

Phys 102 – Lecture 7

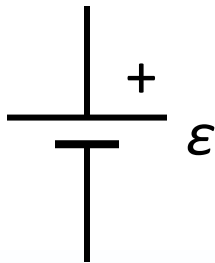
Series and parallel circuits

Recall from last time...

Electric potential difference across circuit element is its “voltage”

V_{element}

Should be “ ΔV ”, but we’ll usually drop the “ Δ ”



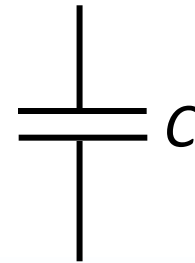
Batteries – pump charges
Provide emf for charges

$$V_{\text{battery}} = \varepsilon$$



Resistors – regulate current
Dissipate power

$$V_R = IR$$



Capacitors – store charge
Store energy

$$V_C = \frac{Q}{C}$$

Wires are ideal conductors, with no resistance. $E = 0$, the electric potential is constant and the voltage across a wire is 0.

Today we will...

- Learn about electric circuits

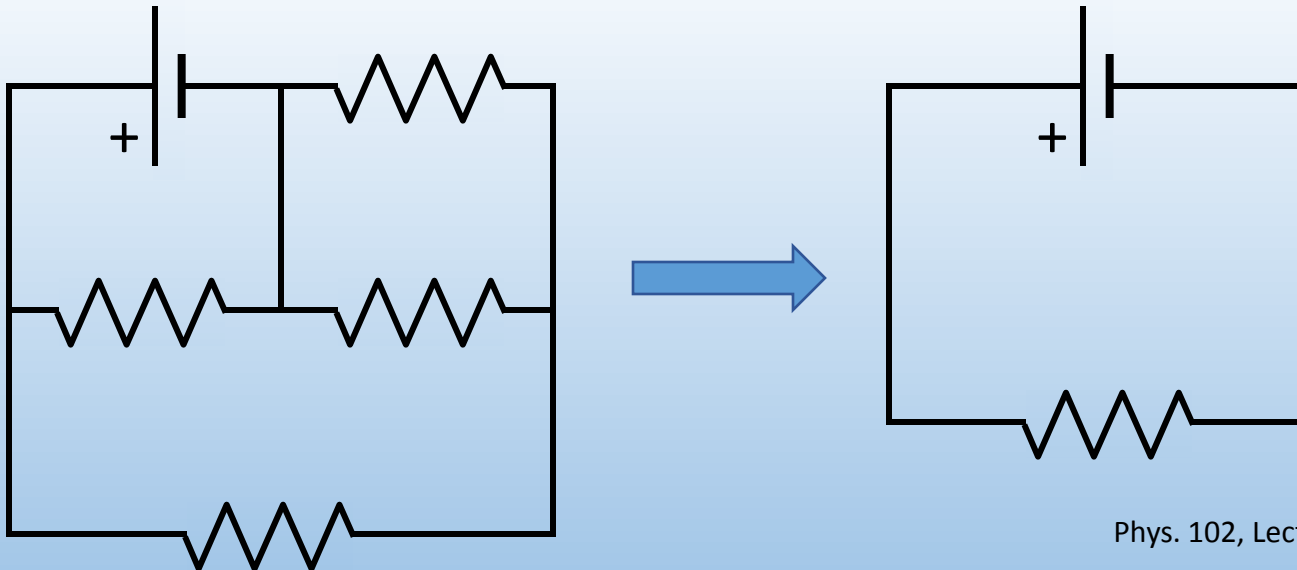
Circuits with a battery, wires, and resistors

Circuits with a battery, wires, and capacitors

- Analyze circuits

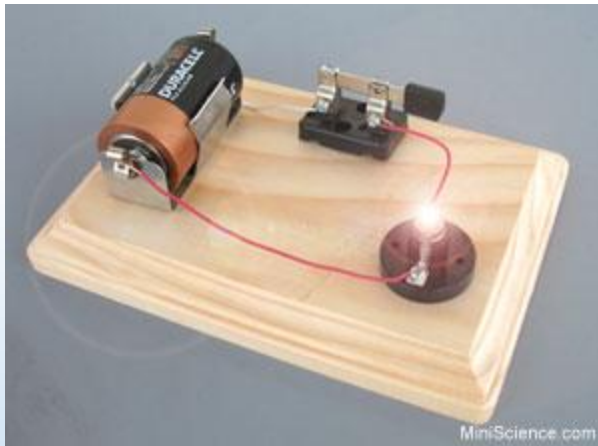
Take a complex-looking circuit like...

...and turn into a simple-looking circuit like

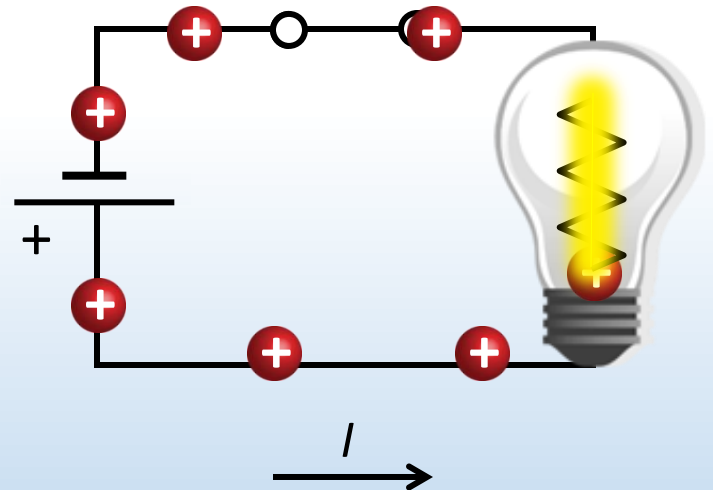


Electric circuits

Electric circuits consist of one or more closed loops around which charges flow

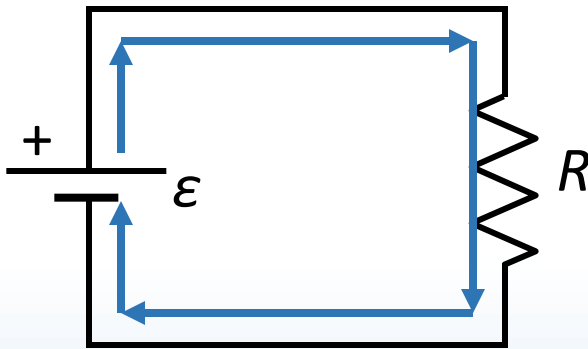


Closed circuit

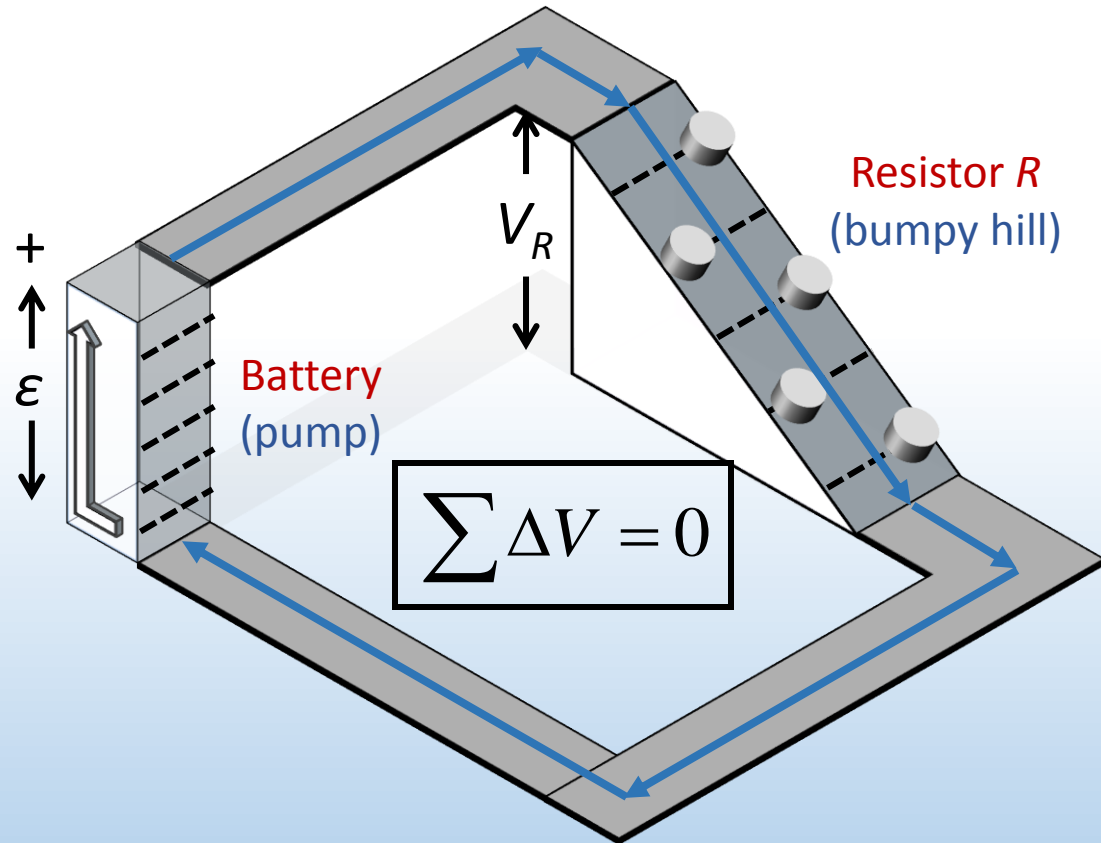


Kirchhoff loop rule

A charge making a complete loop around a circuit must return to the same electric potential (“height”) at which it started

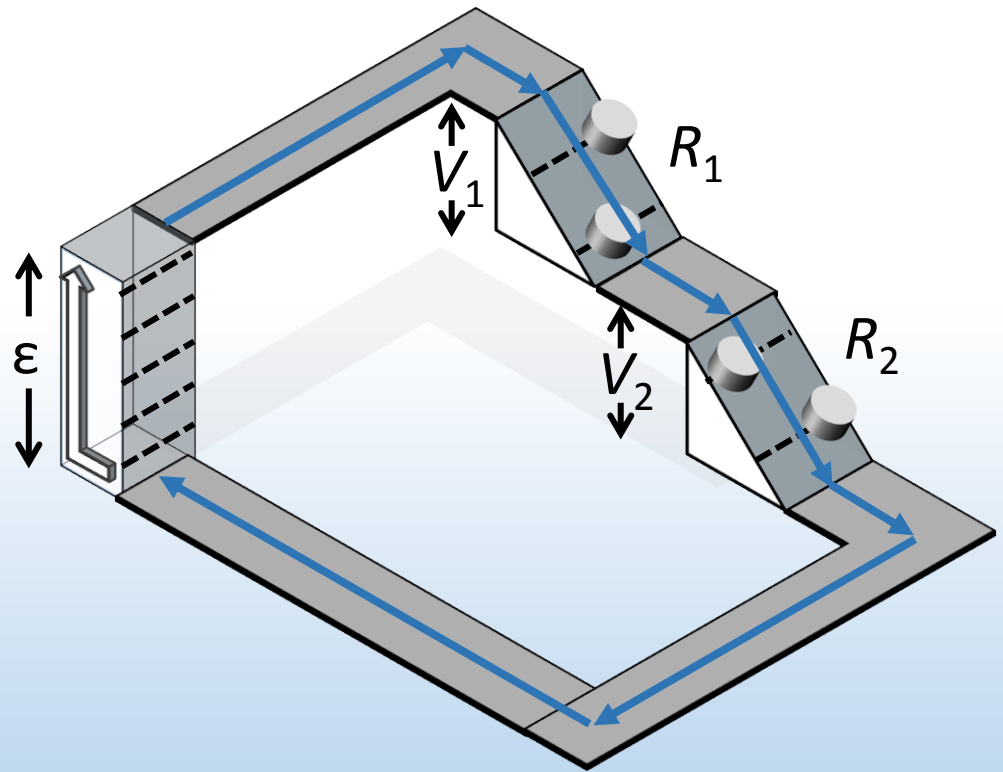
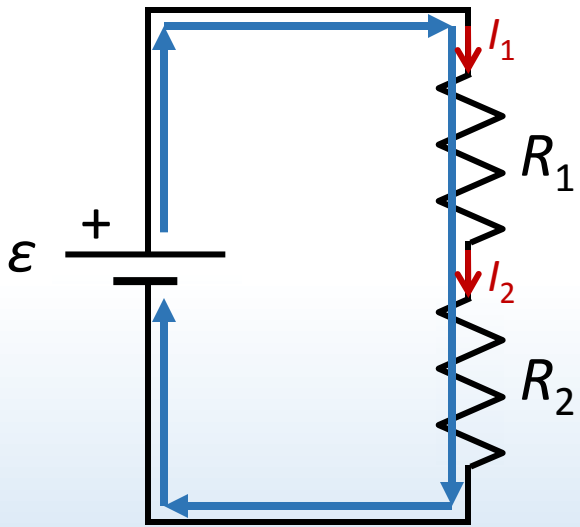


Sum of electric potential differences (voltages) around circuit loop is zero



Series components

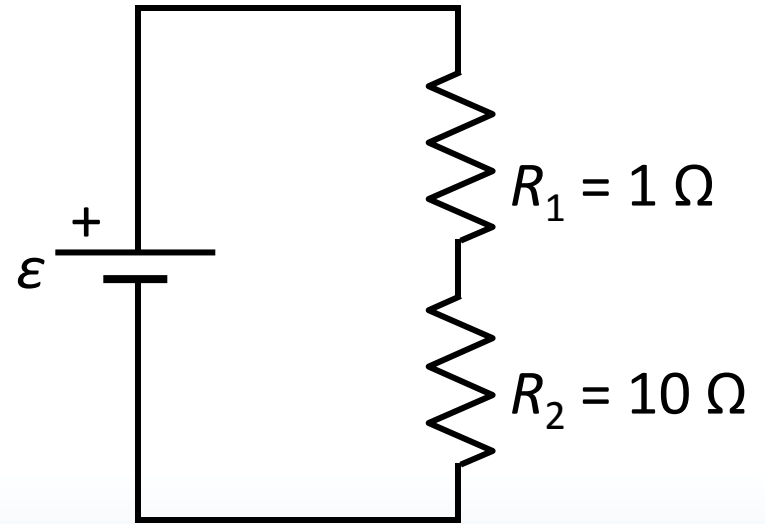
Two components are said to be in series when they are connected end-to-end by a *single* wire





ACT: CheckPoint 1.2

Consider a circuit with two resistors R_1 and R_2 in series. Compare the voltages across the resistors:

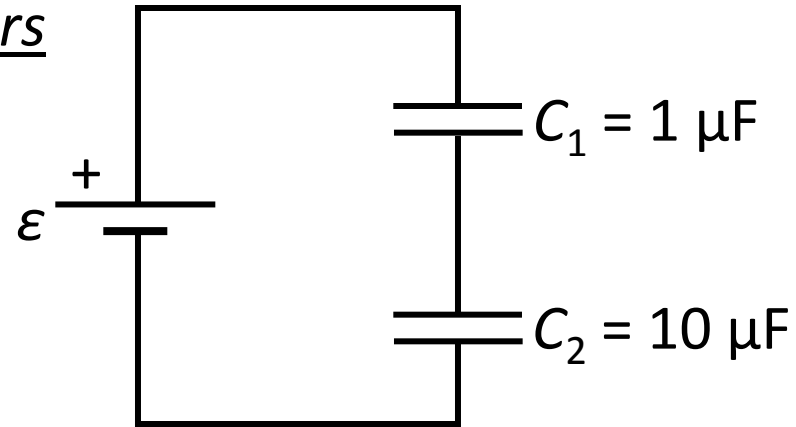


- A. $V_1 > V_2$
- B. $V_1 = V_2$
- C. $V_1 < V_2$



ACT: Capacitors in series

Consider a circuit with two capacitors C_1 and C_2 in series. Compare the voltages across the capacitors:

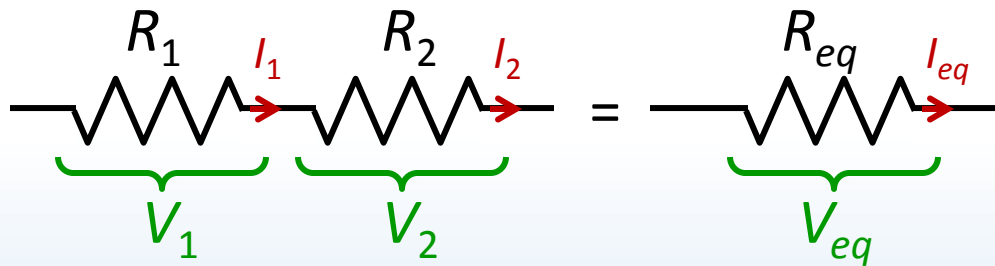


- A. $V_1 > V_2$
- B. $V_1 = V_2$
- C. $V_1 < V_2$

Equivalent resistance & capacitance

Circuit behaves the same as if *series* components were replaced by a *single, equivalent* component

Resistors

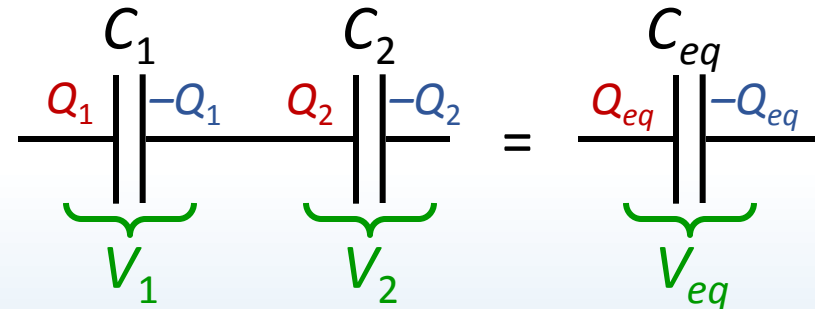


$$I_1 = I_2 = I_{eq}$$

$$V_1 + V_2 = V_{eq}$$

$$R_{eq} = R_1 + R_2$$

Capacitors



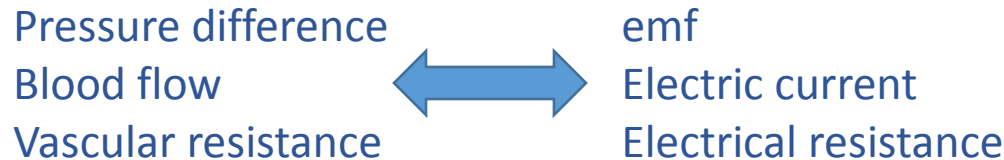
$$Q_{eq} = Q_1 = Q_2$$

$$V_{eq} = V_1 + V_2$$

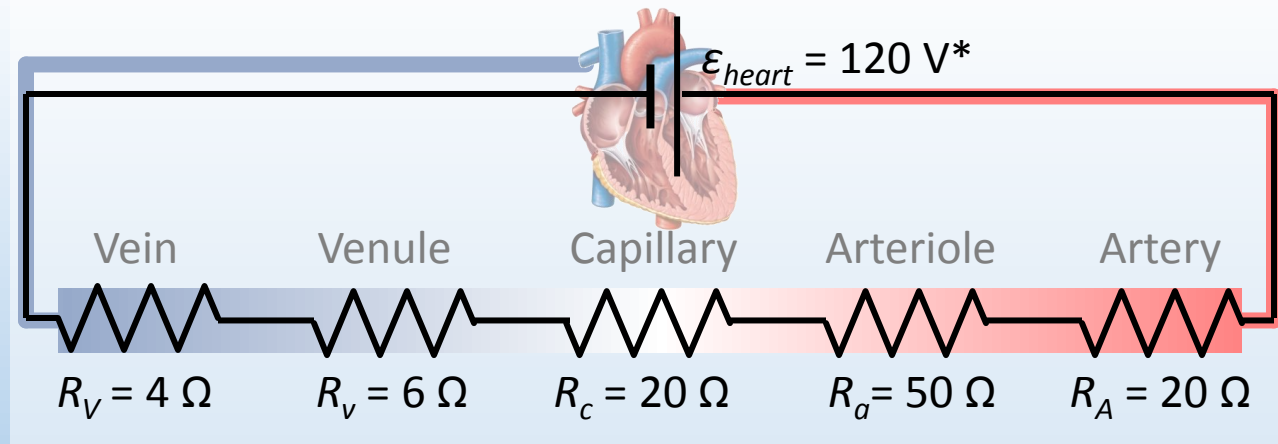
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Calculation: vascular resistance

The circulatory system is analogous to an electric circuit



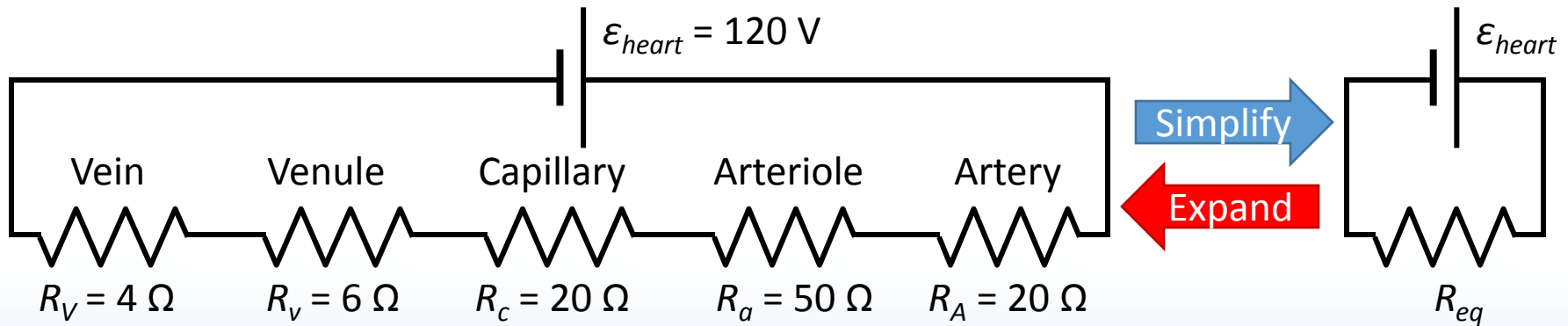
The circulatory system consists of different types of vessels in series with different resistances to flow



*Numbers represent accurate relative values

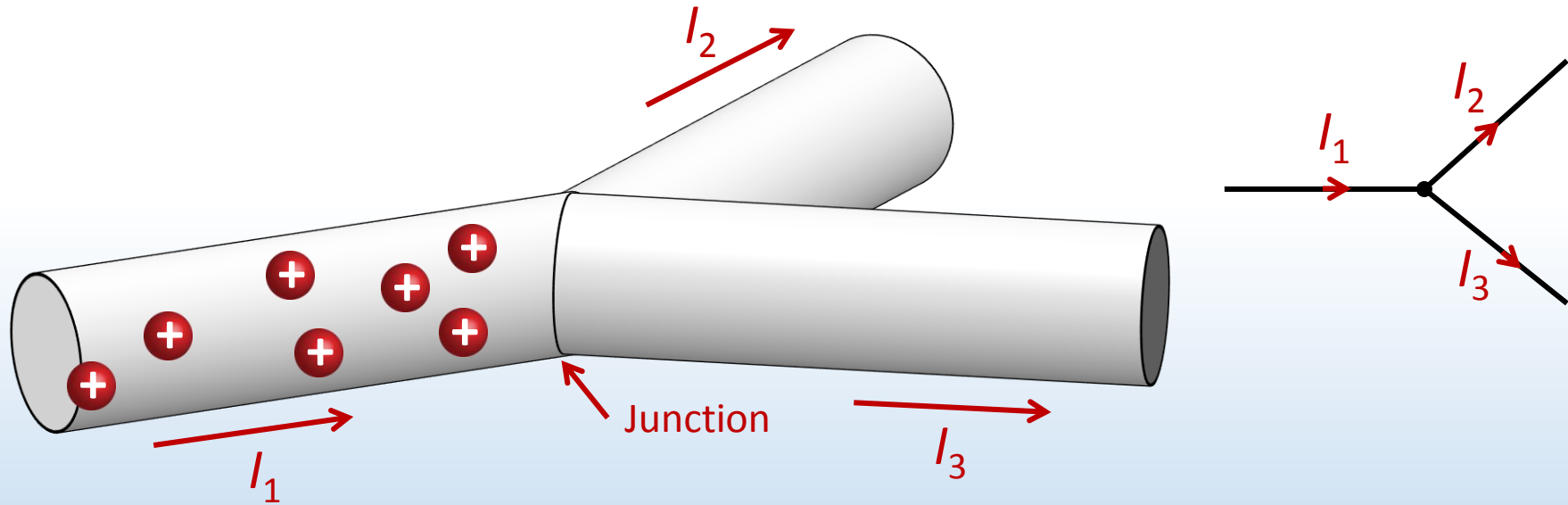
Calculation: vascular resistance

Calculate the current I through the vascular circuit and the voltages across the different types of vessels



Kirchhoff junction rule

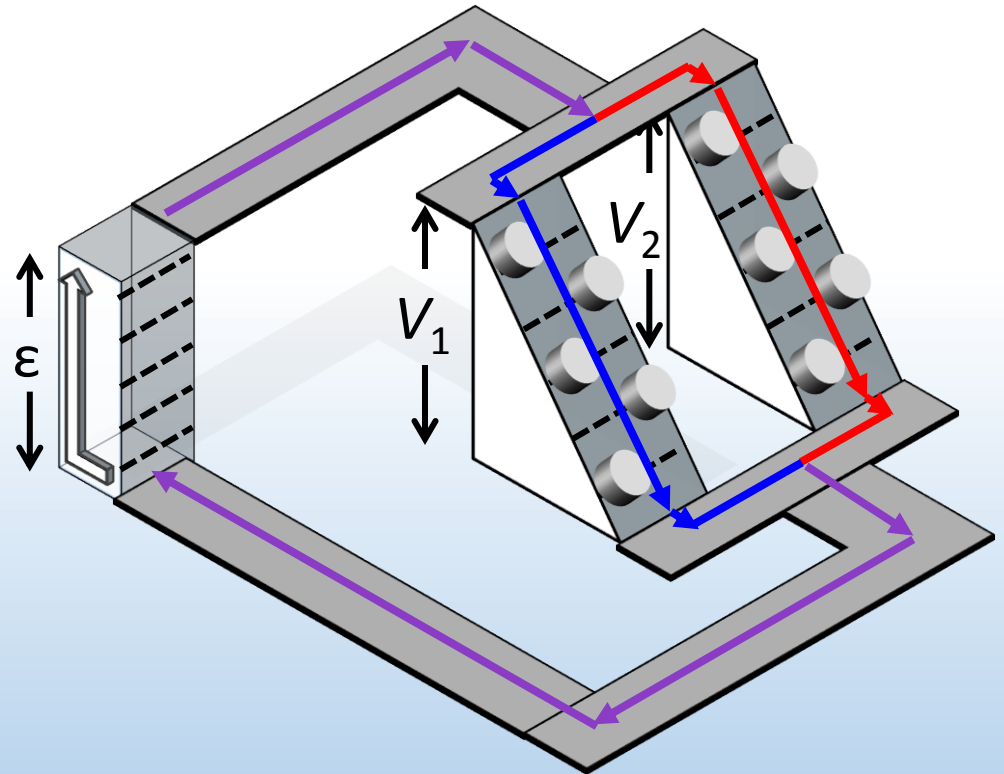
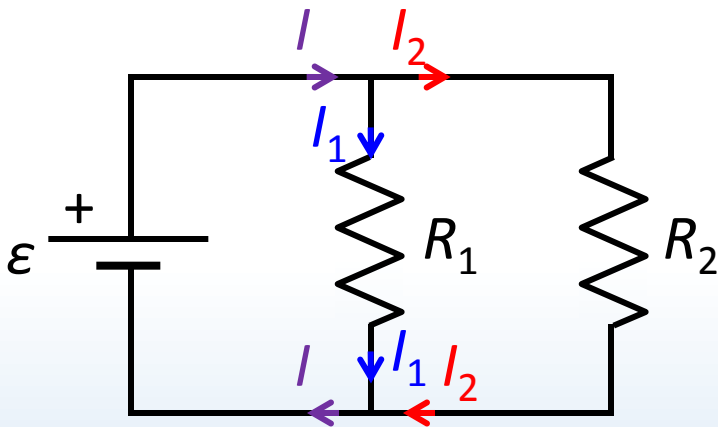
Charges flowing through a junction split. By conservation of charge, the sum of currents into a junction equals the sum of currents out of a junction



$$\sum I_{in} = \sum I_{out}$$

Parallel components

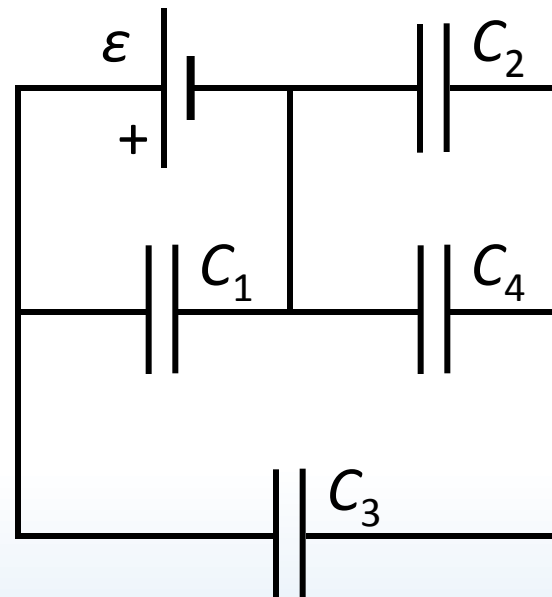
Components are said to be in parallel when both ends are connected to each other, forming a loop containing only them





ACT: Parallel or series?

Consider the circuit to the right. Which of the following statements is true?

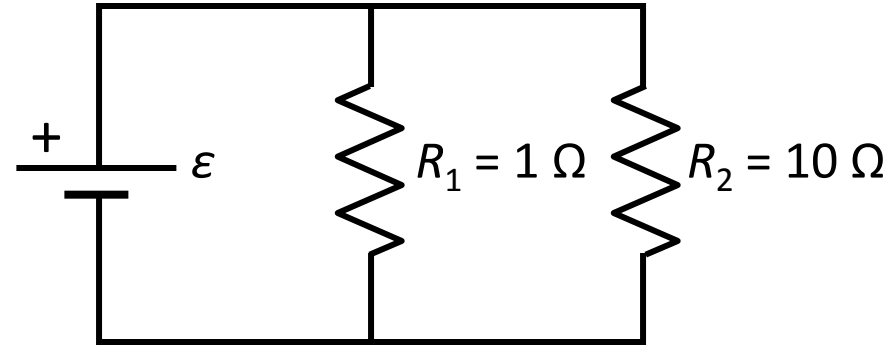


- A. C_1 & C_4 are in series
- B. C_2 & C_4 are in parallel
- C. C_1 & C_3 are in parallel



ACT: Resistors in parallel

Consider a circuit with two resistors R_1 and R_2 in parallel. Compare I_1 , the current through R_1 , to I_2 , the current through R_2 :

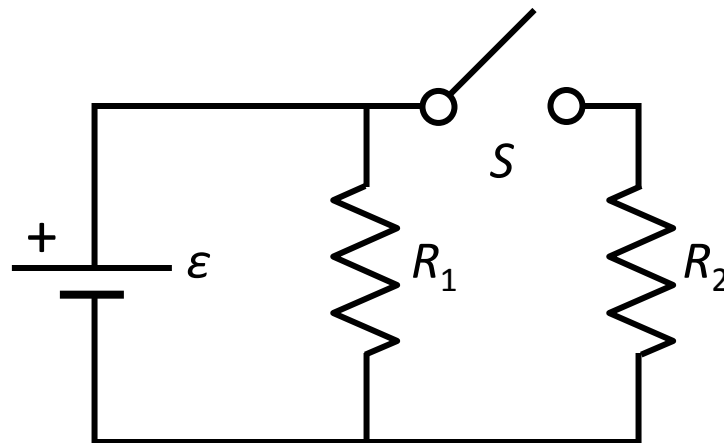


- A. $I_1 > I_2$
- B. $I_1 = I_2$
- C. $I_1 < I_2$



ACT: CheckPoint 2.3

Now we add a switch S . What happens to the current out of the battery when the switch is closed?



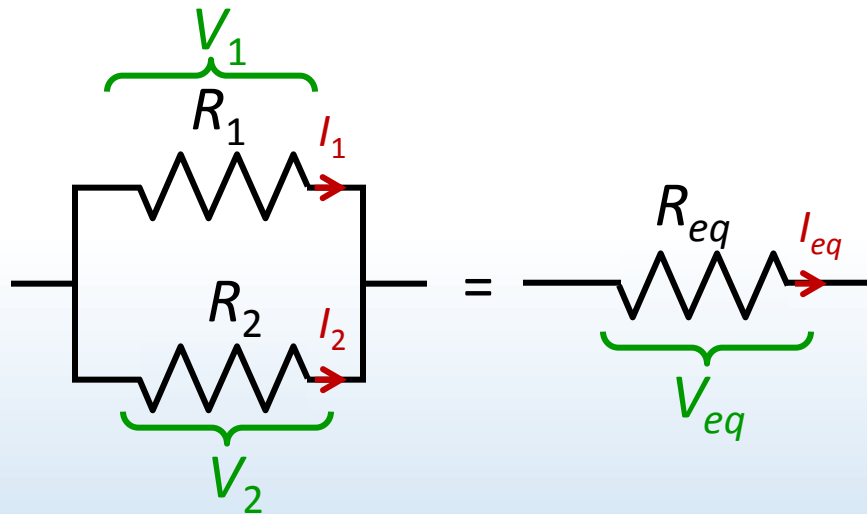
- A. I_{battery} increases
- B. I_{battery} remains the same
- C. I_{battery} decreases

DEMO

Equivalent resistance & capacitance

Circuit behaves the same as if *parallel* components were replaced by a *single, equivalent* component

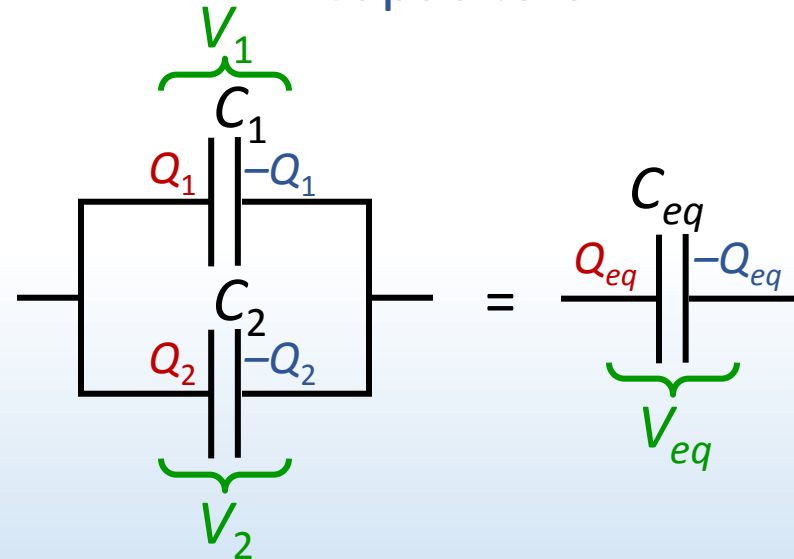
Resistors



$$I_1 + I_2 = I_{eq} \quad V_1 = V_2 = V_{eq}$$

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}}$$

Capacitors

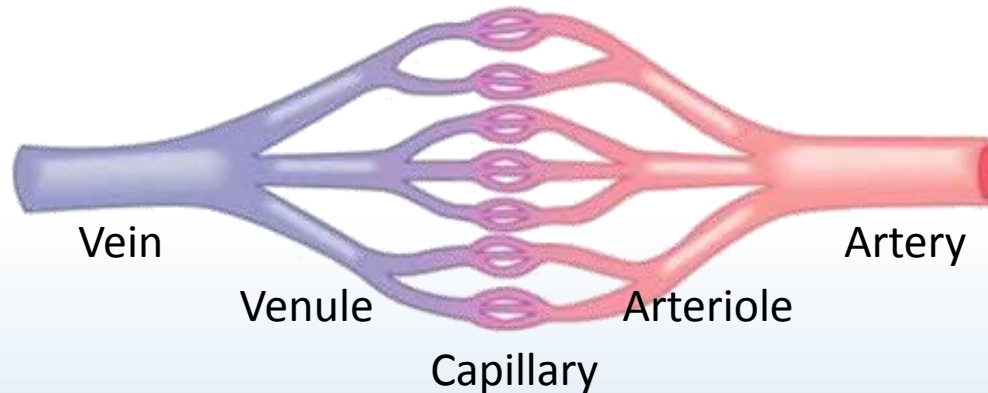


$$Q_1 + Q_2 = Q_{eq} \quad V_1 = V_2 = V_{eq}$$

$$\boxed{C_{eq} = C_1 + C_2}$$

Calculation: vascular resistance

In previous calculation, capillarity resistance accounts for ~20% of total vascular resistance, yet capillaries are the thinnest blood vessels, and should have the *highest* resistance. Why?



Calculation: cardiovascular system

The human cardiovascular system consists of two circuits: pulmonary circulation which carries blood through the lungs, and systemic circulation which carries blood to the organs

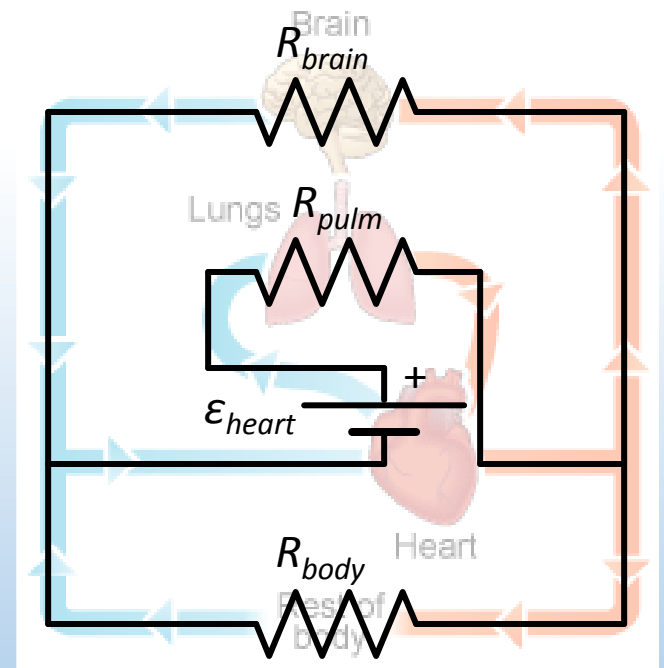
The organs of the body are connected in parallel in the systemic circuit

Simple circuit model*:

$$R_{pulm} = 12 \, \Omega, R_{brain} = 1 \, \text{k}\Omega, \\ R_{body} = 160 \, \Omega, \mathcal{E}_{heart} = 120 \, \text{V}$$

*Numbers represent accurate relative values

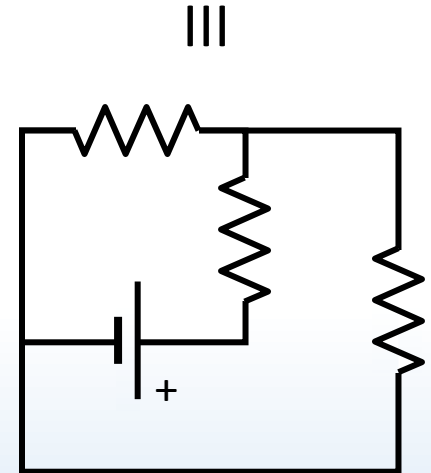
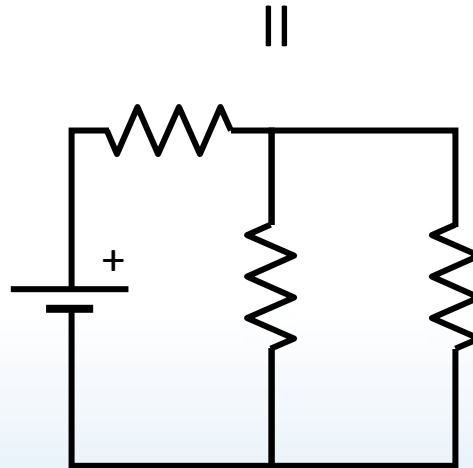
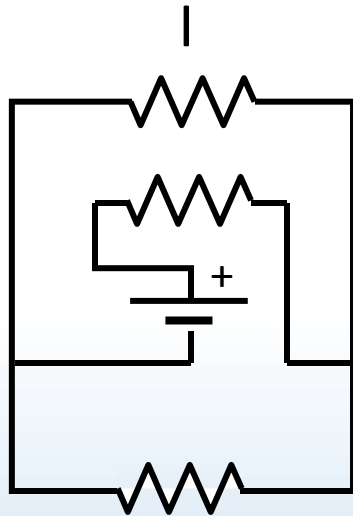
Calculate current through each component of circulatory system





ACT: analyzing circuits

Which of the following circuit is different than the others?

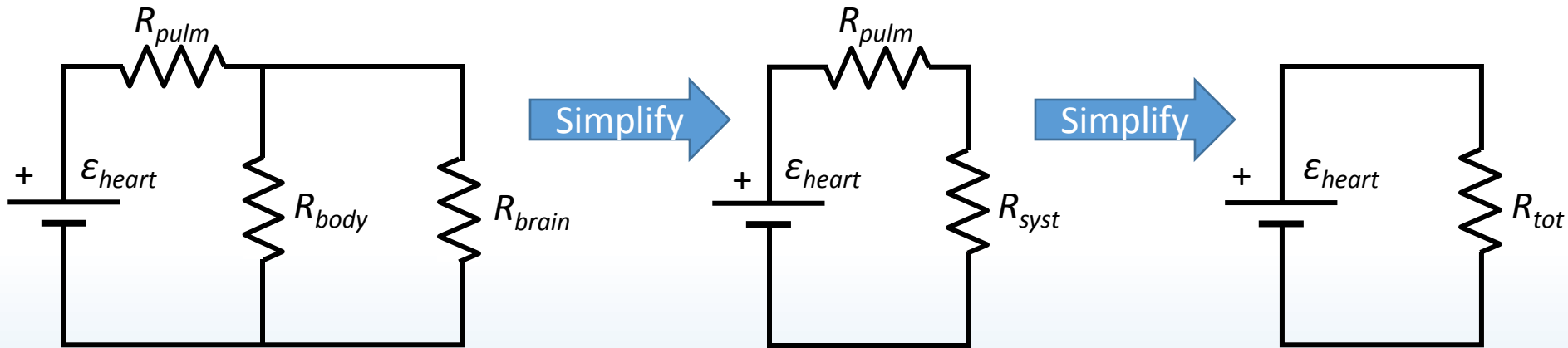


- A. Circuit I
- B. Circuit II
- C. Circuit III
- D. All three are equivalent
- E. All three are different

Calculation: circulatory system

Calculate current through each component of circulatory system

$$R_{pulm} = 12 \, \Omega, R_{brain} = 1 \, \text{k}\Omega, R_{body} = 160 \, \Omega, \varepsilon_{heart} = 120 \, \text{V}$$



R_{brain} & R_{body} are in parallel

$$\frac{1}{R_{syst}} = \frac{1}{R_{brain}} + \frac{1}{R_{body}}$$

$$V_{syst} = V_{brain} = V_{body}$$

$$I_{syst} = I_{brain} + I_{body}$$

R_{pulm} & R_{syst} are in series

$$R_{tot} = R_{pulm} + R_{syst}$$

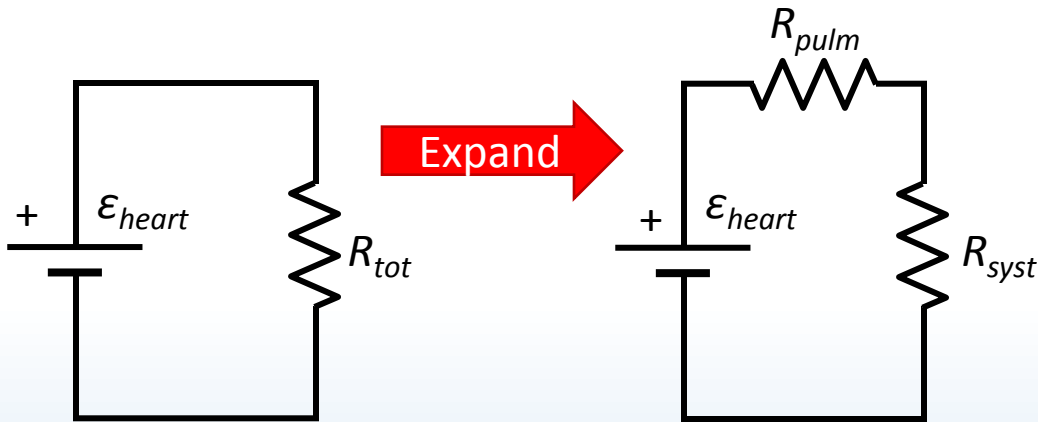
$$V_{tot} = V_{pulm} + V_{syst} = \varepsilon_{heart}$$

$$I_{heart} = I_{pulm} = I_{syst}$$

Calculation: circulatory system

Calculate current through each component of circulatory system

$$R_{pulm} = 12 \, \Omega, R_{brain} = 1 \, \text{k}\Omega, R_{body} = 160 \, \Omega, \varepsilon_{heart} = 120 \, \text{V}$$



R_{pulm} & R_{syst} are in series

$$R_{tot} = R_{pulm} + R_{syst}$$

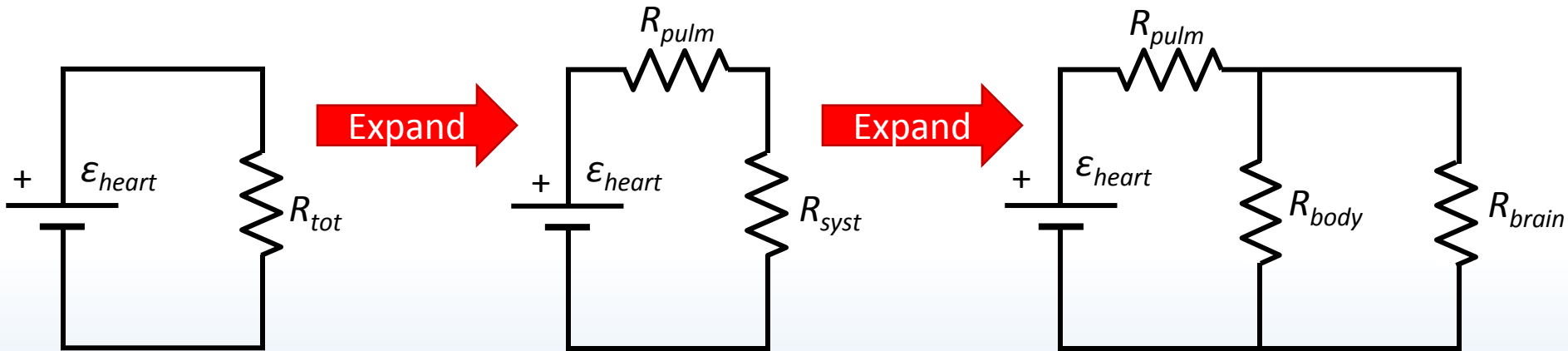
$$V_{tot} = V_{pulm} + V_{syst} = \varepsilon_{heart}$$

$$I_{pulm} = I_{syst} = I_{heart}$$

Calculation: circulatory system

Calculate current through each component of circulatory system

$$R_{pulm} = 12 \, \Omega, R_{brain} = 1 \, \text{k}\Omega, R_{body} = 160 \, \Omega, \varepsilon_{heart} = 120 \, \text{V}$$



R_{brain} & R_{body} are in parallel

$$\frac{1}{R_{syst}} = \frac{1}{R_{brain}} + \frac{1}{R_{body}}$$

$$V_{syst} = V_{brain} = V_{body}$$

$$I_{syst} = I_{brain} + I_{body}$$

Summary of today's lecture

- Two basic principles:
- Kirchhoff loop rule

Voltages around circuit loop sum to zero (based on conservation of energy)

$$\sum \Delta V = 0$$

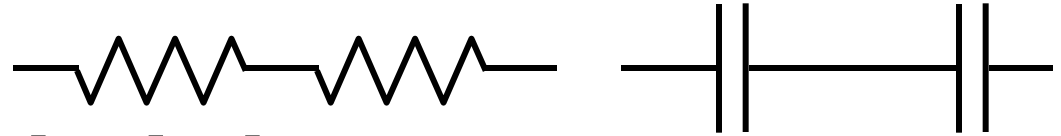
- Kirchhoff junction rule

Currents into a circuit branch equal currents out (based on conservation of charge)

$$\sum I_{in} = \sum I_{out}$$

Summary of today's lecture

- Series components



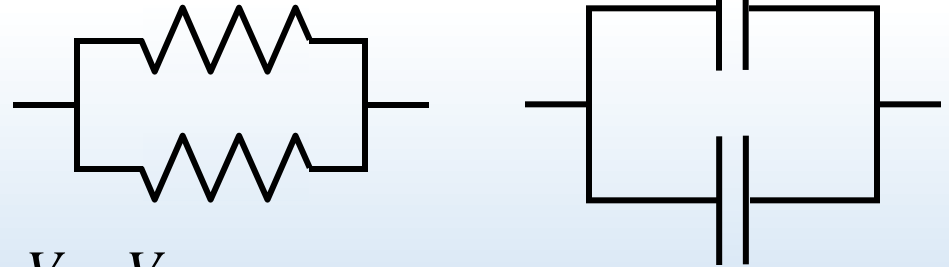
Currents are the same $I_{eq} = I_1 = I_2$

Voltages add $V_{eq} = V_1 + V_2$

Resistors $R_{eq} = R_1 + R_2$

Capacitors $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$

- Parallel components



Voltages are the same $V_{eq} = V_1 = V_2$

Currents add $I_{eq} = I_1 + I_2$

Resistors $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

Capacitors $C_{eq} = C_1 + C_2$

- Don't mix equations!