Lecture 17: 03/12/2024

- Announcements
  Online HW6 due next Monday. No written.

- Last Time
  Parallel plate capacitor
  Series and parallel connections
  Effective Capacitance (and resistance)
  Dielectrics

- This week – Chapters 9 and 10
  Circuits, current, voltage, charge
  Series/parallel resistors/capacitors
  Kirchoff's "laws"
  Internal resistance
  EMF
  Resistance and resistivity

- Current
- Resistance and Ohm's Law
- Power and Ohm's Law
- Combining Resistors
- Series and Parallel circuits
- Kirchoff's Laws
- Internal Resistance
- Resistance and Resistivity
- Drude Model of Conduction

Power is the product of voltage and current (True for ALL devices)

$$P = I V$$

Ohm's law (resistors only)

$$V = I R$$

Resistor power dissipation

$$P = I^2 R$$

$$P = \frac{V^2}{R}$$

Resistance in terms of resistivity

$$R = \rho \frac{L}{A} = \frac{L}{\sigma A}$$

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Electrons in a coulomb

The charge of an electron is 1.6×10^{-19} C

How many electrons are in a coulomb?

(A) 1

(B) 1.6

(C) 1.6×10^{-19}

(D) 10^{19}

(E) 6×10^{18}

$\frac{1}{1.6\times10^{-19}}$

Water current is total mass that passes an observer per second.

Electrical current is charge flow rate past a fixed point.

Units (C/s)

Ampere = C/s

$$I=\frac{\Delta Q}{\Delta t}=\frac{dQ}{dt}$$

Wire "W" carries 1.5 Amperes. A current of one Ampere means a coulomb of electrons pass a point every second.

How many electrons pass through W every second?

$(A)\ 1.5$

$(B)\ 1.5\times10^{-19}$

$(C)\ 9\times10^{18}$

$(D)\ 6.02\times10^{23}$

$$I=\frac{\Delta Q}{\Delta t}=\frac{dQ}{dt}$$

$6\times10^{18}\ e^- = 1\ C$

Hydraulic Analogy

http://en.wikipedia.org/wiki/Hydraulic_analogy

Mass of water (M)	Charge (Q)
Water current (dM/dt)	Current (I = dQ/dt)
Water pressure (P)	Voltage (V)

The charge on a capacitor is given by $Q = 12 - \frac{4}{t^2} + \frac{1}{t}$

$0 + 8t^{-3} - t^{-2} = 8(1^{-3}) - (1^{-2})$

$12 - 4t^{-2} + t^{-1}$

What is the current after 1 second?

$I = \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$

$Q = Q_0 \cos \omega t$

(A) 9 Amps
(B) 7 Coulombs
(C) 3 Amps
(D) -9 Amps
(E) 7 Amps

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Ohm's Law

Not as universal as P=IV or U=qV Or F=ma or Coulomb's law – but works for things called “resistors”.

You can buy a “resistor”, but any wire at all does have some resistance.

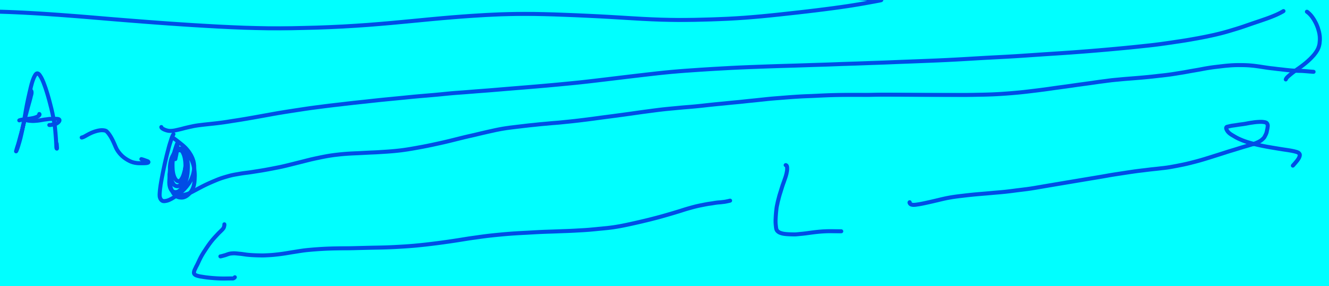
(Ω)

Resistance, measured in Ohms

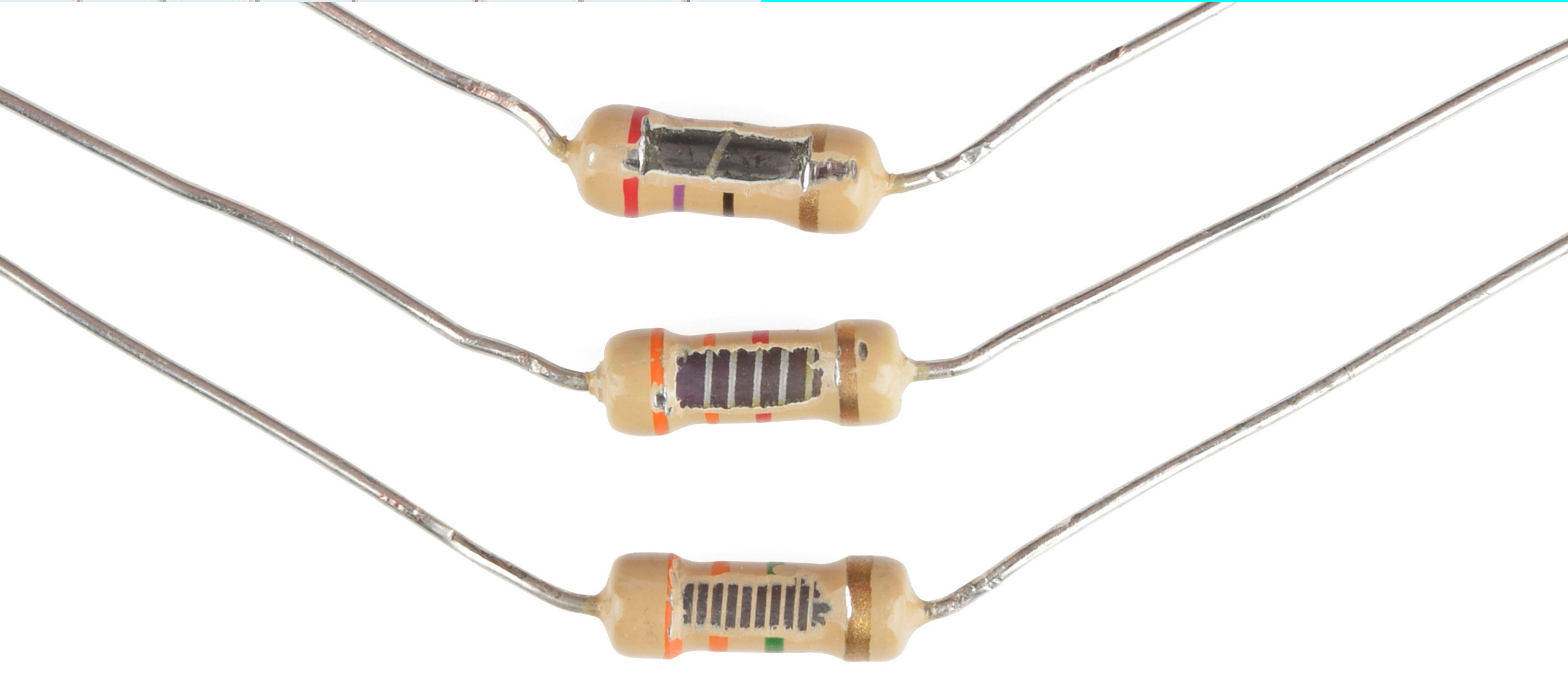
resistivity

$$V = IR \quad \text{Ohm's Law}$$

$$R = \rho \frac{L}{A}$$



Resistors



What's a resistor ... Why do I want one?

Resistors are devices that are meant to resist current flow. They obey Ohm's law.

They make a good way of turning electricity into heat (hair-dryers, electric stoves, space-heaters)

They stop batteries from discharging all at once.

They are unavoidable – because even if you don't want one, all wires have some resistance (except superconductors!).

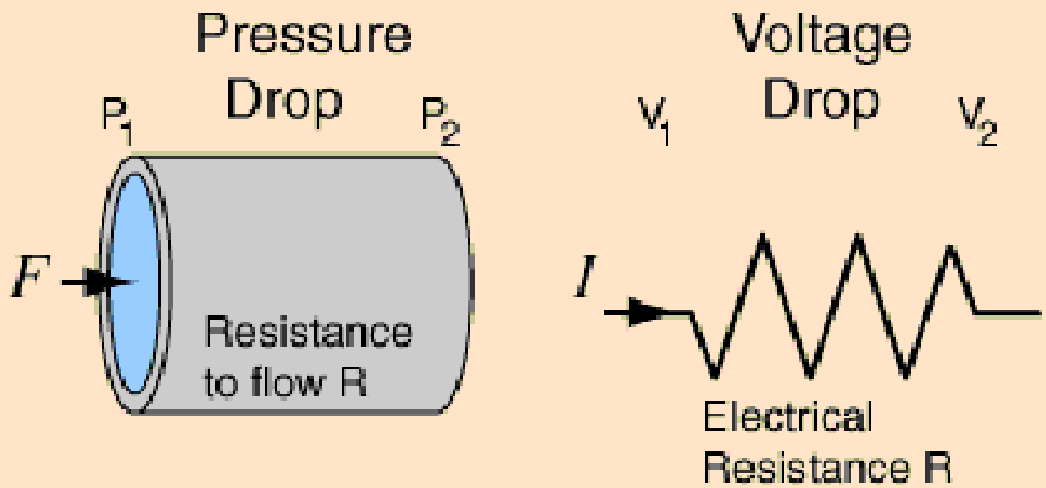
Body tissues have resistance.

Resistance is one of the “big three” basic electrical concepts (capacitance and inductance are the other two)

Ohm's Law-Poiseuille's Law

Ohm's law for electric current flow and Poiseuille's law for the smooth flow of fluids are of the same form.

$V = IR$ (Amps, Ω)



$$F = \frac{P_1 - P_2}{R} \qquad I = \frac{V_1 - V_2}{R}$$

Poiseuille's law for fluids — *Ohm's law for electric circuits*

Water analogy to DC circuits

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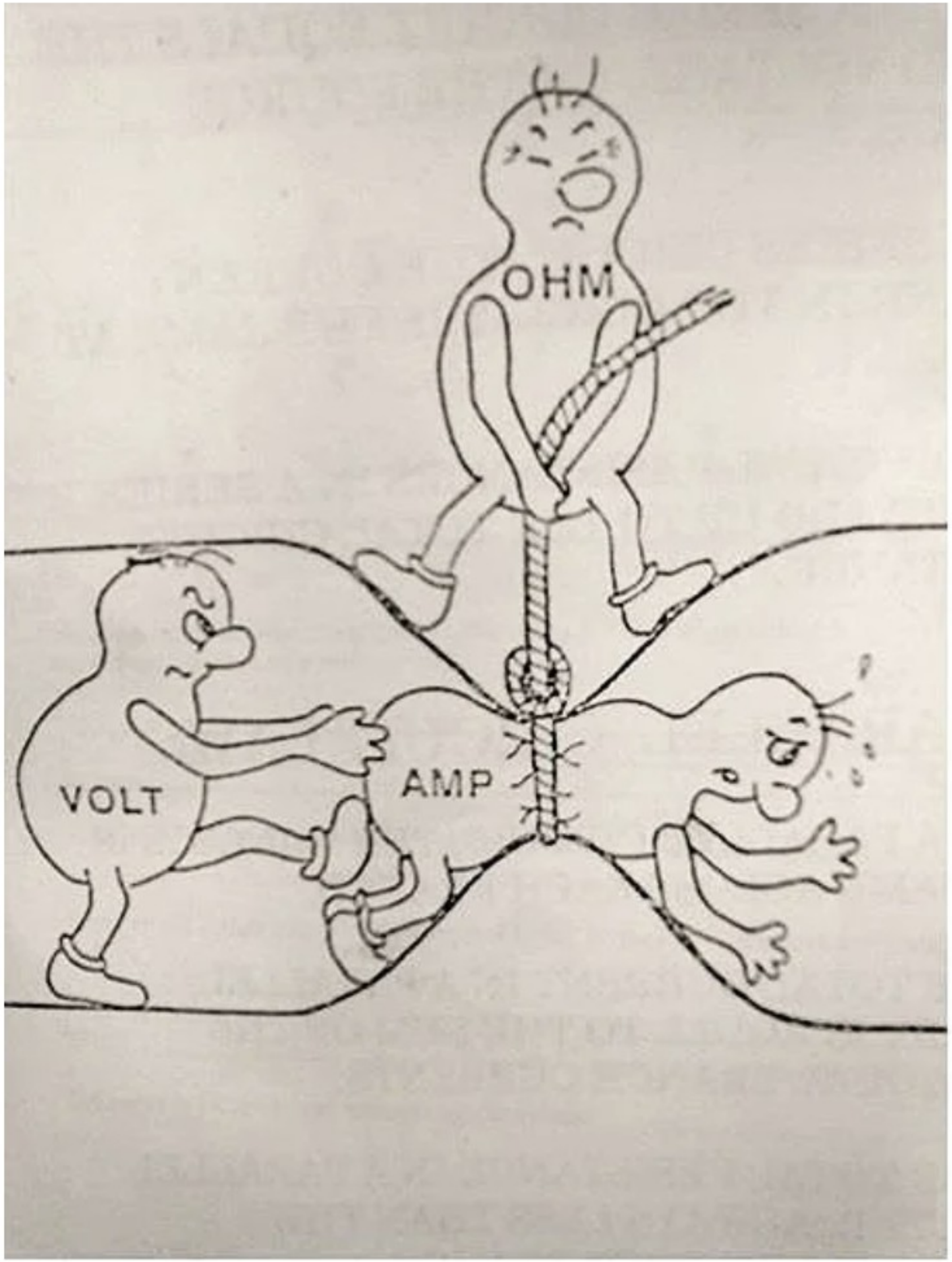
DC Circuits

Posted by u/arbili 7 years ago

1.7k

Electricity explained

i.imgur.com/HsUd5e...



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

Let's talk about electrocution!

"V" is safe, but "delta-V" is not.

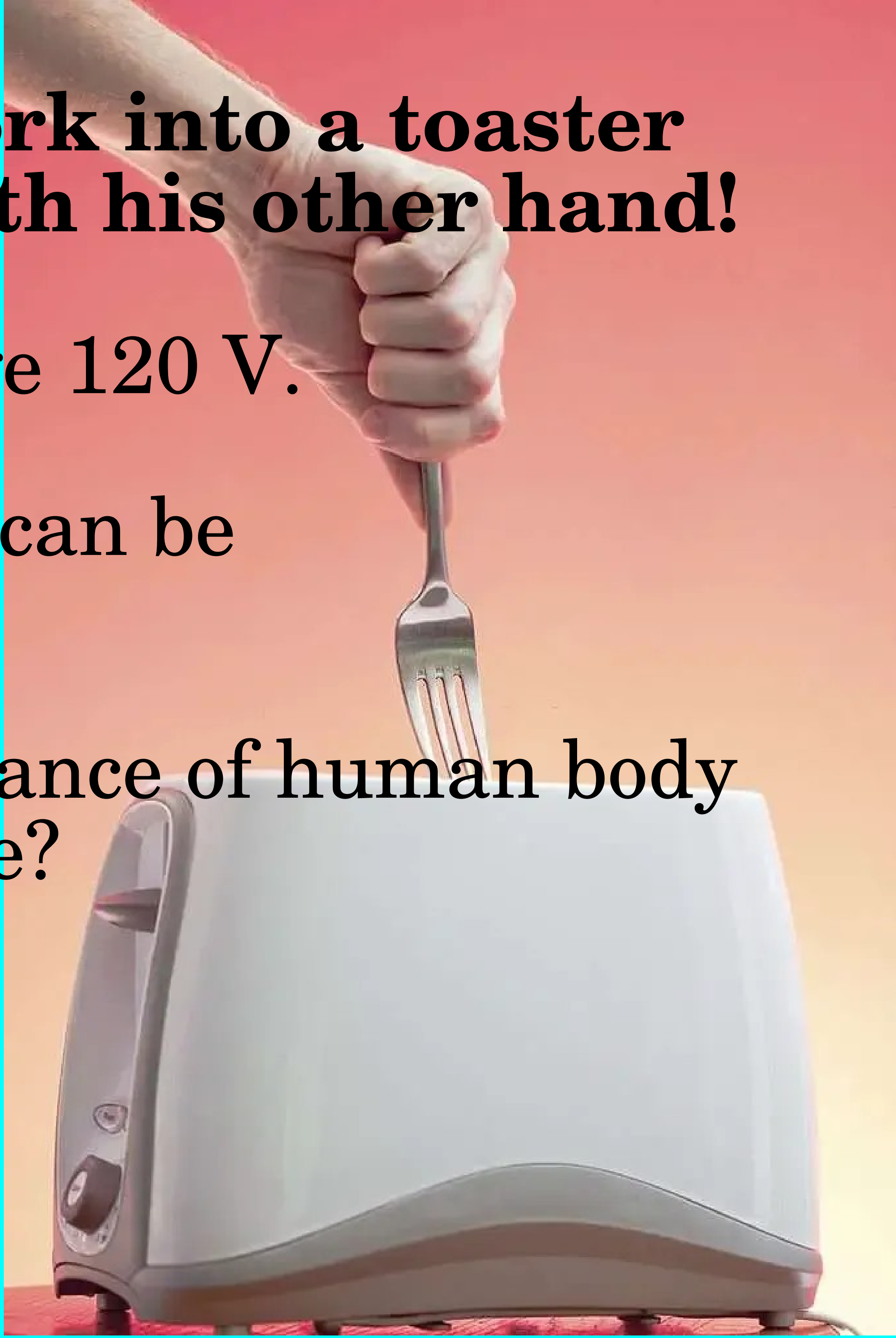
A person stick's a fork into a toaster and grabs a pipe with his other hand!

The toaster has voltage 120 V.

A current of 0.1 amps can be Fatal.

What minimum resistance of human body Would keep them alive?

$R = \rho \frac{L}{A}$



The toaster has voltage 120 V.

A current of 0.1 amps can be Fatal.

$I = \frac{120V}{120\Omega} = 1 \text{ Amp}$

What minimum resistance of human body Would keep them alive?

(A) 12000Ω

(B) 2400Ω

(C) 240Ω

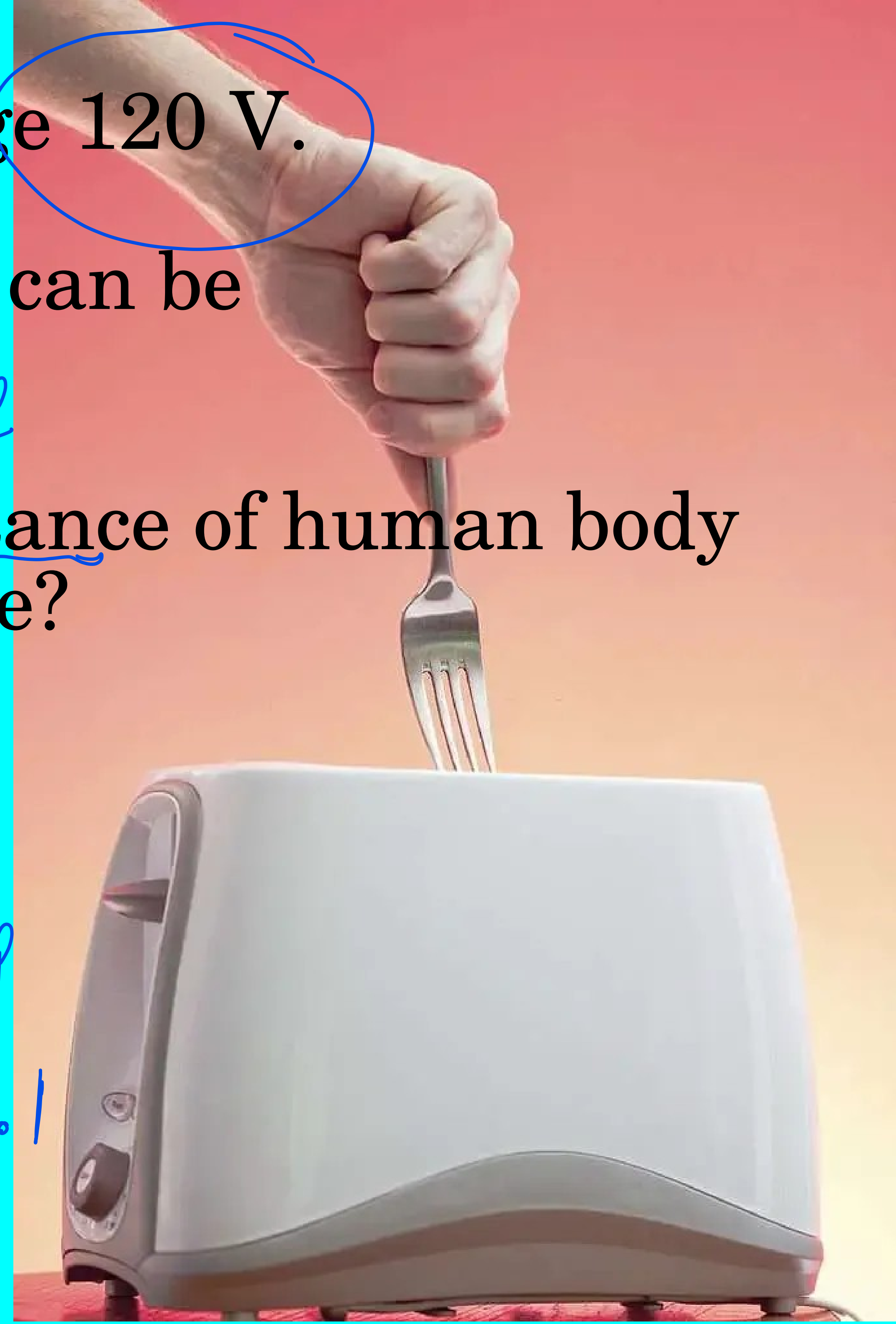
(D) 120Ω

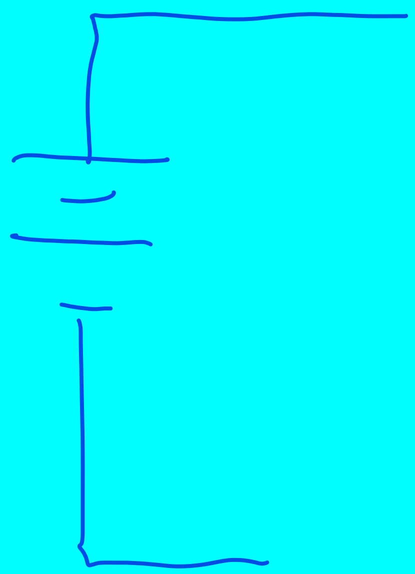
$V = IR$

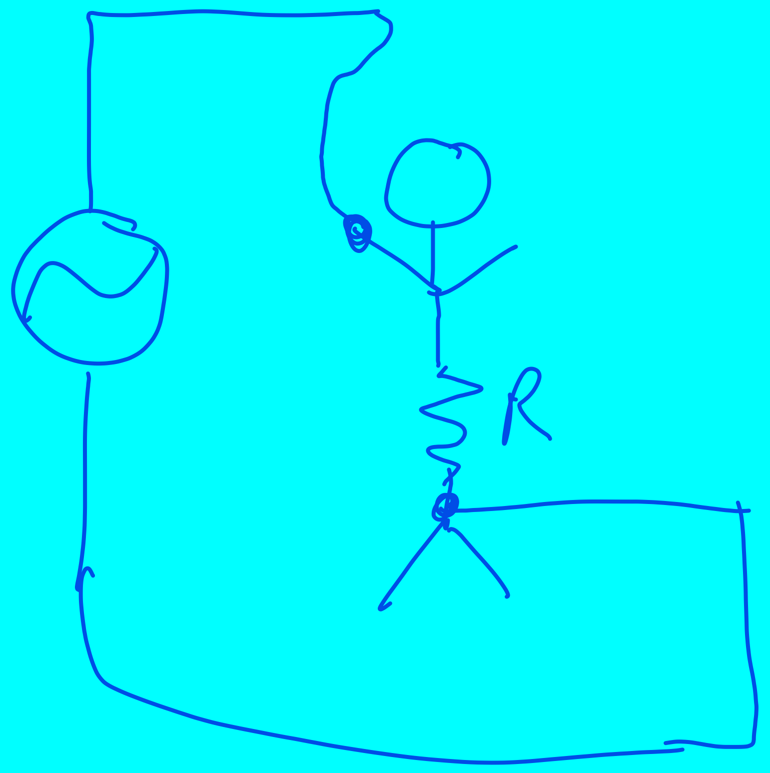
$I < .1 \text{ Amp}$

$\frac{V}{R} = \frac{120}{R} < .1$

$R > 1200\Omega$






R

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$-U = qV$

$[J] = [C][V]$

$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} V$

$P = IV$

$V = IR$

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

$\text{Power} = \frac{\text{Energy}}{\text{Time}}$

$= \frac{\Delta W}{\Delta t} = \frac{\Delta U}{\Delta t}$

$= \frac{\text{Joules}}{\text{sec}} = \text{Watt}$

$P = IV$

$P = I(IR)$

$P = I^2R$

$P = \frac{V}{R}V = \frac{V^2}{R}$

The voltage coming out of a wall outlet in North America is 120 V. How much current does it take to operate a 1800 Watt hair dryer?

$(A)\ 15\ \text{Amps}$

$(B)\ \dfrac{1}{15}\ \text{Amps}$

$(C)\ 9\times10^{18}\ \text{Amperes}$

$(D)\ 1800\ \text{A}$

$P = IV$

$1800\text{W} = (I)\,120$

An electric burner with 35 Ω resistance consumes 1.5 kiloWatts. At what voltage does it operate?

(A) 120 V
(B) 230 V
(C) 52,500 V
(D) 14,400 V
(E) 42.8 V

1500 Watts

$P = IV$

$P = I^2R$

$P = \frac{V^2}{R}$

$V^2 = PR$

$V^2 = (1500)(35)$

$V = \sqrt{(1500)(35)}$

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Resistors and Capacitors in Series & Parallel

$$\frac{1}{C_{series}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

$$R_{series} = R_1 + R_2 + R_3 + \ldots$$

$$C_{parallel.} = C_1 + C_2 + C_3 + \ldots$$

$$\frac{1}{R_{parallel.}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

Resistors(and capacitors) in parallel have equal voltages.

Resistors (and capacitors) in series have equal currents.

Resistors and Capacitors in Series & Parallel

$$V = \frac{Q}{C} \qquad \frac{1}{C_{series}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

$$V = IR \qquad R_{series} = R_1 + R_2 + R_3 + \dots$$

$$C_{parallel.} = C_1 + C_2 + C_3 + \dots$$

$$\frac{1}{R_{parallel.}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

Resistors(and capacitors) in parallel have equal voltages.

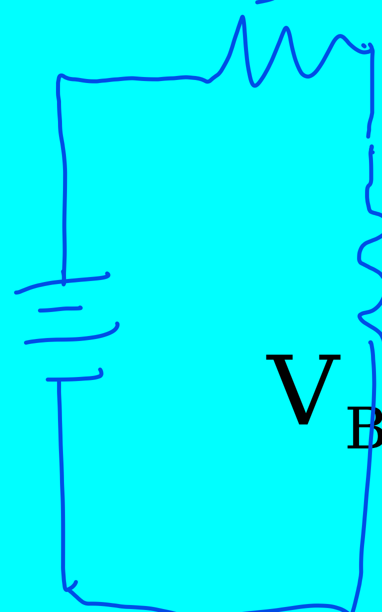
Resistors (and capacitors) in series have equal currents.

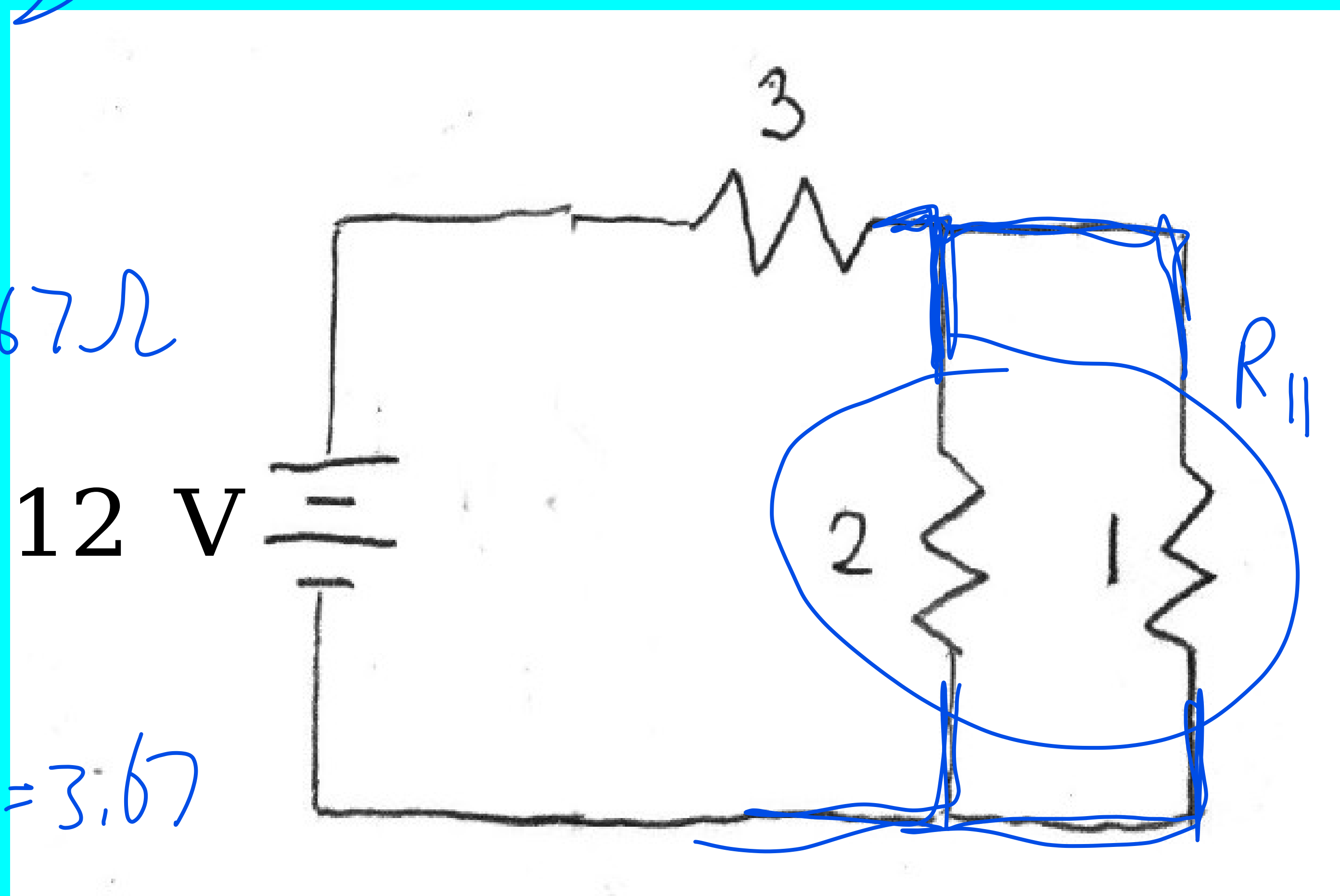
What is the equivalent resistance of this circuit? √

What is the voltage across the 2-Ohm resistor?

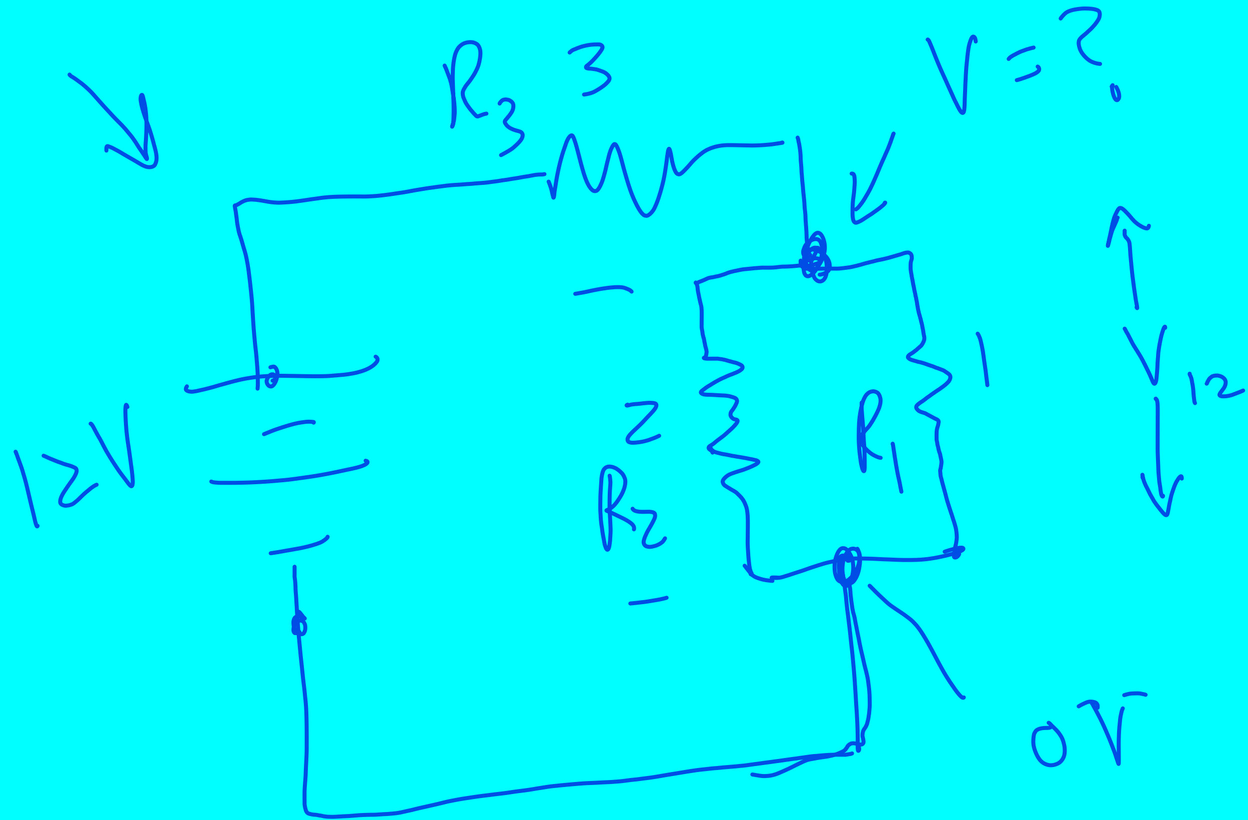
What is the voltage across the 3-Ohm resistor?

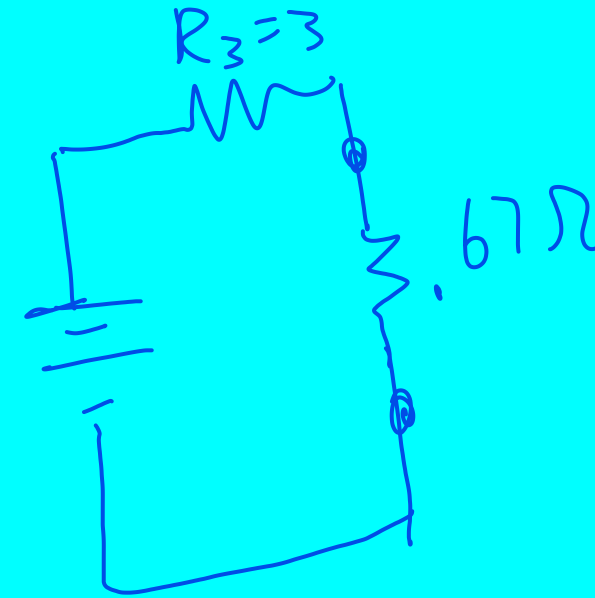
$\frac{1}{R_{\parallel}} = \frac{1}{1} + \frac{1}{2} = \frac{3}{2} \quad R_{\parallel} = \frac{2}{3}$





$R_{eq} = 3 + .67 = 3.67$





$3.67 = R_{eq}$

$$I = \frac{12\,V}{R_{eq}} = 3.27\,A$$

$$= \frac{12\,V}{3.67} = 3.27\,A$$

$$V_{12} = (3.27)(.67\,\Omega) = \ldots = 2.18\,V$$

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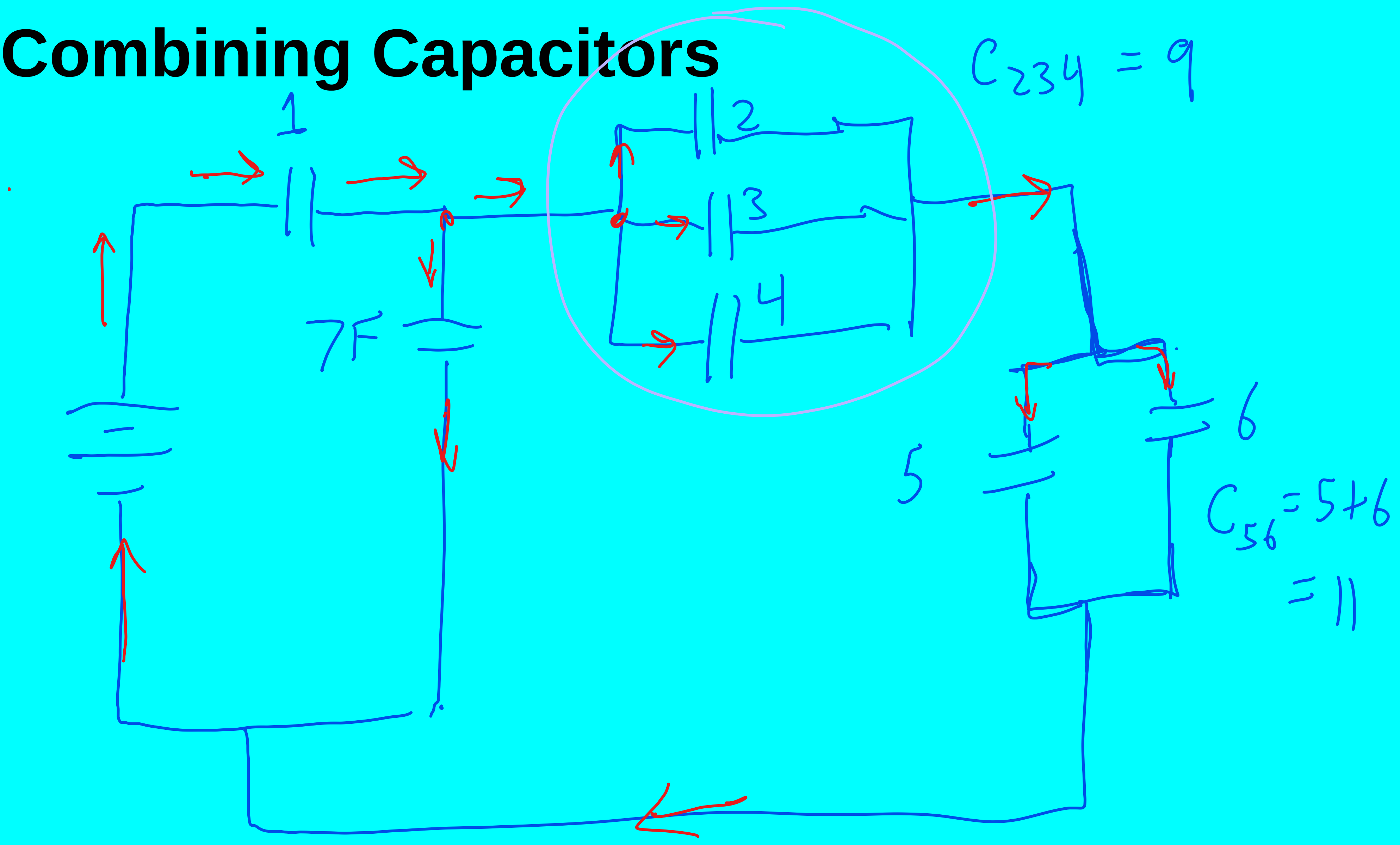
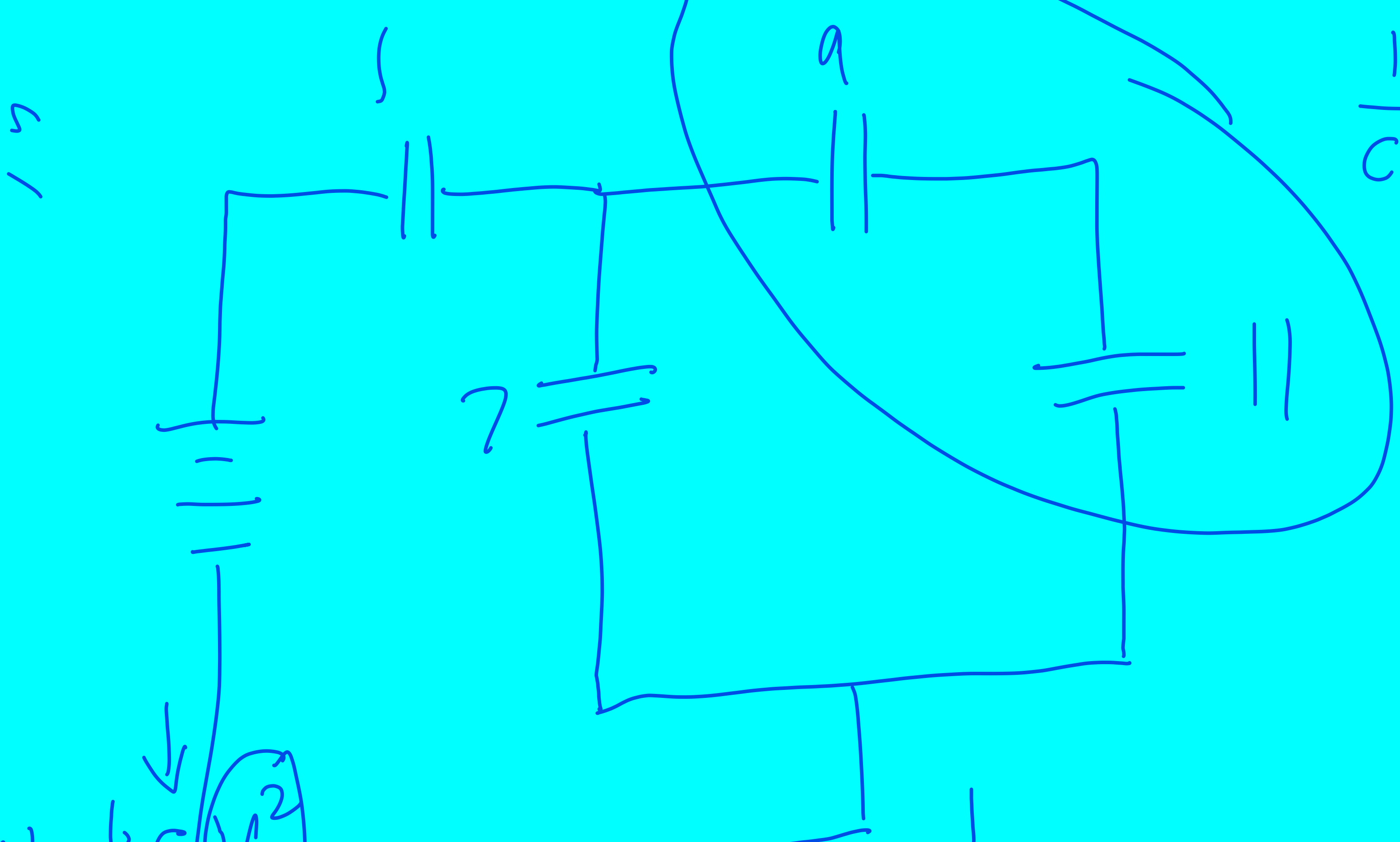
Two (or more) parts are in series if the electrons must go straight through
“no choices”
One “hose”

Two (or more) parts are in parallel if they are connected by a wire top and bottom
“electrons can choose a path”

Combining Capacitors





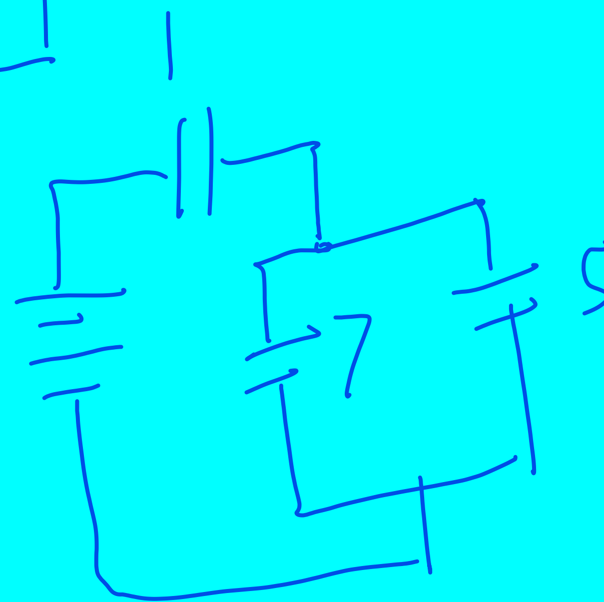
$$\frac{1}{C_{9,11}} = \frac{1}{9} + \frac{1}{11}$$

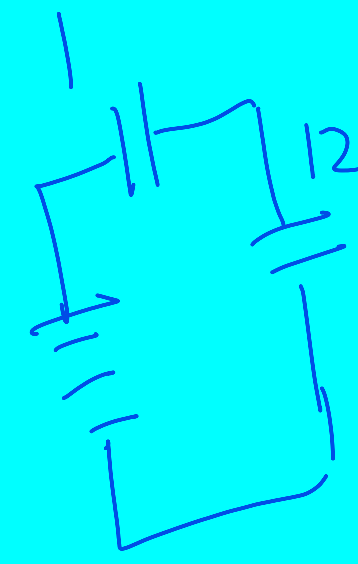
$$C_{9,11} = 4.95 \approx 5$$

$$U = \frac{1}{2} C V^2$$

$$Q = CV$$

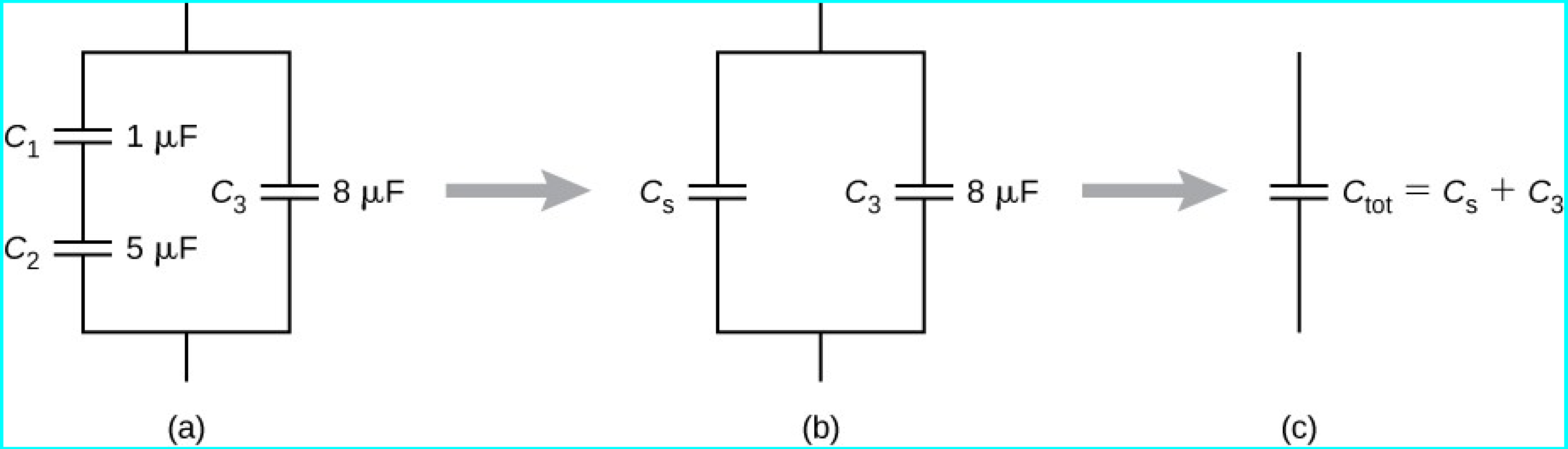
$C_{eff} = .92F$





Example

What is C effective for this circuit?



(A) 1.2 μF

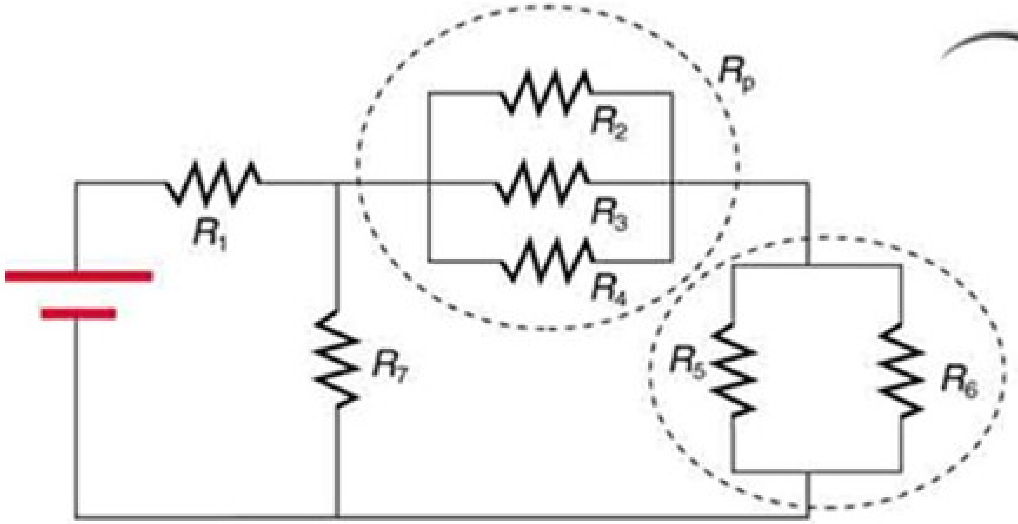
(B) 9.2 μF

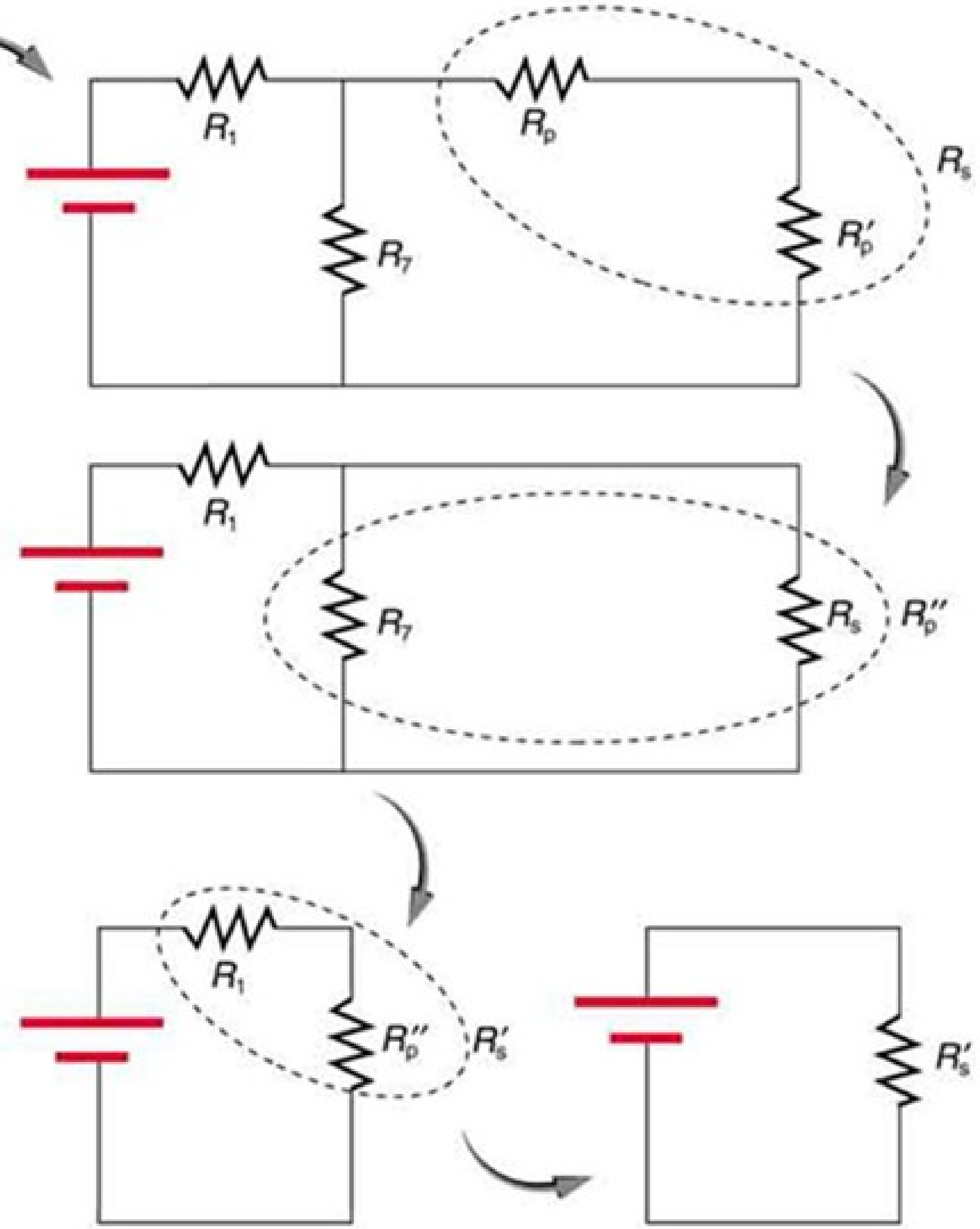
(C) 0.83 μF

(D) 14 μF

(E) 8.83 μF

Combining Resistors





$R_{eff\,s} = R_1 + R_2 + R_3 \ldots$

$V = IR$

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

Terrible electrical myth

"Current follows the path of least resistance" …

This is a HIDEOUS simplification of Ohm's law.

Given a "choice" current divides inversely proportional to the resistance of each path

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Kirchoff's "Laws"

Voltage Law

In a series circuit, voltages across the parts add up to the Battery voltage

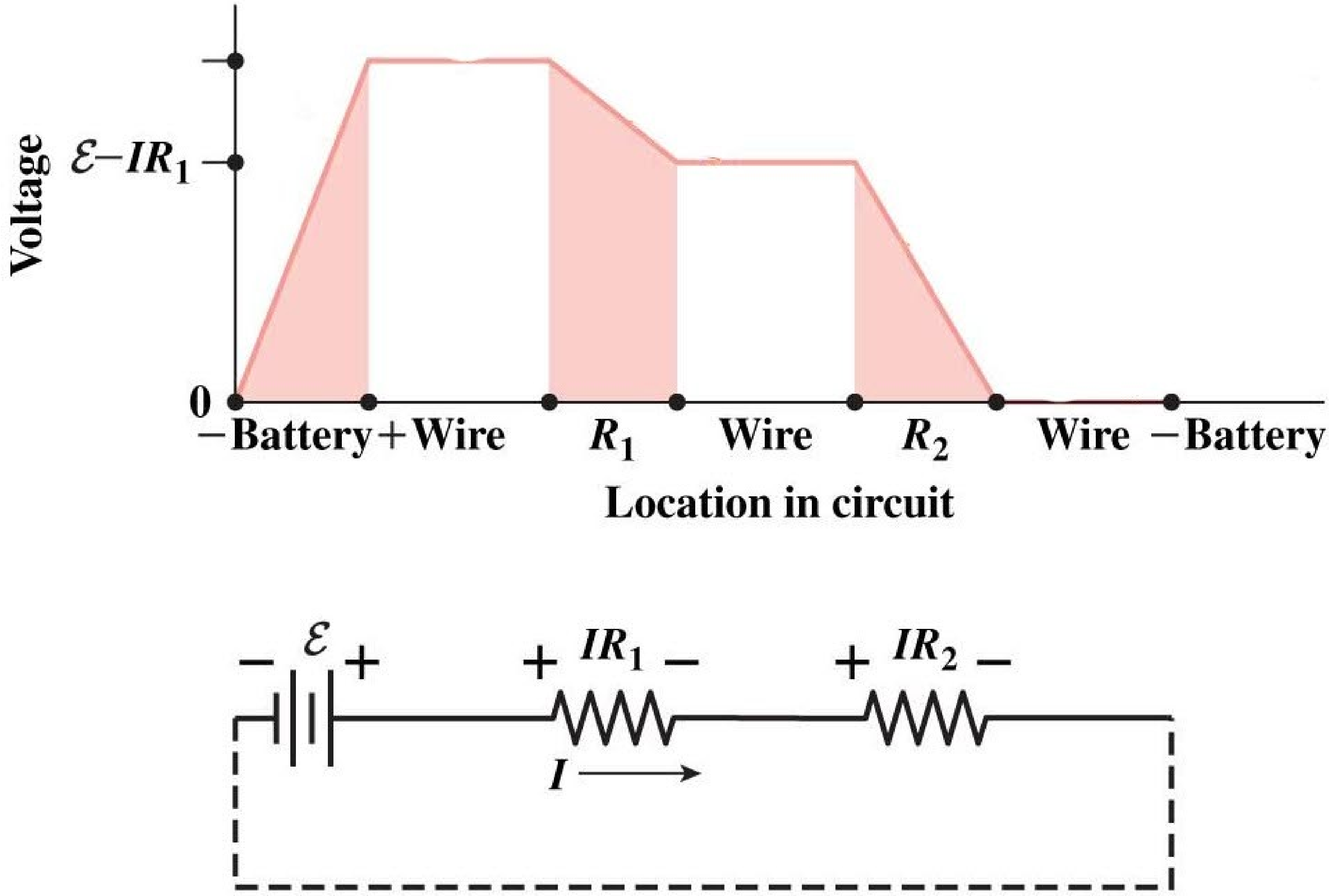
Current Law

In a parallel circuit, currents across the parts add up to the battery current. (In a series circuit all currents are the same)

Series circuits:

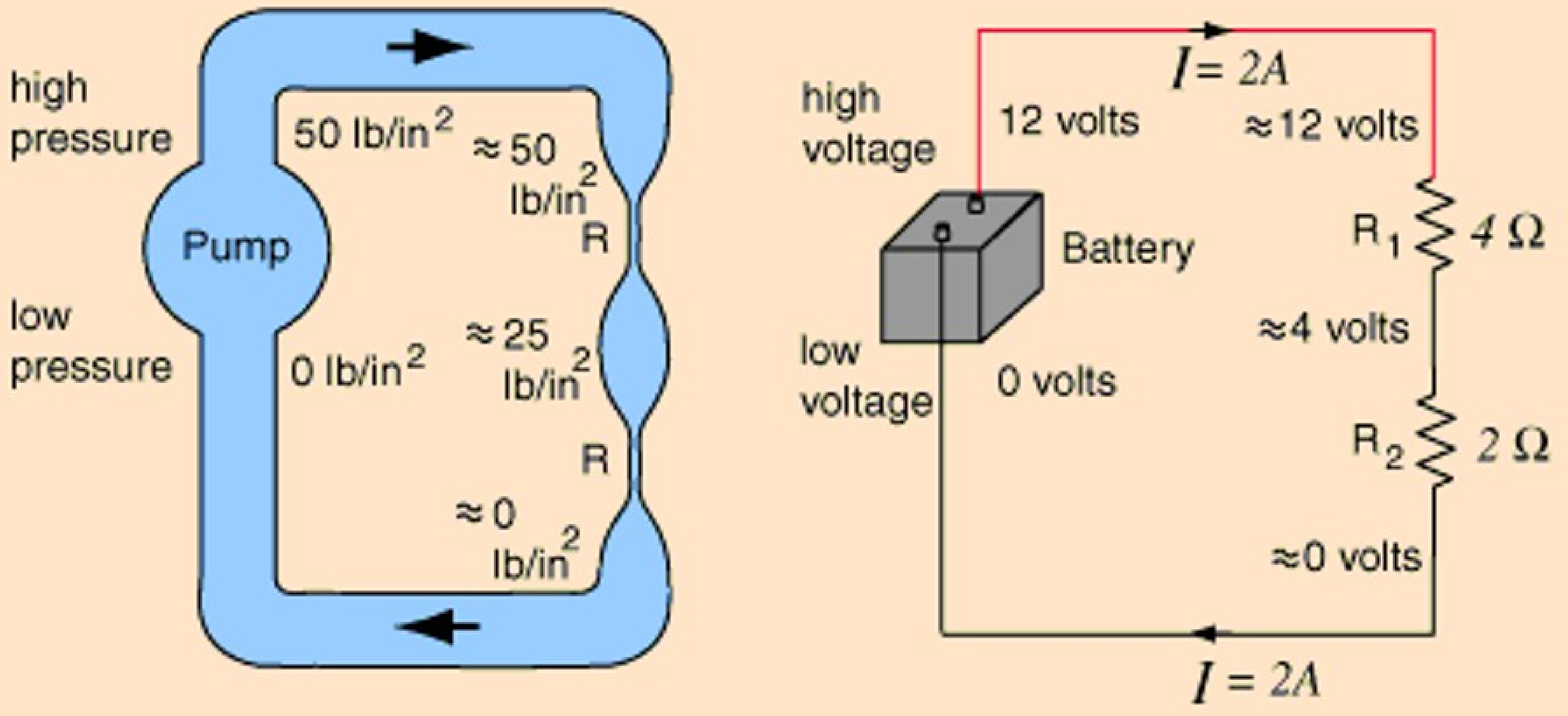
Same current in every part of circuit

Voltage drops at every resistor

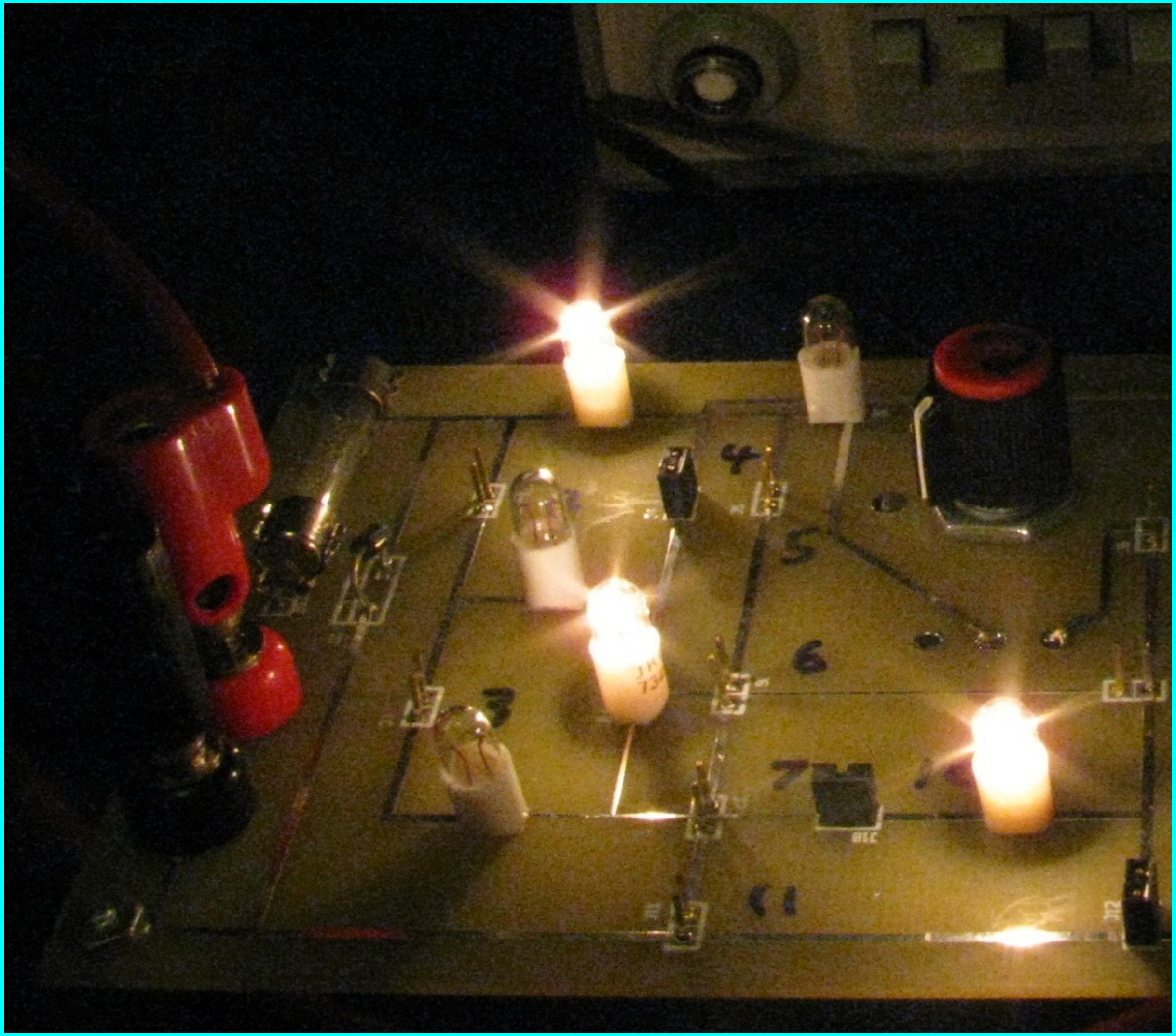


Series circuits:

Same current in every part of circuit.
Voltage drops at every resistor.



Series circuits:
All light bulbs equally bright …

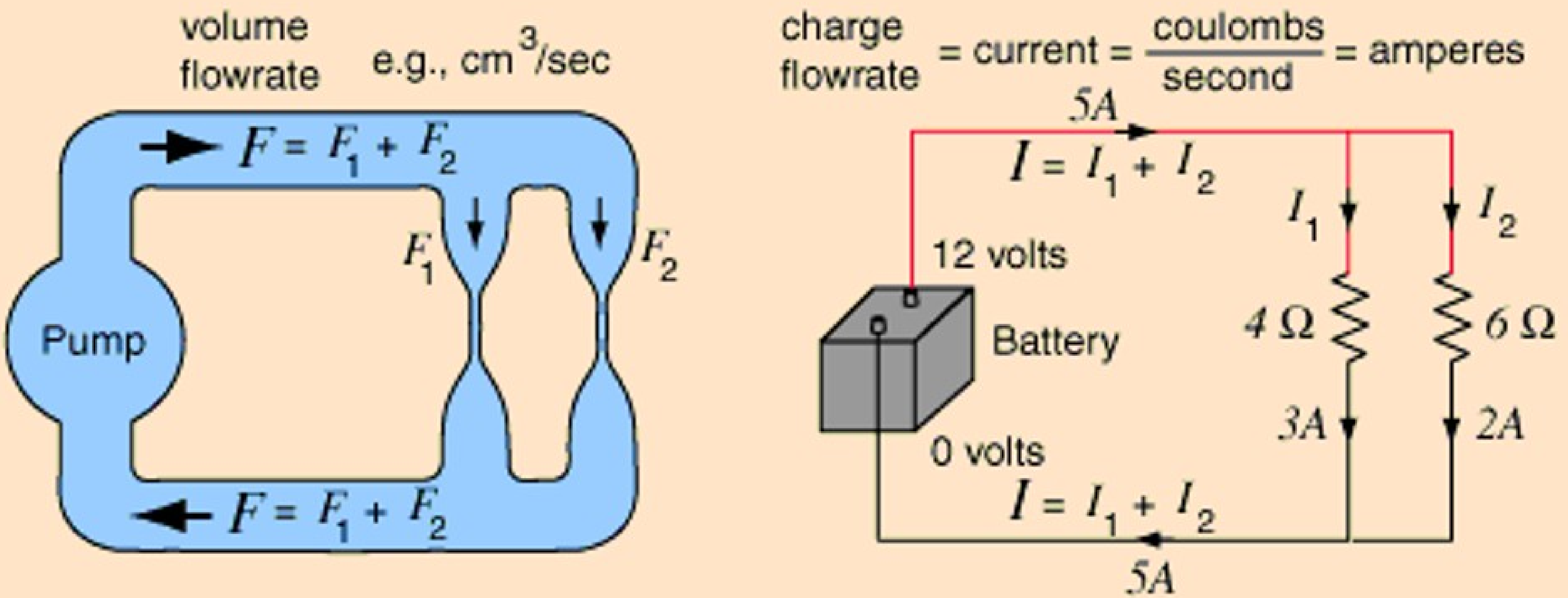


Parallel circuits:

Same voltage drop across resistors.

Current splits between resistors.

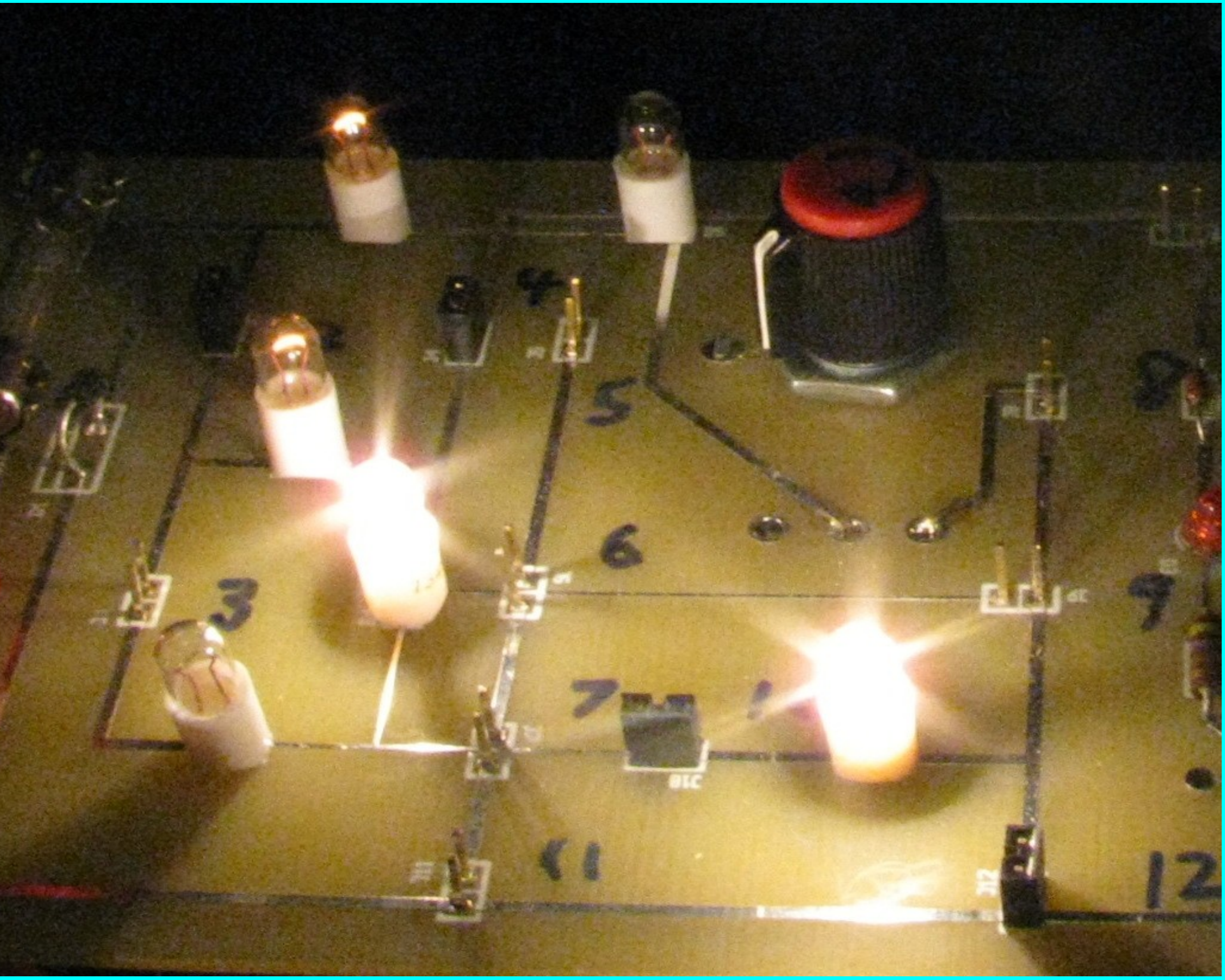
$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$



Parallel circuits:

Same voltage drop across resistors.

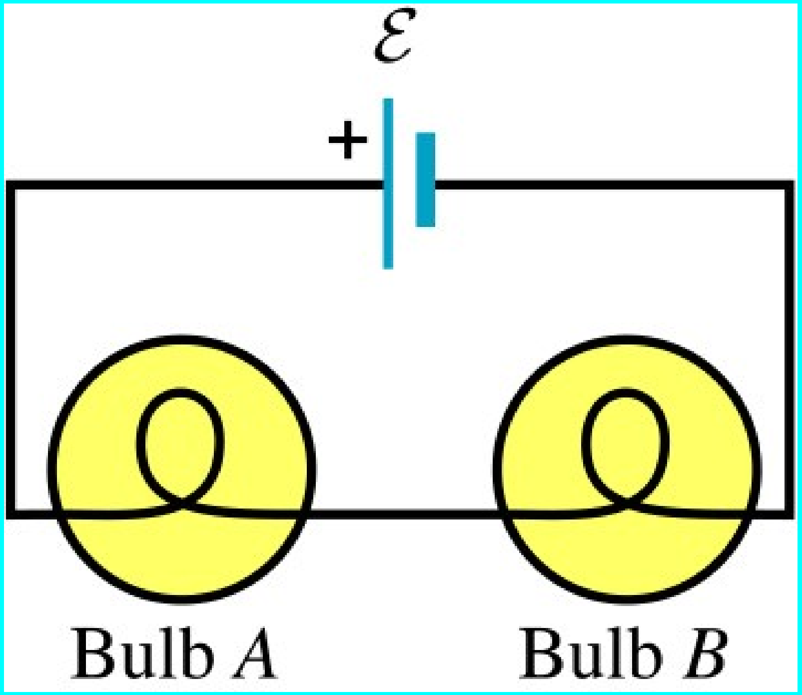
Current splits between resistors.



Clickers: A 2.0 Ω resistor is in series with a 6.0 Ω resistor. If the 2.0 Ω resistor has a current of 1.0 Amp, what is the current through the 6.0 Ω resistor?

[A] also 1.0 Amp
[B] 0.333 Amp
[C] 6.0 Amps
[D] 3.0 Amps
[E] Need more information to decide.

In the circuit shown, the two bulbs *A* and *B* are identical. Compared to bulb *A*,

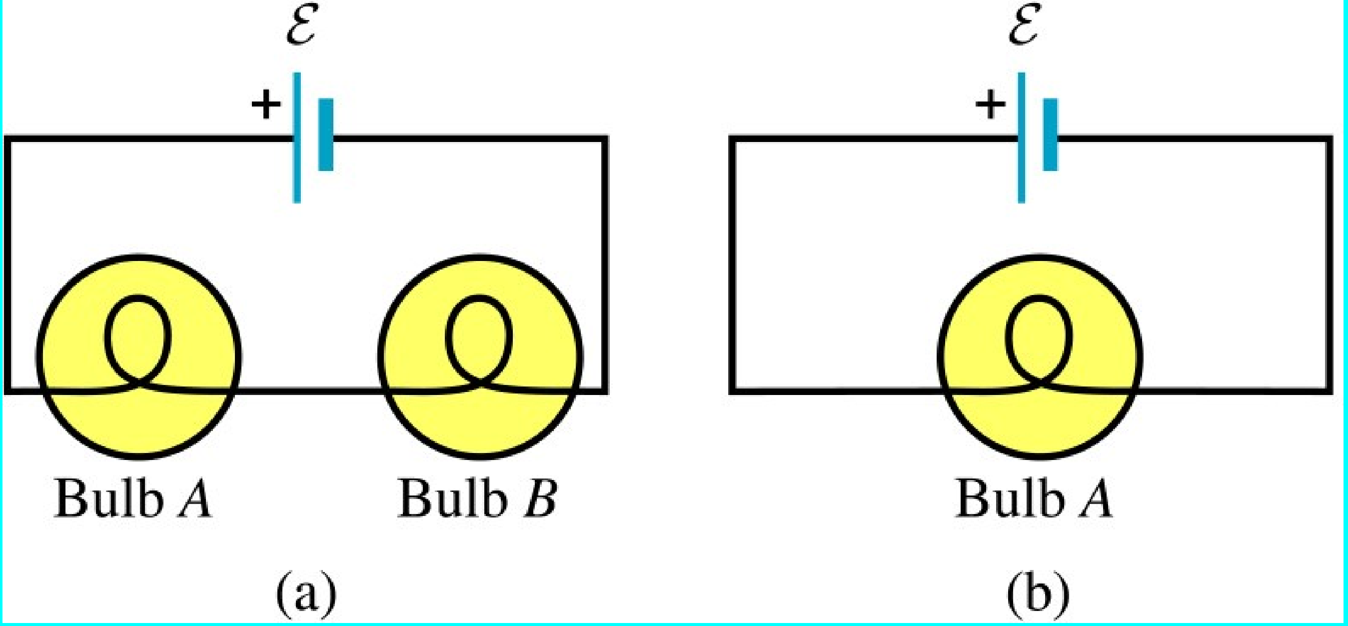


A. bulb *B* glows more brightly

B. bulb *B* glows less brightly

C. bulb *B* glows just as brightly

D. answer depends on whether the mobile charges in the wires are positively or negatively charged



In the circuit shown in (a), the two bulbs *A* and *B* are identical. Bulb *B* is removed and the circuit is completed as shown in (b). Compared to the brightness of bulb *A* in (a), bulb *A* in (b) is

A. brighter

B. less bright

C. just as bright

D. any of the above

Power, Current, and Voltage

Voltage is Energy per unit
Charge

$$V = \frac{U}{Q} \rightarrow U = QV$$

Power is Work per unit time
(or Energy expended per
Unit time)

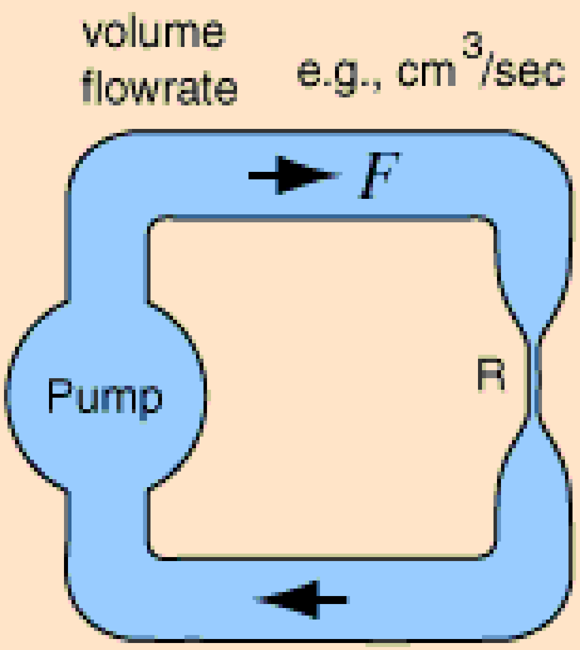
$$P = \frac{W}{\Delta t} = \frac{\Delta U}{\Delta t}$$

For constant voltage (e.g.
Current coming from a battery
Or an electric outlet)

$$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} V = I V$$

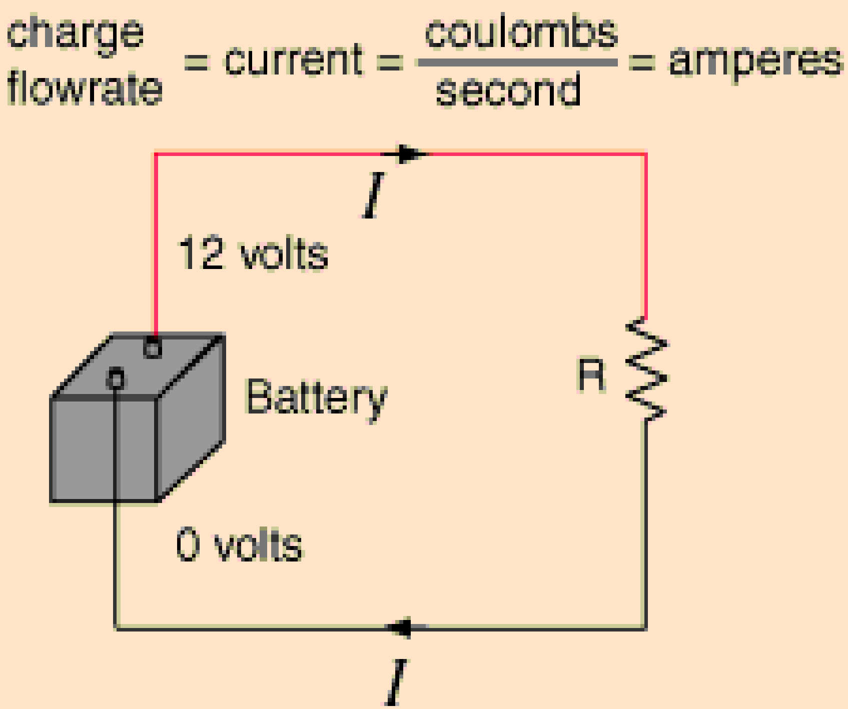
$$P = I V$$

Current Law and Flowrate



With continuous circulation around the pipe system, the volume flowrate must be the same at any cross-section of the pipe system.

Conservation of liquid



The electric current is the charge flowrate and it must be the same at any cross-section of the circuit. This is a general principle called the current law.

Conservation of charge

Internal Resistance

Why can't you start a car with AA batteries?

What is the capacitance of this cable?

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