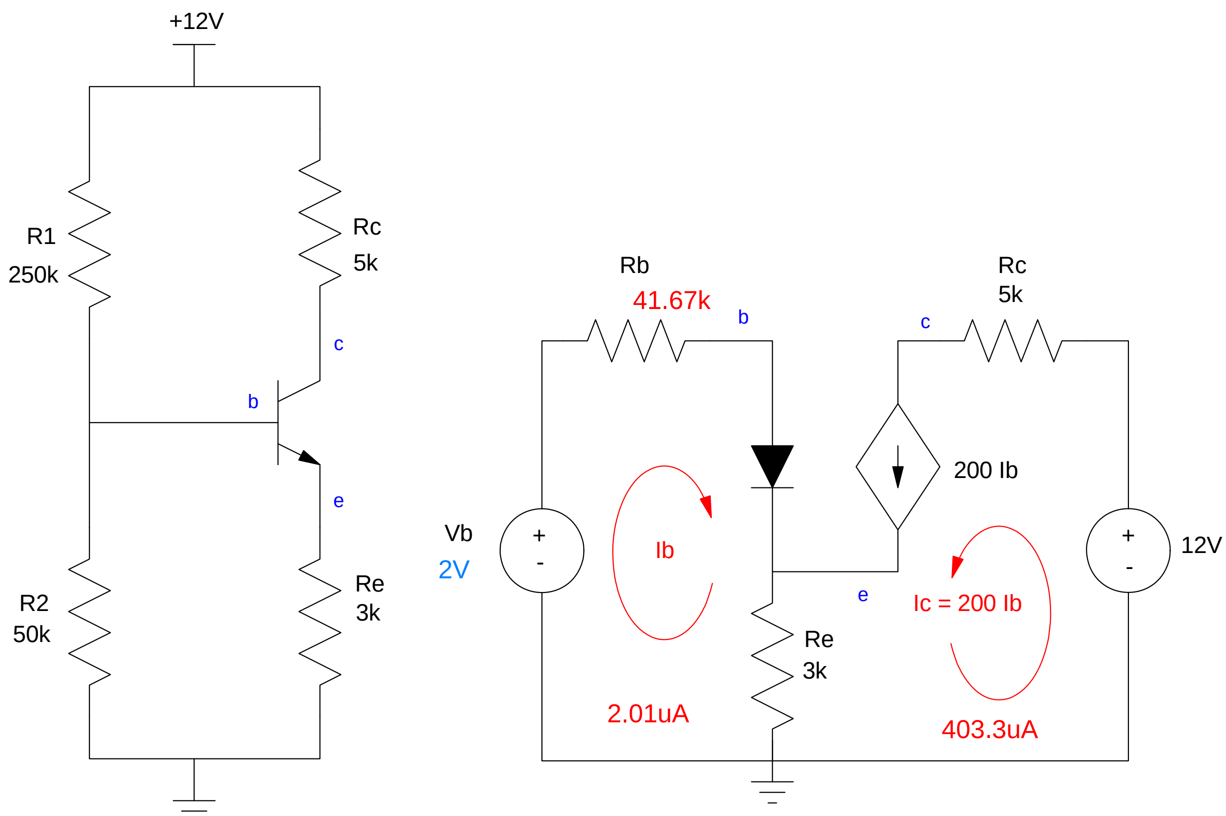
$$k = 1.15 \qquad\qquad k = 2.2346$$

$$k = 1 + \left(\frac{R_1}{100k}\right) \qquad\qquad k = 1 + \left(\frac{R_2}{100k}\right)$$

7) Q-Point Analysis. Determine the Thevenin equivalent for R1 and R2 (Vb and Rb) and determine the Q-point for the following transistor circuit. Assume ideal silicon transistors:

- $V_{be} = 0.7V$
- $\beta = 200$

Vb	Rb	Vce	Ic
2V	**41.67k**	**8.767V**	**403.3uA**



$$R_b = R_1 \,||\, R_2 = 41.67k$$

$$V_b = \left(\frac{R_2}{R_1+R_2}\right) 12V = 2V$$

$$I_b = \left(\frac{2V-0.7V}{R_b+(1+\beta)R_e}\right) = 2.01\mu A$$

$$I_c = 200 I_b = 403.3\mu A$$

$$V_{ce} = 12 - 5k \cdot I_c - 3k \cdot (I_b + I_c) = 8.767V$$

8) Draw the small signal model for the following common emitter amplifier (with Ce removed) and determine the corresponding 2-port model

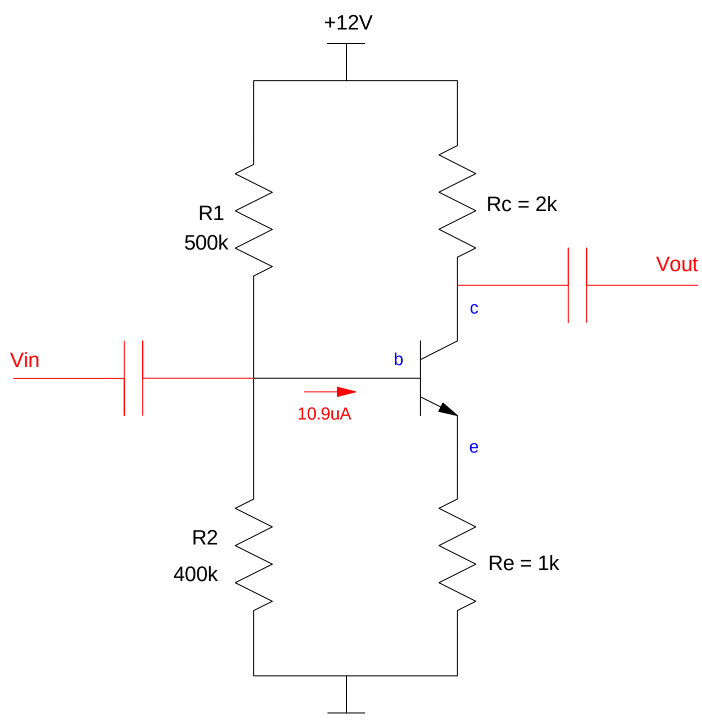
Small Signal Model	Rin	Ao	Rout
draw the AC model. Assume Zc = 0	**106k**	**-1.94**	**2k**

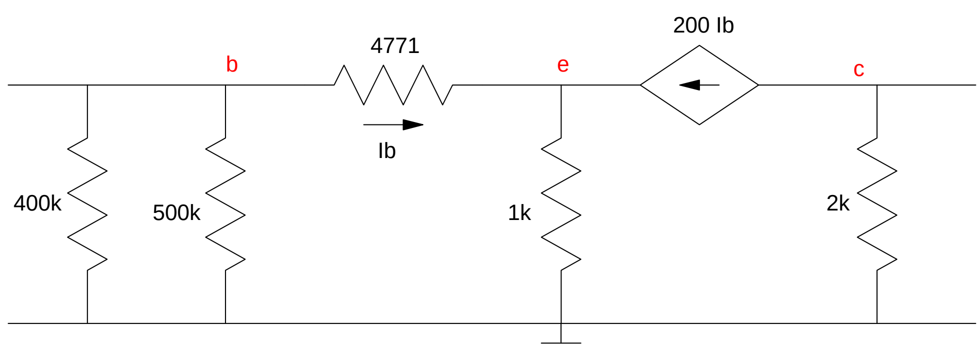
Due to the current source the 1k resistor looks like a 201k resistor looking from the left

$$R_{in} = 400k \,||\, 500k \,||\, 4771 + 201k$$

$$R_{in} = 106k$$

$$A_0 = -\left(\frac{200 \cdot 2k}{4771+201k}\right) = -1.944$$





Bonus! Four for the following are Democratic canidates running for President in 2020, four are Godzilla monsters. Circle the ones who are Democrats

Baragon - **Buttigieg** - Ebirah - **Gabbard** - Kamacuras - **Messam** - Orga - **Swalwell**