
Resistors in Series and Parallel

ECE 211 Circuits I Lecture #3

Please visit [Bison Academy](#) for corresponding
lecture notes, homework sets, and solutions

Objective

- Simplify a resistor network
- Find the equivalent resistance between two terminals

Approach

- Combine resistors that are in series
- Combine resistors that are in parallel
- Keep going until you are left with a single resistance

Note:

- Not always possible
-

Resistors in Series:

- Series: All the current through R1 also goes through R2
- $I(R1) = I(R2) = I(R3)$

Problem: Find the net resistance of this circuit:

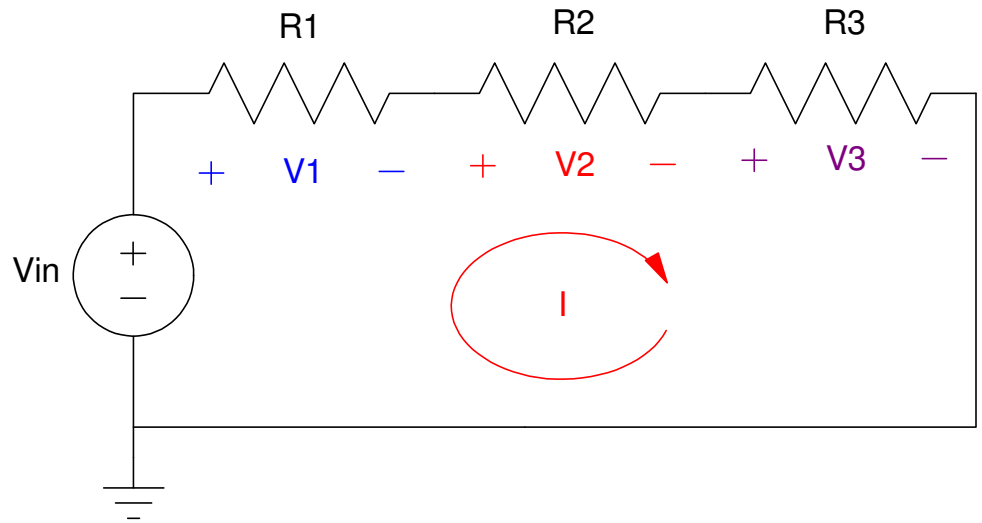
Using Kirchhoff's voltage law:

$$V_{in} = V1 + V2 + V3$$

$$V_{in} = I \cdot R_1 + I \cdot R_2 + I \cdot R_3$$

$$V_{in} = I \cdot (R_1 + R_2 + R_3)$$

$$V_{in} = I \cdot R_{net}$$



Resistors in series add

Examples:

Let $R_1 = 100 \text{ Ohms}$, $R_2 = 200 \text{ Ohms}$, $R_3 = 300 \text{ Ohms}$. Find the total resistance.

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

$$R_{net} = 100\Omega + 200\Omega + 300\Omega$$

$$R_{net} = 600\Omega$$

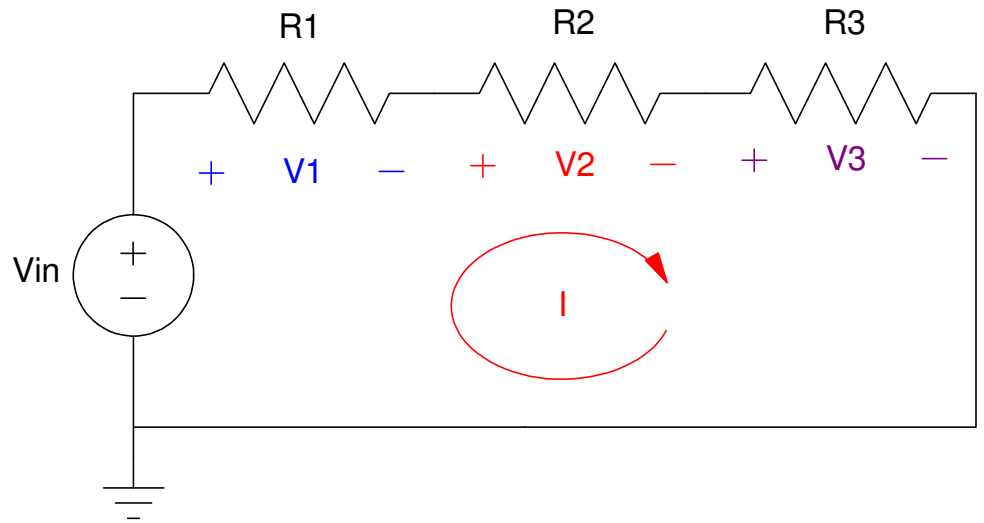
Let $R_1 = 100 \text{ Ohms}$, $R_2 = 200 \text{ Ohms}$

- If $R_{net} = 1000 \text{ Ohms}$. Find R_3

Answer: Resistors in series add:

$$1000\Omega = 100\Omega + 200\Omega + R_3$$

$$R_3 = 700\Omega$$



Resistors in Parallel:

- Parallel: The voltages are the same on both sides of each resistor
- $V_{a1} = V_{b1} = V_{c1}$
- $V_{a2} = V_{b2} = V_{c2}$

Find the net resistance:

$$I_{in} = I_1 + I_2 + I_3$$

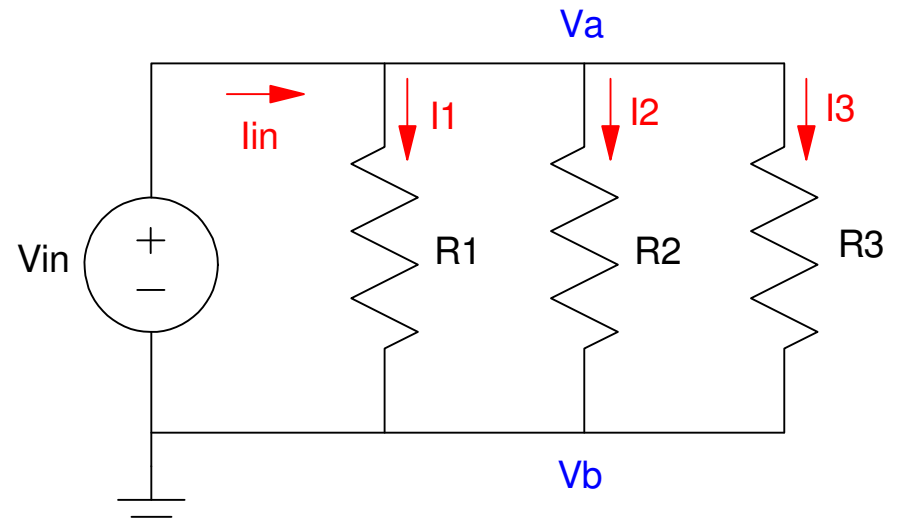
$$I_{in} = \left(\frac{V_{in}}{R_1} \right) + \left(\frac{V_{in}}{R_2} \right) + \left(\frac{V_{in}}{R_3} \right)$$

$$I_{in} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right) V_{in}$$

$$V_{in} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right)^{-1} I_{in}$$

In general:

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



Examples:

Let $R_1 = 100\ \Omega$, $R_2 = 200\ \Omega$, $R_3 = 300\ \Omega$. Find the total resistance.

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

$$R_{net} = \left(\frac{1}{100} + \frac{1}{200} + \frac{1}{300} \right)^{-1}$$

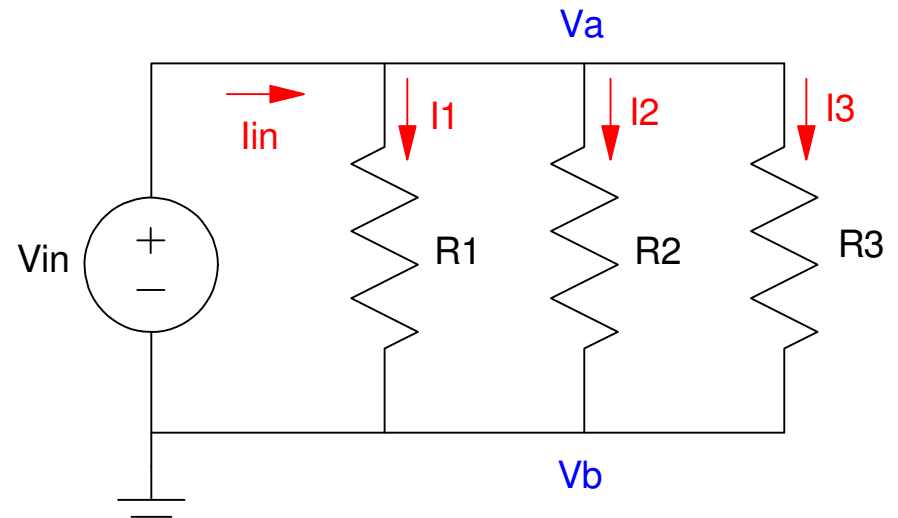
$$R_{net} = 54.54\ \Omega$$

Let $R_2 = 200\ \Omega$, $R_3 = 300\ \Omega$,
 $R_{net} = 100\ \Omega$. Find R_1 .

$$\frac{1}{R_{net}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{100} = \frac{1}{R_1} + \frac{1}{200} + \frac{1}{300}$$

$$R_1 = 600\ \Omega$$



Find the resistance from a to b

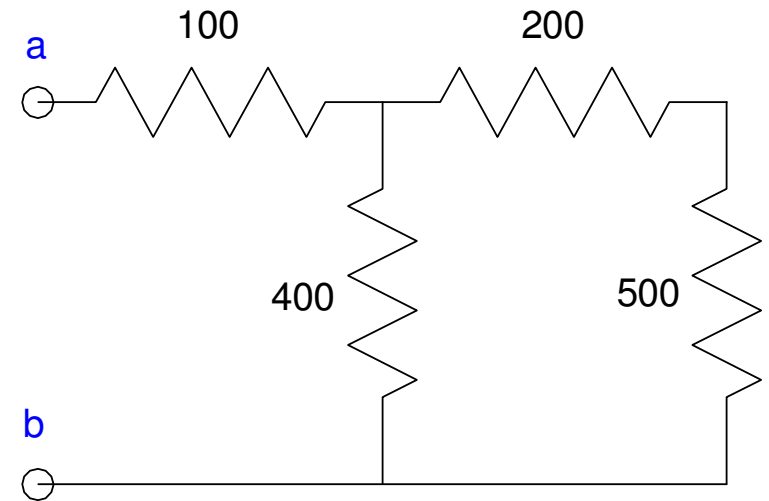
Combine resistors that are in series and parallel

Series:

- All current through R1 also goes through R2

Parallel

- Voltages on the same on both sides



Solution:

The 200 and 500 Ohm resistor are in series

$$200 + 500 = 700$$

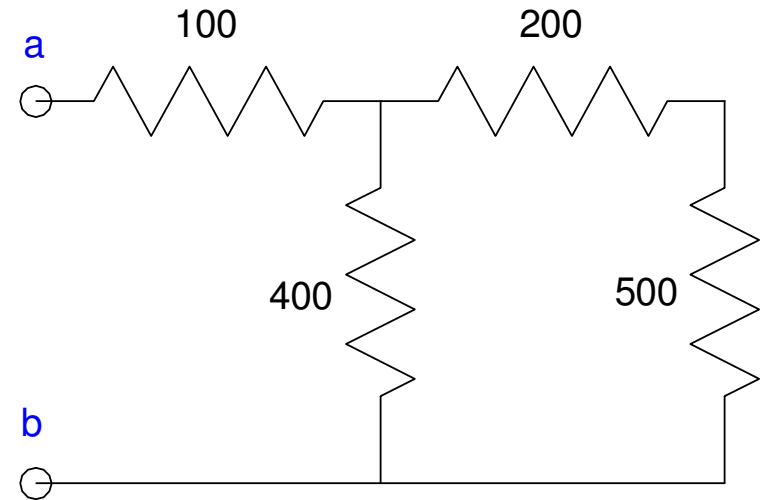
This is in parallel with 400 Ohms

$$700 \parallel 400 = \left(\frac{1}{700} + \frac{1}{400} \right)^{-1} = 254.54$$

This is in series with 100 Ohms

$$254.54 + 100 = 354.54$$

The net resistance is 354.54 Ohms.



Matlab Calculations

```
>> R1 = 200 + 500
```

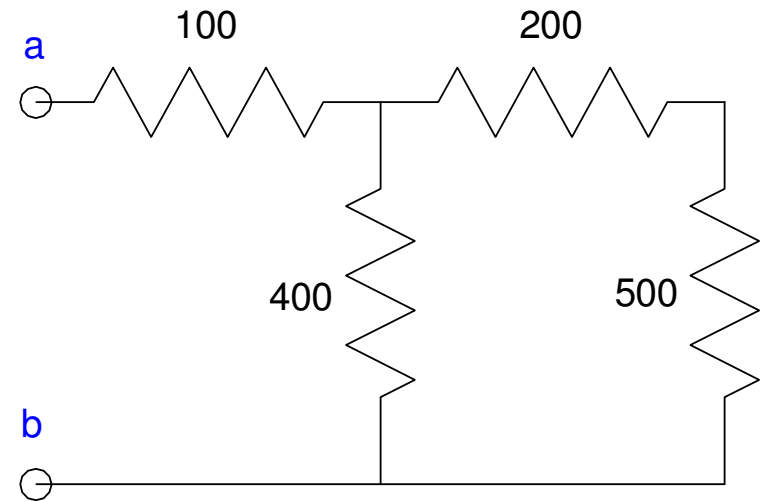
```
R1 = 700
```

```
>> R2 = 1 / (1/R1 + 1/400)
```

```
R2 = 254.5455
```

```
>> R3 = R2 + 100
```

```
R3 = 354.5455
```



HP42 Calculations (Free42 app)

RPN Calculators are really efficient at these types of calculations

- HP is essentially a company of electrical and computer engineers
- They likewise build really good calculators for ECE majors
- Free app on your cell phone

Note: These use Reverse Polish Notation (RPN)

- No equals sign
- Operation operate on the stack
 - + $Y + X$ X
 - - $Y - X$ X
 - * $Y * X$ X
 - / Y / X X

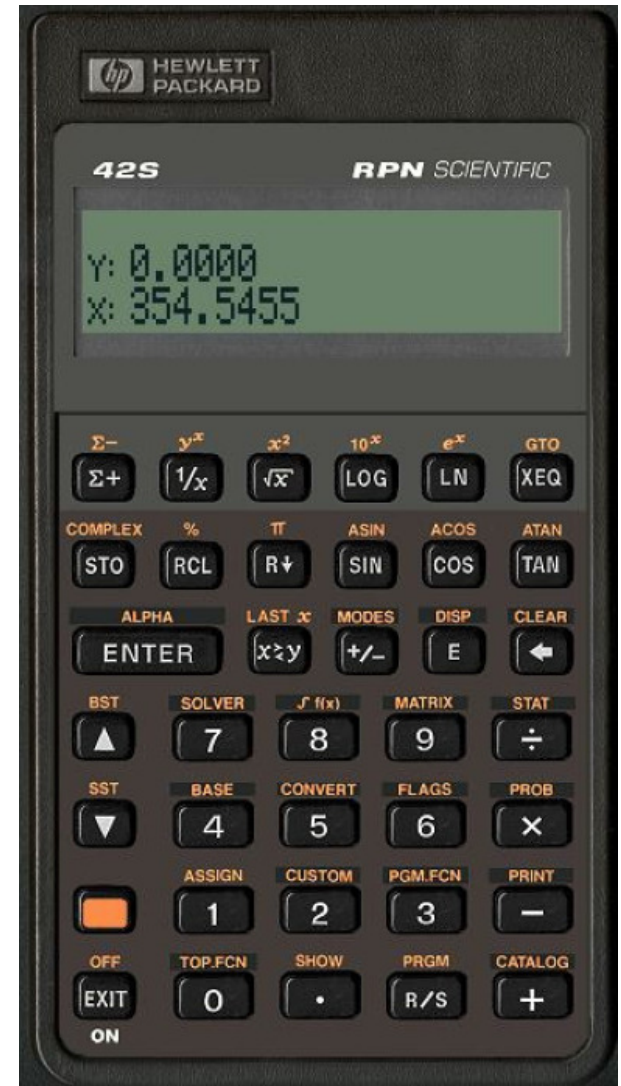
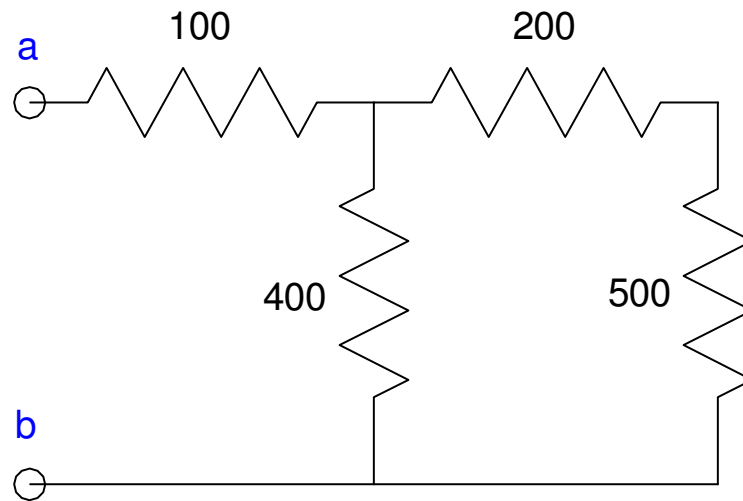


RPN Calculations

200
enter
500
+

1/x
400
1/x
+

100
+



Checking in CircuitLab

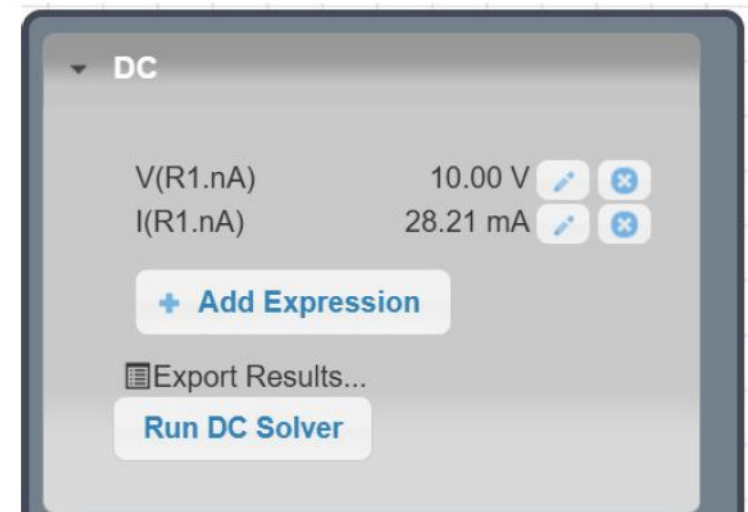
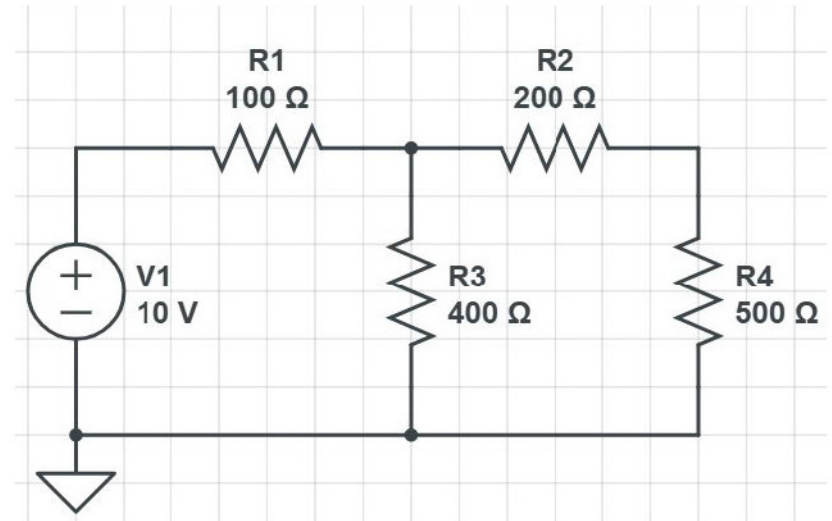
Build the circuit in CircuitLab

- Apply a test voltage (10V)
- Measure the net current draw
 - $I = 28.21\text{mA}$
- Compute the net resistance

$$R = \frac{V}{I}$$

$$R = \frac{10\text{V}}{28.21\text{mA}}$$

$$R = 354.48\Omega$$



Check in Lab

Build the circuit on a breadboard

Apply a test voltage

- Whatever is convenient
- 5.0V is usually available

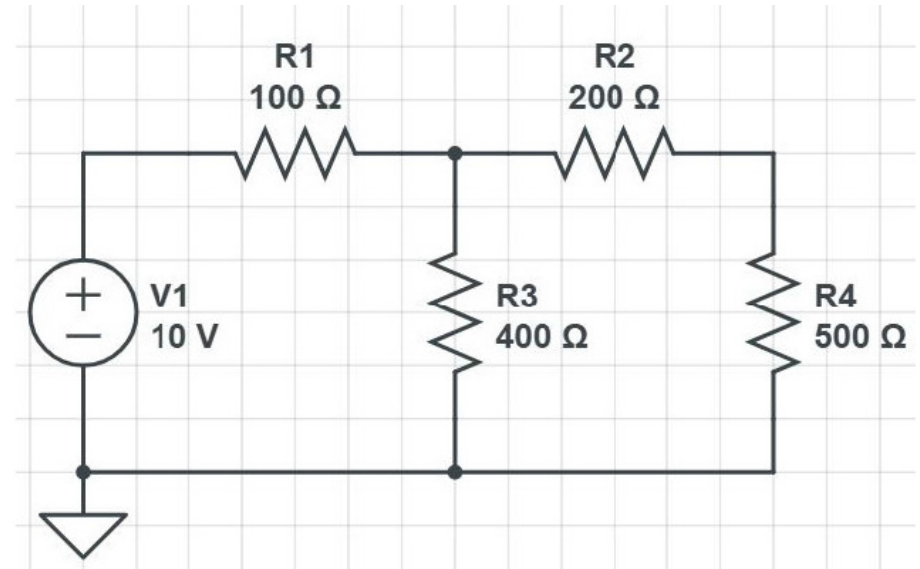
Measure the current draw

- Measure the voltage across the 100 Ohm resistor
- Compute the current

$$I_1 = \frac{V(R_1)}{R_1}$$

Compute the implied resistance

$$R_{net} = \frac{10V}{I_1}$$



CircuitLab vs Chegg vs ChatGPT

CircuitLab is really useful

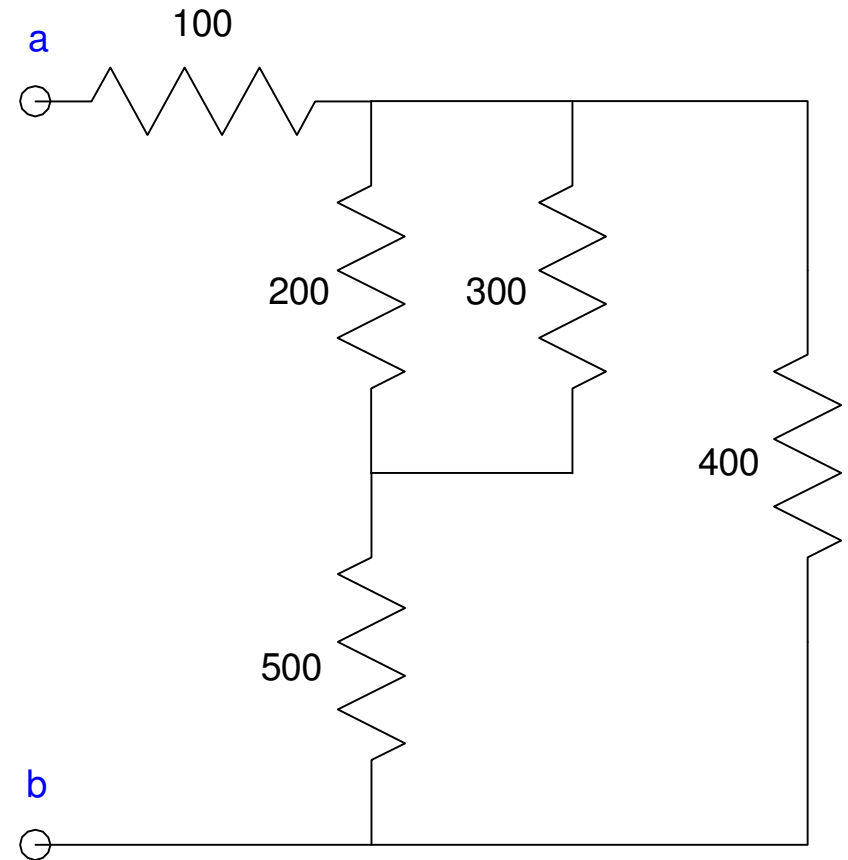
- You can check your calculations using CircuitLab
- Your results should match
- Chegg isn't needed
- ChatGPT isn't needed

If you want to know if your calculations are correct

- Check using CircuitLab, or
- Build the circuit and take measurements in lab

Example 2: Find Rab

- Combine resistors that are in series
- Combine resistors that are in parallel



Calculations

The 200 and 300 are in parallel

$$200 \parallel 300 = 120 \text{ Ohms}$$

This is in series with 500

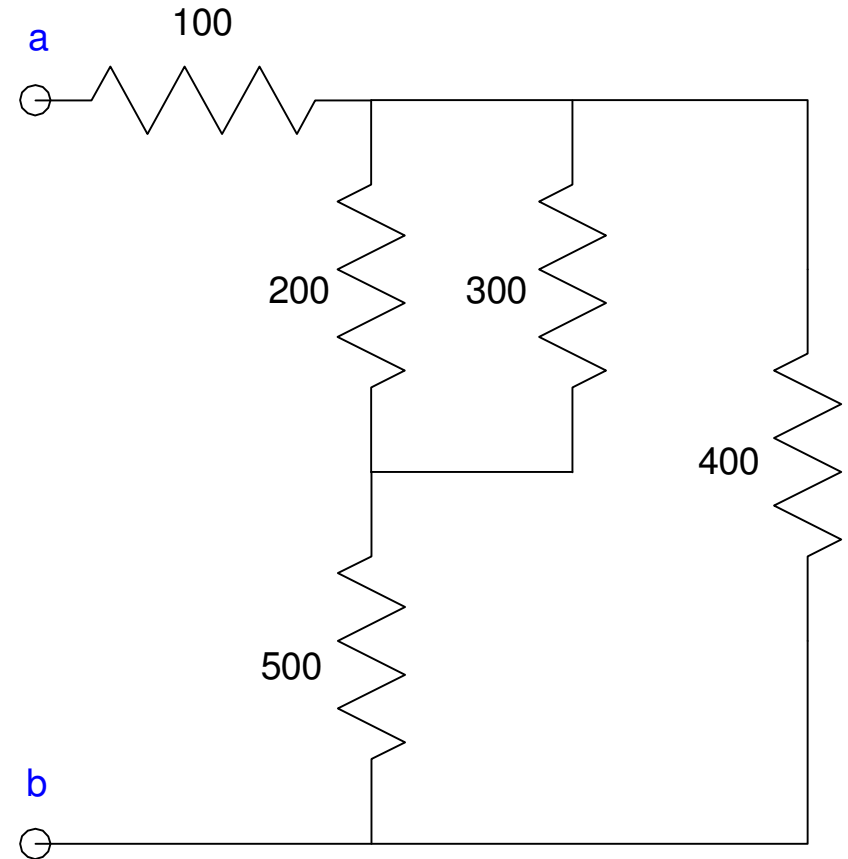
$$120 + 500 = 620$$

This is in parallel with 400

$$620 \parallel 400 = 243.137$$

This is in series with 100

$$243.137 + 100 = \mathbf{343.137}$$



Calculations in Matlab

```
>> R1 = 1 / (1/200 + 1/300)
```

```
R1 = 120
```

```
>> R2 = R1 + 500
```

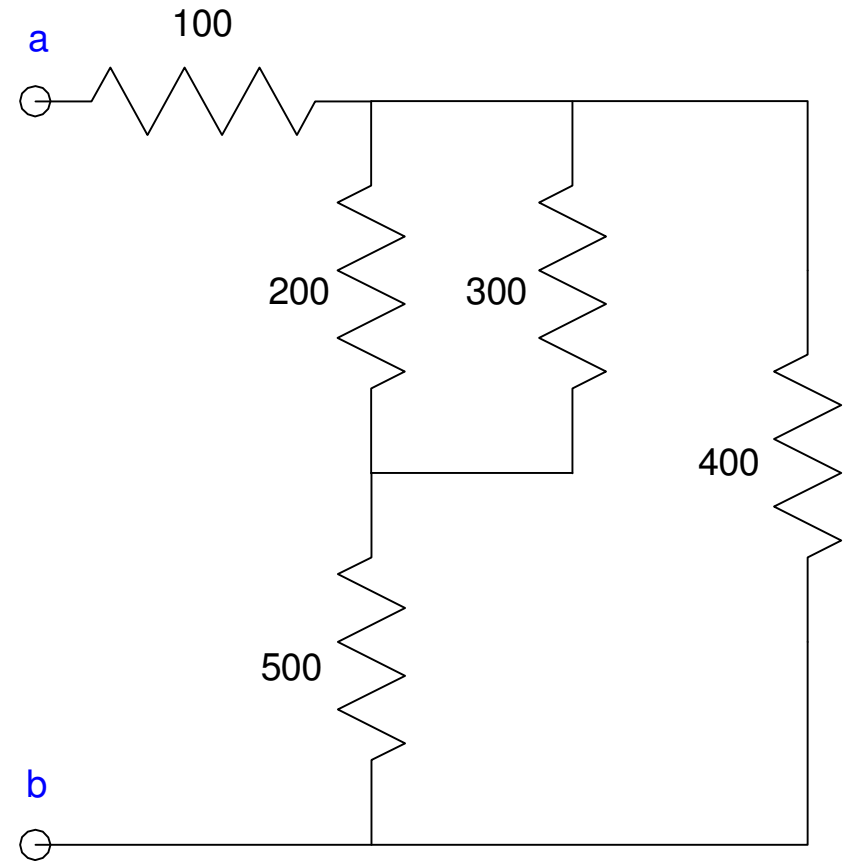
```
R2 = 620
```

```
>> R3 = 1 / ( 1/R2 + 1/400)
```

```
R3 = 243.1373
```

```
>> Rab = R3 + 100
```

```
Rab = 343.1373
```



Calculations with an HP42

200

 $1/x$

300

 $1/x$

+

 $1/x$

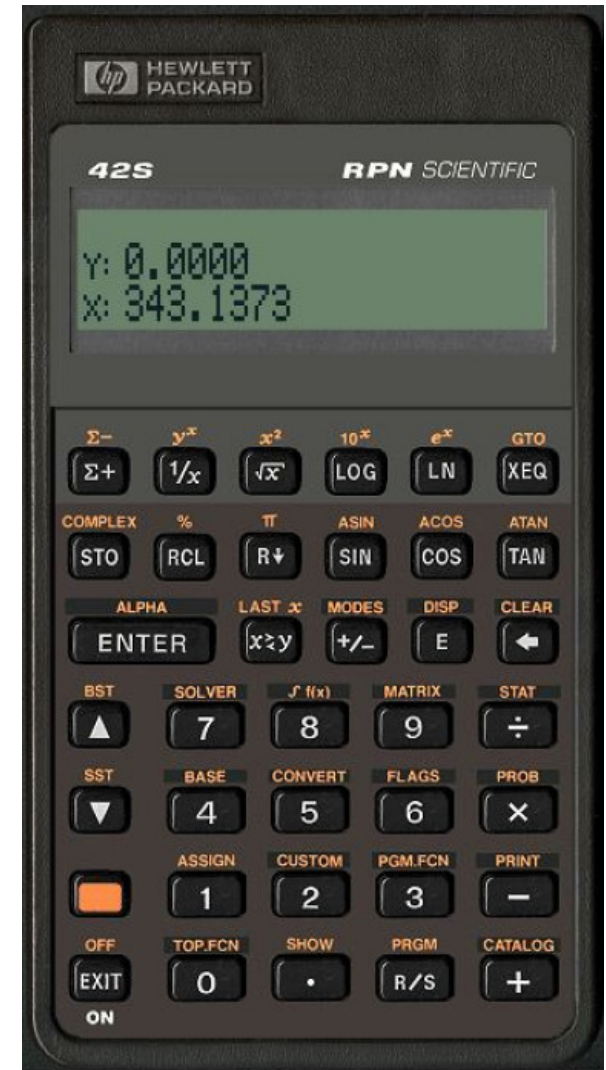
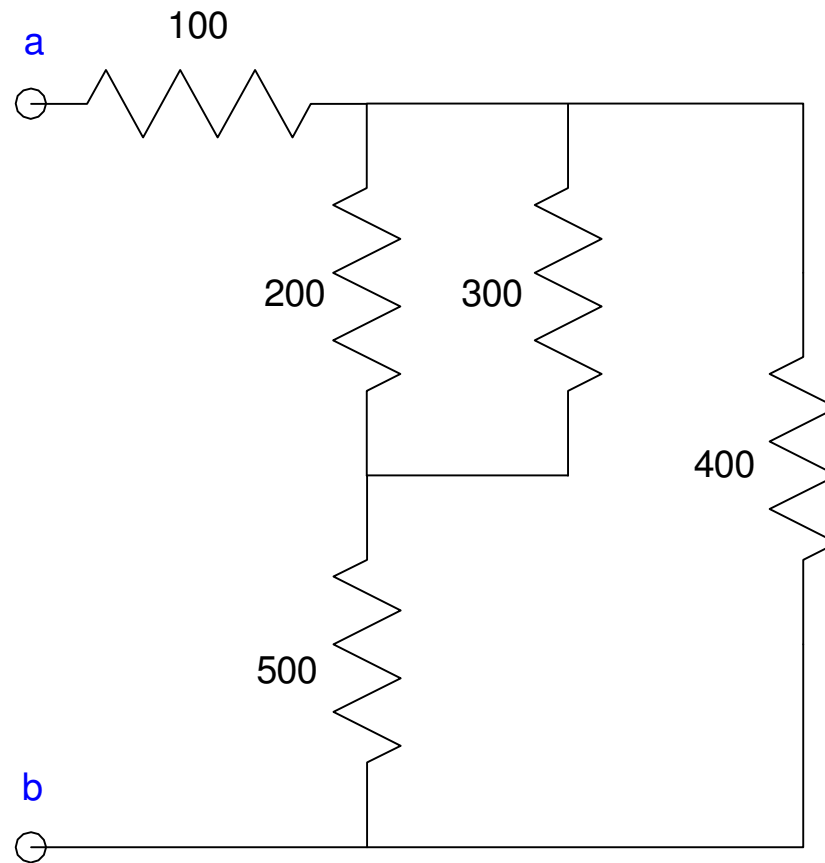
500

 $+$ $1/x$

400

 $1/x$ $+$ $1/x$

100

 $+$ 

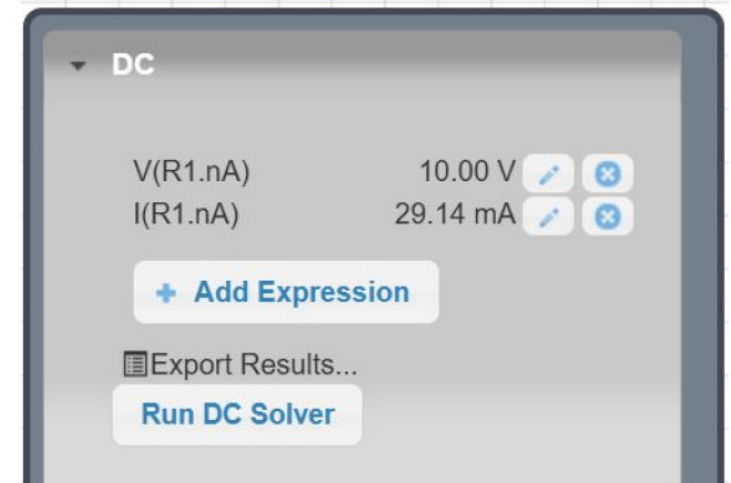
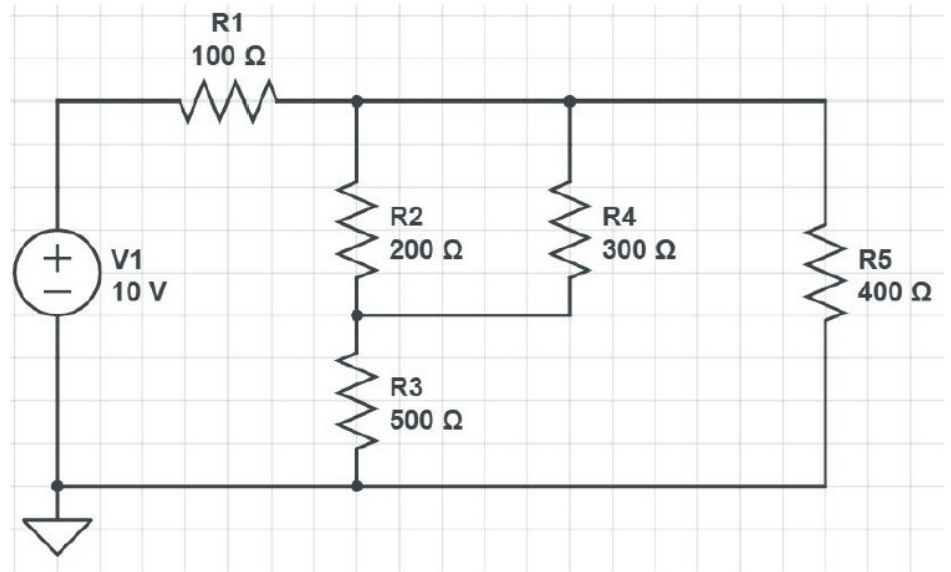
CircuitLab Calculations

- Build the circuit
- Apply a test voltage (10V)
- Measure the net current draw
- Compute R

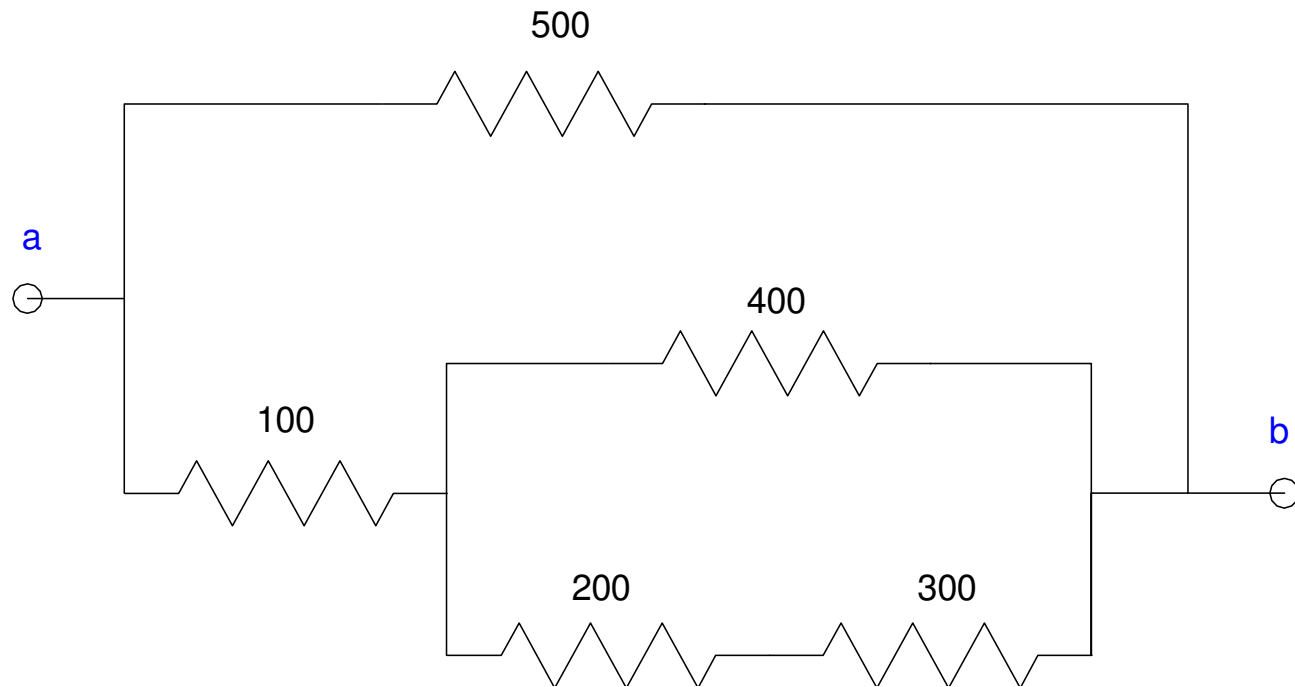
$$R = \frac{V}{I}$$

$$R = \frac{10V}{29.14mA}$$

$$R = 343.17\Omega$$



Handout: Find R_{ab}

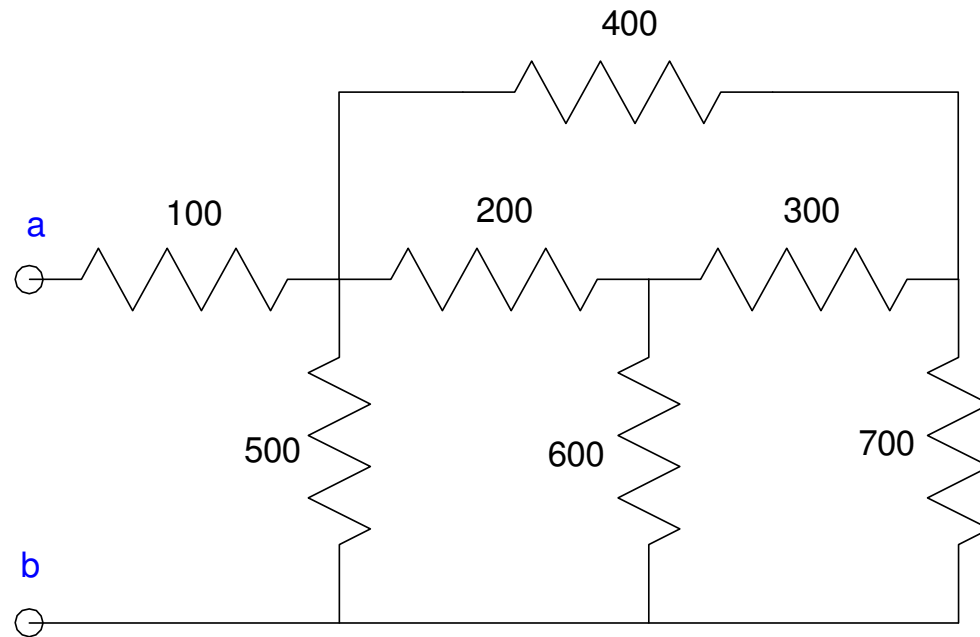


Comment

Series & parallel simplification doesn't always work

- CircuitLab always works though

Methods to compute the net resistance in these cases will be covered later in this course



Summary

Resistors in series add

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

Resistors in parallel add as

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

CircuitLab can be used to check your answers

You can also build the circuit in lab to check your answers

