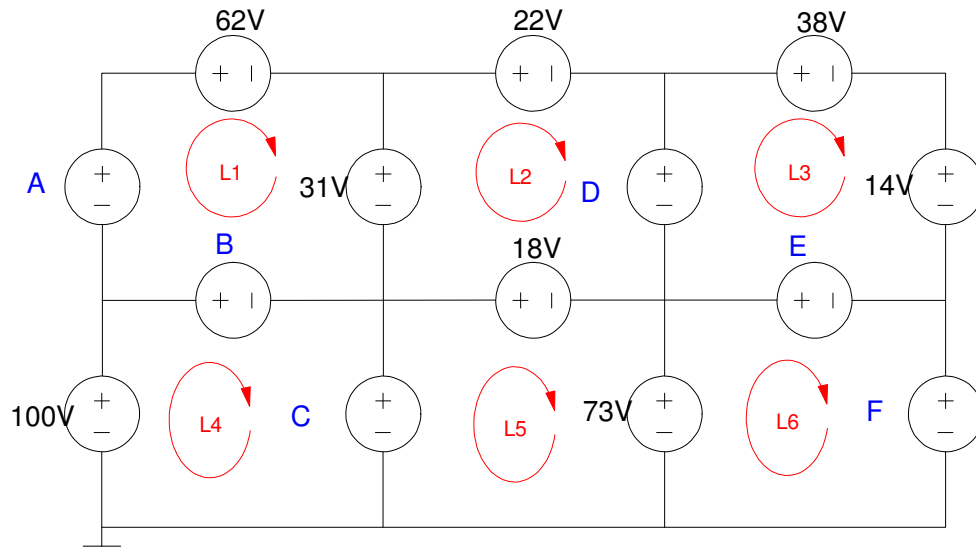


ECE 211: Homework #2

Kirchoff's Laws, Resistors in Series and Parallel, Voltage and Current Division

Kirchoff's Laws:

1) Use conservation of voltage to determine the unknown voltages



Trick: Find a loop where there is one unknown

Around loop L2. Start in the lower-left corner

$$-31 + 22 + D - 18 = 0$$

$$D = 27V$$

Around loop L3

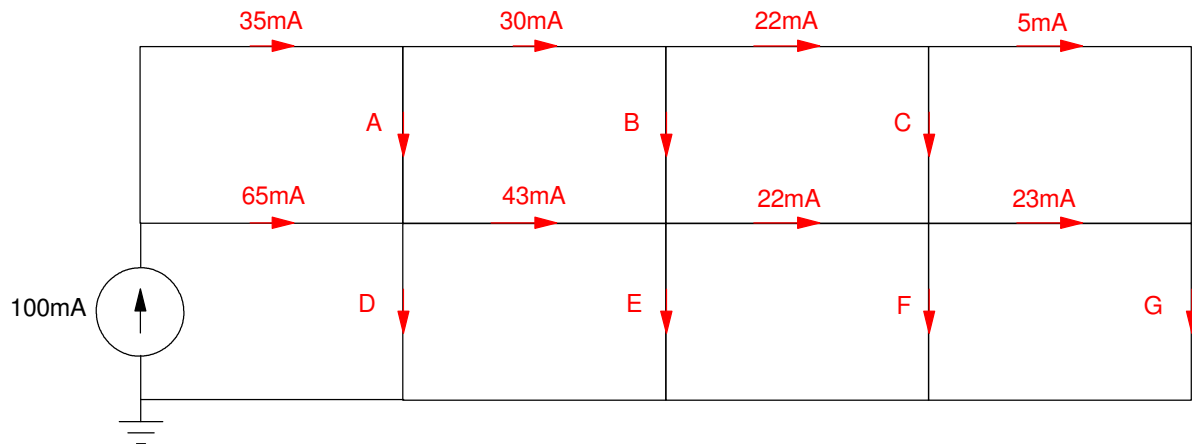
$$-D + 38 + 14 - E = 0$$

$$E = 25V$$

Net result:

- **A = 84V**
- **B = 9V**
- **C = 91V**
- **D = 27V**
- **E = 25V**
- **F = 48V**

2) Use conservation of current to determine the unknown currents



At each node, the currents must balance

current in = current out

Top row, node #1

$$35\text{mA} = 30\text{mA} + A$$

$$A = 5\text{mA}$$

Node #2

$$30\text{mA} = 22\text{mA} + B$$

$$B = 8\text{mA}$$

2nd Row, node #1

$$65\text{mA} + A = 43\text{mA} + D$$

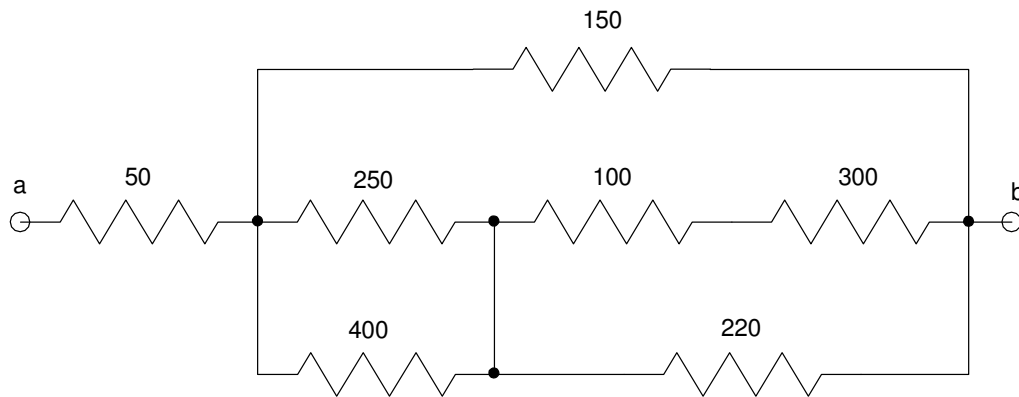
$$D = 27\text{mA}$$

Net result

- $A = 5\text{mA}$
- $B = 8\text{mA}$
- $C = 17\text{mA}$
- $D = 27\text{mA}$
- $E = 29\text{mA}$
- $F = 16\text{mA}$
- $G = 28\text{mA}$

Resistors in Series and Parallel

3) Determine the resistance R_{ab} for the following circuit



Resistors in series add as

$$R_{net} = R_1 + R_2 + R_3$$

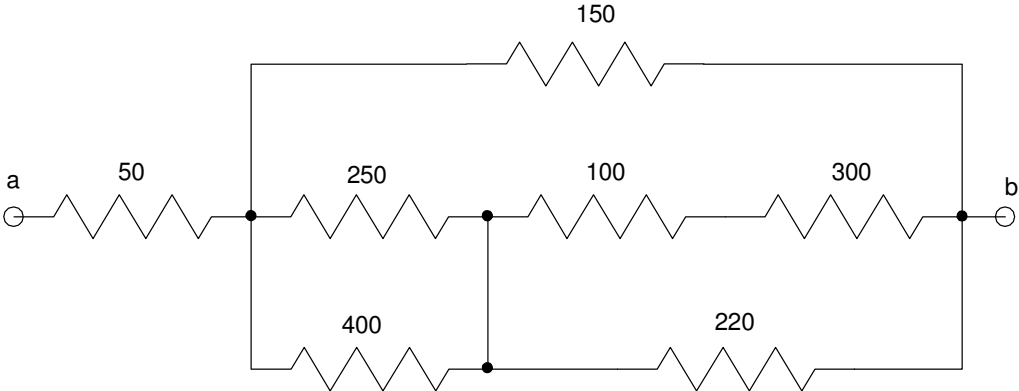
Resistors in parallel add as

$$R_{net} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right)^{-1}$$

Using Matlab

```
>> R1 = 100 + 300  
  
R1 =    400  
  
>> R2 = 1 / (1/R1 + 1/220)  
  
R2 =   141.9355  
  
>> R3 = 1 / (1/250 + 1/400)  
  
R3 =   153.8462  
  
>> R4 = R2 + R3  
  
R4 =   295.7816  
  
>> R5 = 1 / (1/150 + 1/R4)  
  
R5 =    99.5269  
  
>> Rab = R5 + 50  
  
Rab =   149.5269
```

Using an HP42 calculator (the free app Free42)



```
100
enter
300
+

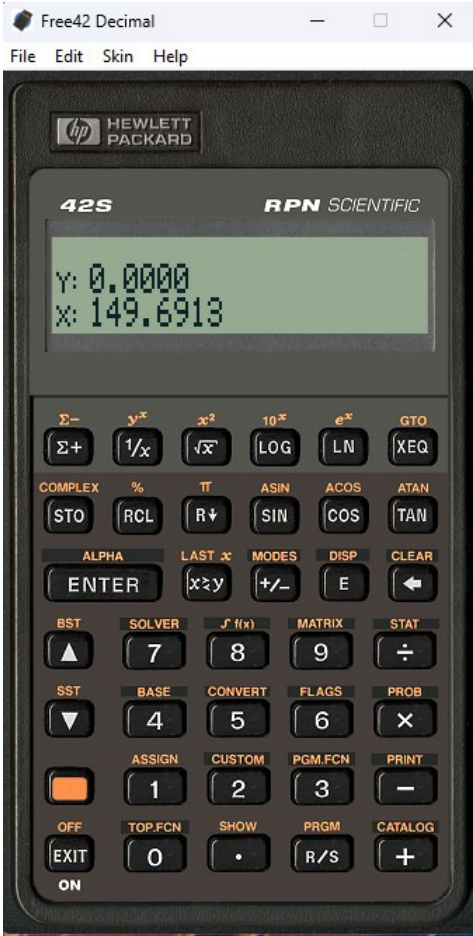
1/x
220
1/x
+
1/x

250
1/x
400
1/x
+
1/x

+

1/x
150
1/x
+
1/x

50
+
```

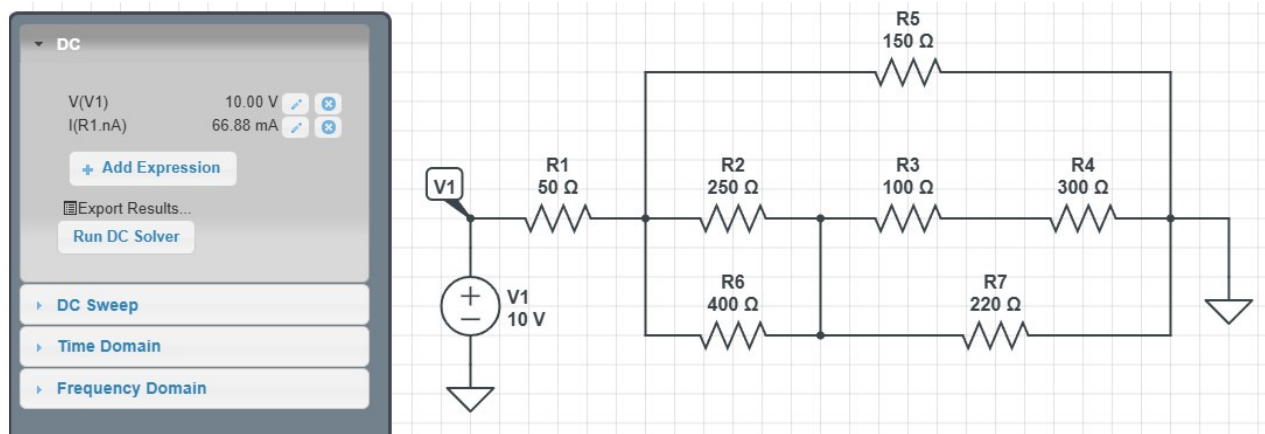


4) Determine Rab using CircuitLab

- Build the circuit using CircuitLab
- Apply +10V to (a) and ground (b)
- Run a DC simulation and find the current draw
- The net resistance is V / I

From CircuitLab

- Apply a 10V DC source (arbitrary)
- Results in the current being 66.88mA



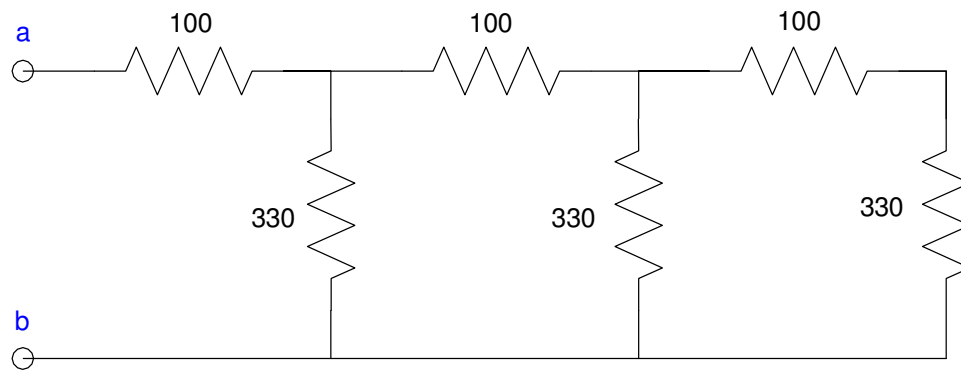
From Ohm's law

$$R = \left(\frac{V}{I} \right) = \left(\frac{10V}{66.88mA} \right)$$

$$R = 149.52\Omega$$

This matches previous calculations

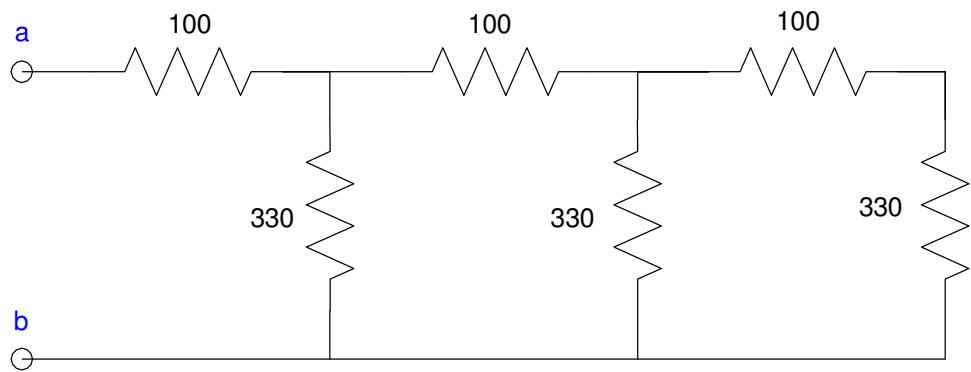
5) Determine the resistance R_{ab} for the following circuit



Solving using Matlab

```
>> R1 = 100 + 330  
R1 = 430  
>> R2 = 1 / (1/330 + 1/R1)  
R2 = 186.7105  
>> R3 = 100 + R2  
R3 = 286.7105  
>> R4 = 1 / (1/330 + 1/R3)  
R4 = 153.4180  
>> Rab = R4 + 100  
Rab = 253.4180
```

Solving using an HP42 calculator



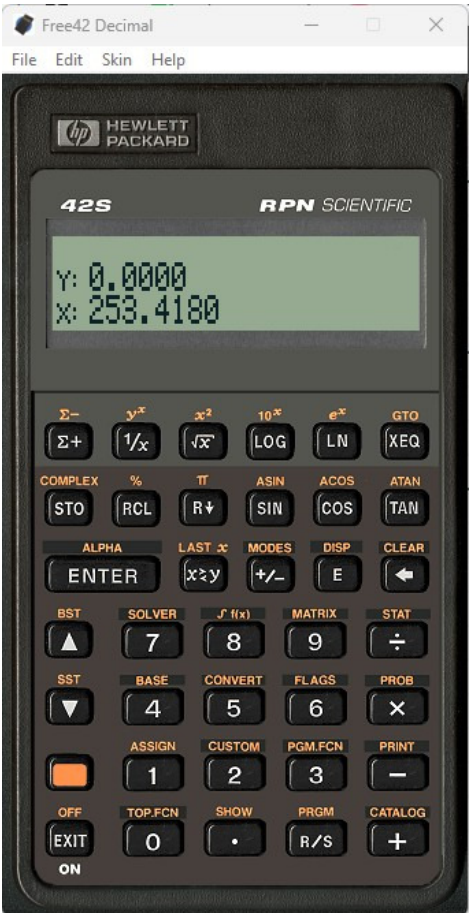
```
330
enter
100
+

1/x
330
1/x
+
1/x

100
+

1/x
330
1/x
+
1/x

100
+
```



6) Determine Rab using CircuitLab

Apply a 10V source (arbitrary)

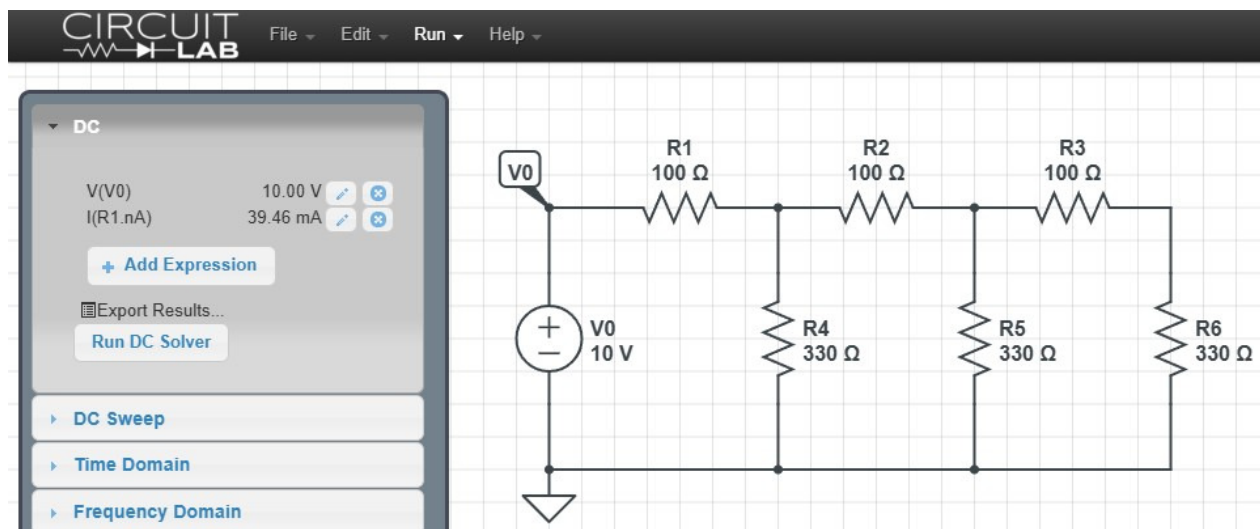
- Find the resulting current draw
- $I = 39.46\text{mA}$

From Ohm's law

$$R = \left(\frac{V}{I} \right) = \left(\frac{10V}{39.46\text{mA}} \right)$$

$$R = 253.42\Omega$$

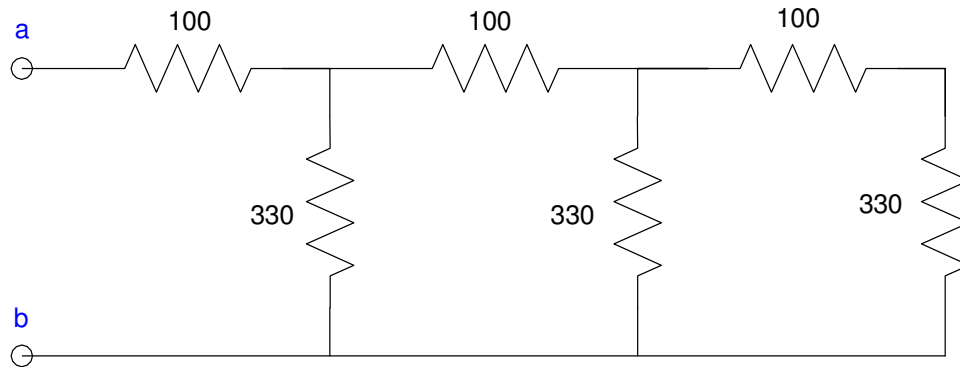
This matches previous calculations



Lab (part 1)

7) Build this circuit using your breadboard. Measure the resistance R_{ab} using your multimeter

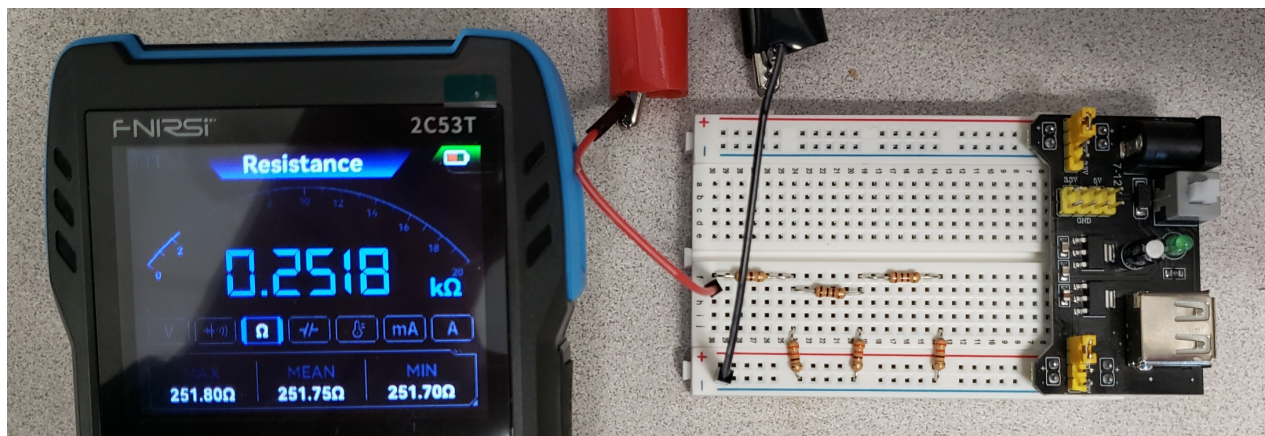
- Check that your answers for problems 5, 6, and 7 all match (or are close)
- Include a photo of your multimeter and circuit in your solution



$R = 251.8 \text{ Ohms}$

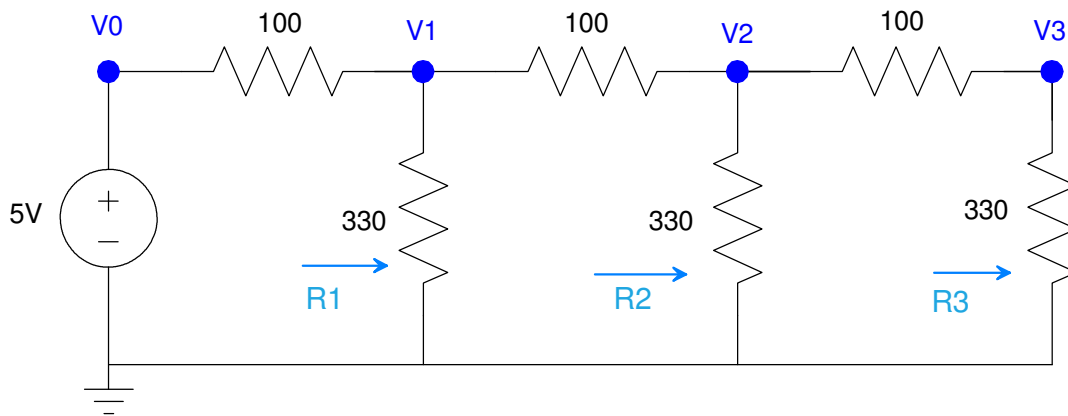
- This is slightly different than calculations and CircuitLab
- Actual resistors are 5% tolerance (gold band)

Method	R
Calculation	253.418
CircuitLab	253.42
Measured	251.8



Voltage Division

8) Using voltage division, determine the voltages at {V0, V1, V2, V3}



The current looking right is

$$R3 = 330 \text{ Ohms}$$

$$R2 = 330 \parallel (R3 + 100) = 186.71 \text{ Ohms}$$

$$R1 = 330 \parallel (R2 + 100) = 153.41 \text{ Ohms}$$

Voltages are then

$$V_0 = 5.00V$$

$$V_1 = \left(\frac{R_1}{R_1 + 100} \right) \cdot V_0$$

$$V_1 = 3.0270V$$

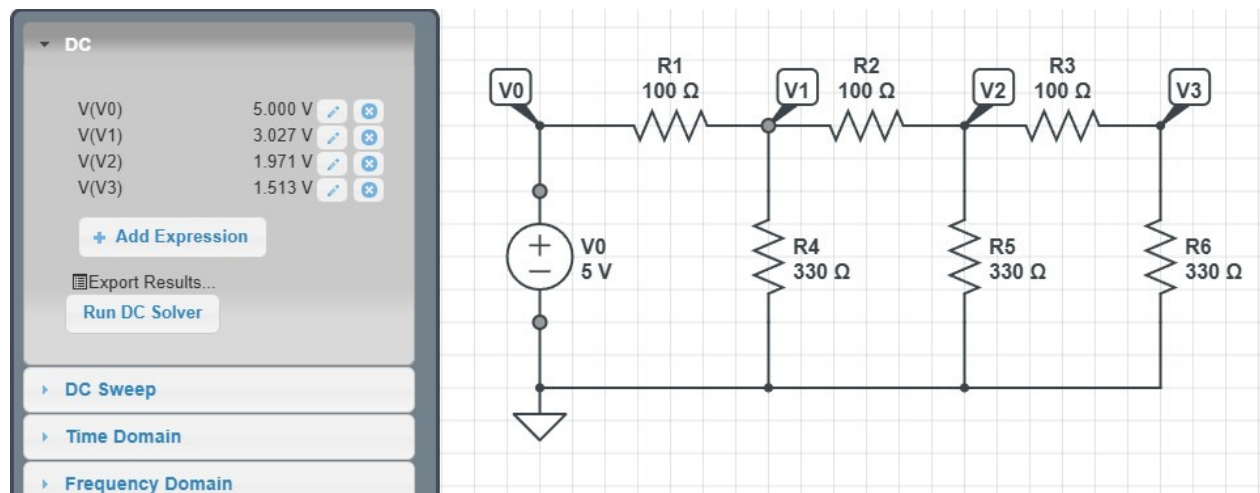
$$V_2 = \left(\frac{R_2}{R_2 + 100} \right) V_1$$

$$V_2 = 1.9712V$$

$$V_3 = \left(\frac{R_3}{R_3 + 100} \right) V_2$$

$$V_3 = 1.5128V$$

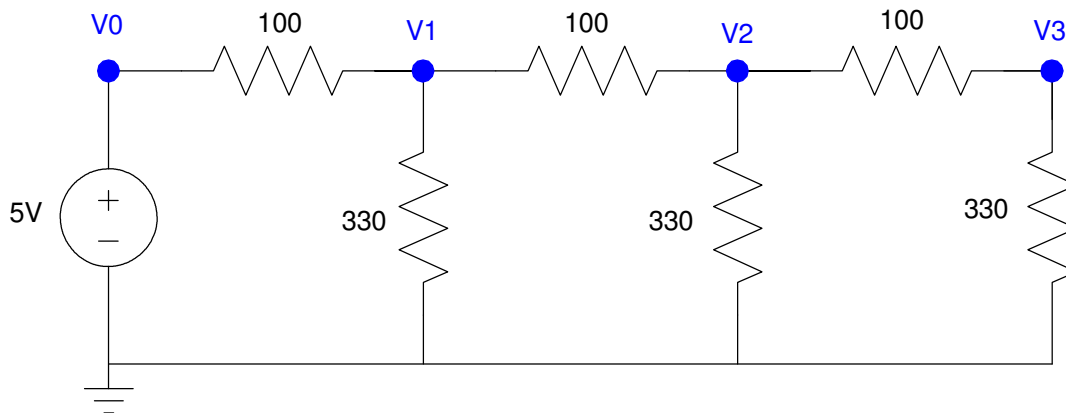
9) Using CircuitLab, determine the voltages at {V0, V1, V2, V3}



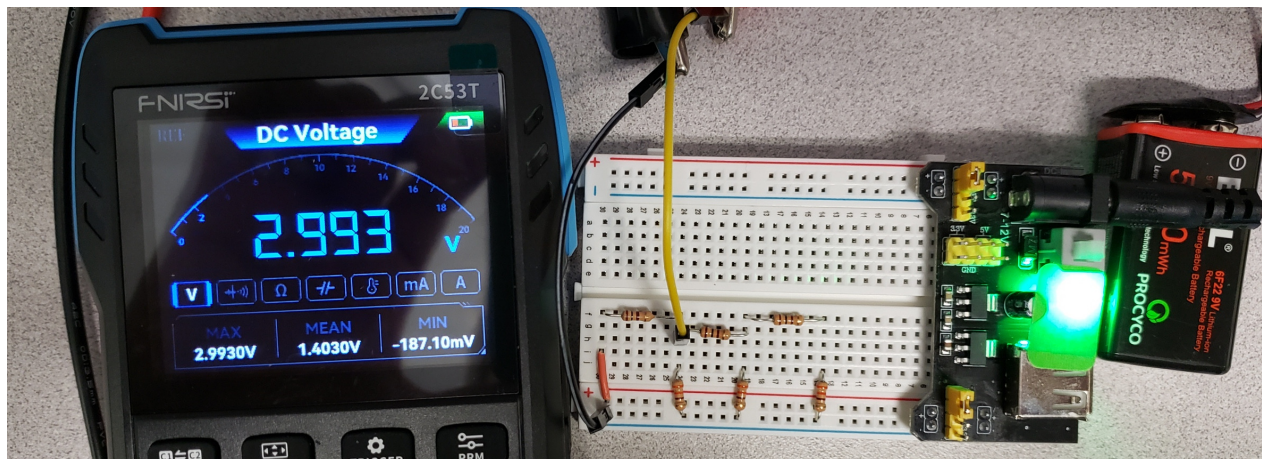
Lab (part 2)

10) Build this circuit using your lab on a breadboard.

- Once built, measure the voltages at V0, V1, V2, and V3
- Check that your answers for problem 8, 9, and 10 match (or are close)
- Include a photo of your breadboard circuit and your multimeter with one of the readings

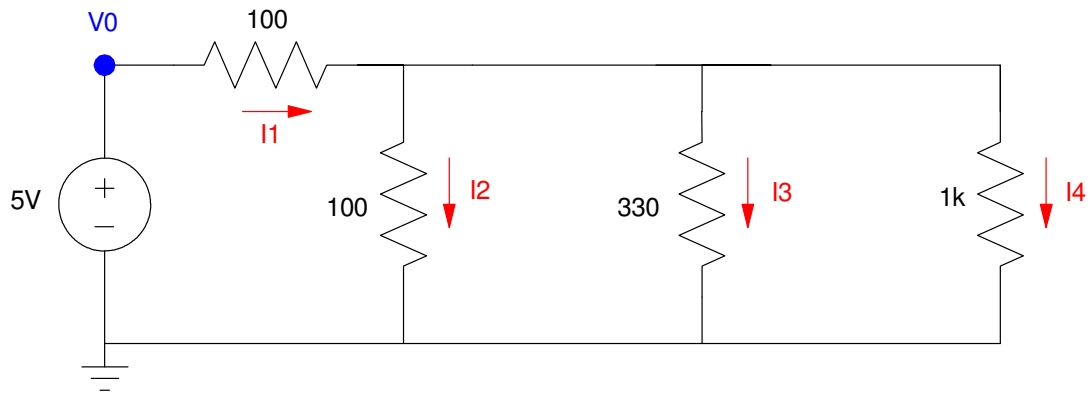


	V0	V1	V2	V3
Calculated	5.00 V	3.0270 V	1.9712 V	1.5128 V
CircuitLab	5.00 V	3.027 V	1.971 V	1.513 V
Measured	4.942 V	2.994 V	1.9496 V	1.4946 V



Current Division

11) Using current division, determine the currents in this circuit



Find the net resistance

$$R_a = 100 || 330 || 1000 = \left(\frac{1}{100} + \frac{1}{330} + \frac{1}{1000} \right)^{-1}$$

$$R_a = 71.27420 \Omega$$

$$R_{net} = 100 + R_a = 172.27 \Omega$$

$$I_1 = \left(\frac{5V}{172.27 \Omega} \right) = 29.1929 mA$$

By current division

$$I_2 = \left(\frac{\left(\frac{1}{100} \right)}{\left(\frac{1}{100} \right) + \left(\frac{1}{330} \right) + \left(\frac{1}{1000} \right)} \right) I_1$$

$$I_2 = 20.8071 mA$$

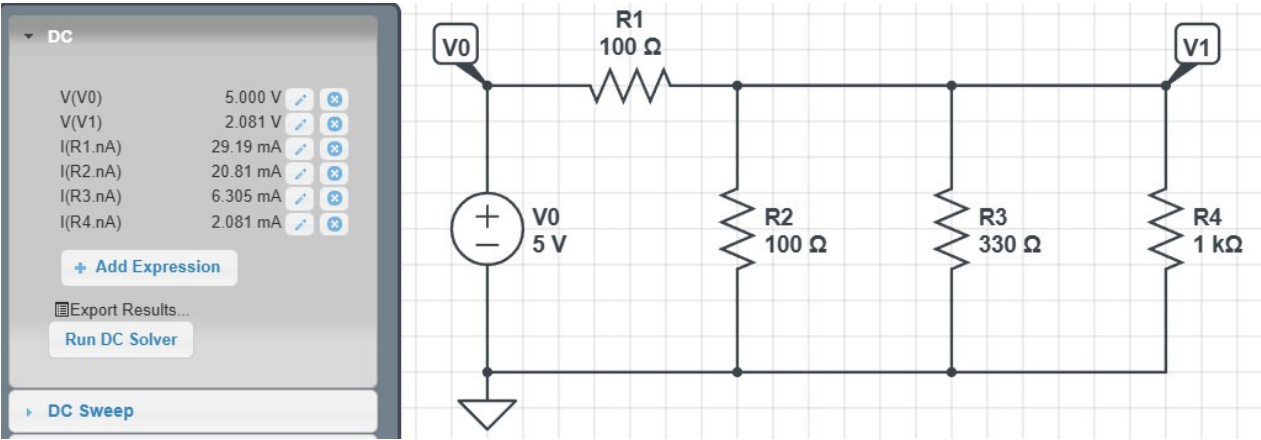
$$I_3 = \left(\frac{\left(\frac{1}{330} \right)}{\left(\frac{1}{100} \right) + \left(\frac{1}{330} \right) + \left(\frac{1}{1000} \right)} \right) I_1$$

$$I_3 = 6.3052 mA$$

$$I_4 = \left(\frac{\left(\frac{1}{1000} \right)}{\left(\frac{1}{100} \right) + \left(\frac{1}{330} \right) + \left(\frac{1}{1000} \right)} \right) I_1$$

$$I_4 = 2.0807 mA$$

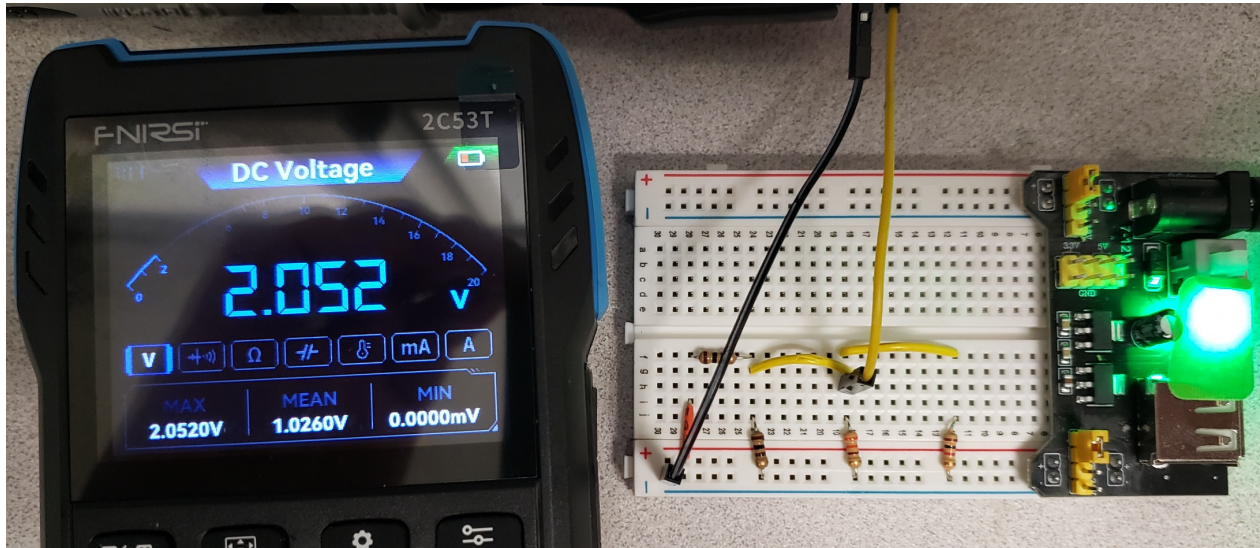
12) Verify your answer using CircuitLab



	I1	I2	I3	I4
Calculated	29.1929 mA	20.8071 mA	6.3052 mA	2.0807 mA
CircuitLab	29.19 mA	20.81 mA	6.305 mA	2.001 mA
Measured	-	-	-	-

13) (Lab): Build this circuit with your lab kit

- Include a photo of your circuit board for full credit



14) (Lab): Measure the currents $\{I_1, I_2, I_3, I_4\}$

- note: To measure current, measure the voltage across a known resistor. From this, compute the current from $V = IR$

Measured Voltages:

- $V_0 = 4.918V$
- $V_1 = 2.052V$

Currents can be computed from $V = I \cdot R$

$$I_1 = \left(\frac{V_0 - V_1}{100\Omega} \right) = 28.66mA$$

$$I_2 = \left(\frac{V_1}{100\Omega} \right) = 20.52mA$$

$$I_3 = \left(\frac{V_1}{330\Omega} \right) = 6.2182mA$$

$$I_4 = \left(\frac{V_1}{1000\Omega} \right) = 2.052mA$$

	I1	I2	I3	I4
Calculated	29.1929 mA	20.8071 mA	6.3052 mA	2.0807 mA
CircuitLab	29.19 mA	20.81 mA	6.305 mA	2.001 mA
Measured	28.66 mA	20.52 mA	6.2182 mA	2.052mA