# 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

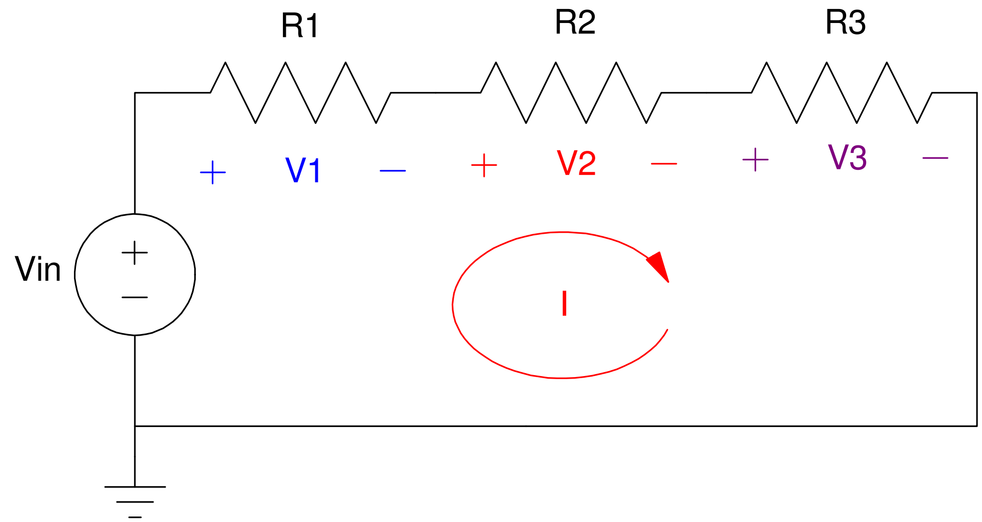
Note:

- 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 Kirchoff's voltage law:

$$\text{Vin} = \text{V1} + \text{V2} + \text{V3}$$

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

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

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

Resistors in series add

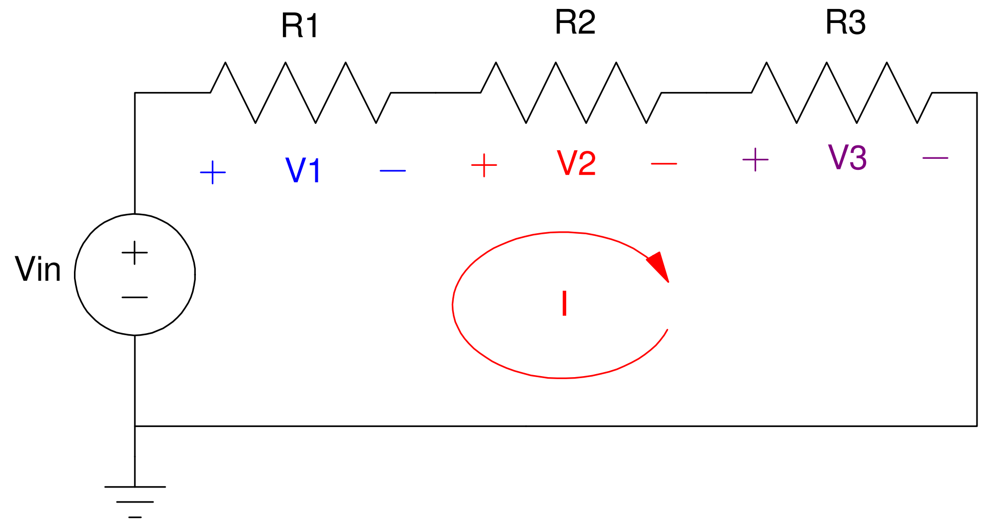
# Examples:

Let $R_1$ = 100 Ohms, $R_2$ = 200 Ohms, $R_3$ = 300 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 Ohms, $R_2$ = 200 Ohms

- If $R_{net}$ = 1000 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
- Va1 = Vb1 = Vc1
- Va2 = Vb2 = Vc2

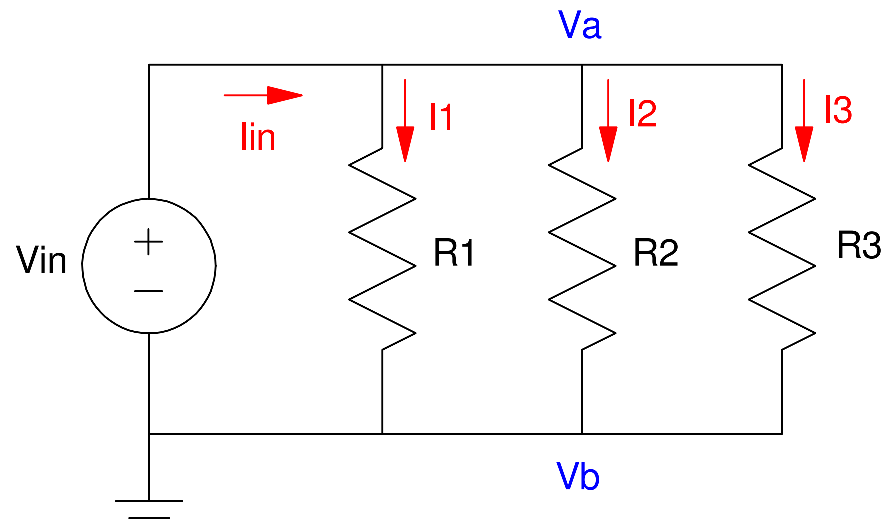
Find the net resistance:

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

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

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

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




In general:

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

## Examples:

Let R1 = 100 Ohms, R2 = 200 Ohms, R3 = 300 Ohms. Find the total resistance.

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

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

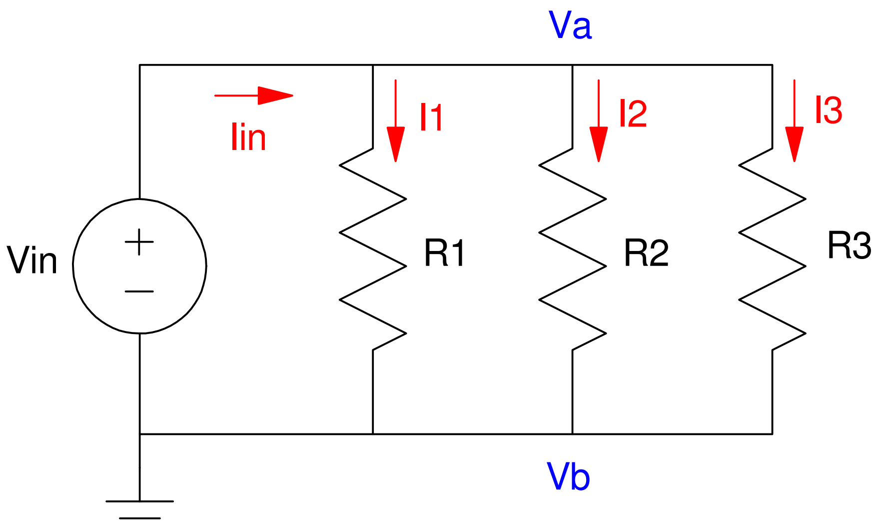
$$R_{net} = 54.54\Omega$$

Let R2 = 200 Ohms, R3 = 300 Ohms,
Rnet = 100 Ohms. Find R1.

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

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

$$R_1 = 600\Omega$$



# Find the resistance from a to b

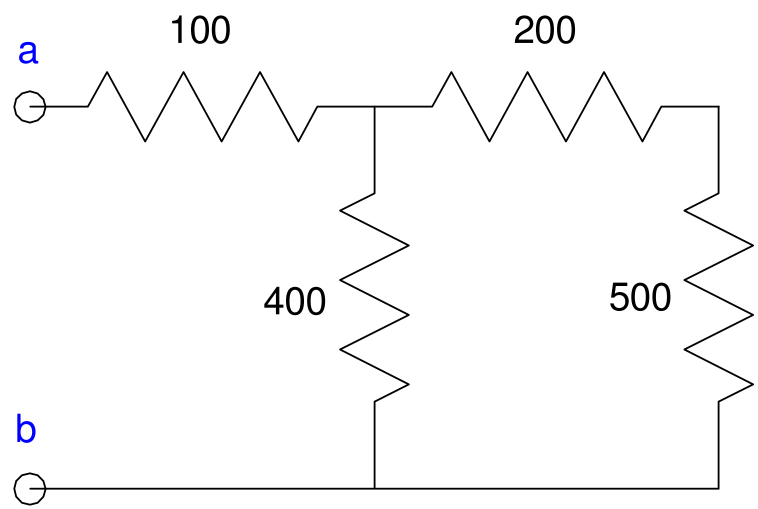
Combine resistors that are in series and parallel

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

$$200 + 500 = 700$$

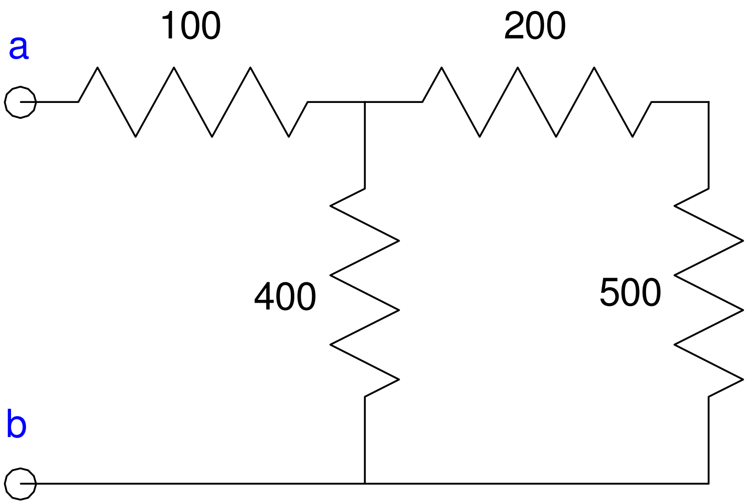
This is in parallel with 400 Ohms

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

This is in series with 100 Ohms

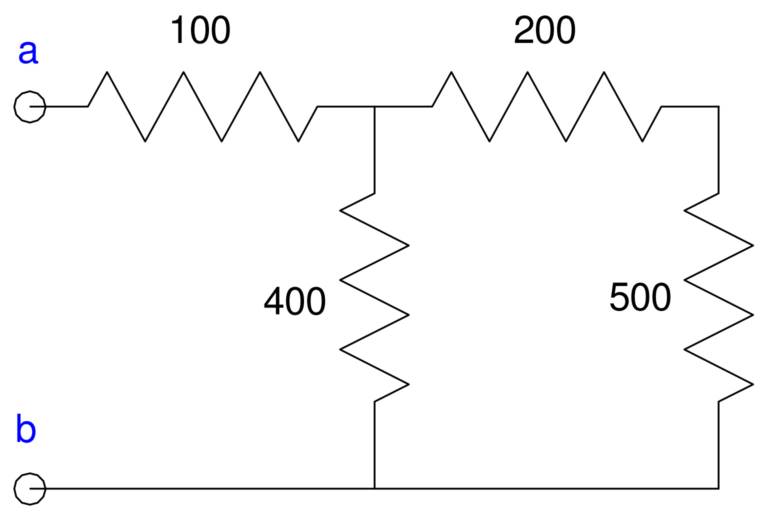
$$254.54 + 100 = 354.54$$

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

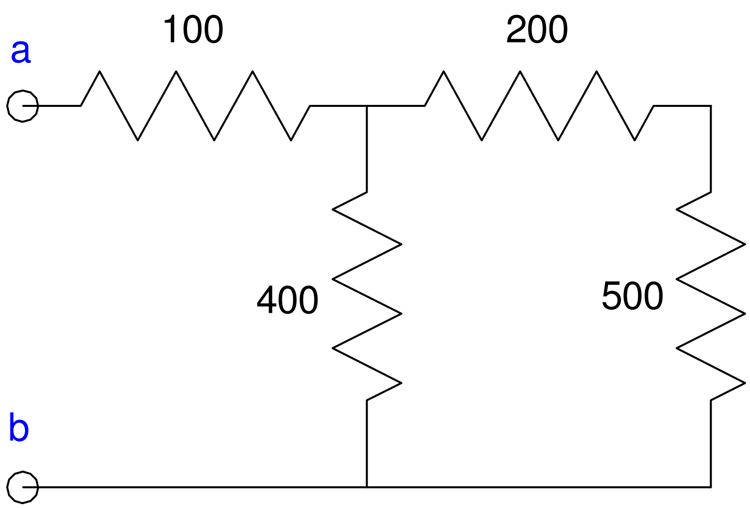
- HP is essentially a company of electrical and computer engineers
- They likewise build really good calculators for ECE majors
- Free app on your cell phone

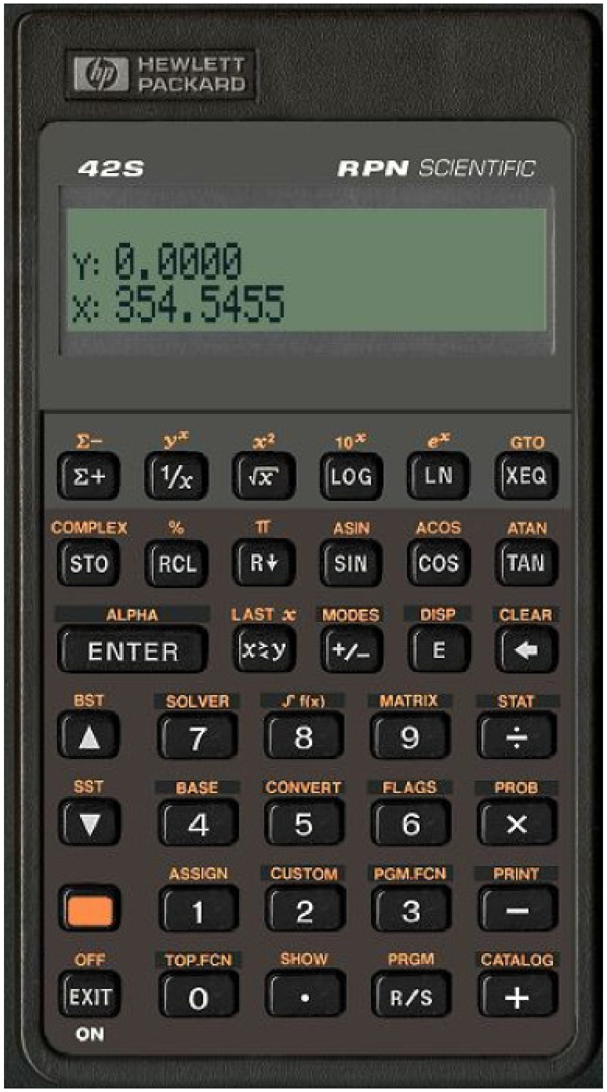

Note: These use Reverse Polish Notation (RPN)

- 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
+
1/x

100
+
```



# Checking in CircuitLab

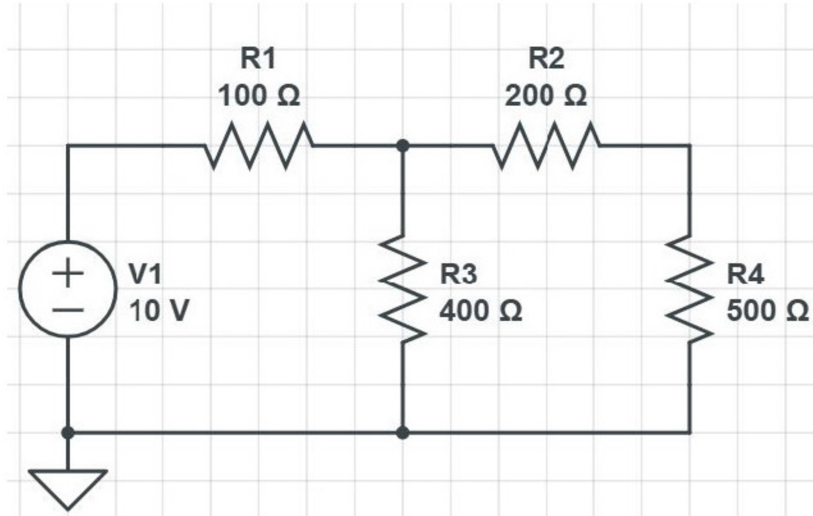
Build the circuit in CircuitLab

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

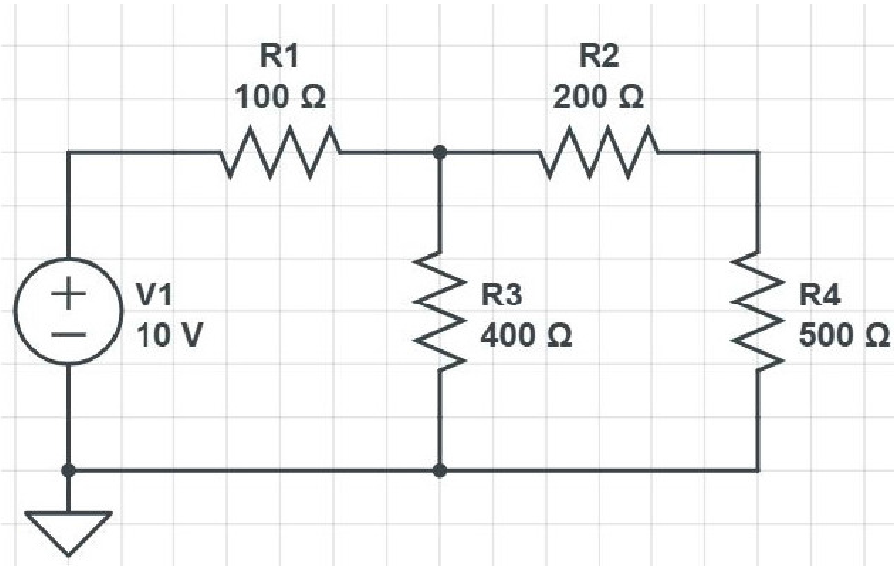
$$R = \frac{V}{I}$$

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

$$R = 354.48\Omega$$




## 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

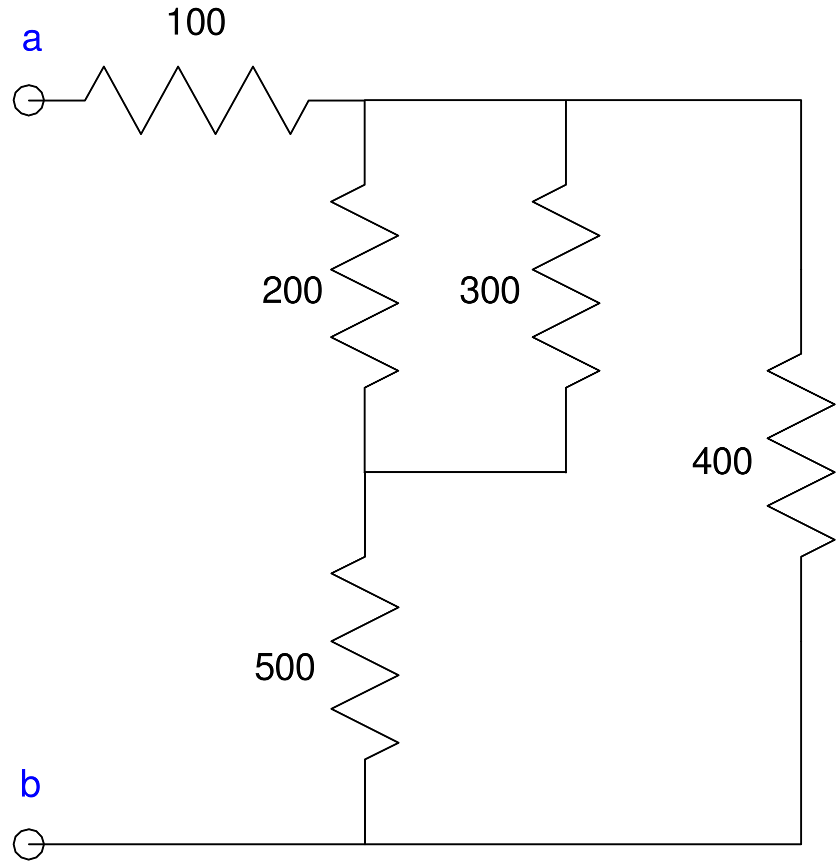
- You can check your calculations using CircuitLab
- Your results should match
- Chegg isn't needed
- ChatGPT isn't needed

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

$200 \parallel 300 = 120$ Ohms

This is in series with 500

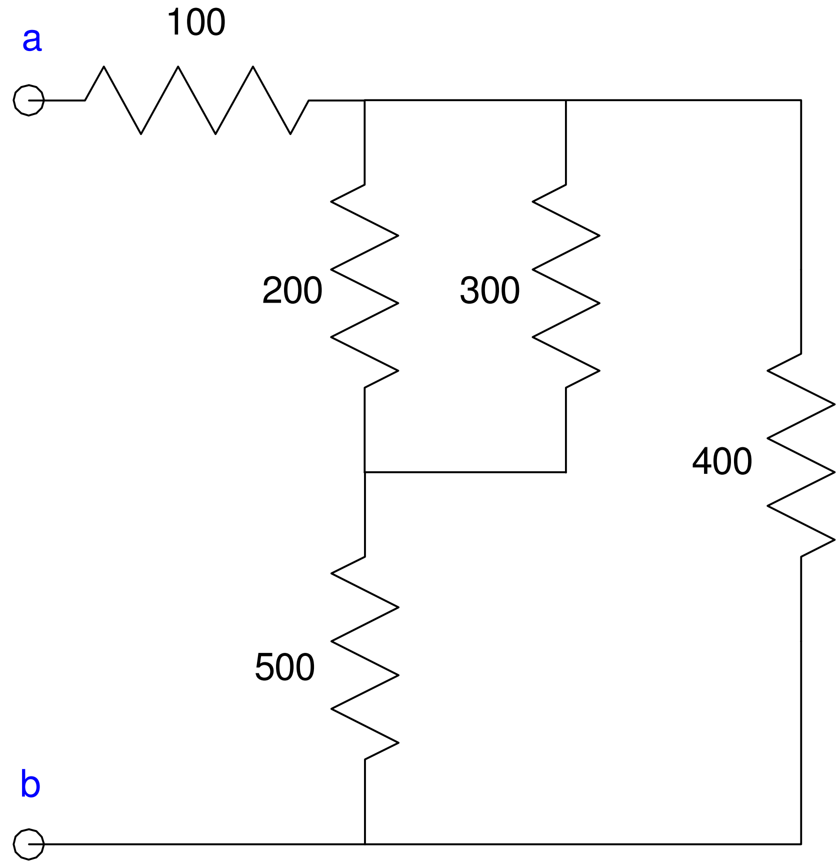
$120 + 500 = 620$

This is in parallel with 400

$620 \parallel 400 = 243.137$

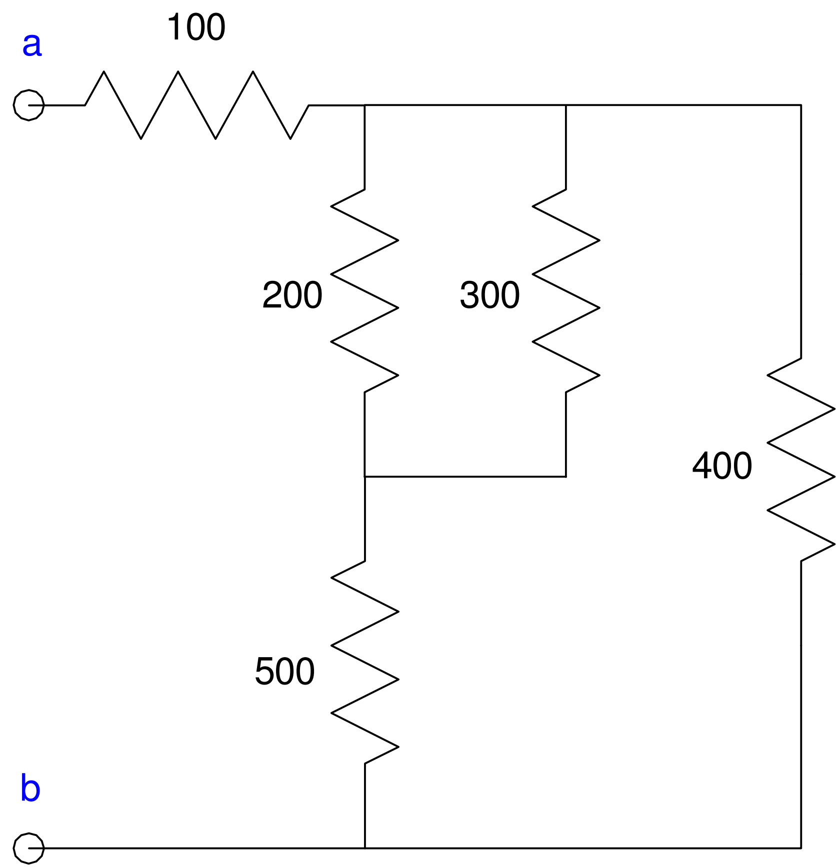
This is in series with 100

$243.137 + 100 =$ **343.137**



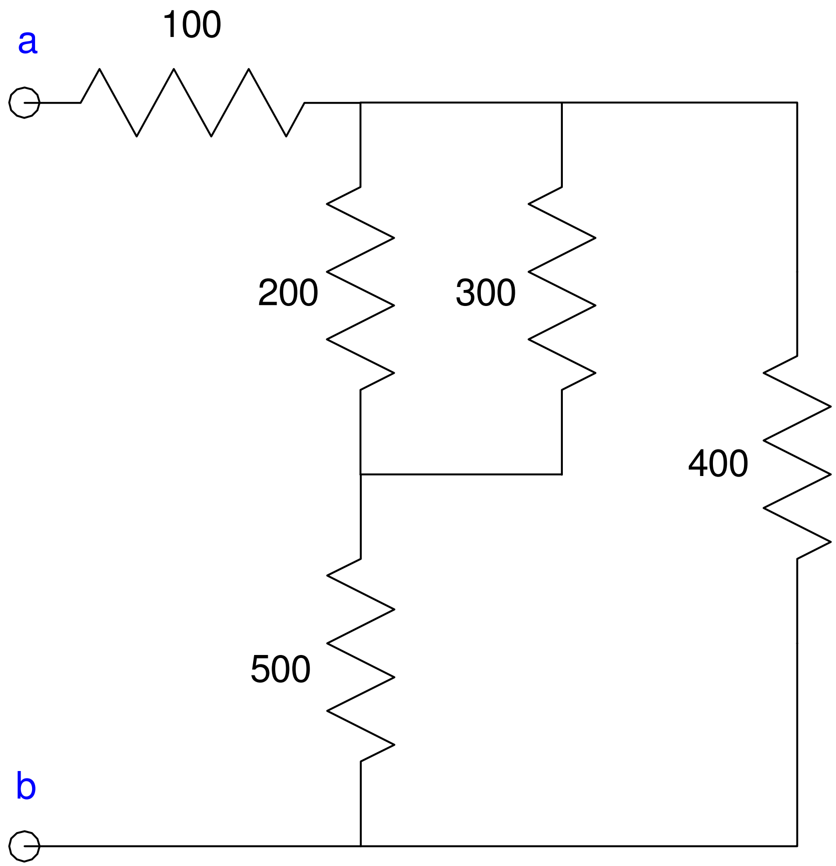
# Calculations in Matlab

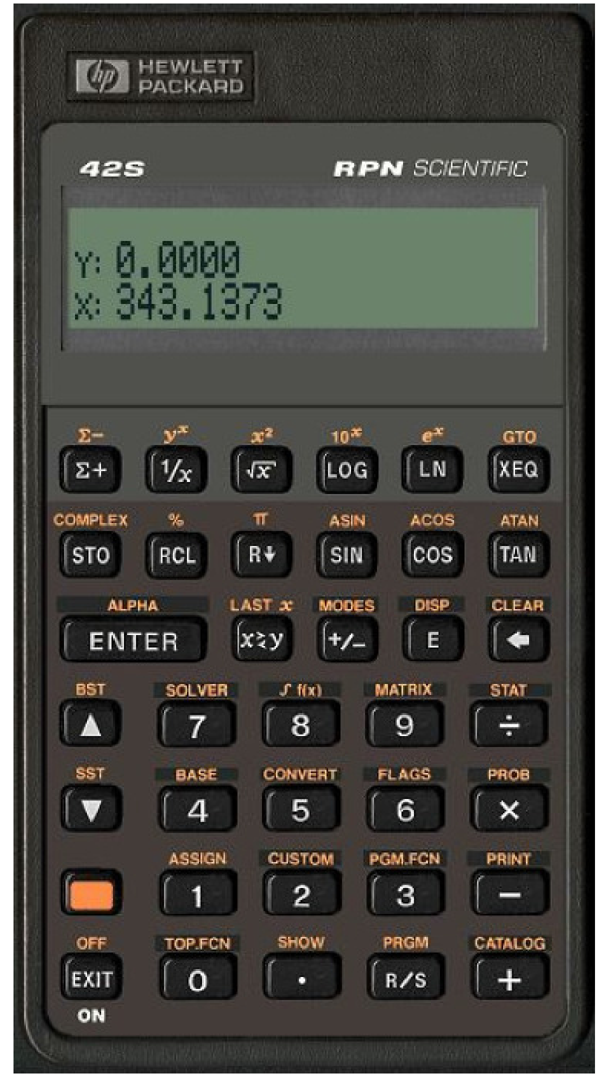
```
>> R1 = 1 / (1/200 + 1/300)

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
+
```



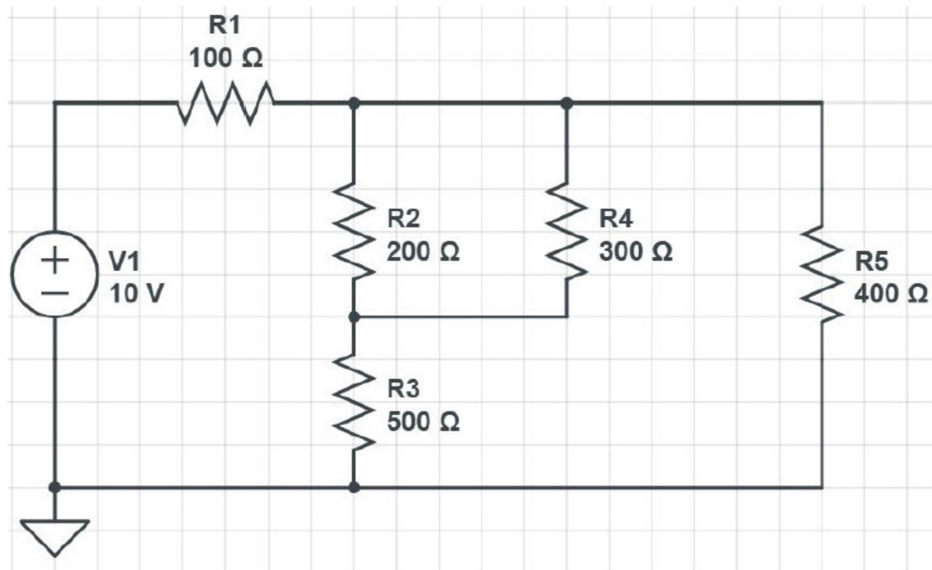
# CircuitLab Calculations

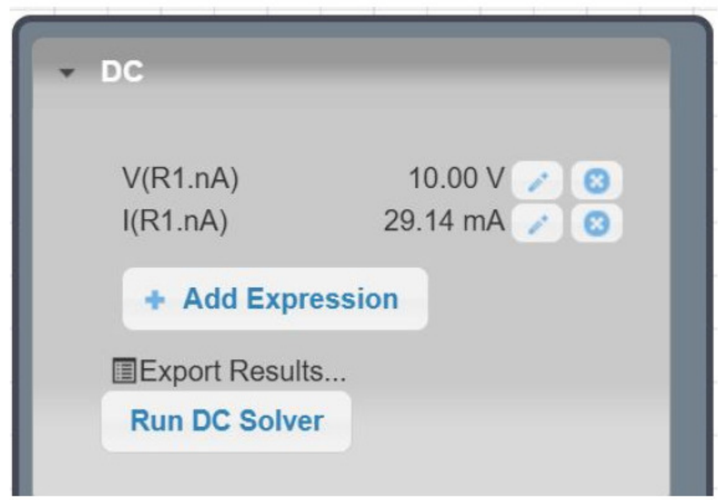
- Build the circuit
- Apply a test voltage (10V)
- Measure the net current draw
- Compute R

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

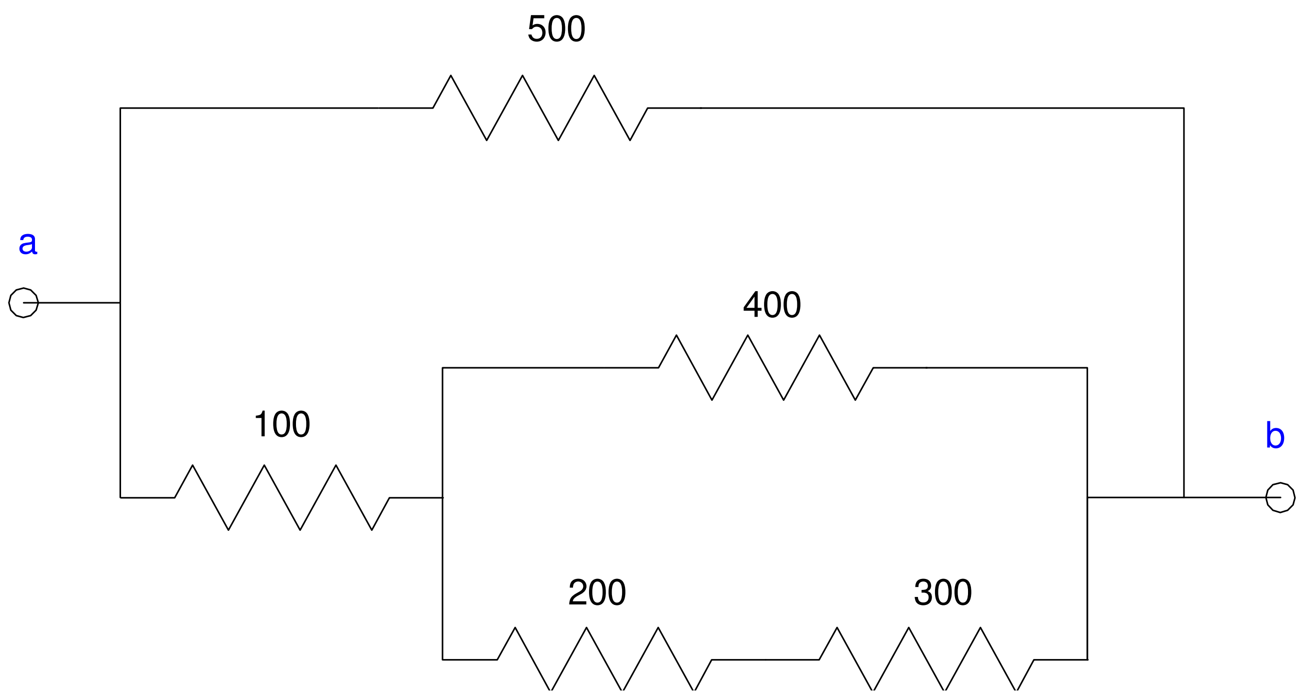
$$R = \frac{10V}{29.14mA}$$

$$R = 343.17\Omega$$



# Handout: Find Rab

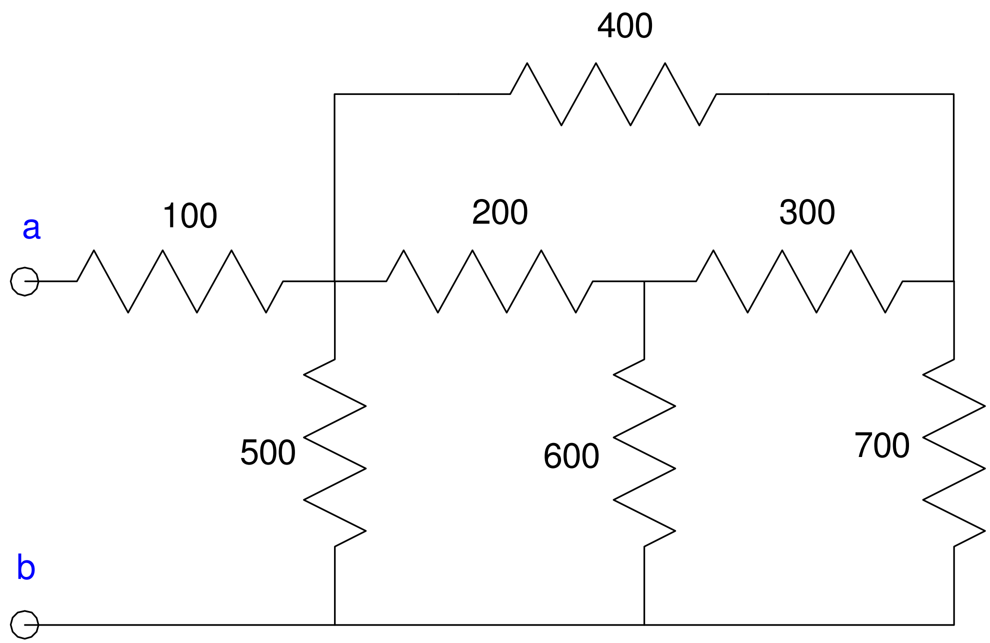


## Comment

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

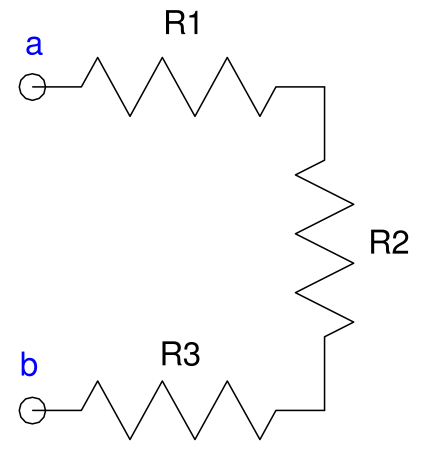
$$R_{net} = R_1 + R_2 + R_3$$

Resistors in parallel add as

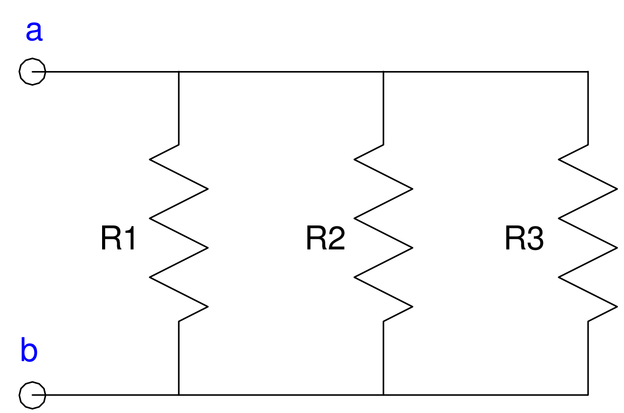
$$R_{net} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1}$$

CircuitLab can be used to check your answers

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



Series



Parallel