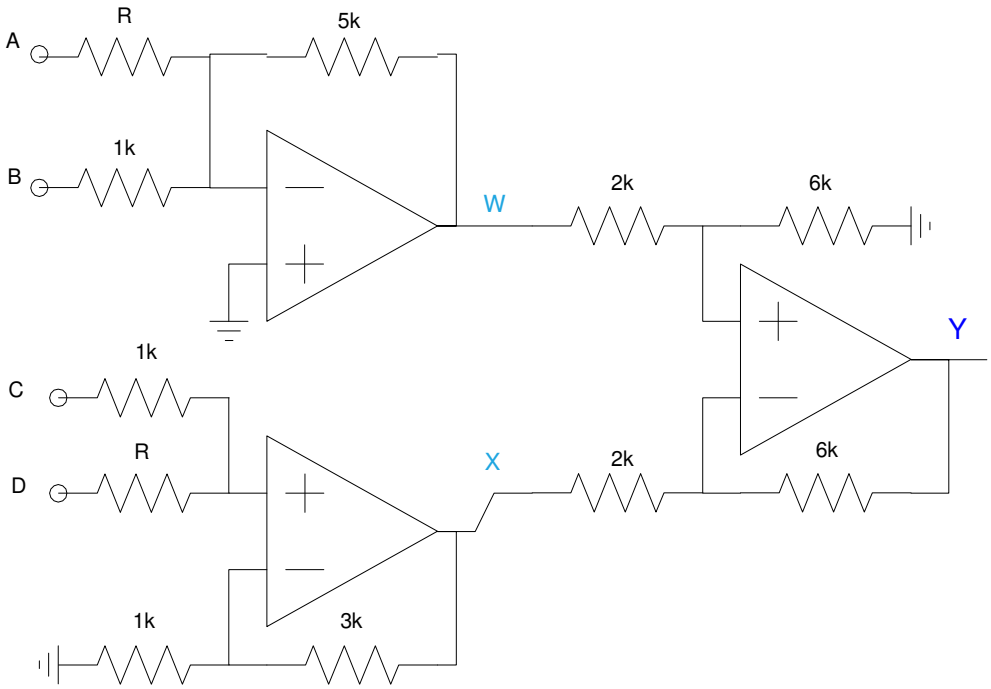
ECE 321 - Final Exam - Name _____

Spring 2023

1. OpAmp Circuits: Determine y as a function of A, B, C, and D. Assume

- Ideal op-amps
- R 800 + 100*(your birth month) + (your birth day).

R 800 + 100*mo + day	Y = aA + bB + cC + dD
1314	$Y = -11.41A - 15.00B - 6.81C - 5.18D$



$$W = -\left(\frac{5k}{1314}\right)A - \left(\frac{5k}{1k}\right)B$$

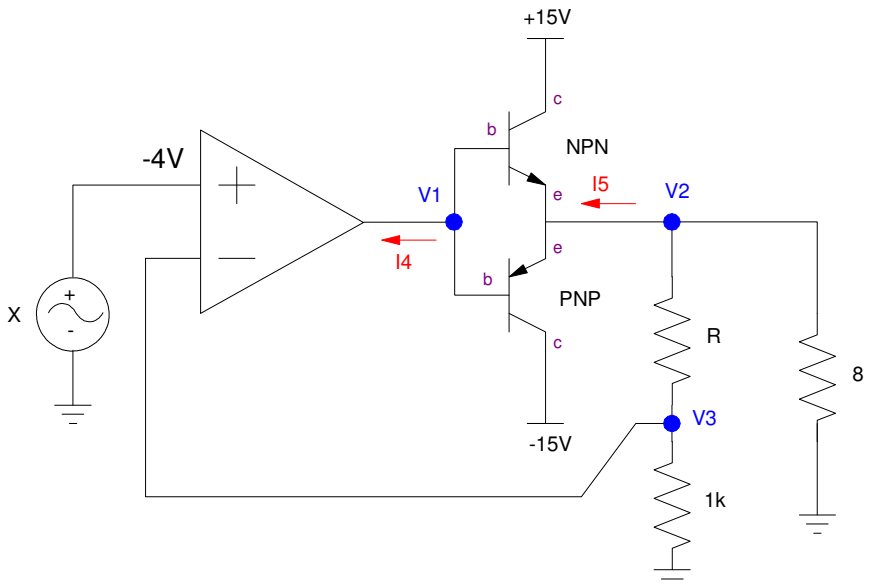
$$X = \left(1 + \frac{3k}{1k}\right)\left(\left(\frac{1314}{1k+1314}\right)C + \left(\frac{1k}{1314+1k}\right)D\right)$$

$$Y = 6(W - X)$$

2. Push-Pull: Determine the voltages and currents for the following push-pull amplifier when X = -4V. Assume

- R = 800 + 100*(birth month) + (birth day).
- | Vce | = 0.7V (ideal silicon diodes)
- $\beta = 30$

R 800 + 100*mo + day	V1	V2	V3	I4	I5
1314	**-9.9560**	**-9.2560**	**-4.000**	**37.45mA**	**1.161A**



$$V_3 = -4V$$

$$V_2 = \left(1 + \frac{R}{1k}\right) V_3 = -9.256V$$

$$V_1 = V_2 - 0.7 = -9.9560V$$

$$I_5 = \frac{V_2}{8} + \frac{V_2}{1k+R} = 1.161A$$

$$I_4 = \frac{I_5}{\beta+1} = 37.45mA$$

3. Instrumentation Amplifier: Assume an RTD has the temperature - resistance relationship of

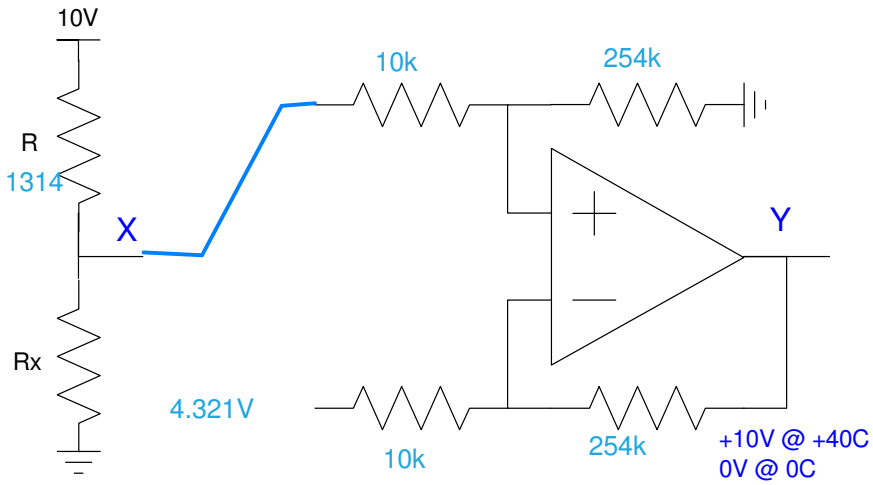
$$R_x = 1000 \cdot (1 + 0.0043T)\Omega$$

where T is the temperature in degrees C. Design a circuit which outputs

- +10V at +40C, and
- 0V at 0C

Assume

- R = 800 + 100*(your birth month) + (your birth date)



At 0C

Rx = 1000

$$X = \left(\frac{R_x}{R_x+1314}\right) 10V = 4.321V$$

At 40C

$$R_x = 1172\Omega$$

$$X = \left(\frac{R_x}{R_x+1314}\right) 10V = 4.7144V$$

Offset = 4.321V (where Y = 0)

Connect to the + input (Y goes up as X goes up)

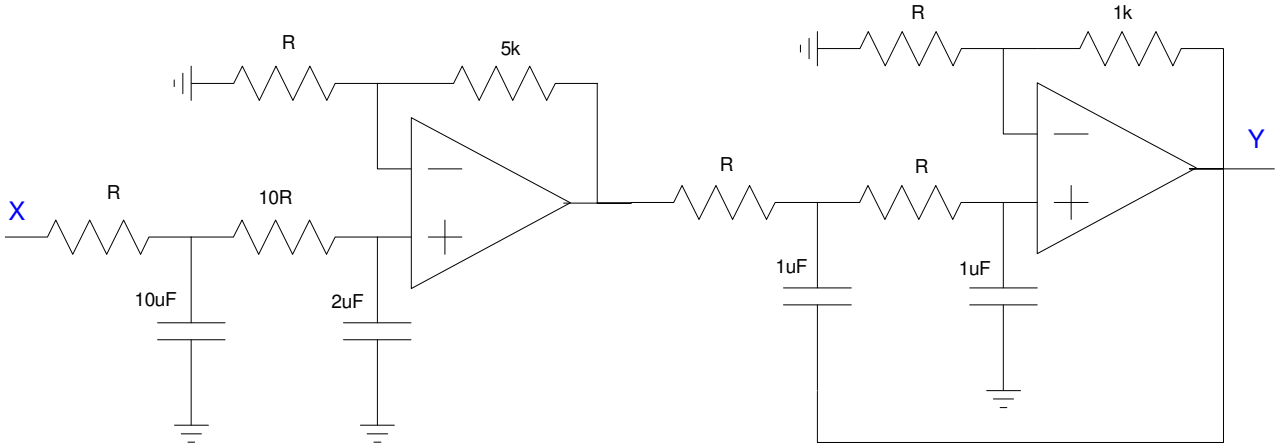
$$gain = \left(\frac{10V-0V}{4.6714V-4.321V}\right) = 25.45$$

4. Filters: Let

- R 800 + 100*(your birth month) + (your birth day).

Determine the poles and the DC gain

R 800 + 100*mo + day	Transfer Function Y = G(s) * X
1314	$\left(\frac{8.4621 \cdot 76.10 \cdot 38.05 \cdot 761.03^2}{(s+76.10)(s+38.05)\left(s+761.03\angle\pm 51.72^0\right)}\right)$



pole 1:76.1035 38.0518 761.0350 51.7216 8.4621

$$pole = -\left(\frac{1}{RC}\right) = -\left(\frac{1}{1314 \cdot 10\mu F}\right) = -76.103$$

$$pole = -\left(\frac{1}{RC}\right) = -\left(\frac{1}{1340 \cdot 2\mu F}\right) = -38.0518$$

$$pole3 = -\left(\frac{1}{RC}\right) = -\left(\frac{1}{1314 \cdot 1\mu F}\right) = -761.03$$

$$k = 1 + \frac{1k}{R} = 1.7610$$

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

$$\theta = 57.721^0$$

$$DC = \left(1 + \frac{5k}{R}\right)\left(1 + \frac{1k}{R}\right) = 8.4621$$

5) Filter Analysis: Determine y(t) given

$$Y = \left(\frac{20s}{s^2+2s+100} \right) X$$

$$x(t) = 4 + m\cos(10t) + d\sin(10t)$$

$$x(t) = 4 + 5\cos(10t) + 14\sin(10t)$$

where

- m is your birth month(1..12) and
- d is your birth date (1..31)

DC:

s = 0

X = 4

$$Y = \left(\frac{20s}{s^2+2s+100} \right)_{s=0} \cdot (4)$$

$$Y = 0$$

AC:

s = j10

X = 5 - j14

$$Y = \left(\frac{20s}{s^2+2s+100} \right)_{s=j10} \cdot (5 - j14)$$

$$Y = 50 - j140$$

$$y(t) = 50\cos(10t) + 140\sin(10t)$$ *real = cosine, -imag = sine*

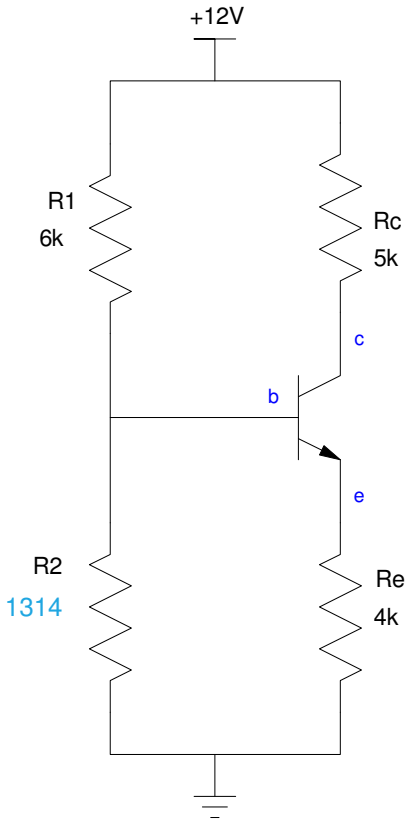
Total

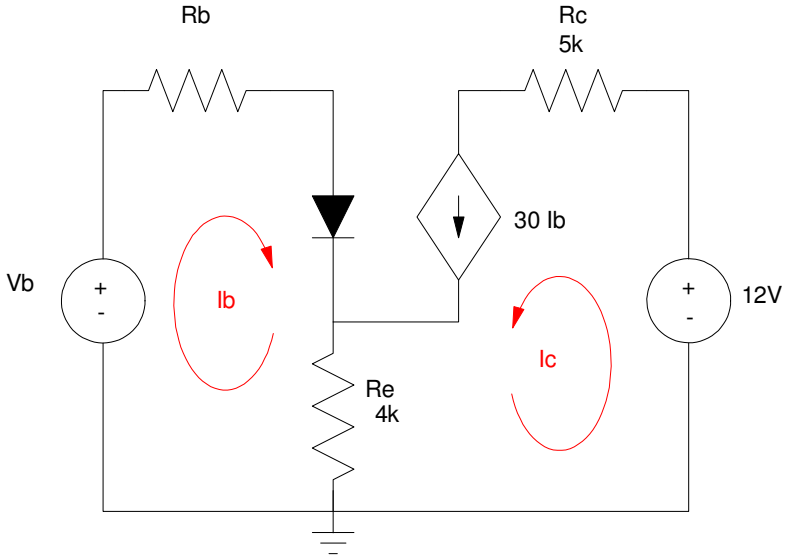
$$Y = 0 + 50\cos(10t) + 140\sin(10t)$$

6. CE Amplifiers (DC analysis): Determine the Q-point for the following circuit. Assume

- R2 = 800 + 100*(your birth month) + (your birth date)
- $\beta = 30$
- | Vbe | = 0.7V (ideal silicon diode)

R2 800 + 100*mo + day	Vb	Rb	Vce	Ic
1314	**2.1559 V**	**1077.9 Ohms**	**8.8107 V**	**349.2uA**





$$R_b = R_1 || R_2 = 1077.9\Omega$$

$$V_b = \left(\frac{R_2}{R_1+R_2}\right) 12V = 2.1559V$$

$$I_b = \left(\frac{V_b - 0.7}{R_b+(1+\beta)R_e}\right) = 11.64\mu A$$

$$I_c = \beta I_b = 349.2\mu A$$

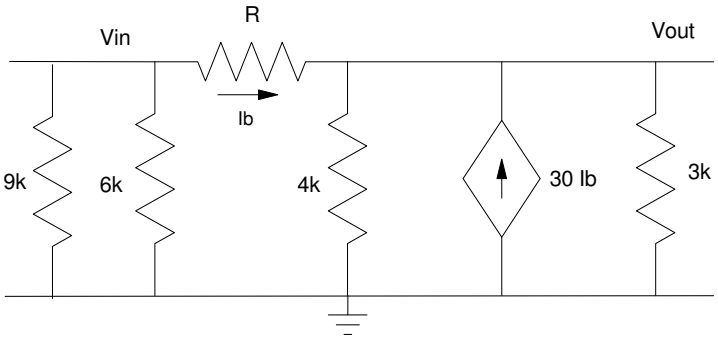
$$V_{ce} = 12 - R_c I_c - R_e(I_b + I_c) = 8.8107V$$

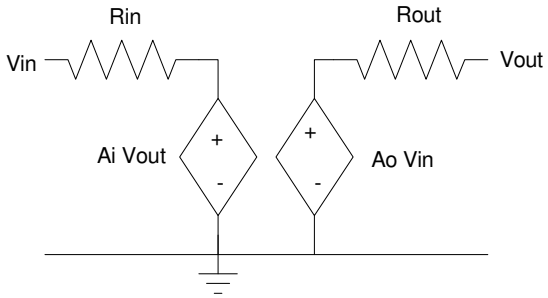
7. 2-Port model: Determine the 2-port parameters for the following circuit. Assume

- R = 800 + 100*(your birth month) + (your birth date) Ohms

R 800 + 100*mo + day	Rin	Ai	Rout	Ao
1314	**962.6 Ohms**	**0.7326**	**41.36 Ohms**	**0.9759**

0.9626 0.7326 41.3643 0.9759





Rin: Short Vout, measure the resistance at the input.

$$R_{in} = 9k||6k||R = 962.6\Omega$$

Ain: Apply 1V at Vout, measure Vin. By voltage division

$$A_{in} = \left(\frac{9k||6k}{9k||6k+R}\right) = 0.7326$$

Rout: Short Vin. Apply 1V to Vout and compute the current draw

$$I = \left(\frac{1}{3k}\right) + \left(\frac{1}{4k}\right) + \left(\frac{1}{R}\right) + 30\left(\frac{1}{R}\right) = 24.18mA$$

$$R_{out} = \frac{1V}{24.18mA} = 41.36\Omega$$

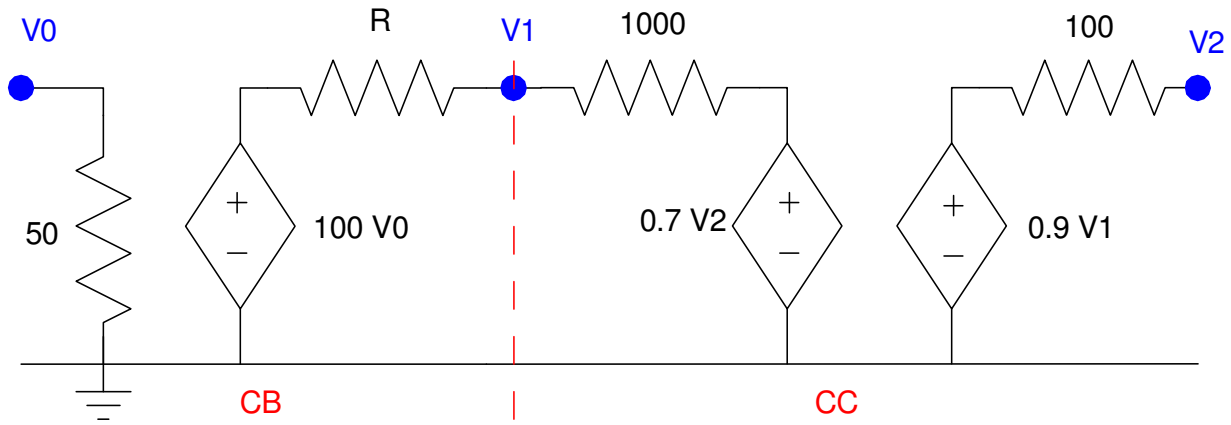
Aout: Apply 1V to Vin, compute Vout. Do a voltage node equation at Vout

$$\left(\frac{V_o-1}{R}\right) + \left(\frac{V_o}{4k}\right) + 30\left(\frac{V_o-1}{R}\right) + \left(\frac{V_o}{3k}\right) = 0$$

$$V_o = 0.9759V$$

8. 2-Port model: Determine the 2-port parameters for a Common-Base amplifier cascaded with a Common Collector amplifier. Assume

- R = 800 + 100*(your birth month) + (your birth date) Ohms



R 800 + 100*mo + day	Rin	Ain	Rout	Aout
1314	**50**	**0**	**155.70 Ohms**	**60.55**

By inspection

Rin = 50

Ain = 0

Rout: Short V0, Apply 1V to V2. Compute the current draw

$$V_1 = \left(\frac{R}{R+1000}\right)0.7V = 0.3975V$$

$$I = \left(\frac{1V - 0.9 \cdot 0.3975V}{100\Omega}\right) = 6.423mA$$

$$R_{out} = \frac{1V}{I} = 155.7\Omega$$