Lecture 18: 03/15/2024

- Announcements
  Online HW6 due next Monday. No written.
  This week, Ch. 9/10

- Last Time
  Circuits, current, voltage, charge
  Series/parallel resistors/capacitors
  Kirchoff's "laws"

- Today
  Internal resistance
  EMF
  Resistance and resistivity

Scientists:

What's true? Are there exceptions?

How does it work?

Why does it work?

How does it relate to things we already knew?

How can I make it simple?

Scientists:

What's true? Are there exceptions?

How does it work?

Why does it work?

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How can I make it simple?

Engineers:

It's true most of the time, good enough!

That's cool!

What can I build with it?

Oh … by the way, why doesn't my thing work right?

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

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

Resistance in terms of Resistivity

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

Current density

$$I = \vec{J} \cdot \vec{A} \qquad \vec{J} = \sigma \vec{E}$$

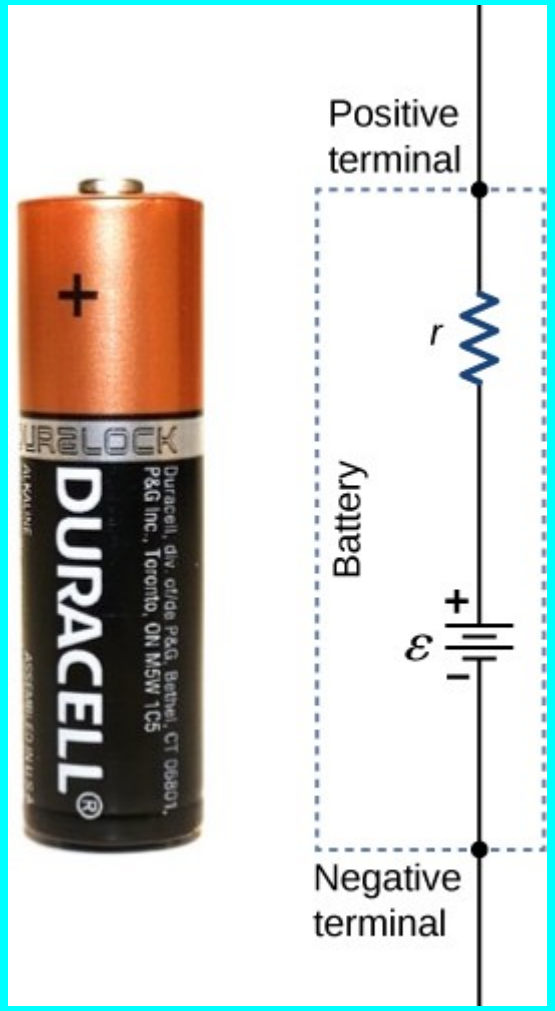
Drude Model

$$\vec{J} = n q \vec{v}_{drift}$$

- EMF and Voltage
- How Kirchoff's Rules lead to parallel/series formulae
- Internal Resistance
- Resistance and Resistivity
- Drude Model of Conduction

EMF vs. Voltage

When the current inside flows AGAINST the electric field (e.g. a battery) we call it EMF.



EMF vs. Voltage

When the current inside flows AGAINST the electric field (e.g. a battery) we call it EMF.

To make it less confusing … haha

It is fine to consider that voltage and EMF are the same thing.

Just call everything “voltage”

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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)

Resistors and Capacitors in Series & Parallel

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

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

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

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

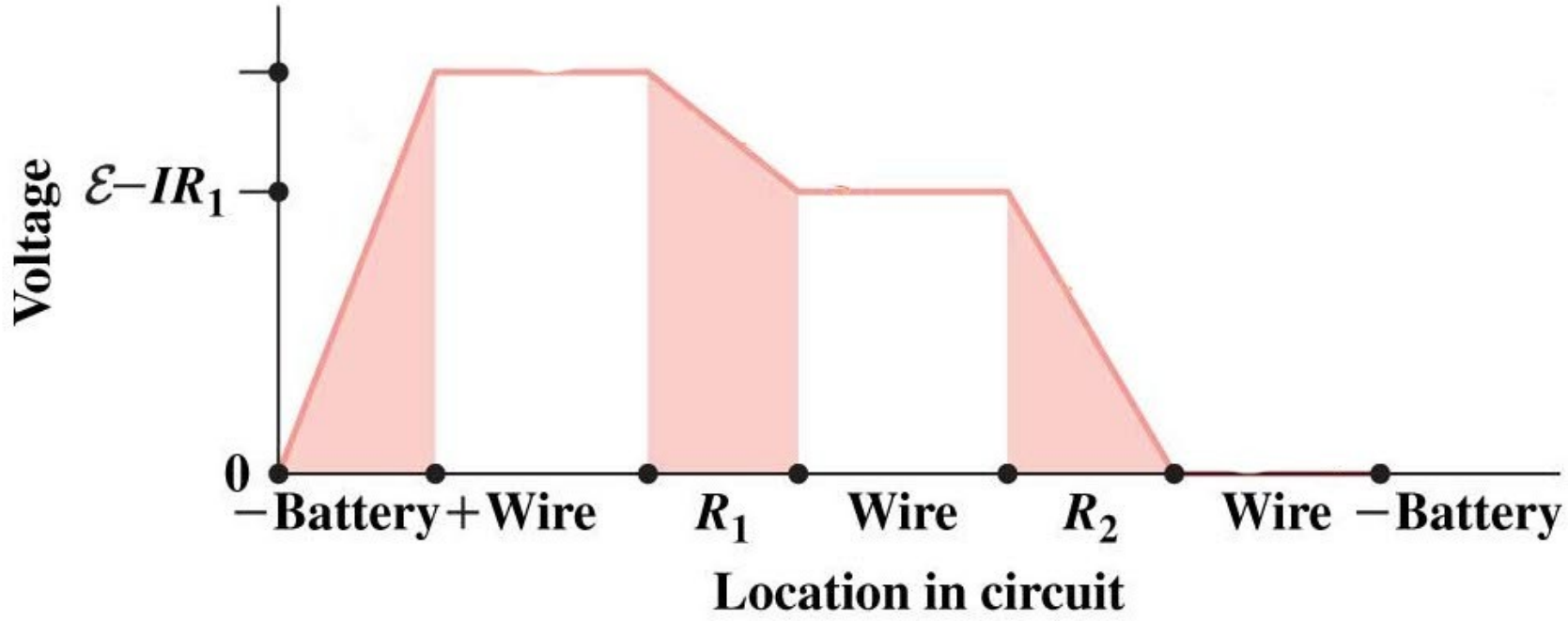
Resistors(and capacitors) in parallel have equal voltages.

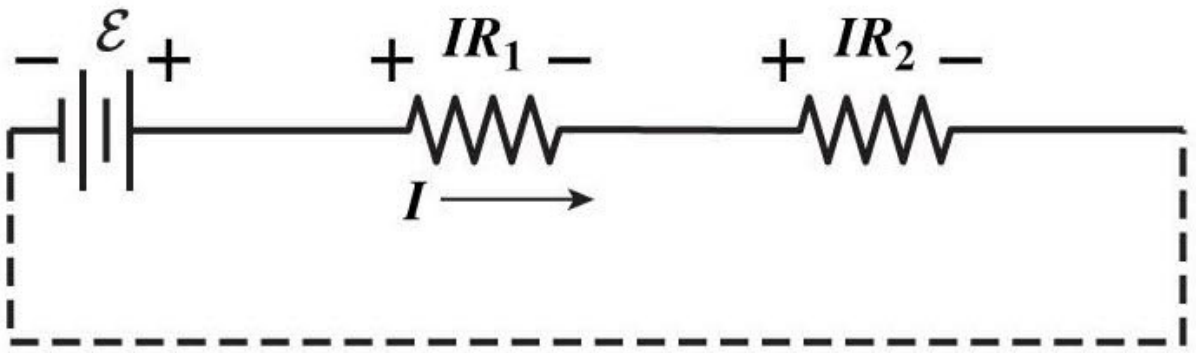
Resistors (and capacitors) in series have equal currents.

Series circuits:

Same current in every part of circuit

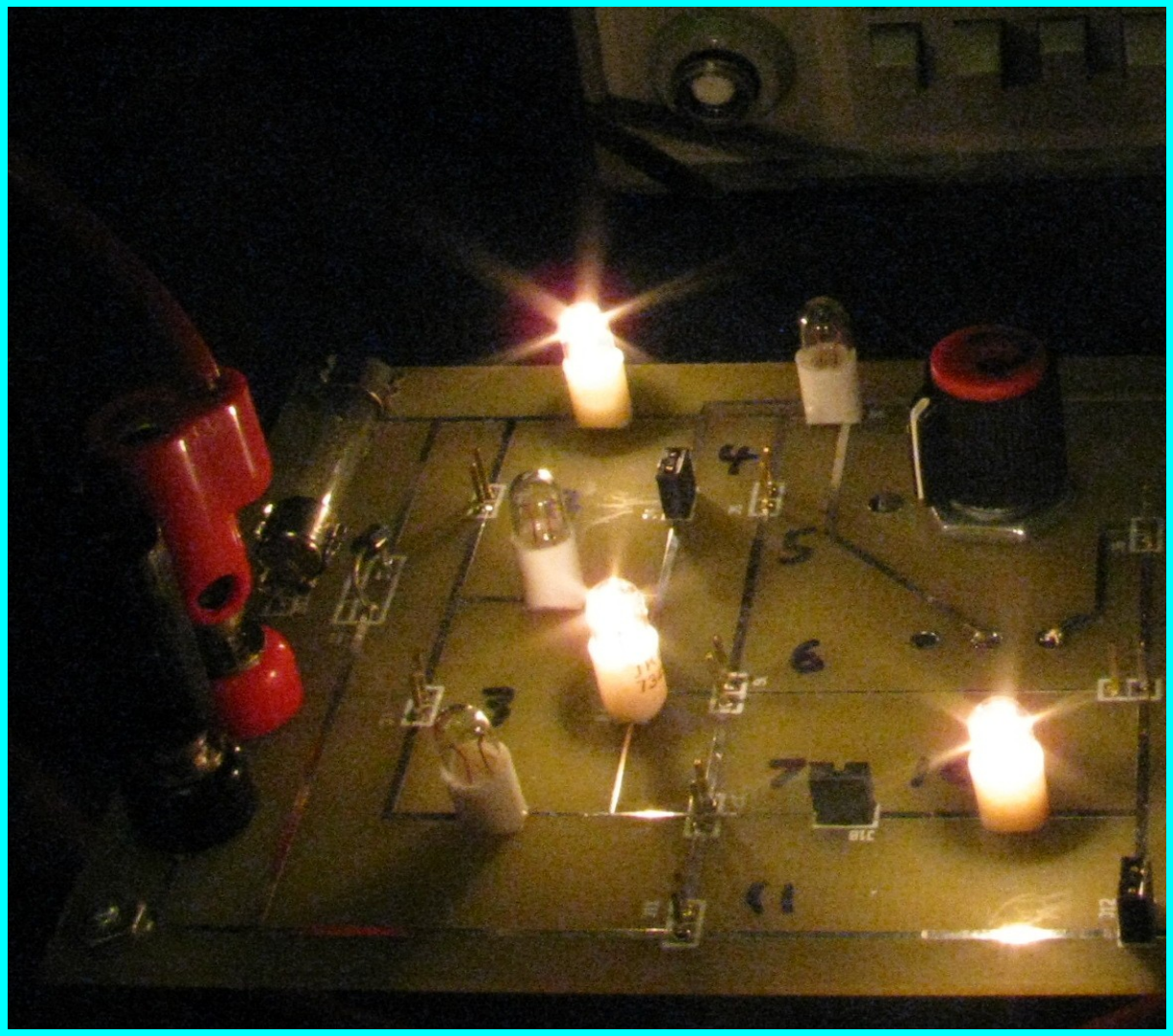
Voltage drops at every resistor





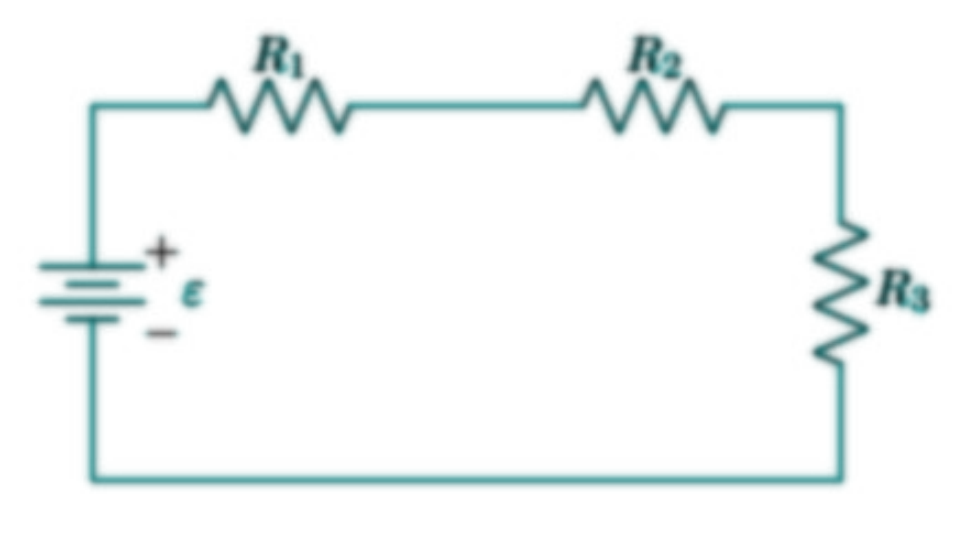
Series circuits:

All light bulbs equally bright …



Origin of series formula

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

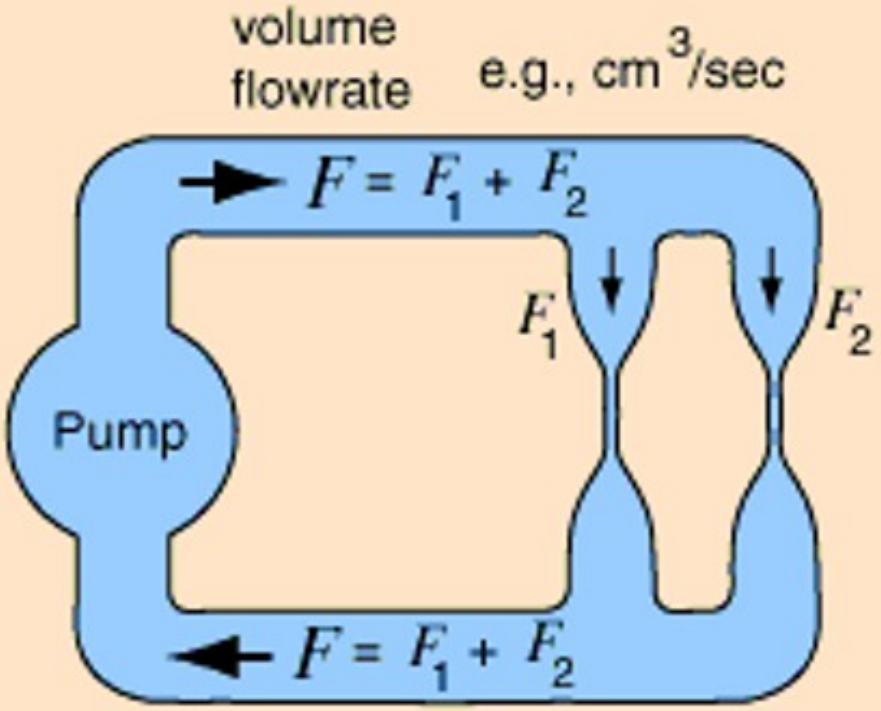


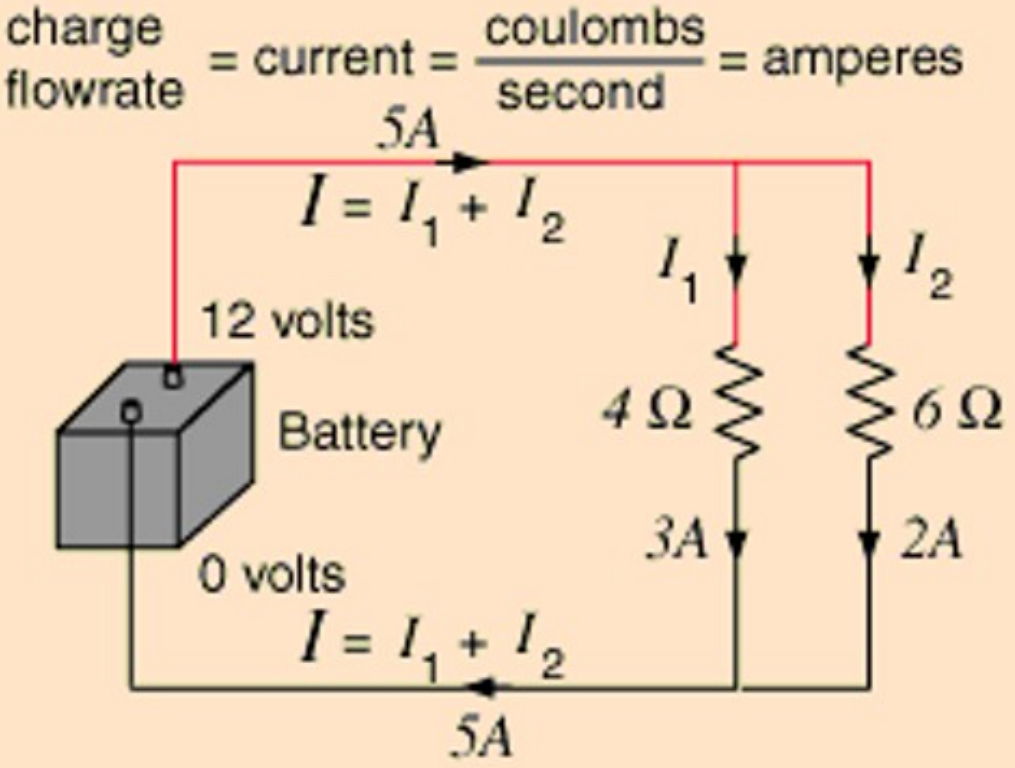
Parallel circuits:

Same voltage drop across resistors.

Current splits between resistors.

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





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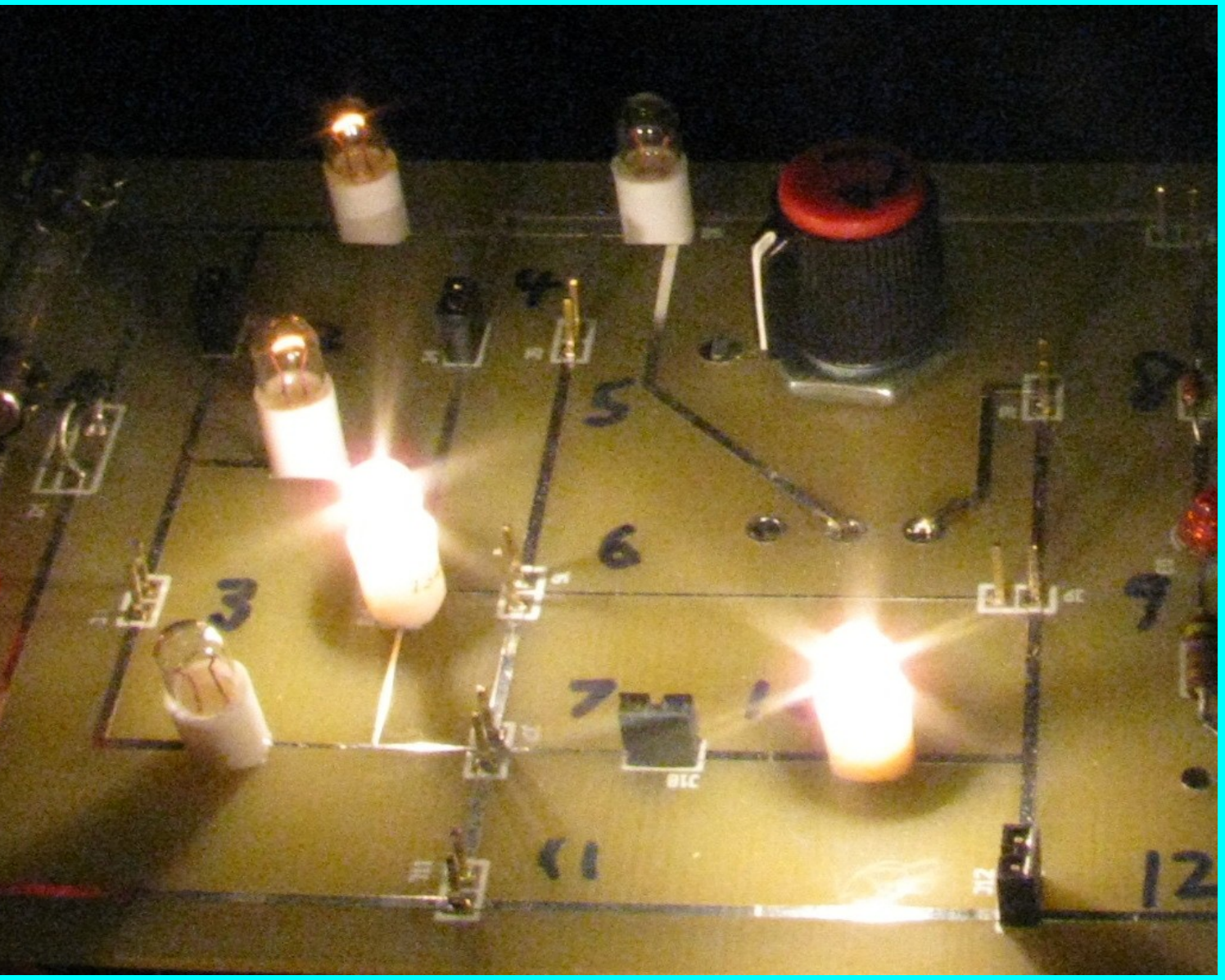

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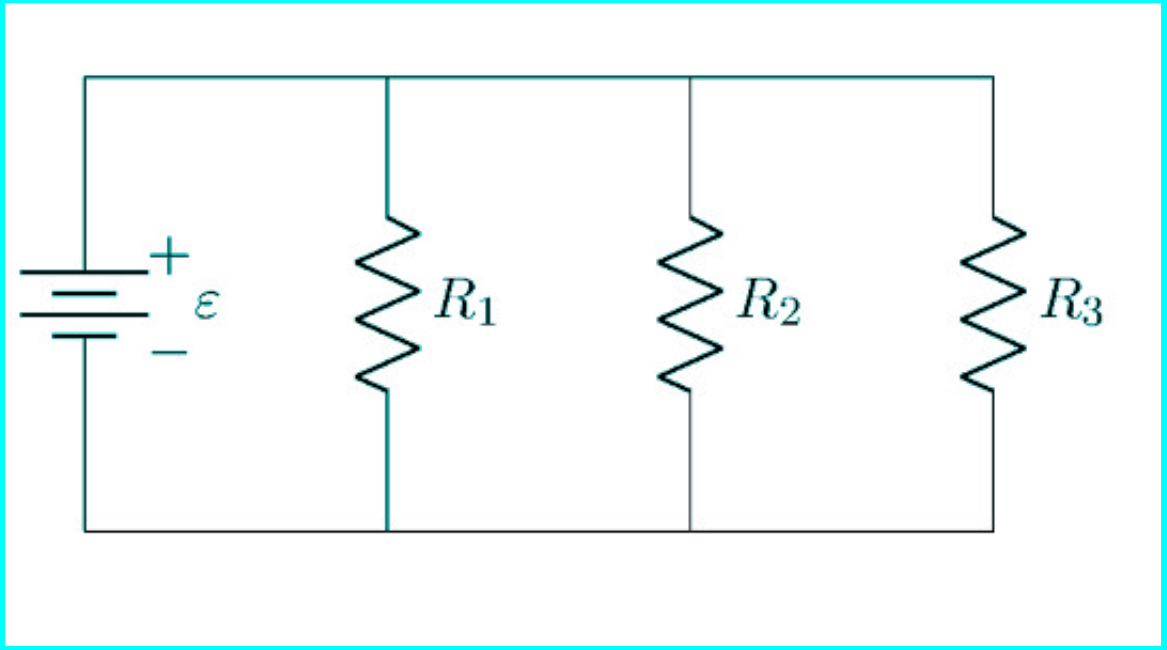
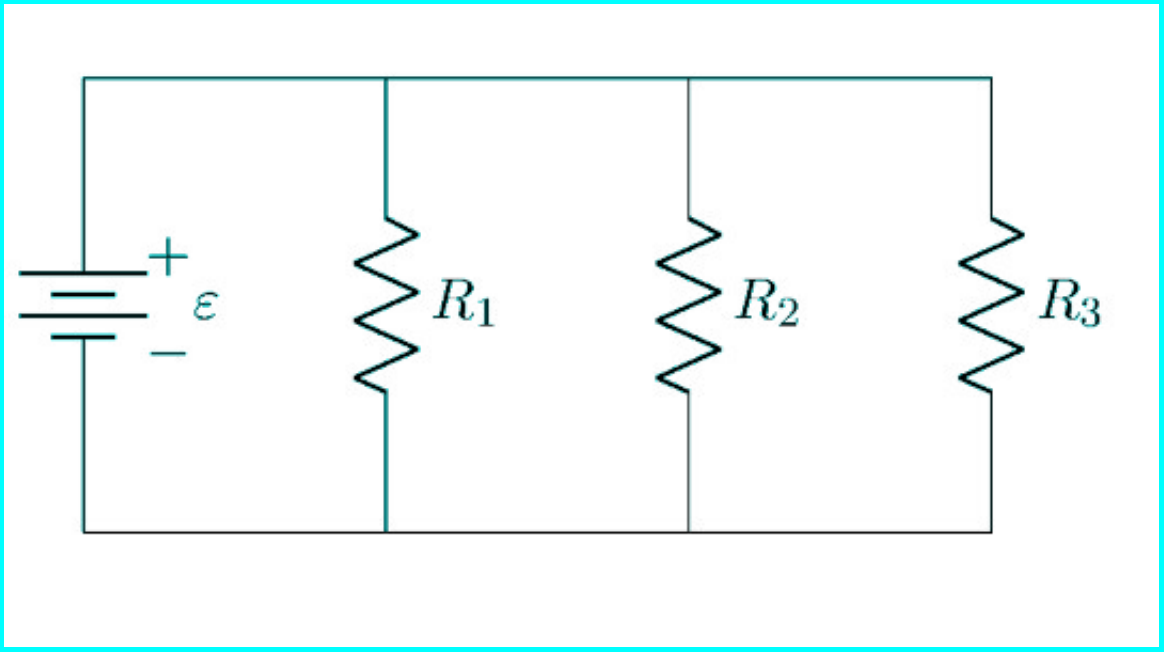
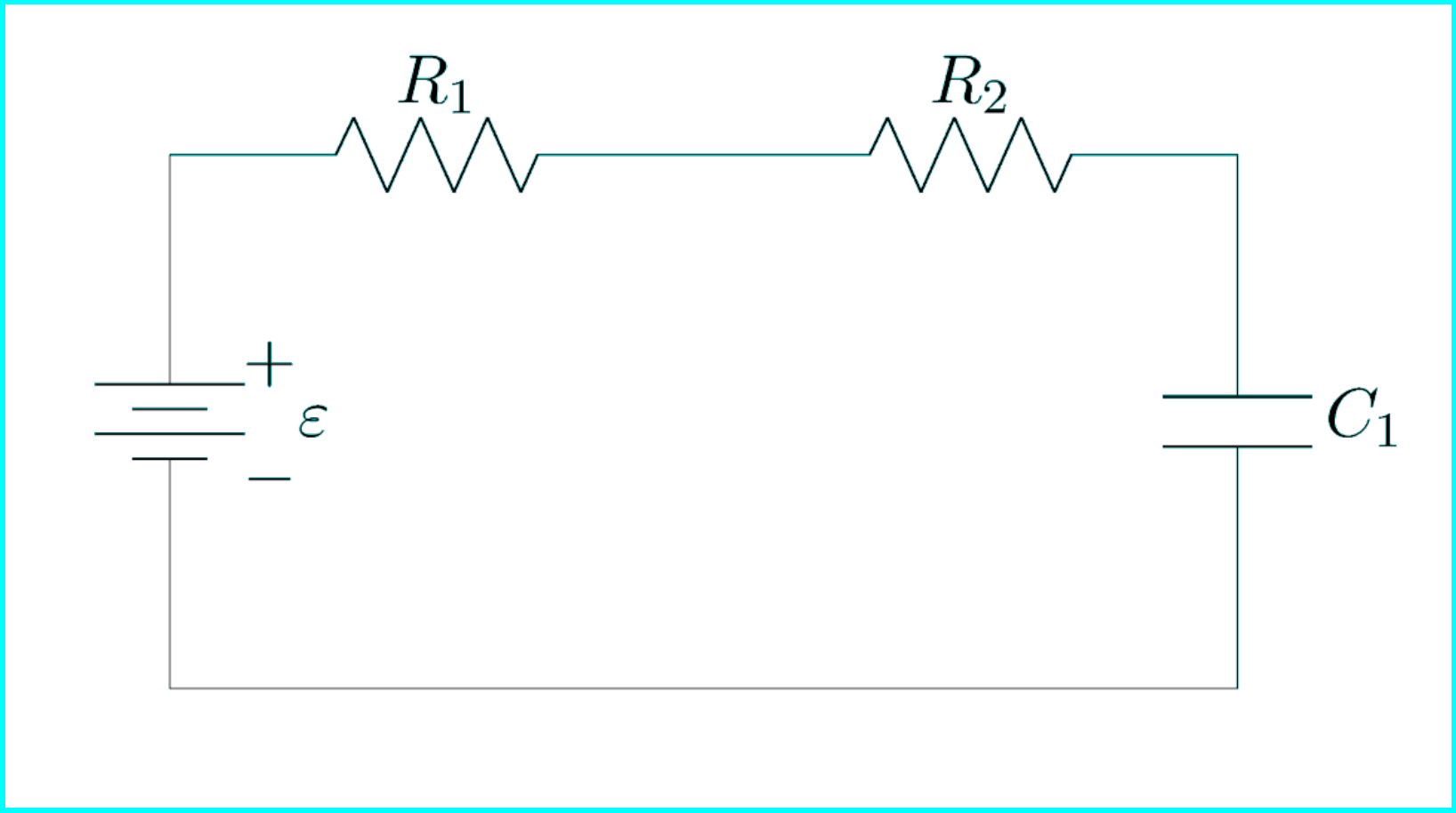



+
ε
−
R_1
R_2
R_3

What is the voltage across C1?

$\varepsilon = 10\,\mathrm{V}; I_1 = 2\,\mathrm{A}; R_1 = 1\,\Omega, R_2 = 2\,\Omega$



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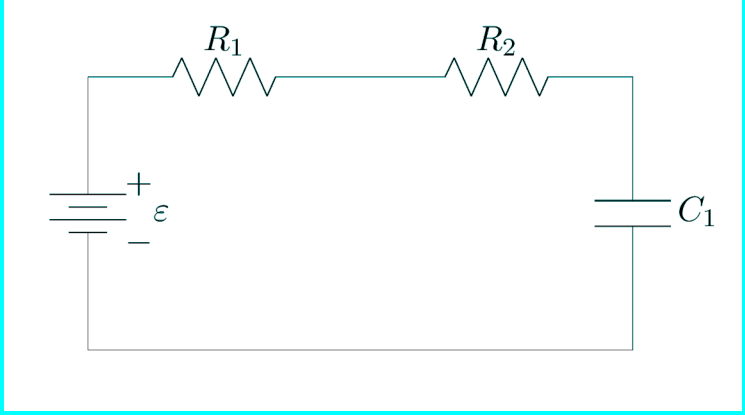

(A) 1 V

(B) 2 V

(C) 4 V

(D) 6 V

(E) 10 V

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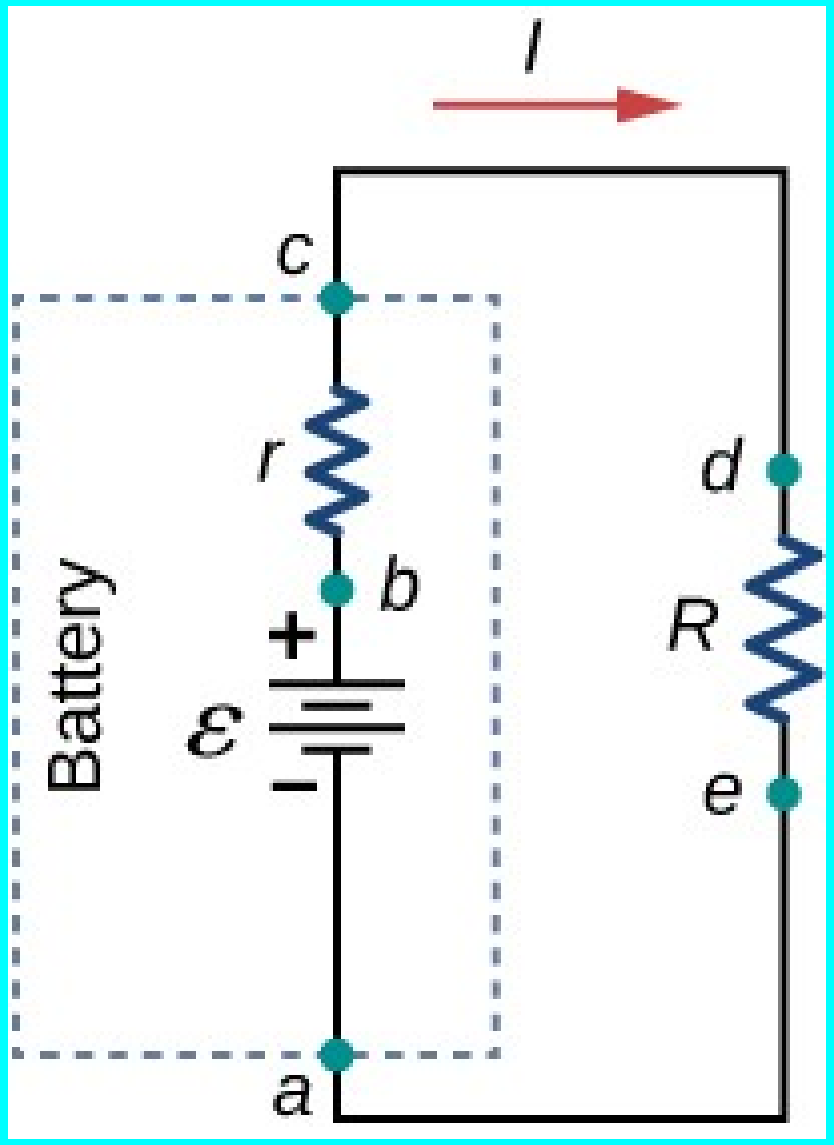
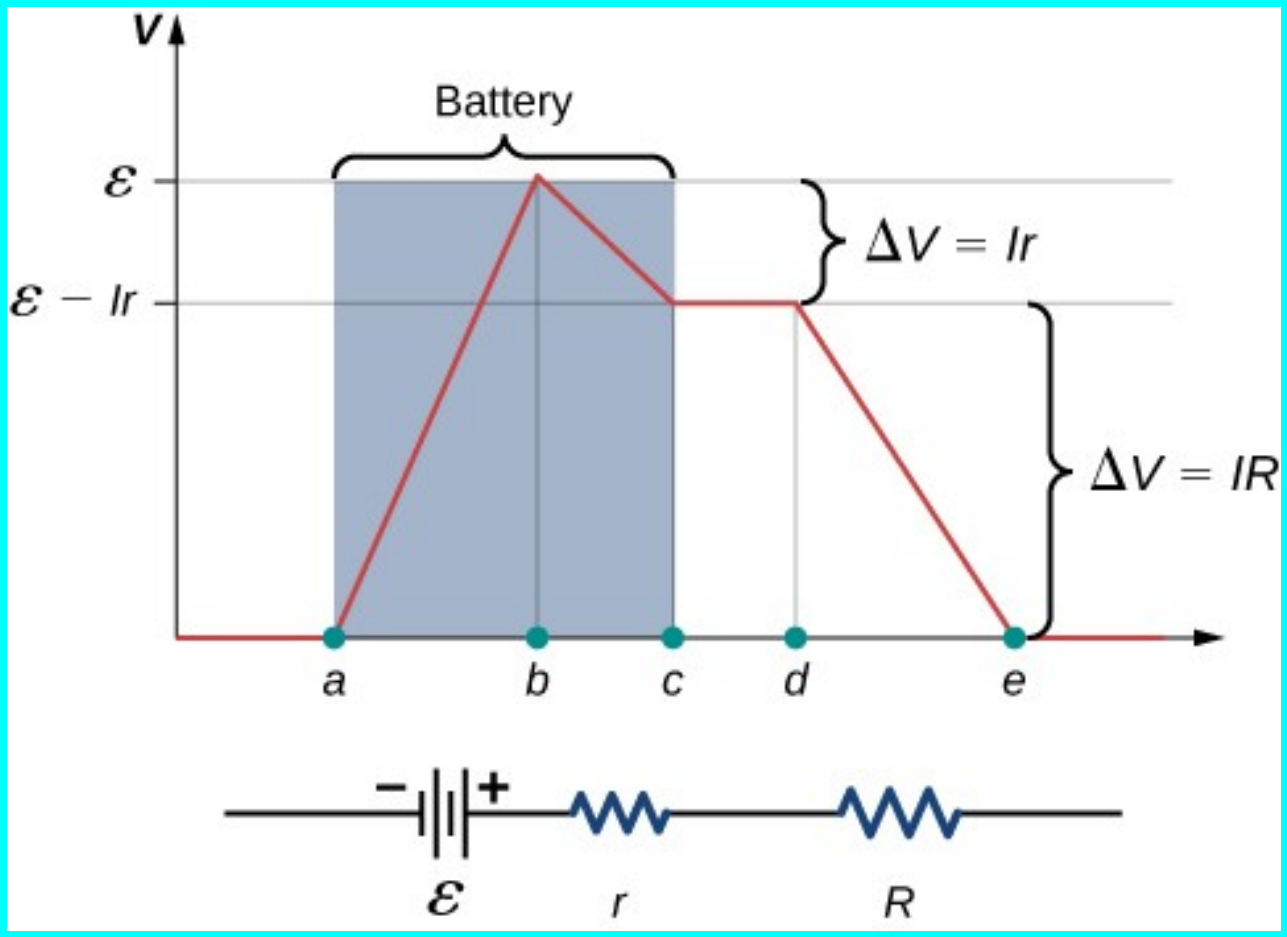
Internal Resistance

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


I
c
r
d
b
Battery
+
R
ε
−
e
a


V
Battery
ε
ε − Ir
ΔV = Ir
ΔV = IR
a
b
c
d
e
−
+
ε
r
R

A 12 Volt car battery has 0.01 Ohm internal resistance

The Engine takes 500 Amps to start.
What voltage do you measure at the battery terminals?

(A) 1 V

(B) 3 V

(C) 5 V

(D) 7 V

(E) 12 V

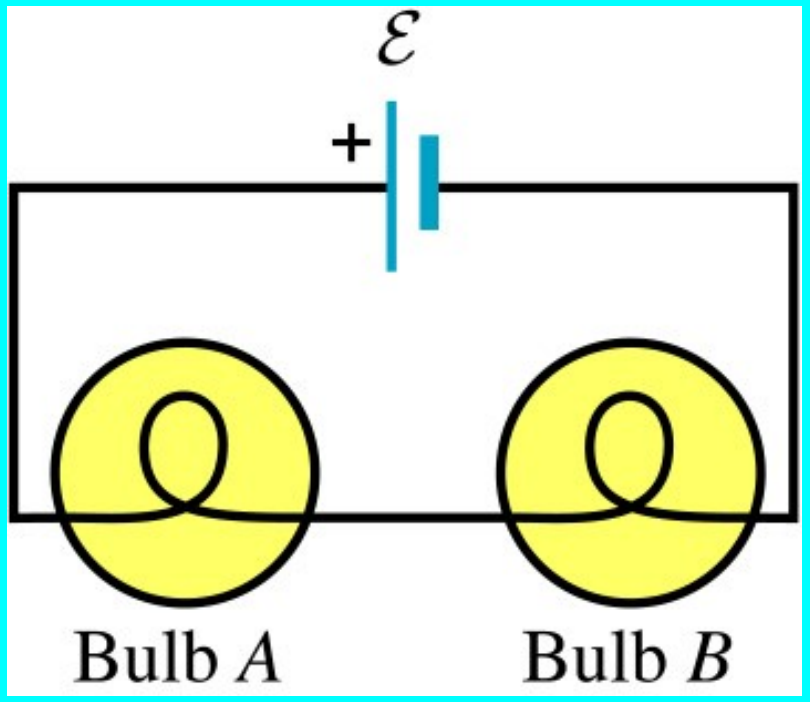
Internal Resistance

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

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*,

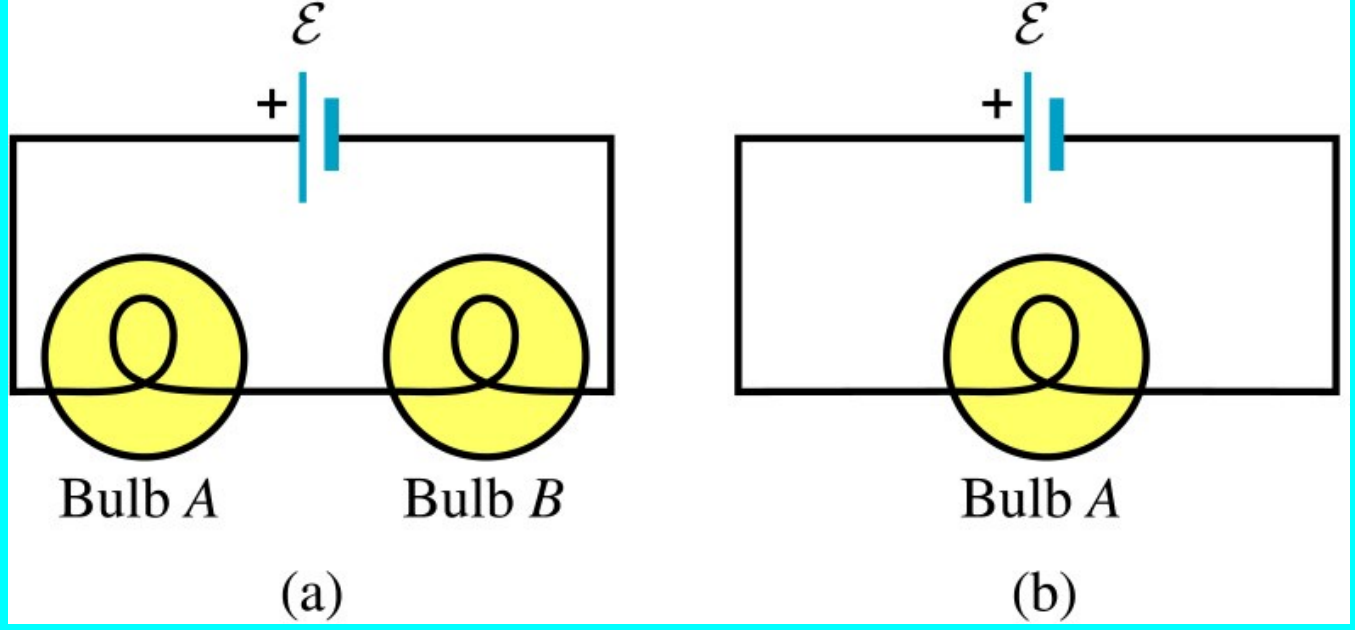


A. bulb *B* glows more brightly

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

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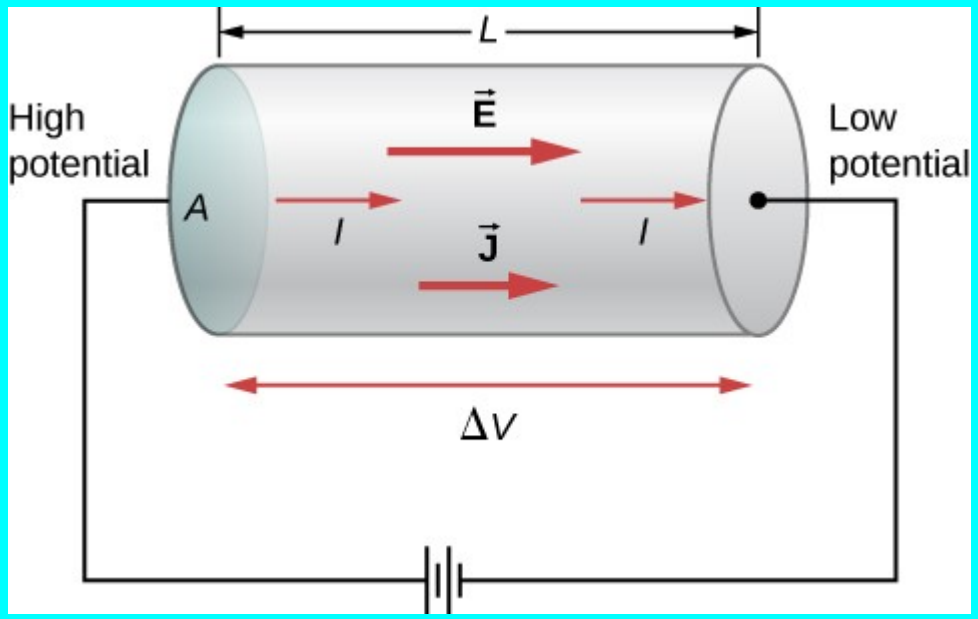
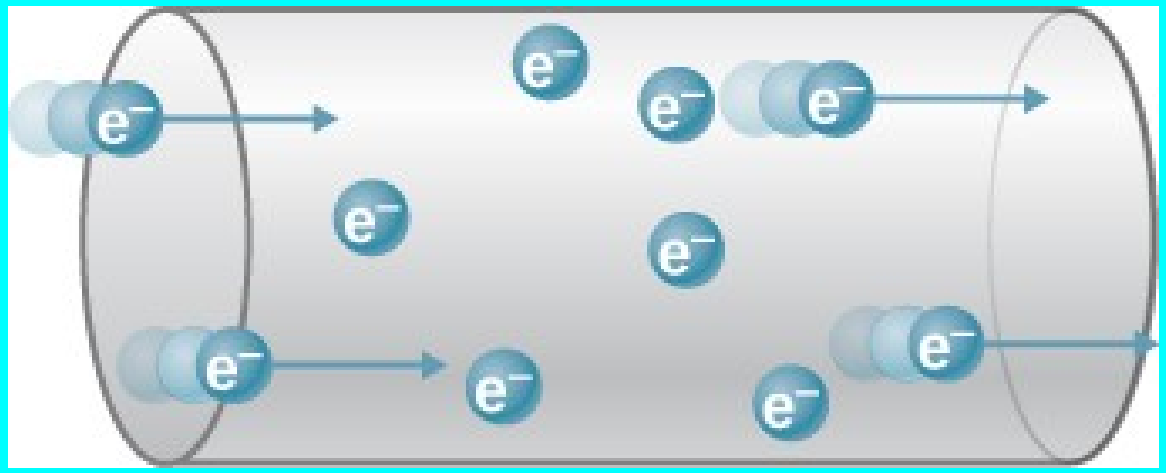
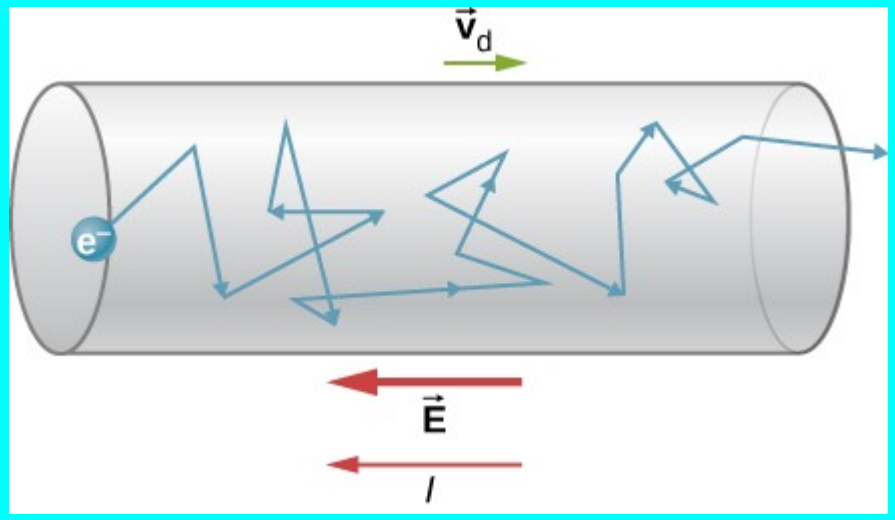
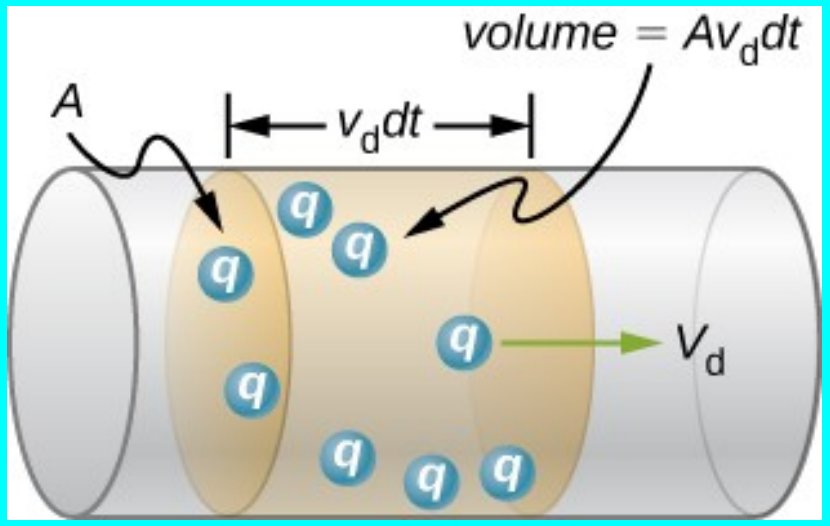
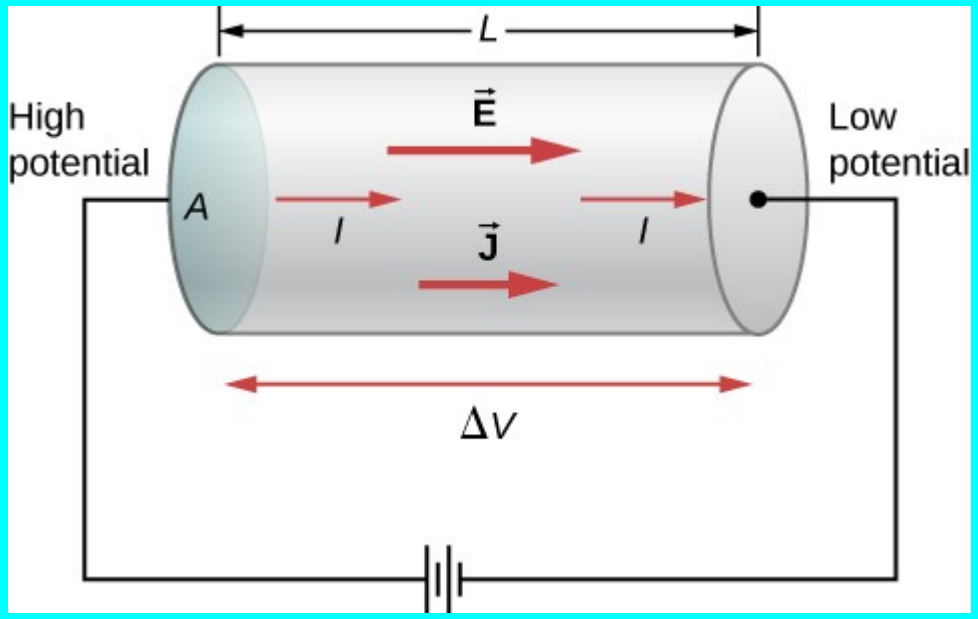

L
High
potential
Low
potential
A
E
I
J
I
ΔV


e⁻
e⁻
e⁻
e⁻
e⁻
e⁻
e⁻
e⁻
e⁻


$\vec{v}_d$
e⁻
$\vec{E}$
I


volume = $Av_d dt$
A
$v_d dt$
q
q
q
q
q
q
q
q
v_d


L
High
potential
A
$\vec{E}$
I
$\vec{J}$
I
Low
potential
ΔV

Circuit Simulator

https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_all.html

LECTURE 18 RECAP

- EMF and Voltage
- How Kirchoff's Rules lead to parallel/series formulae
- Internal Resistance
- Resistance and Resistivity
- Drude Model of Conduction

Scientists:

What's true? Are there exceptions?

How does it work?

Why does it work?

How does it relate to things we already knew?

How can I make it simple?

Engineers:

It's true most of the time, good enough!

That's cool!

What can I build with it?

Oh … by the way, why doesn't my thing work right?

Managers:

How can we make more money?

If we rush the engineers, can we still sell it without getting sued?

Who wants scientists? … they just want to mess around in the lab all day.

Can't we just hire young engineers? The old ones cost too much and tell us what won't work.