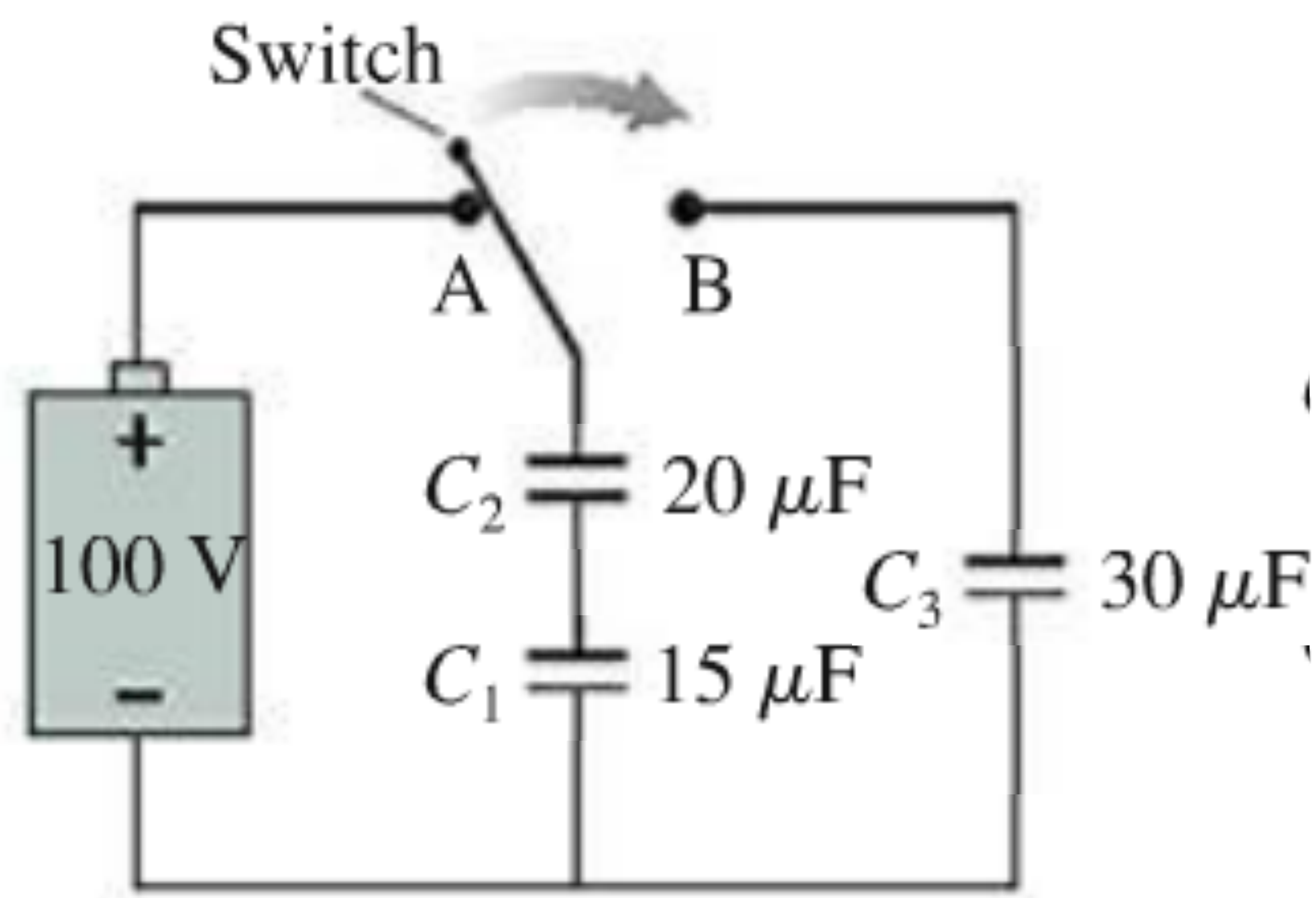
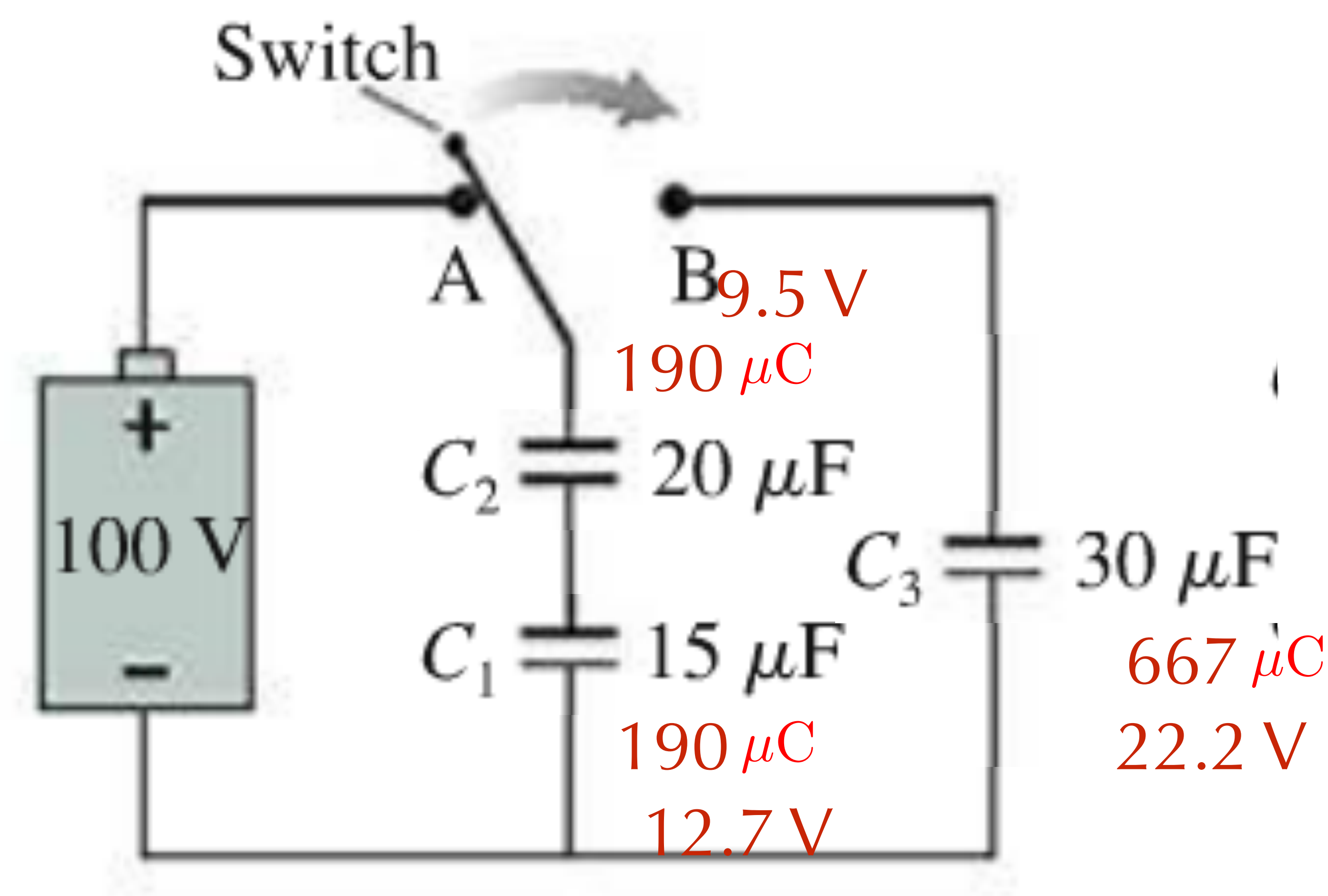
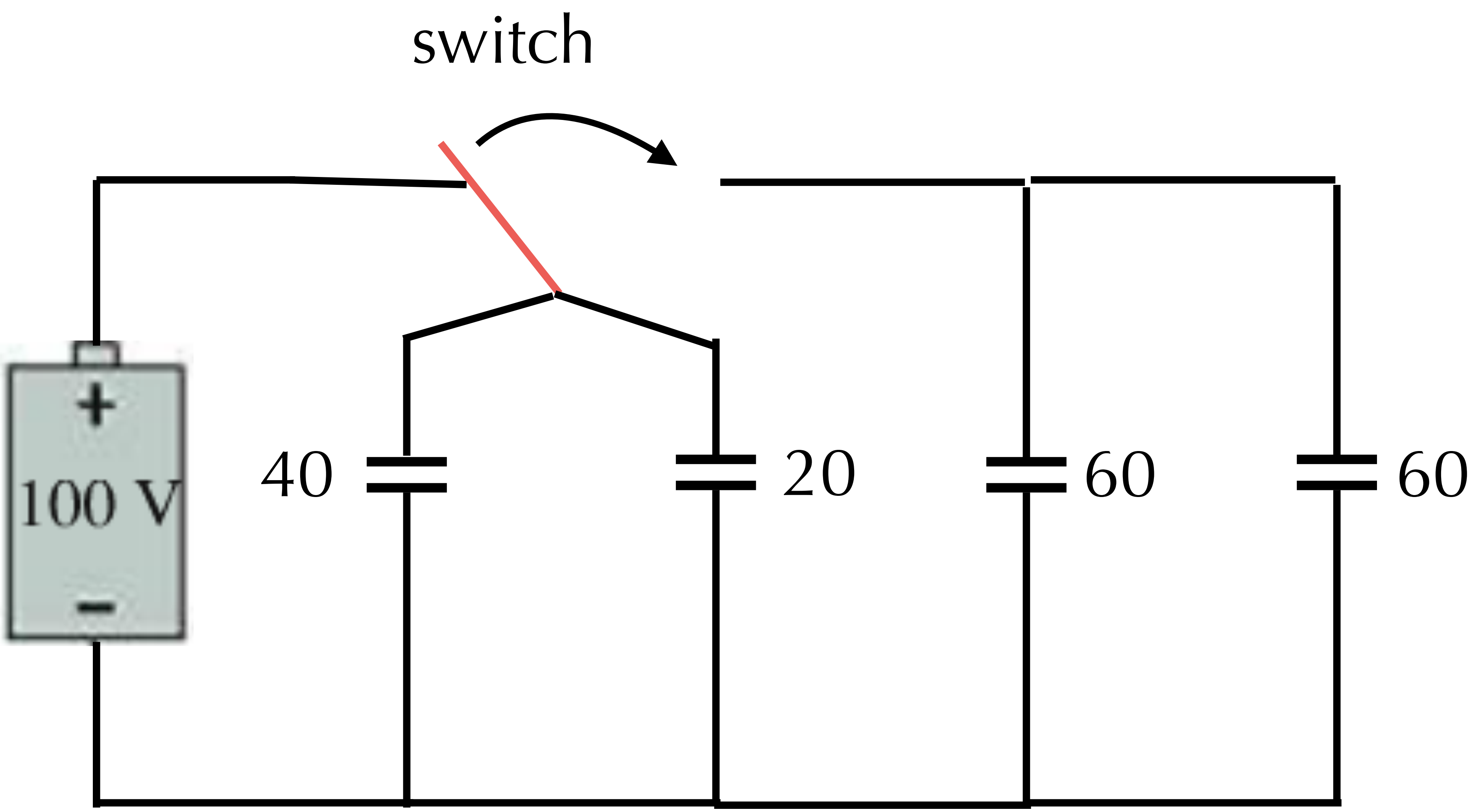

PH 220
Lance Nelson



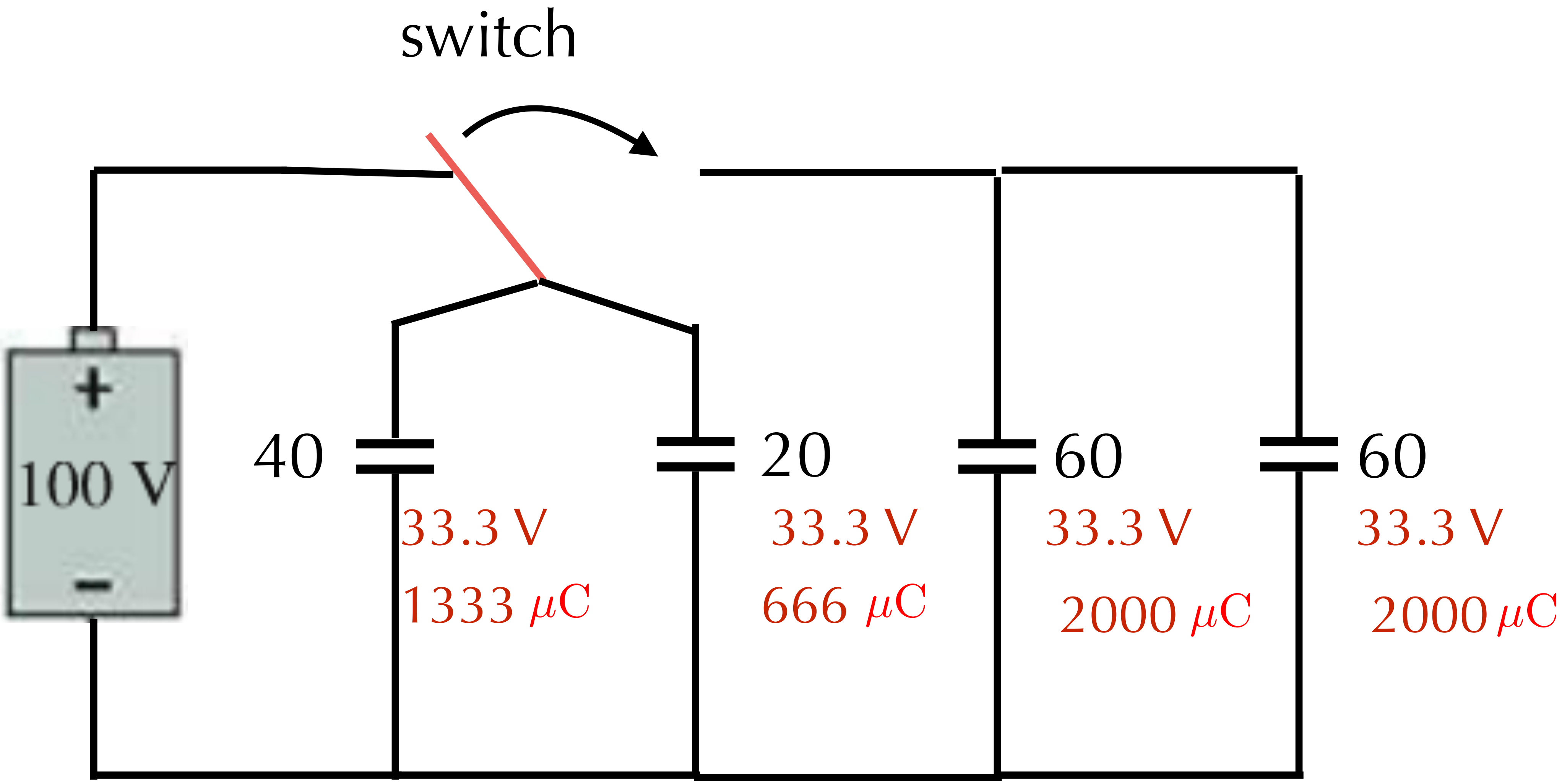
Switch
A
B
100 V
+
–
C_2 20 μF
C_1 15 μF
C_3 30 μF



Switch
A
B
9.5 V
190 µC
100 V
C_2
20 µF
C_3
30 µF
C_1
15 µF
667 µC
22.2 V
190 µC
12.7 V



switch
100 V
40
20
60
60

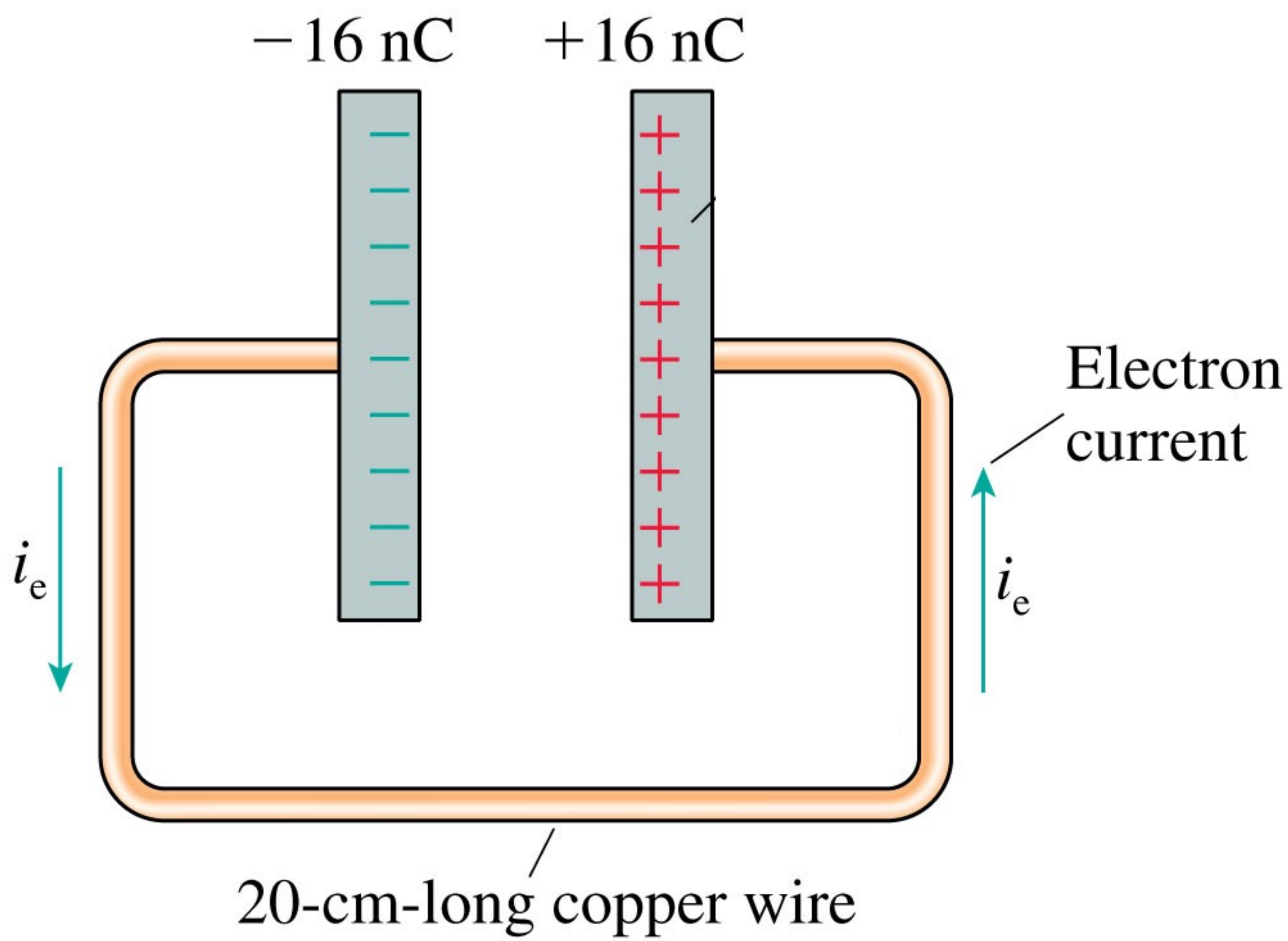

switch
100 V
40
20
60
60
33.3 V
1333 μC
33.3 V
666 μC
33.3 V
2000 μC
33.3 V
2000 μC

Discharging a capacitor

Typical drift velocities are on the order:

$$v_d = 10^{-4} \text{ m/s}$$

If the wire were 20 cm long, how long would it take for a single electron to get to the positive plate?



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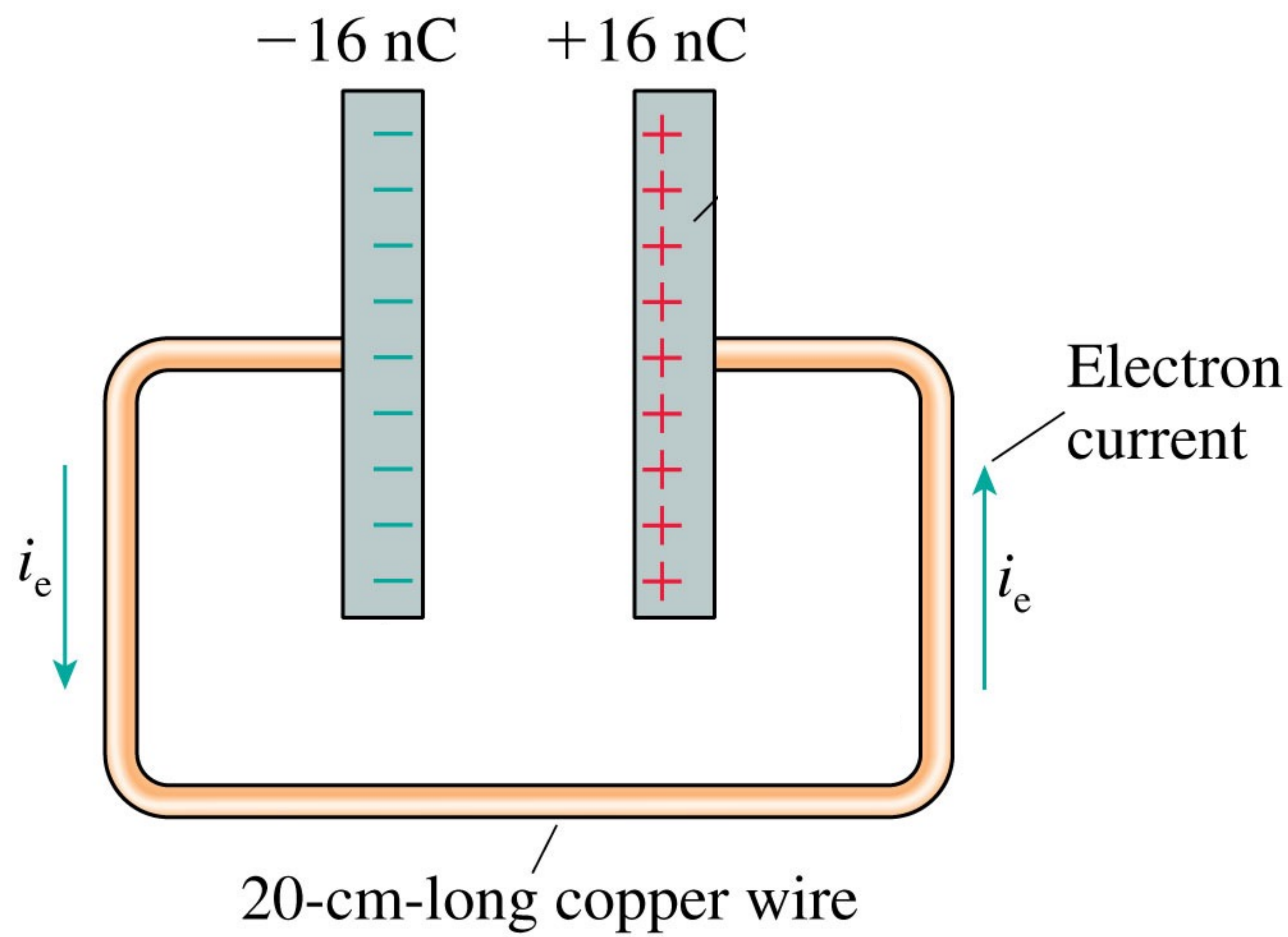
$$2000\ \mathrm{s}$$



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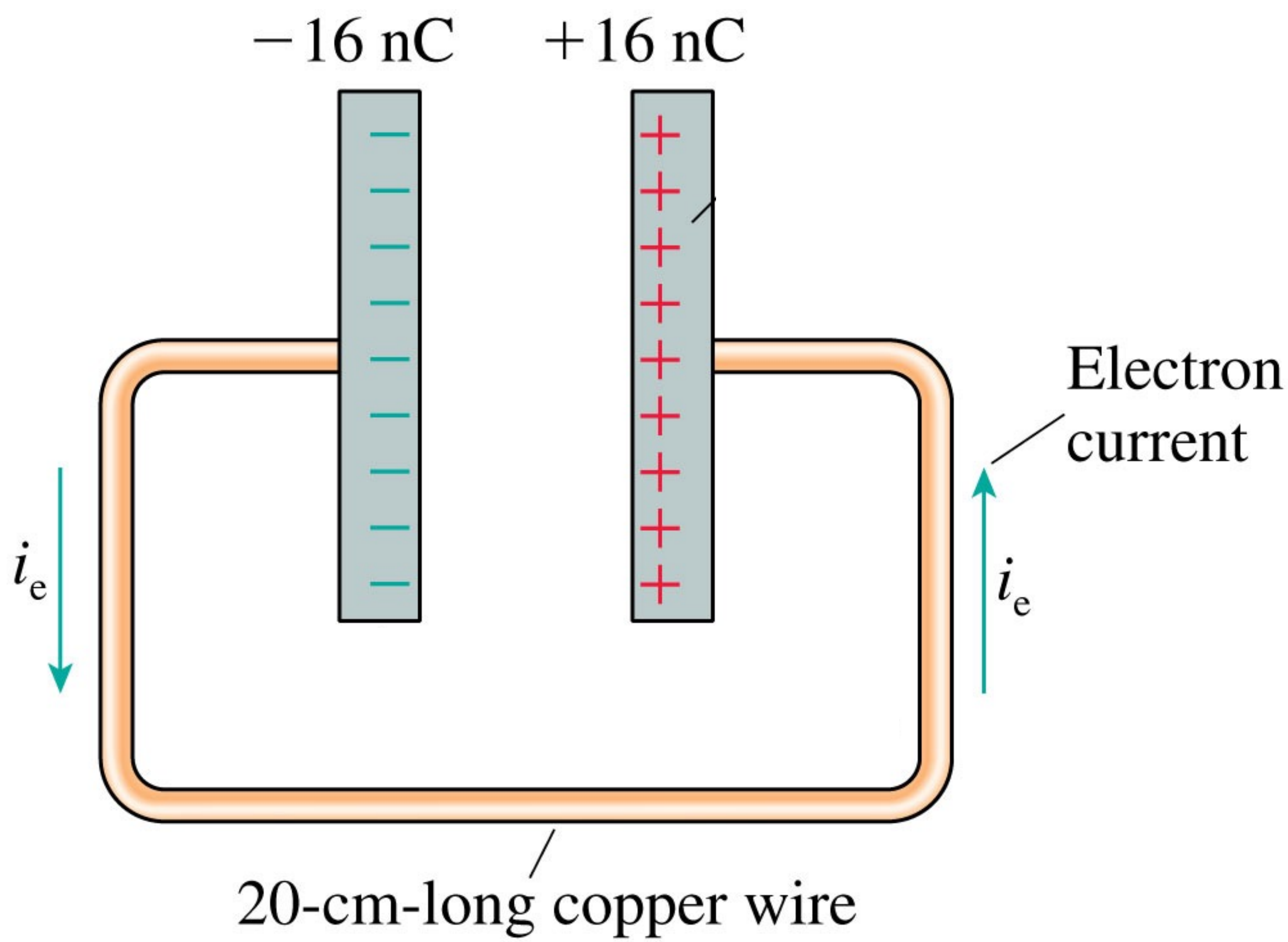
$2000\ \mathrm{s}$ What???



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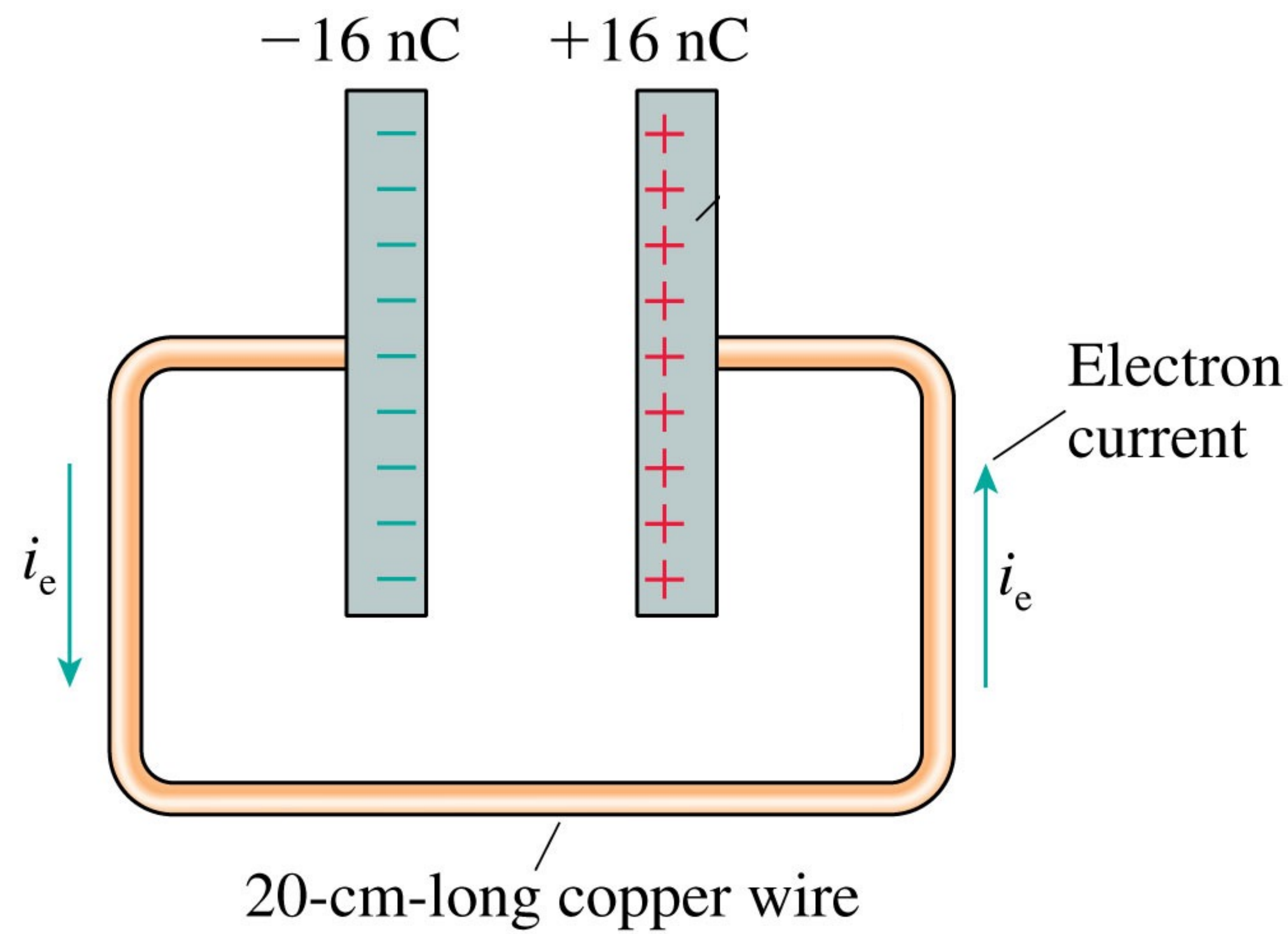
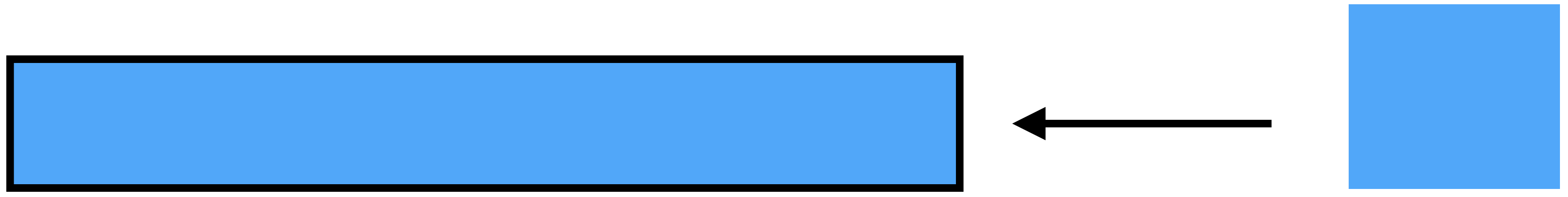


Capacitors discharge nearly instantaneously!

Water-in-pipe analogy

How long will it take for this amount of water to emerge from the left side?



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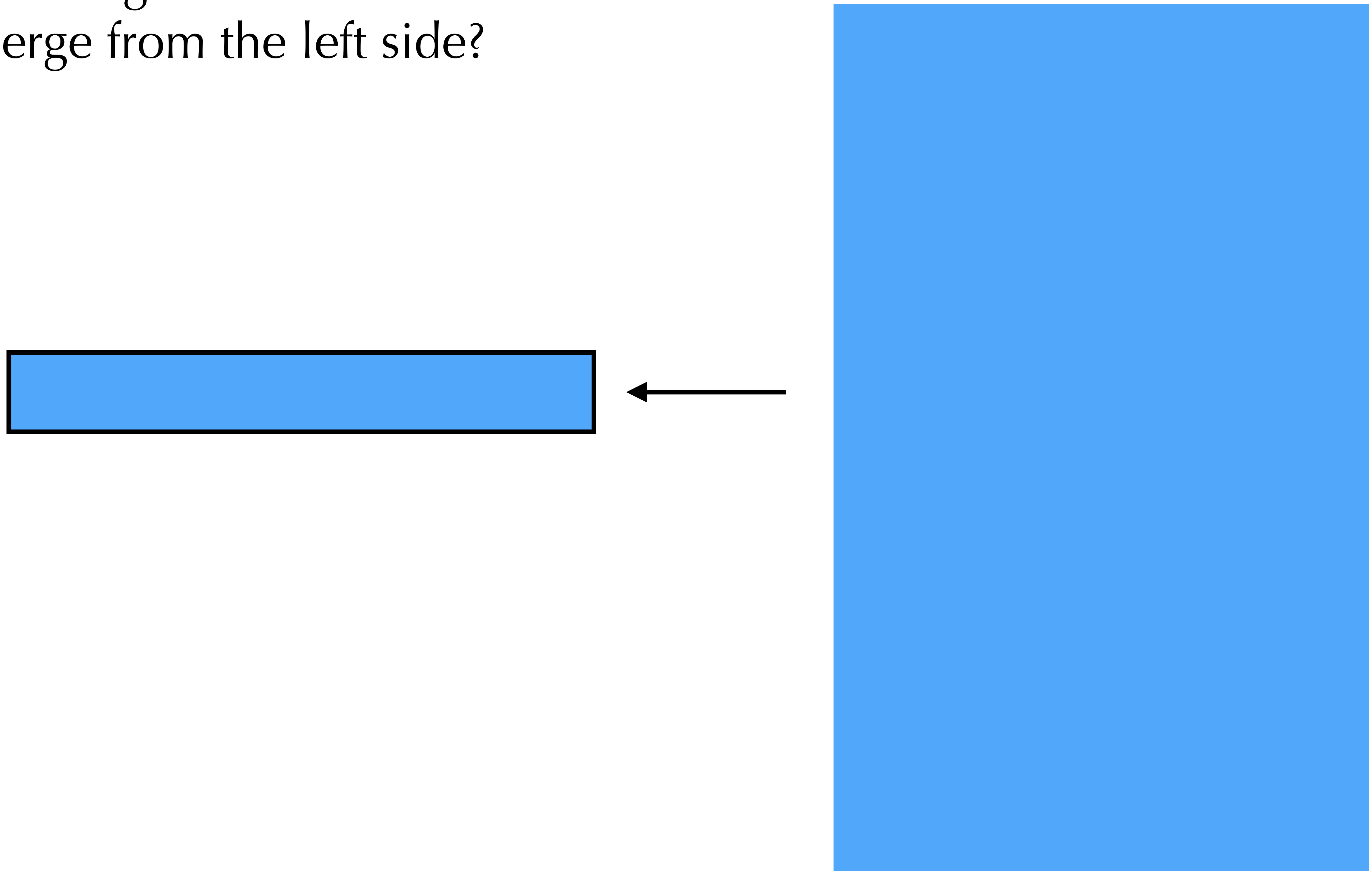
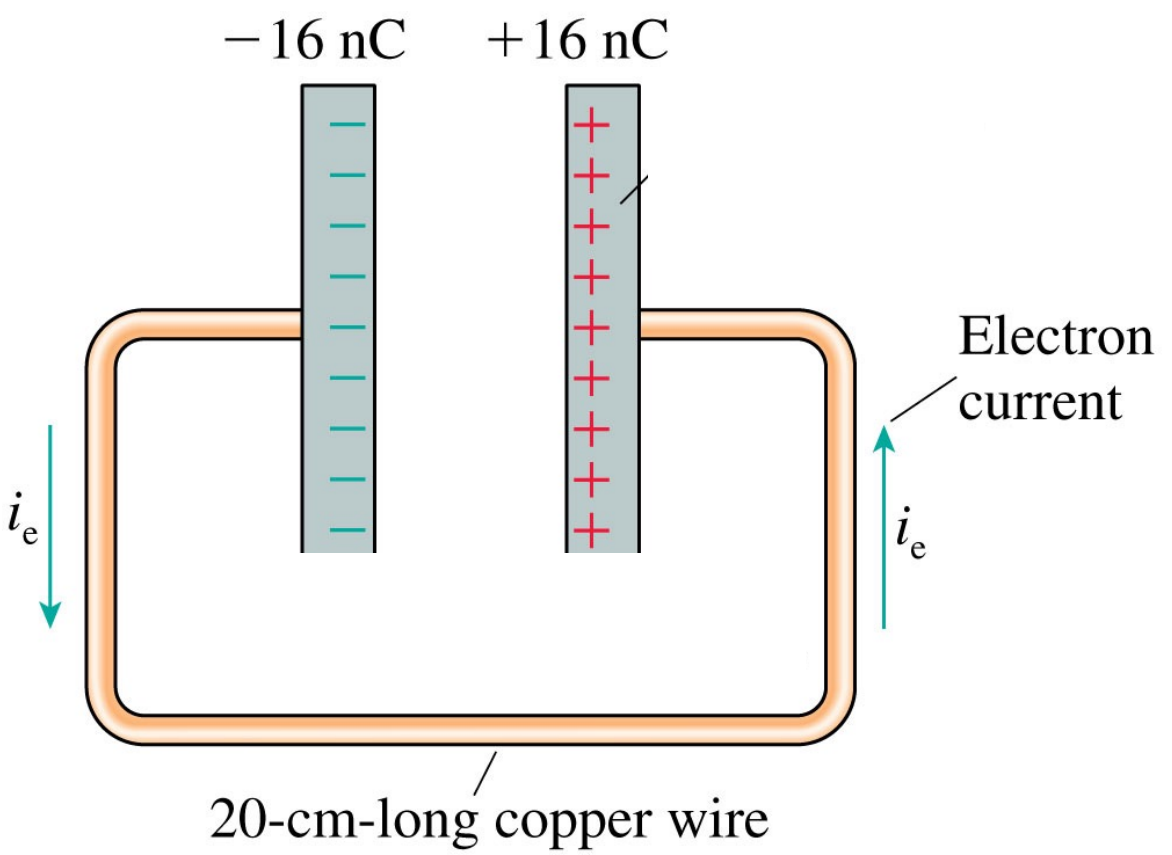
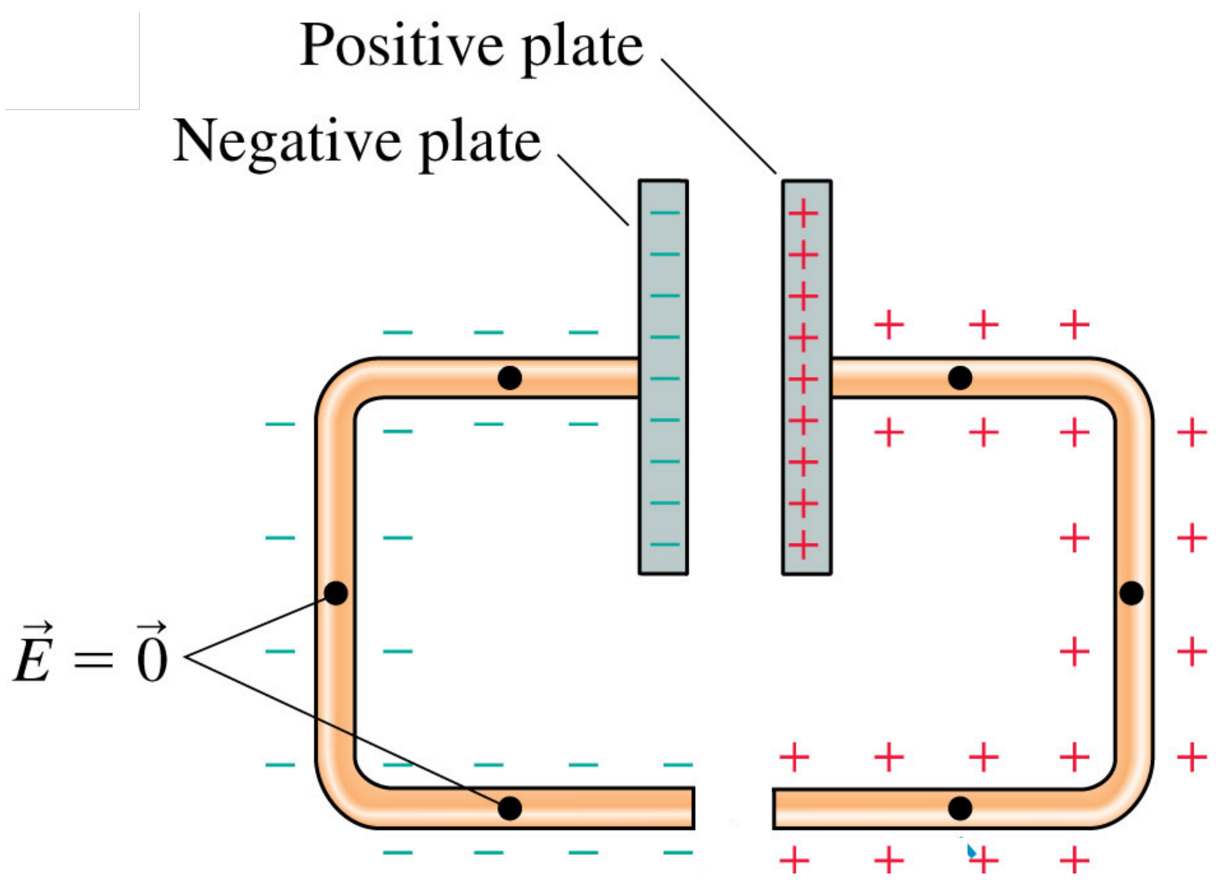


5×10^{22}

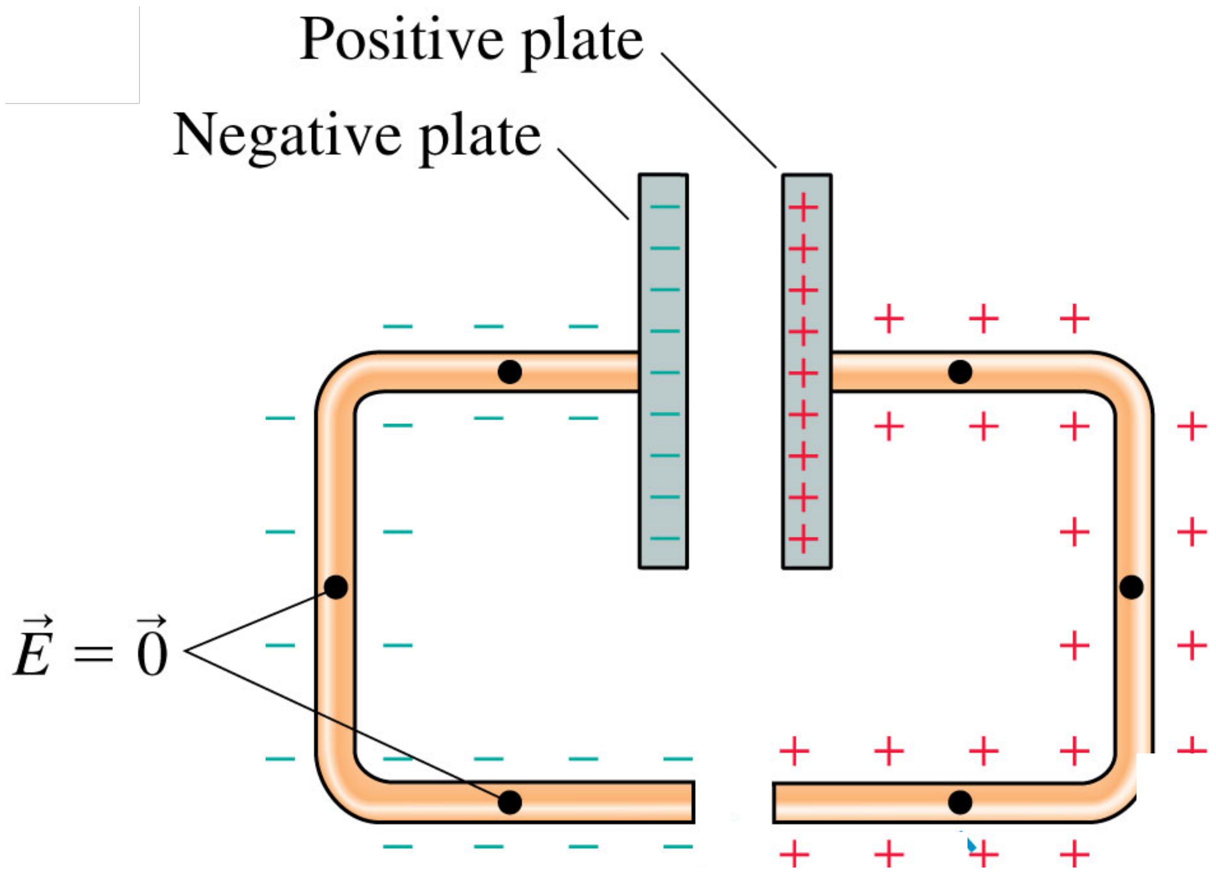
10^{11}

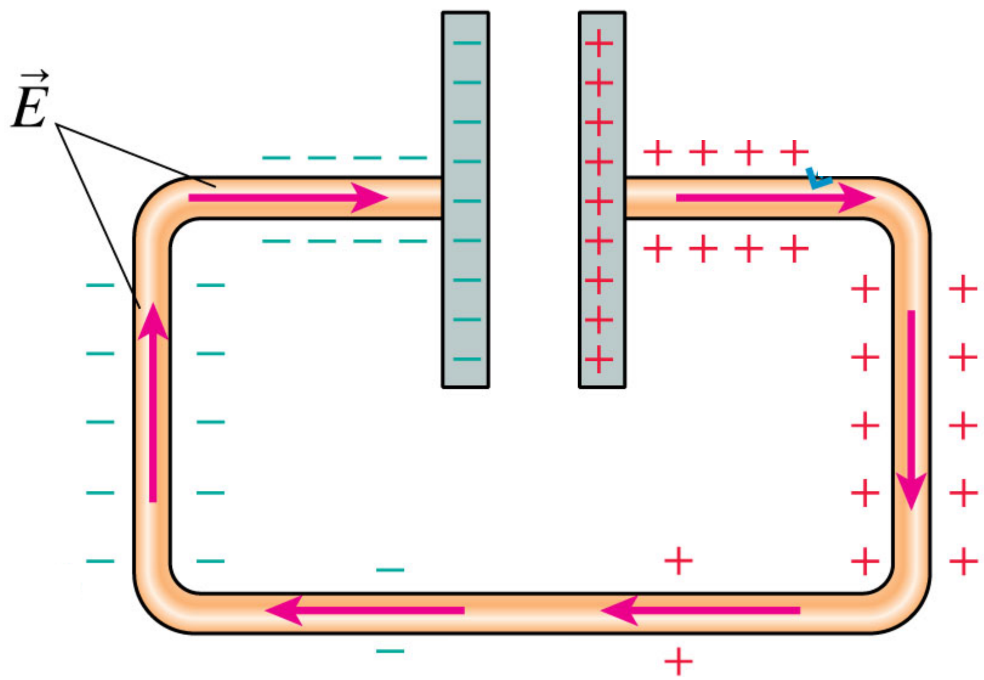


Conceptualizing Current

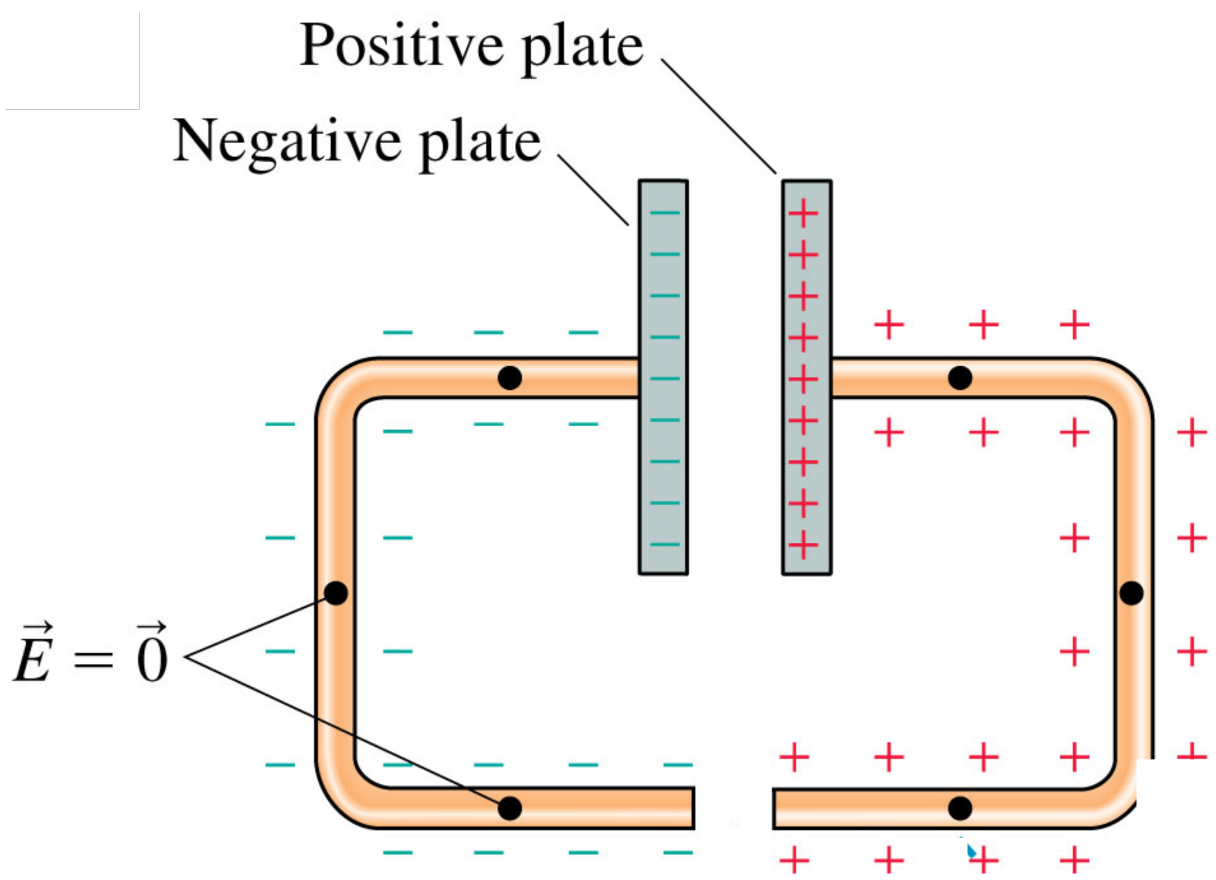


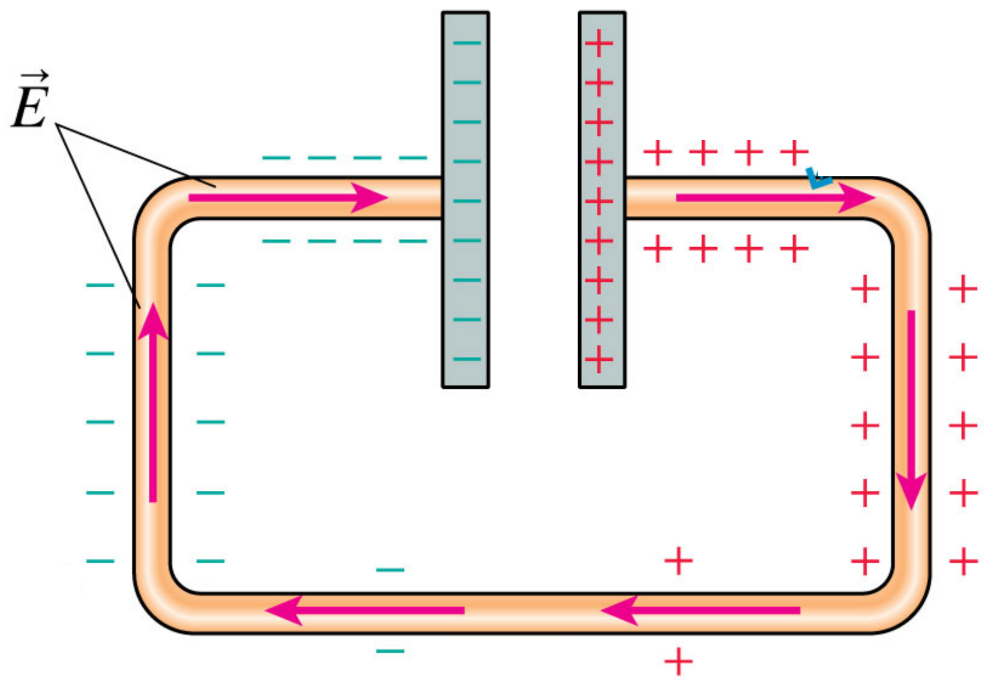
Conceptualizing Current

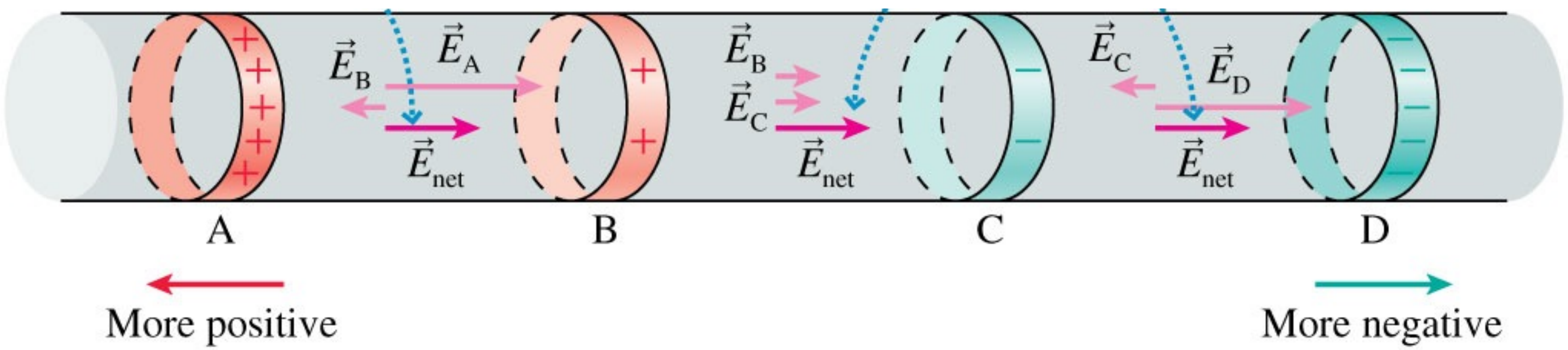




Conceptualizing Current

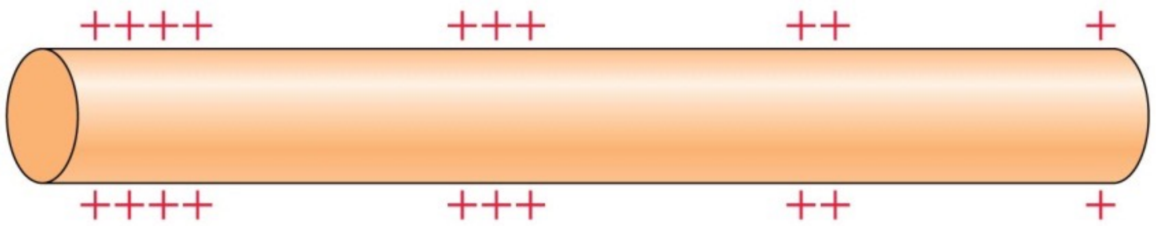






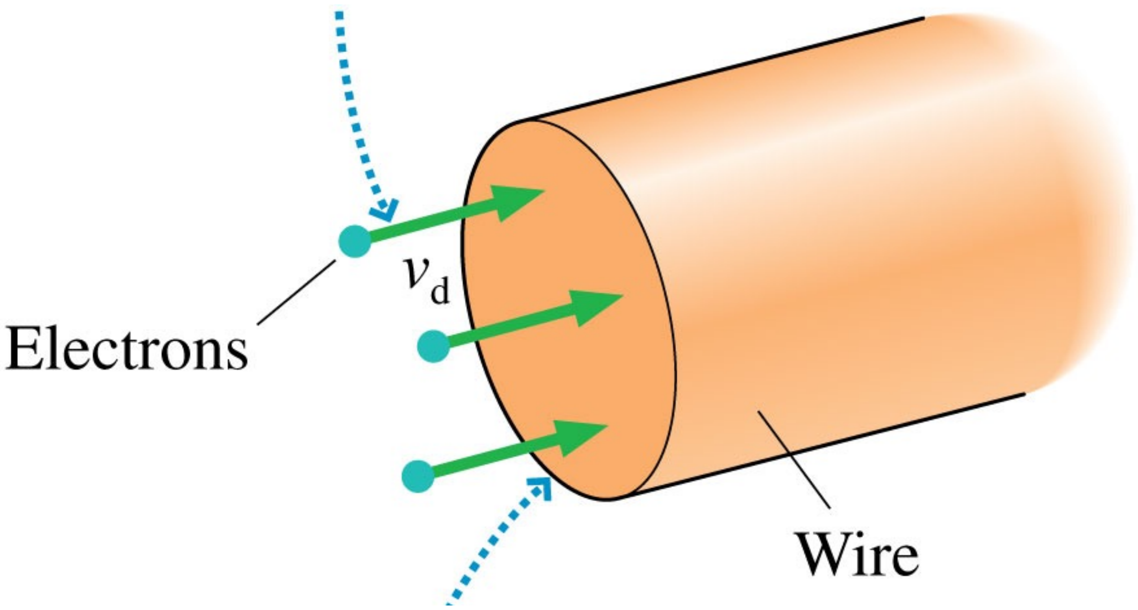
Question #28

Surface charge is distributed on a wire as shown. Electrons in the wire



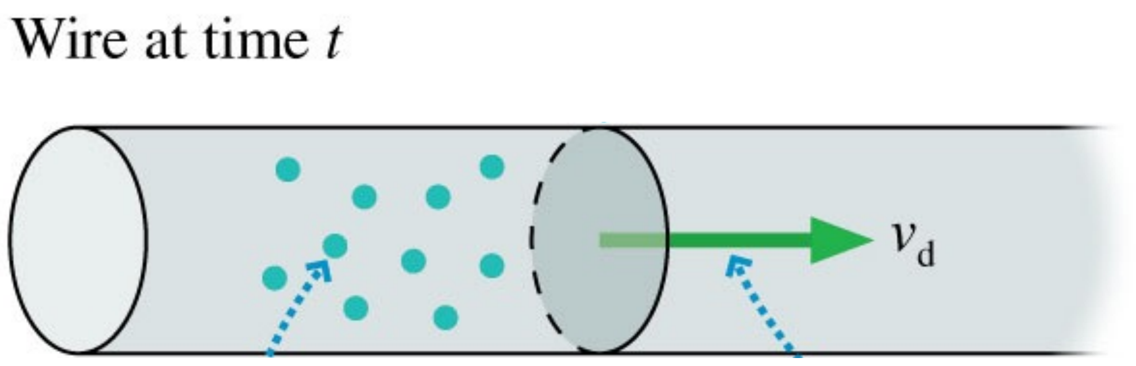
A. Drift to the right.
B. Move downward.
C. Move upward.
D. Drift to the left.
E. On average, remain at rest.

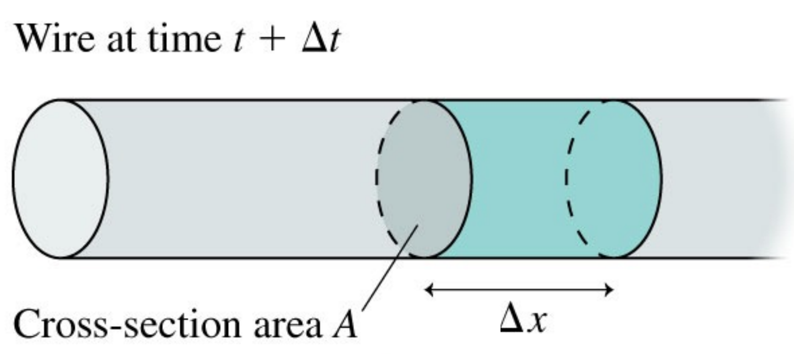
Current



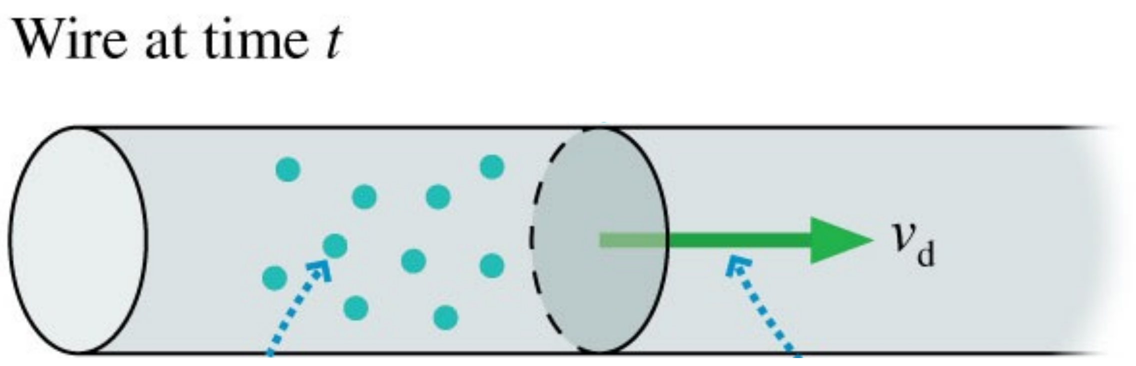
$$i_e = \frac{N_e}{\Delta t}$$

$$N_e = i_e \Delta t$$

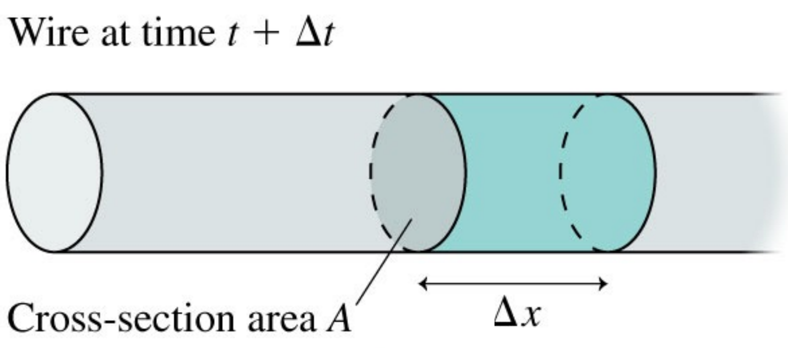

Wire at time t
v_d


Wire at time $t + \Delta t$
Cross-section area A
Δx

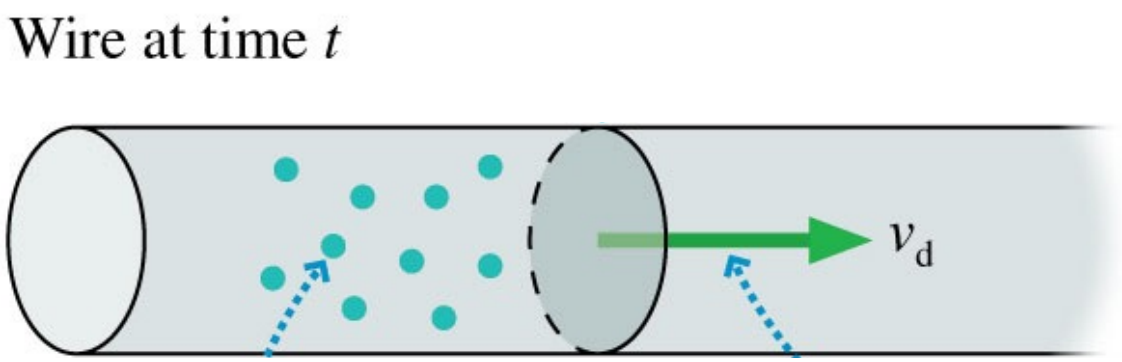
$$N_e = i_e \Delta t$$



$$N_e = n_e V$$

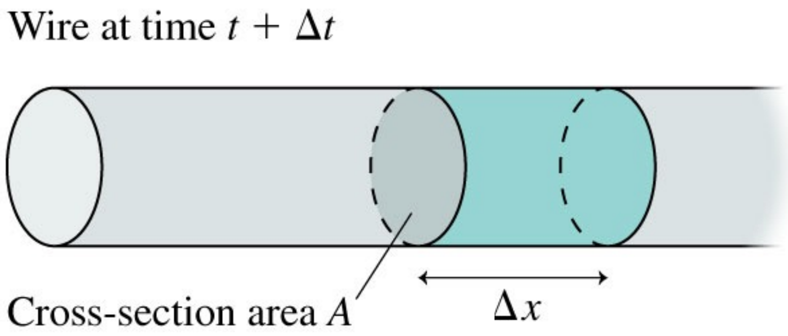


$$N_e = i_e \Delta t$$

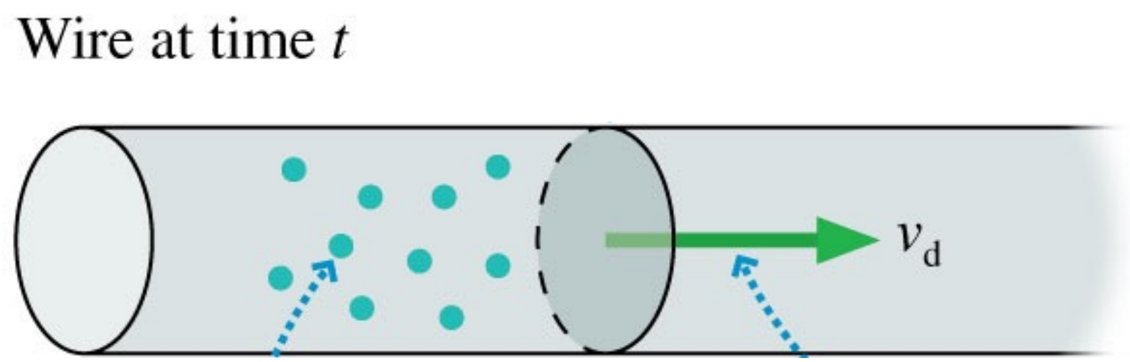


$$N_e = n_e V$$

$$= n_e A \Delta x$$



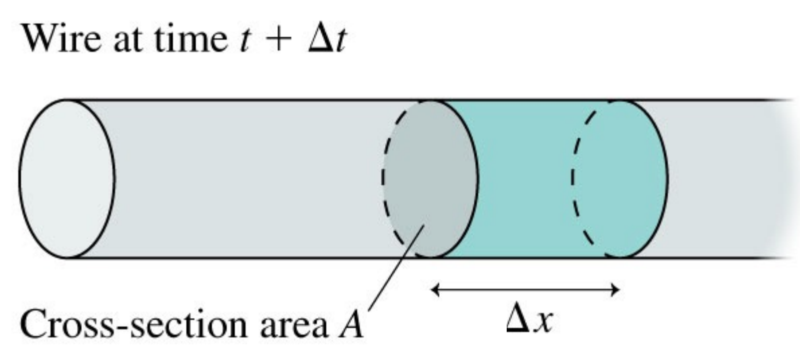
$$N_e = i_e \Delta t$$



$$N_e = n_e V$$

$$= n_e A \Delta x$$

$$= n_e A v_d \Delta t$$



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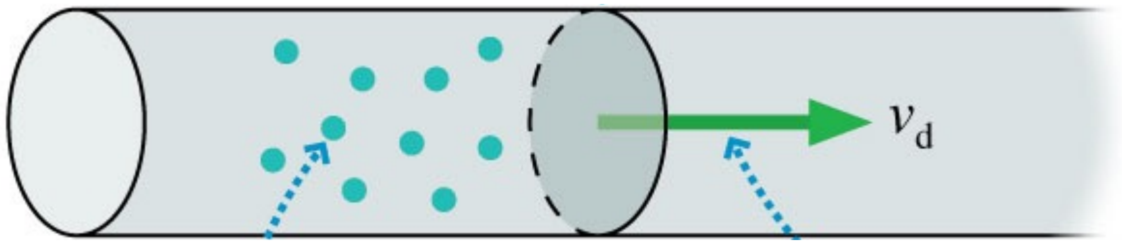

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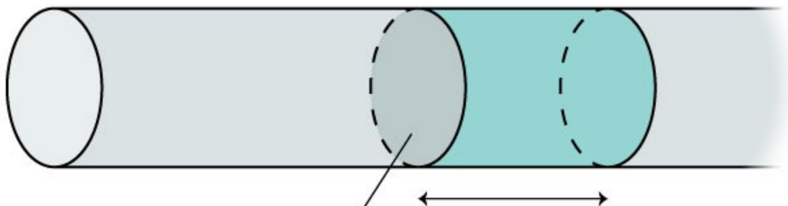
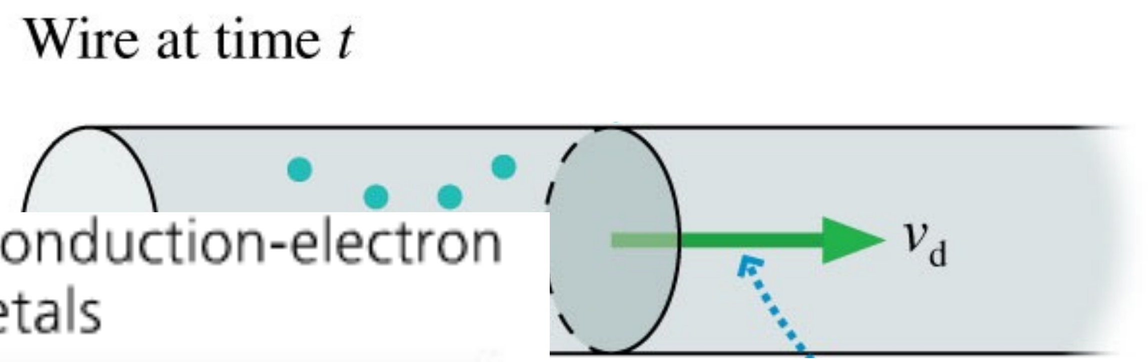


$$i_e = n_e A v_d$$

$$N_e = i_e \Delta t$$



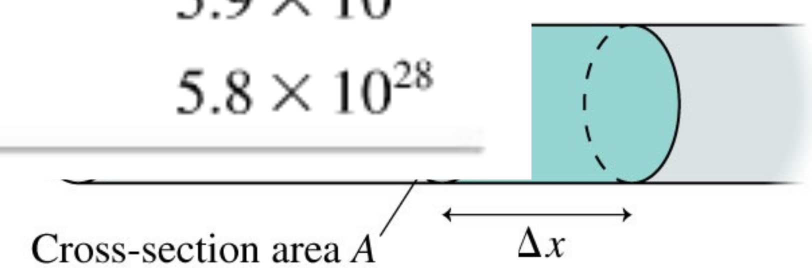
$$N_e = n_e V$$

$$= n_e A \Delta x$$

$$= n_e A v_d \Delta t$$

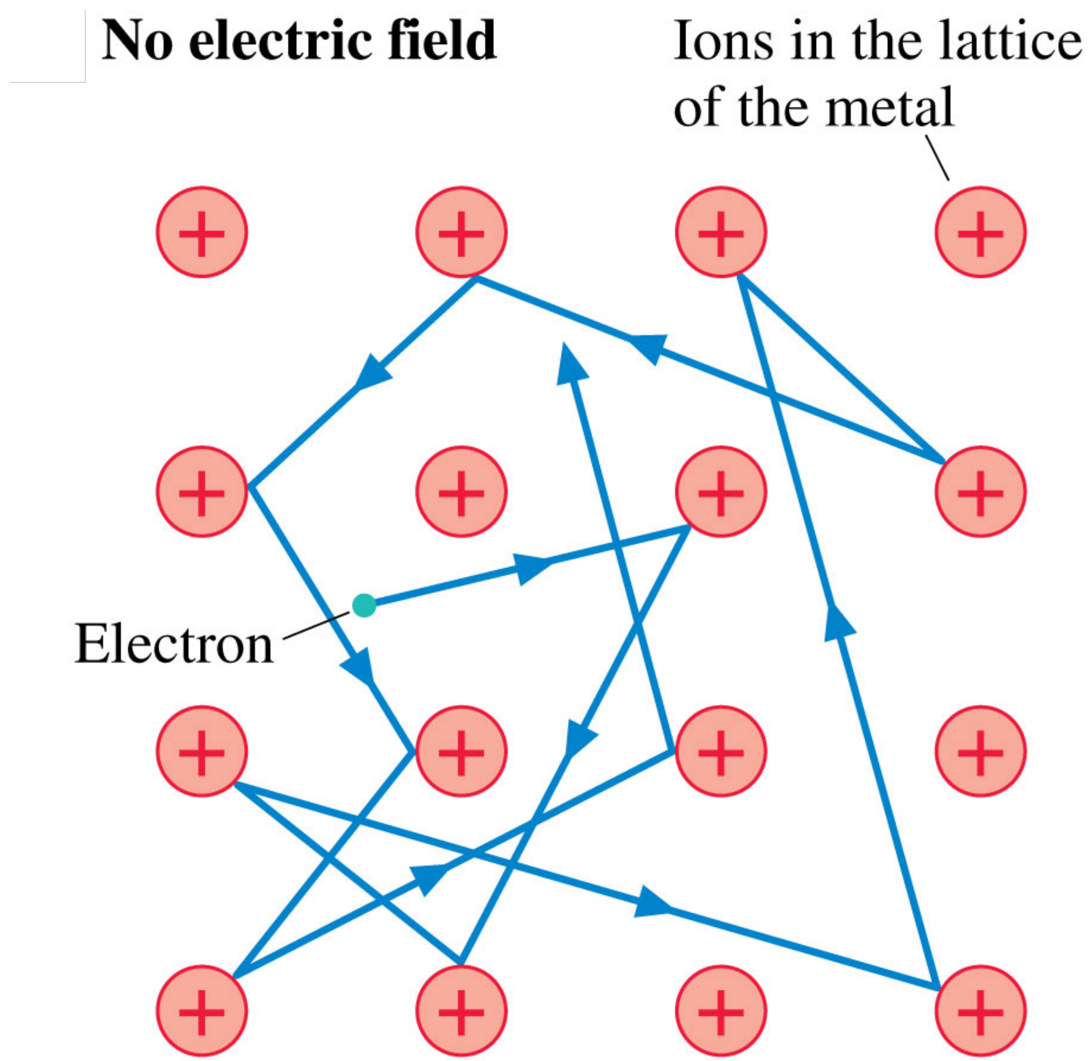
TABLE 30.1 Conduction-electron density in metals

Metal	Electron density (m^{-3})
Aluminum	6.0×10^{28}
Copper	8.5×10^{28}
Iron	8.5×10^{28}
Gold	5.9×10^{28}
Silver	5.8×10^{28}



$$i_e = n_e A v_d$$

Model of Conduction



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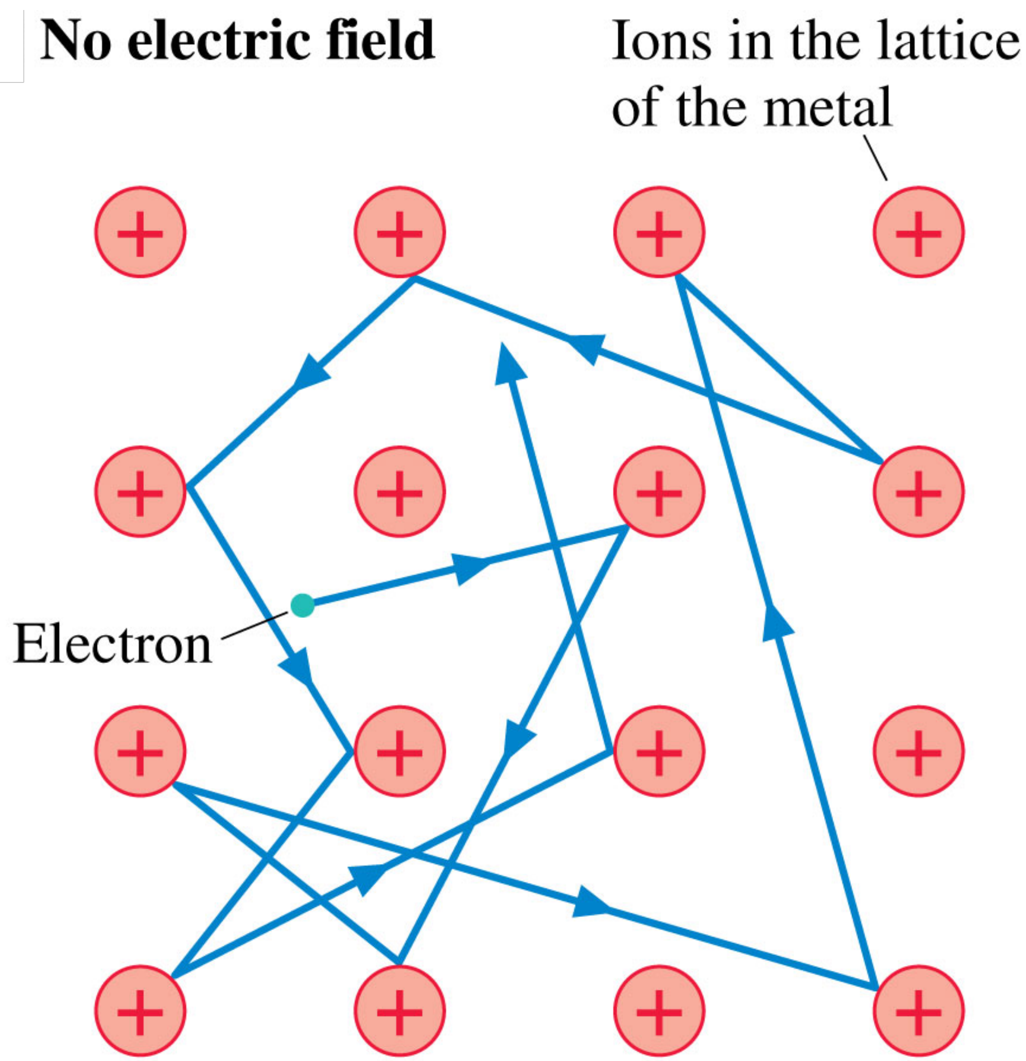
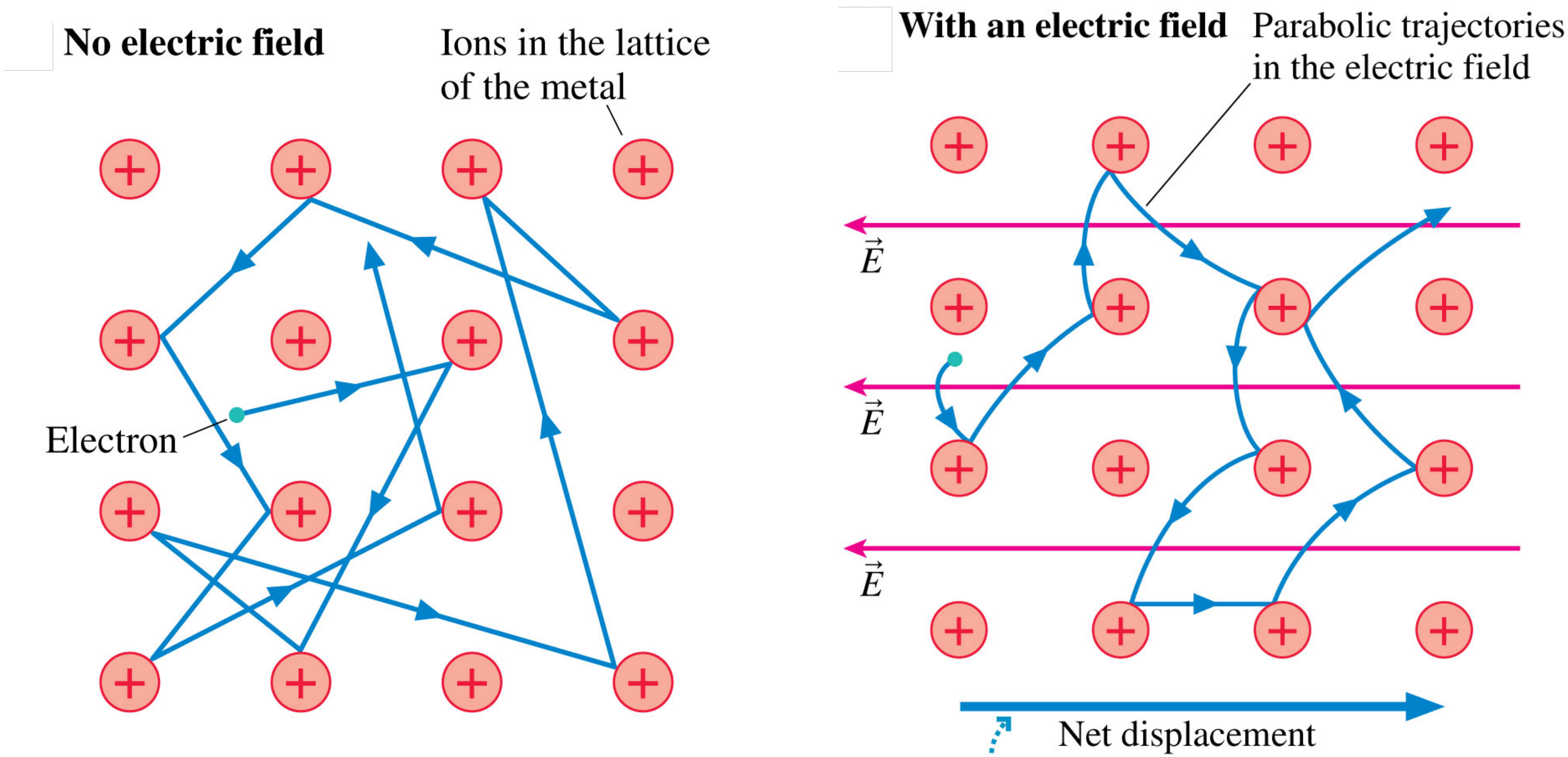


What will the trajectories look like when an E field is present?

Model of Conduction



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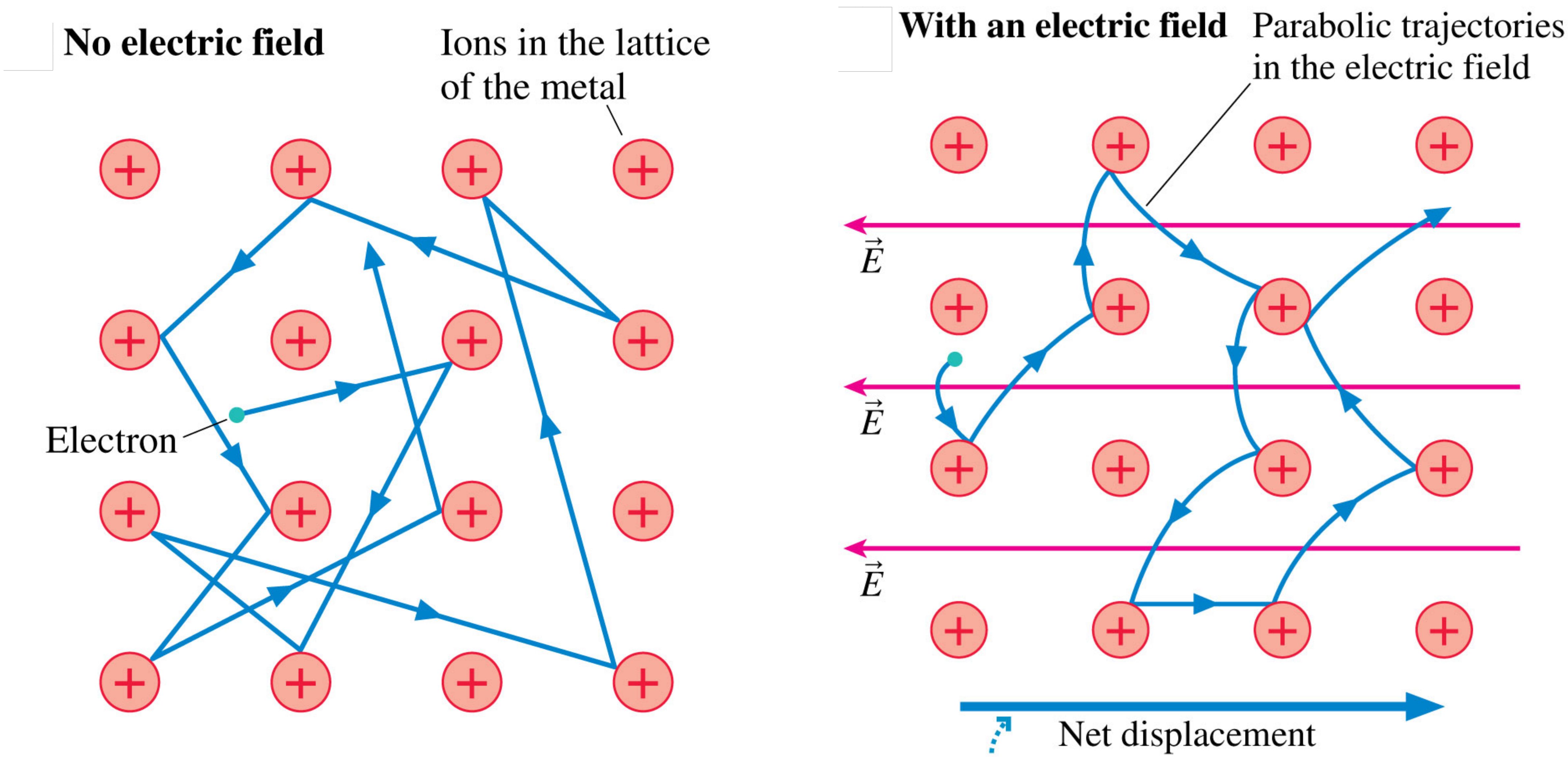

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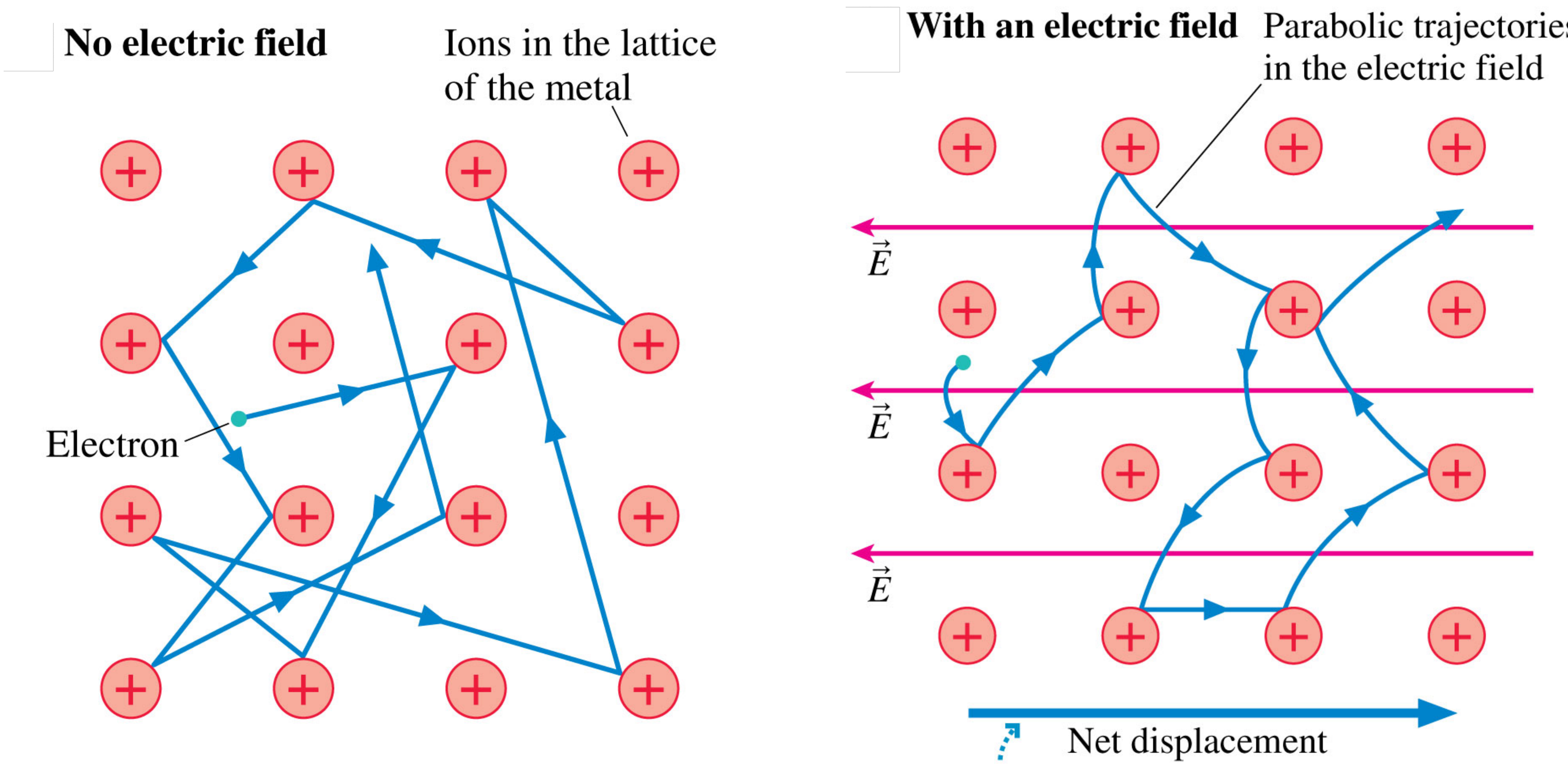
Write an expression for the acceleration of the electrons in between collisions

Model of Conduction



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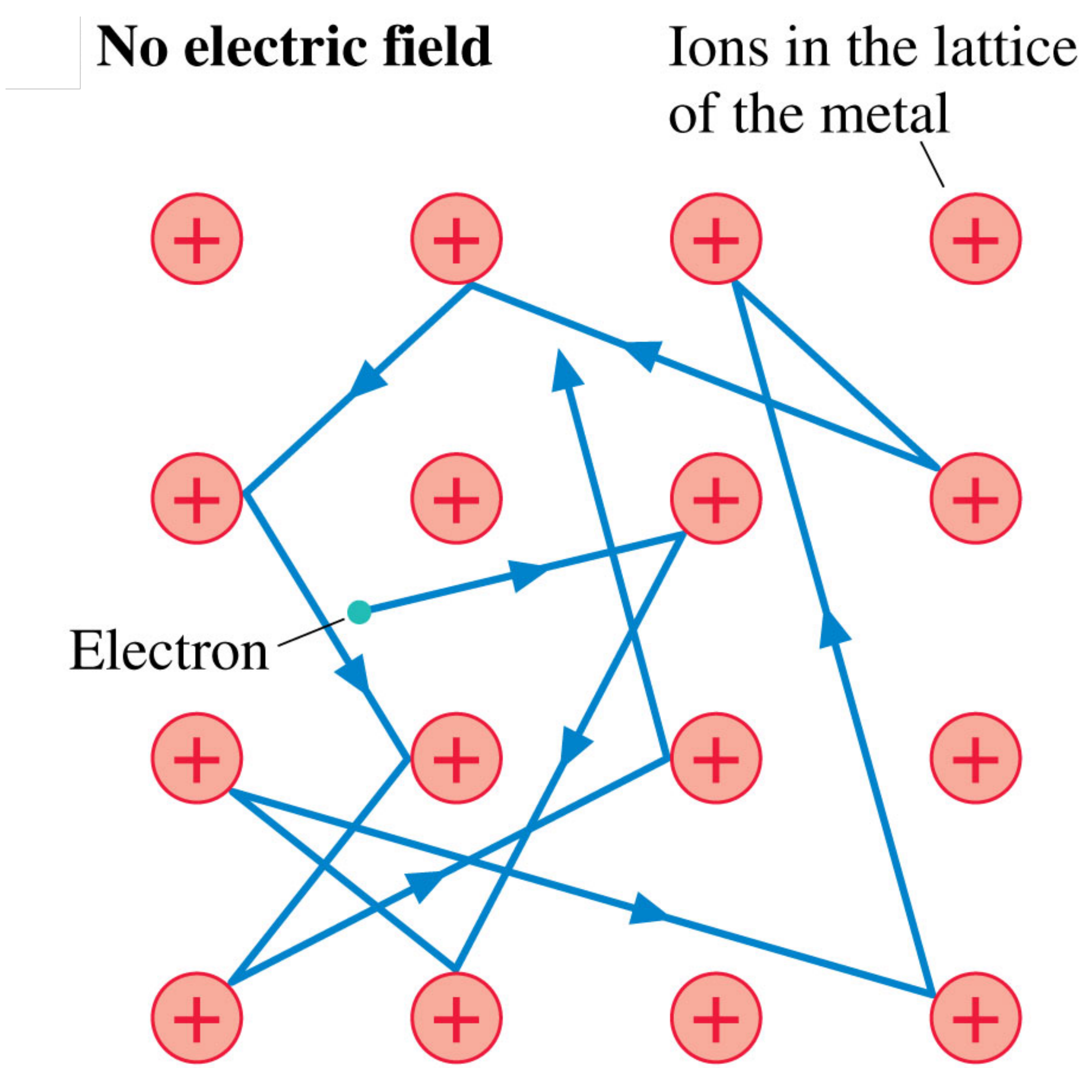
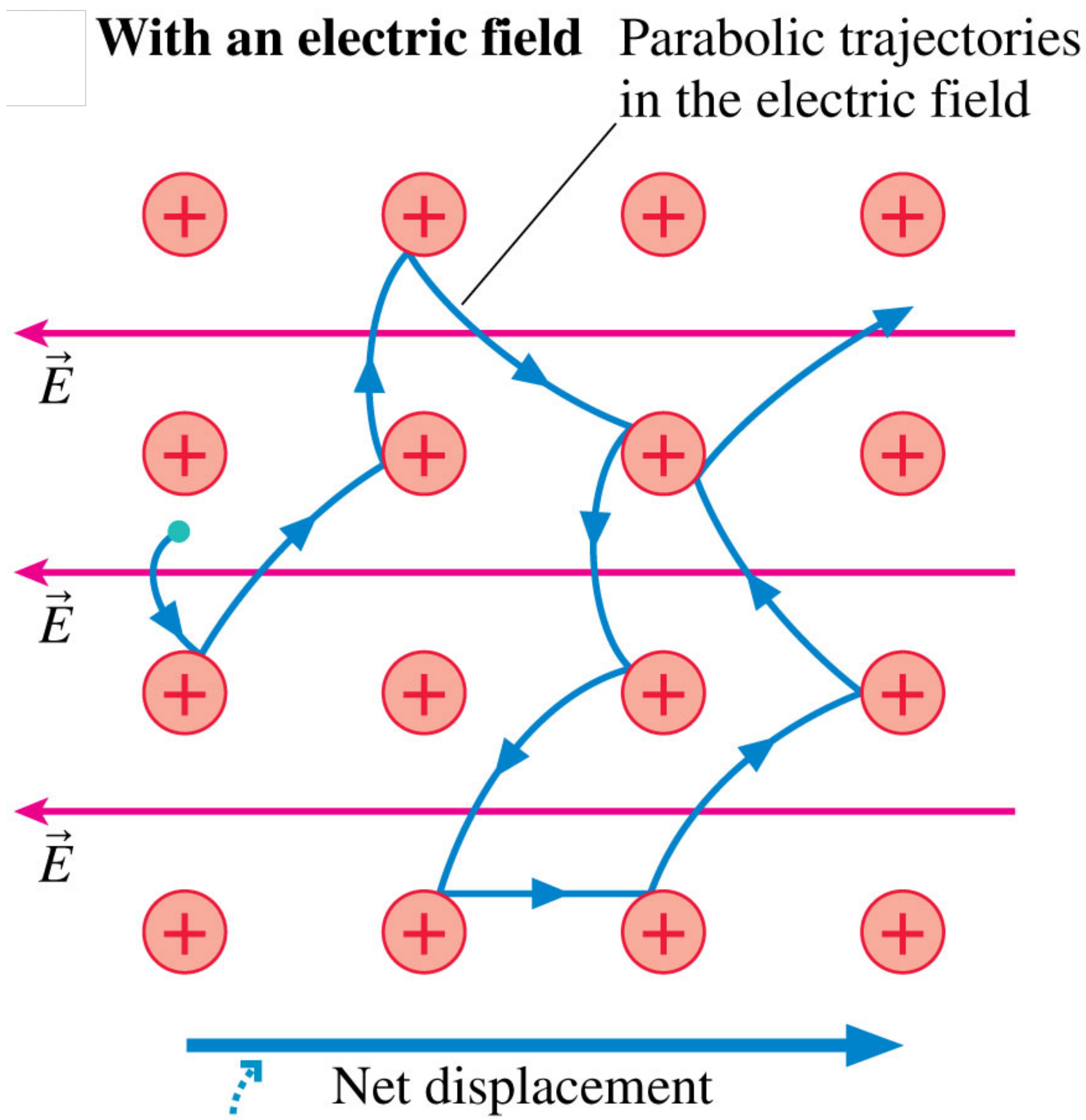
$$a = \frac{eE}{m}$$

Model of Conduction

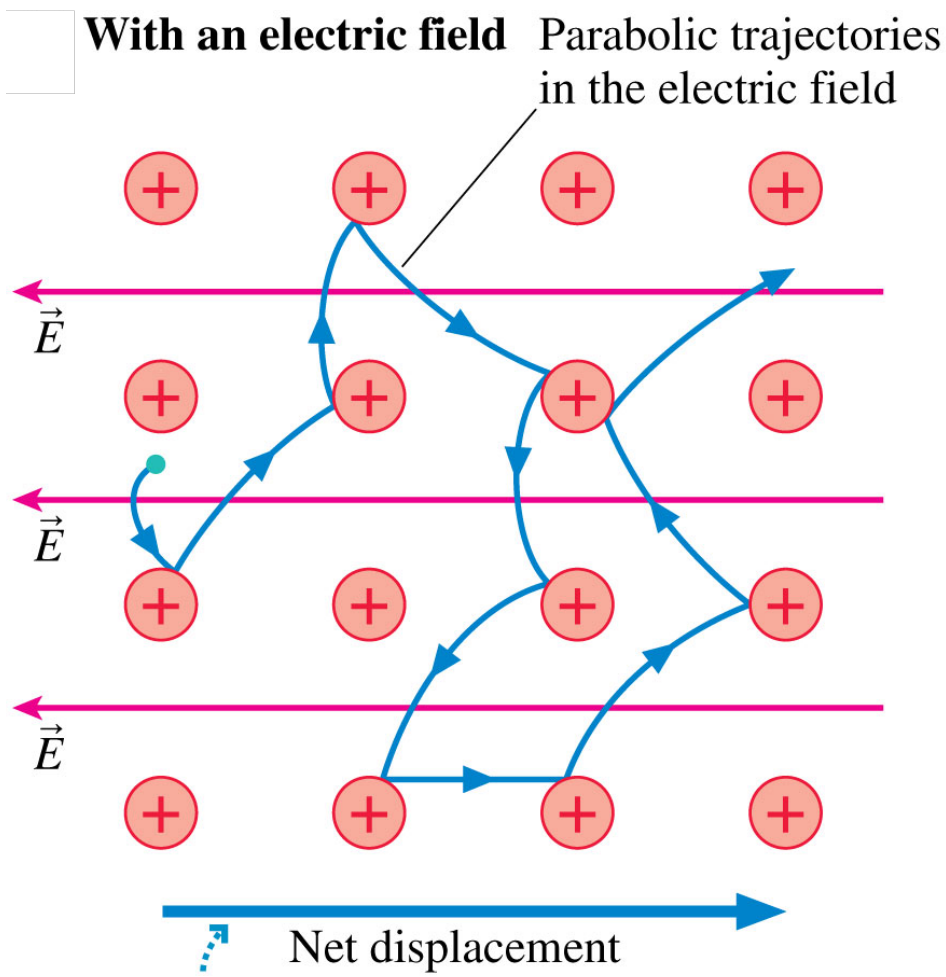


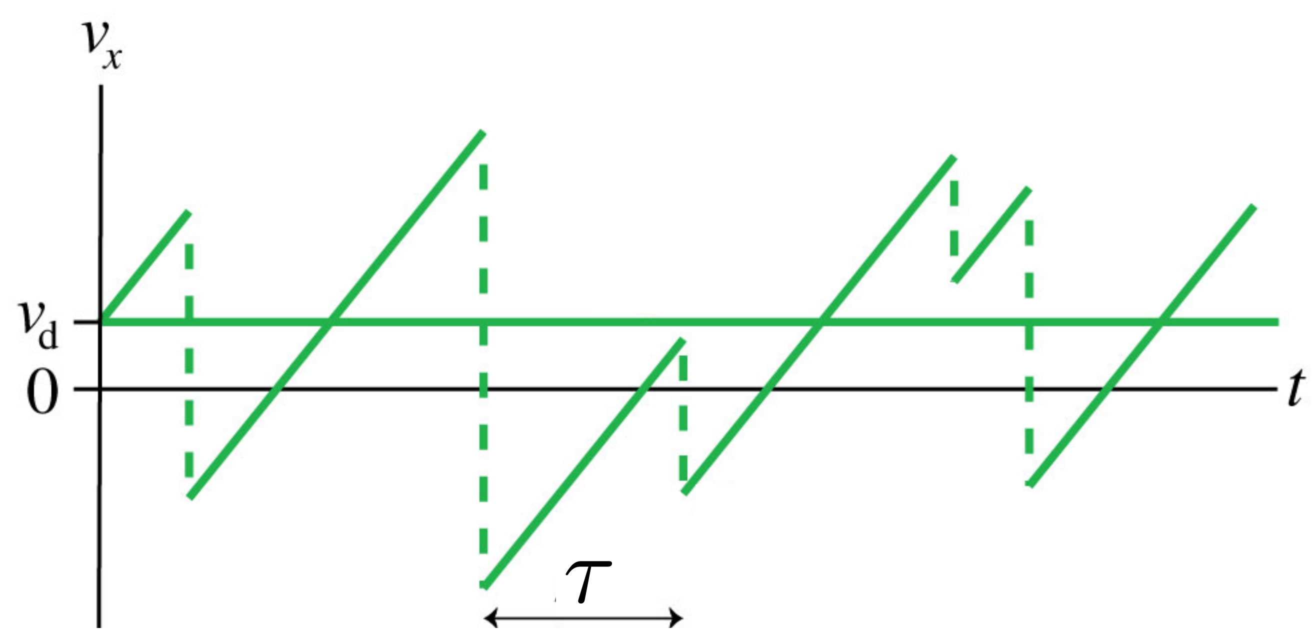


What will the trajectories look like when an E field is present?

Write an expression for the acceleration of the electrons in between collisions

$$a = \frac{eE}{m} \qquad v_d = \frac{eE}{m}\tau$$





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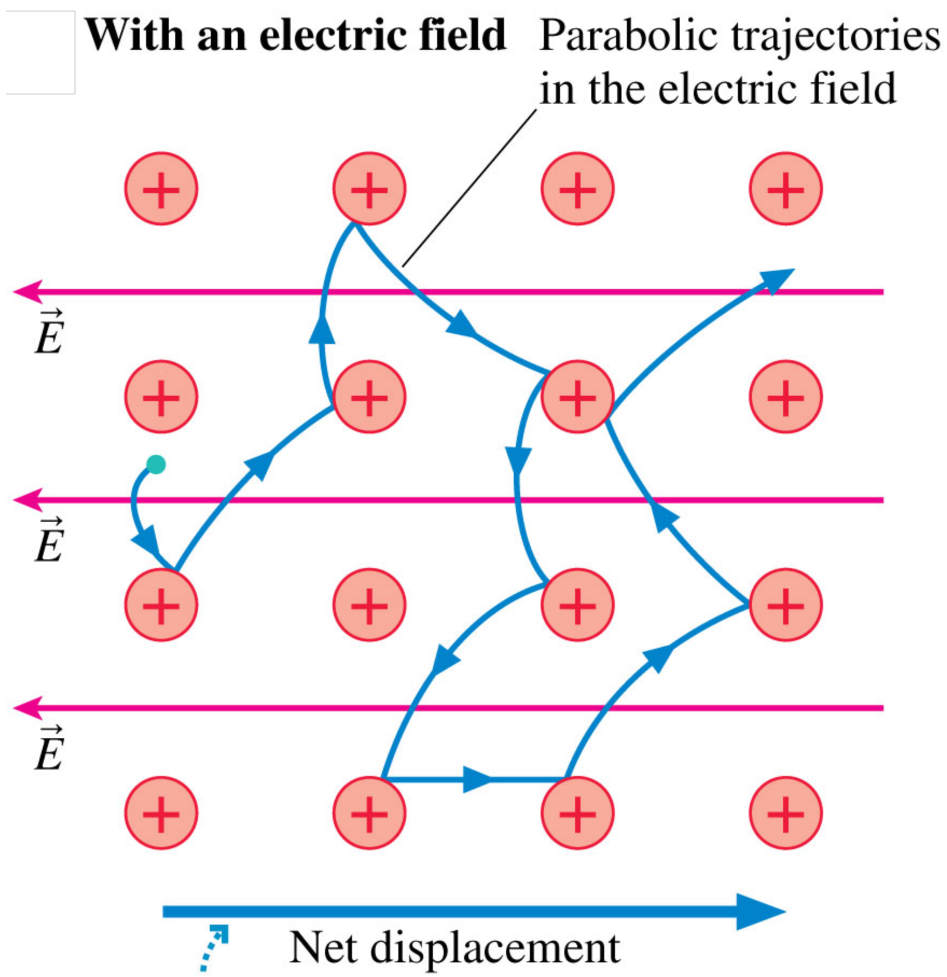
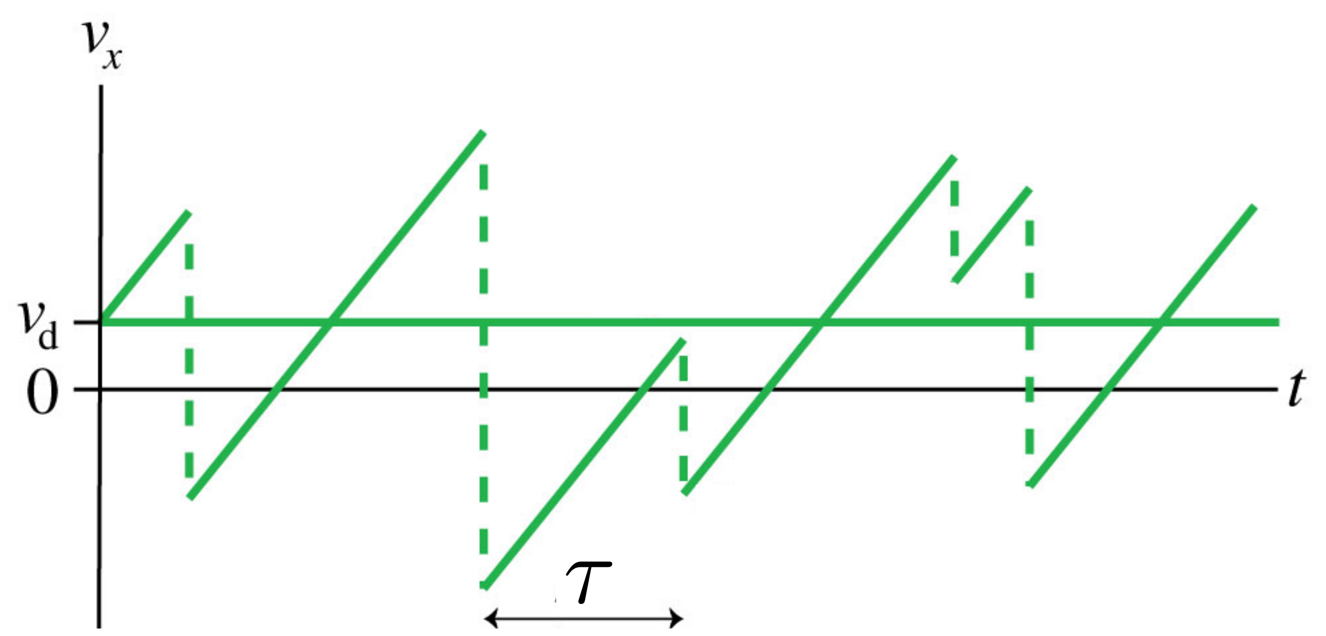
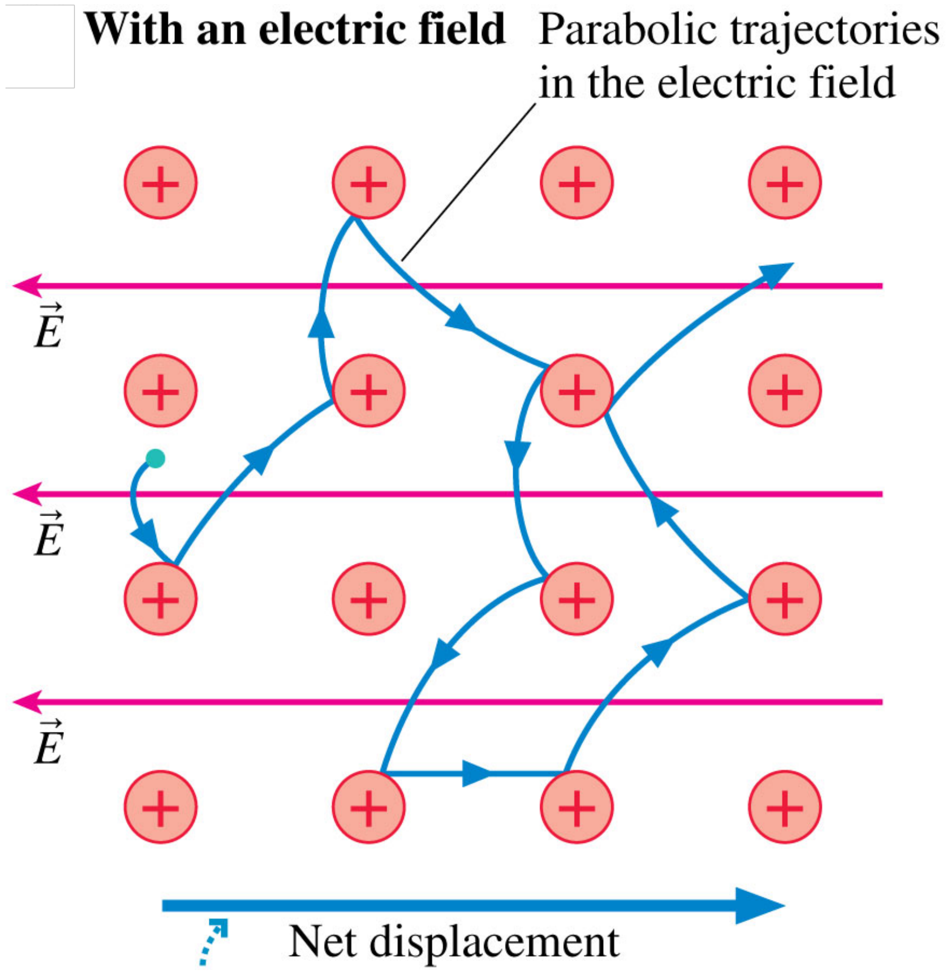
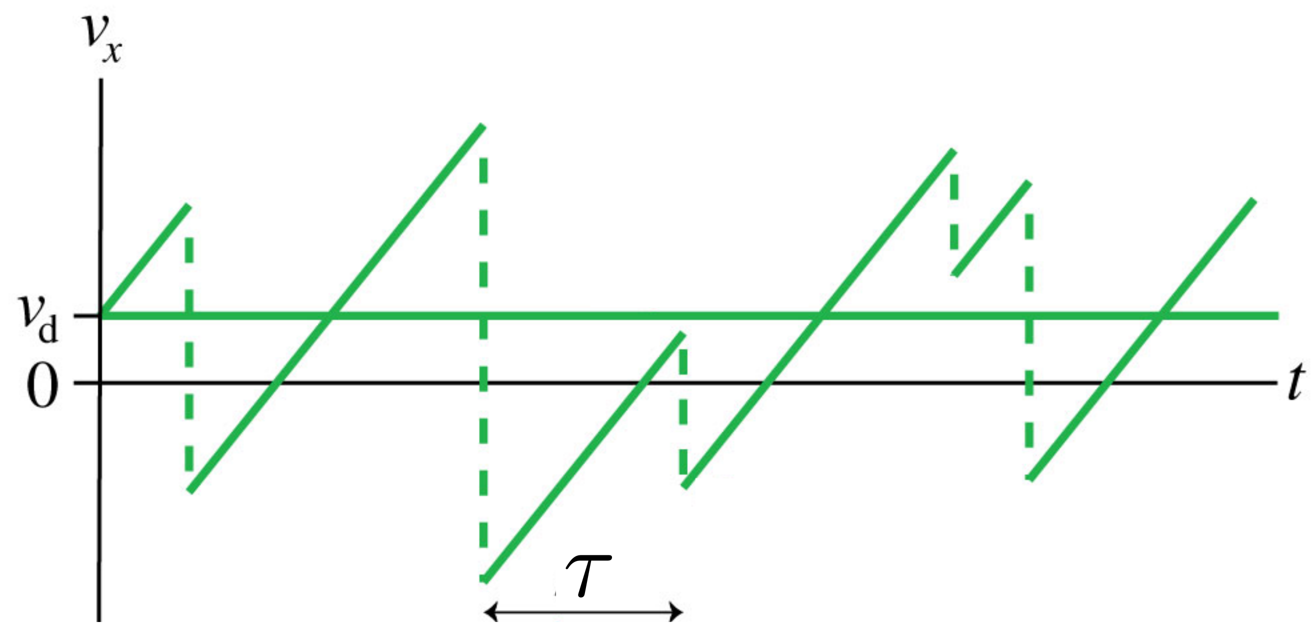




$$v_d = \frac{eE}{m}\tau$$

$$\boxed{i_e = \frac{n_e A e E \tau}{m}}$$





$$v_d = \frac{eE}{m}\tau \qquad i_e = n_e A v_d$$

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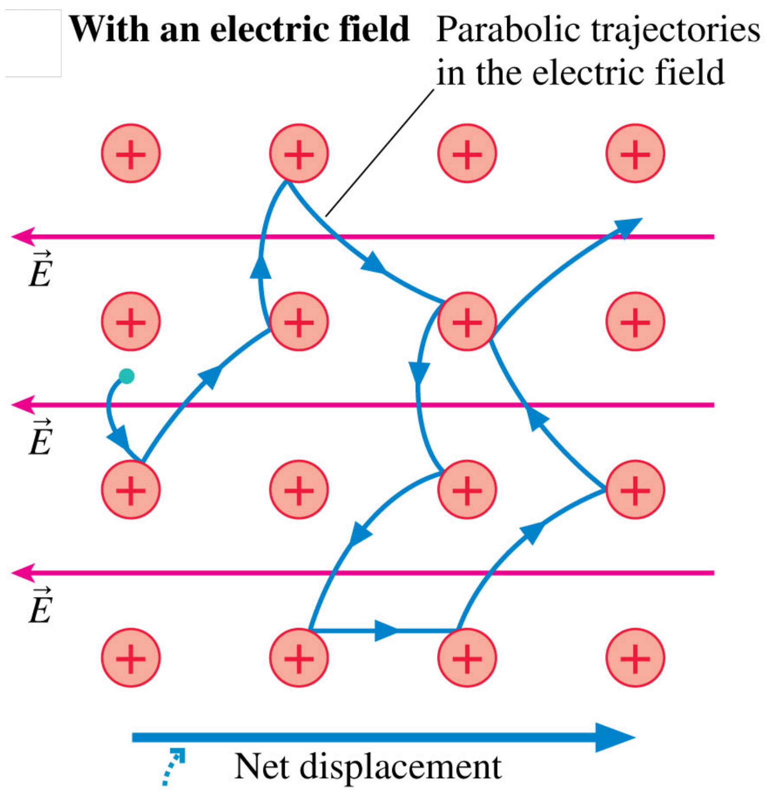
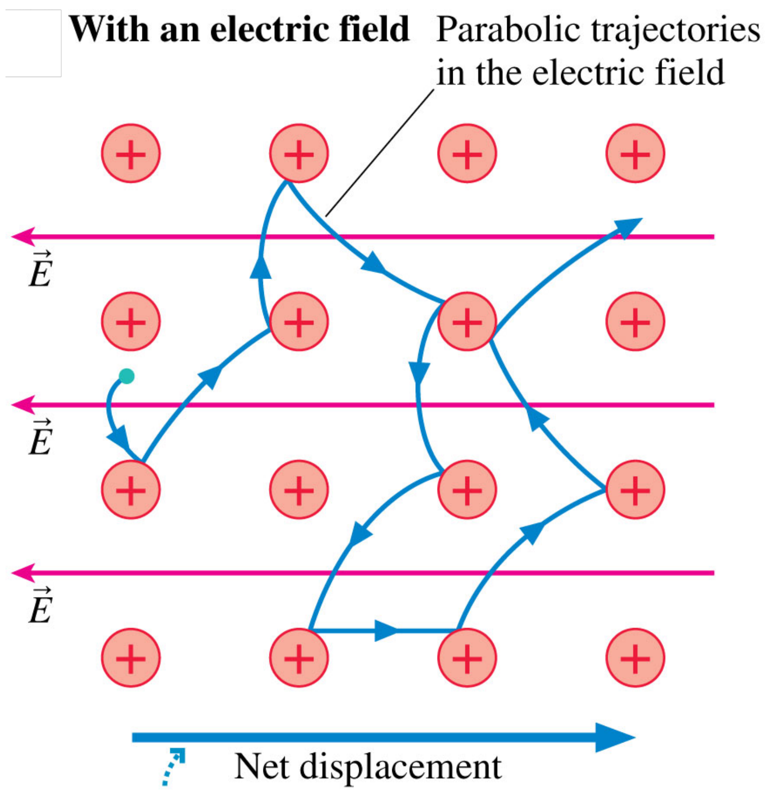


$$i_e = \frac{n_e A e E \tau}{m}$$

Perform a unit analysis on this expression. What are the units of i_e?



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# of electrons/time

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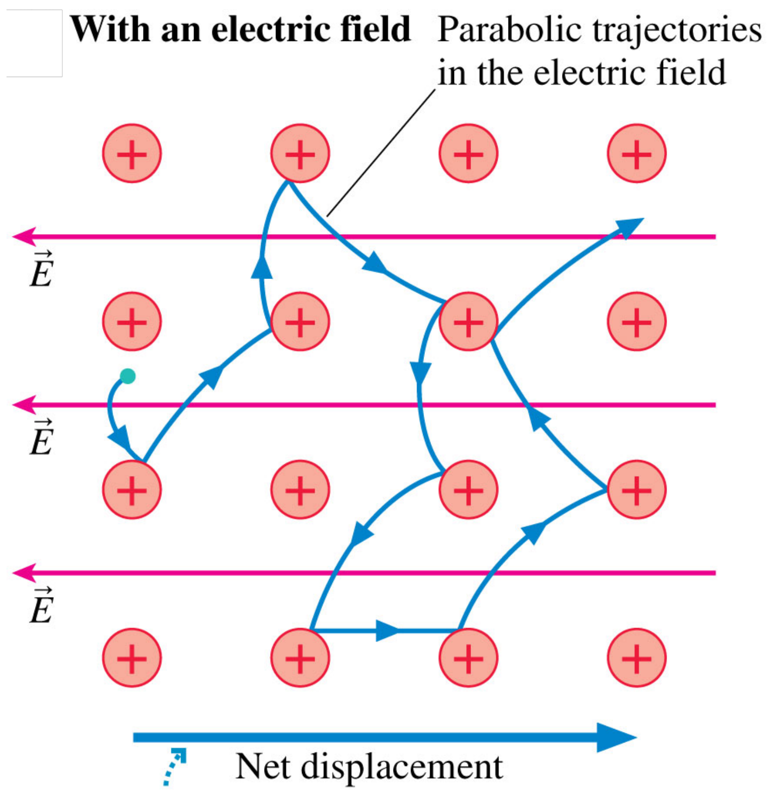

$$i_e = \frac{n_e A e E \tau}{m}$$

# of electrons/time

$$I = \frac{dQ}{dt} = \frac{n_e A e^2 E \tau}{m} = \frac{n_e A e^2 \tau}{m} E$$

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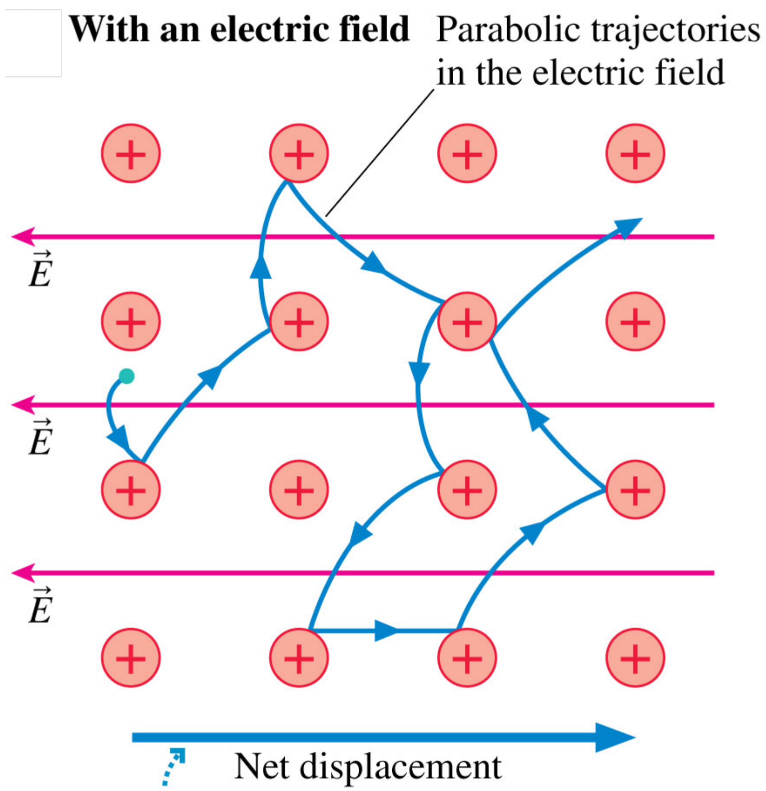

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charge/time

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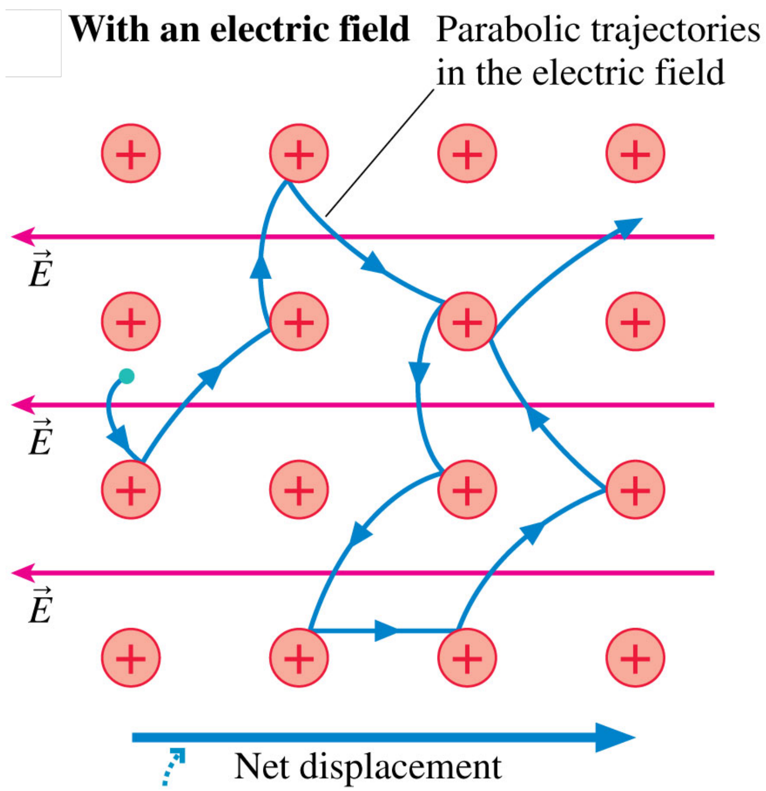

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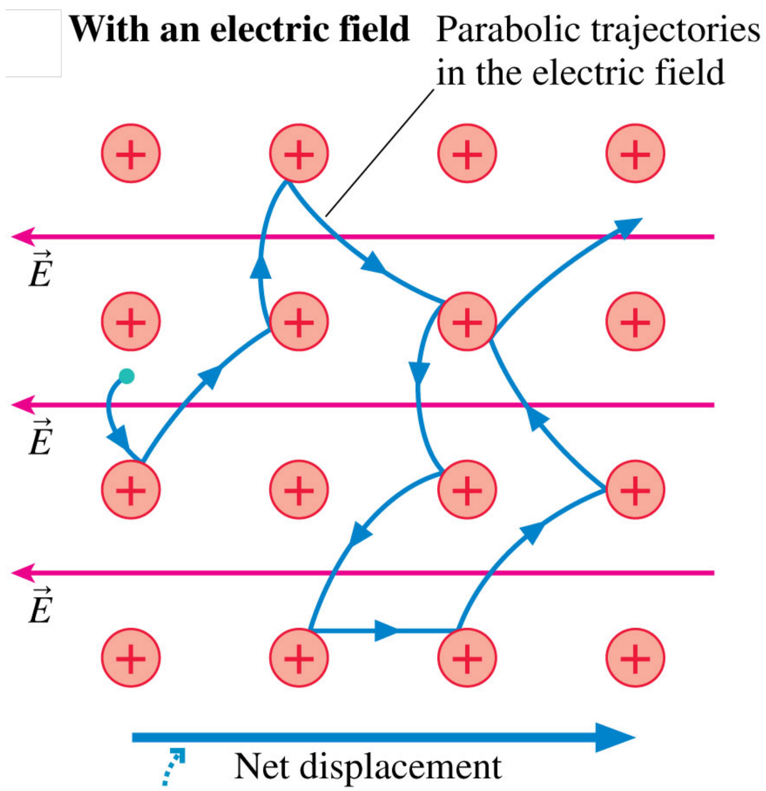
charge/time

Perform a unit analysis on this expression. What are the units of i_e?

$$J = \frac{I}{A} = \frac{n_e e^2 \tau}{m} E$$



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charge/time

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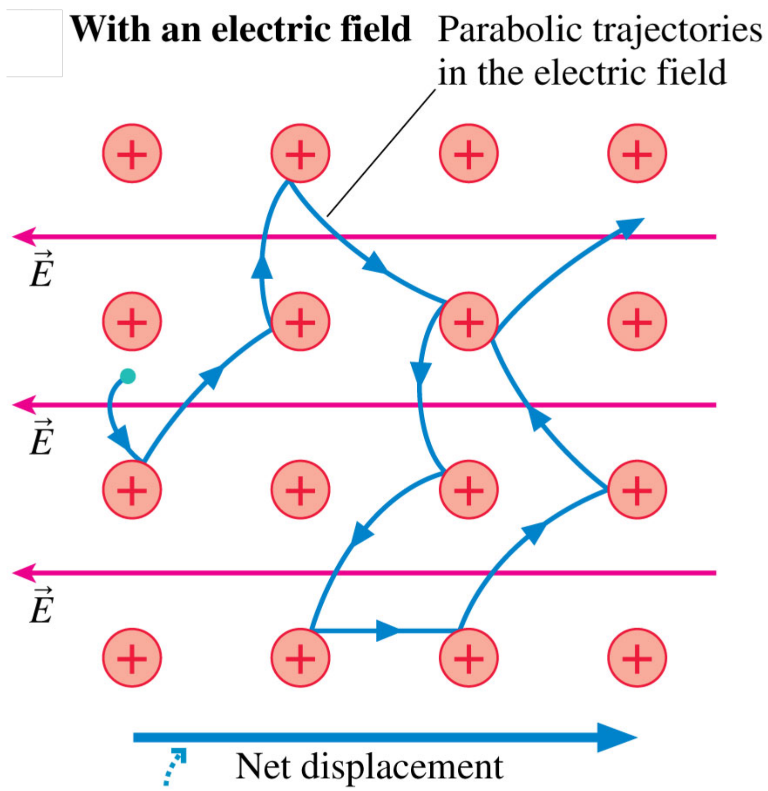


$$i_e = \frac{n_e A e E \tau}{m}$$ # of electrons/time

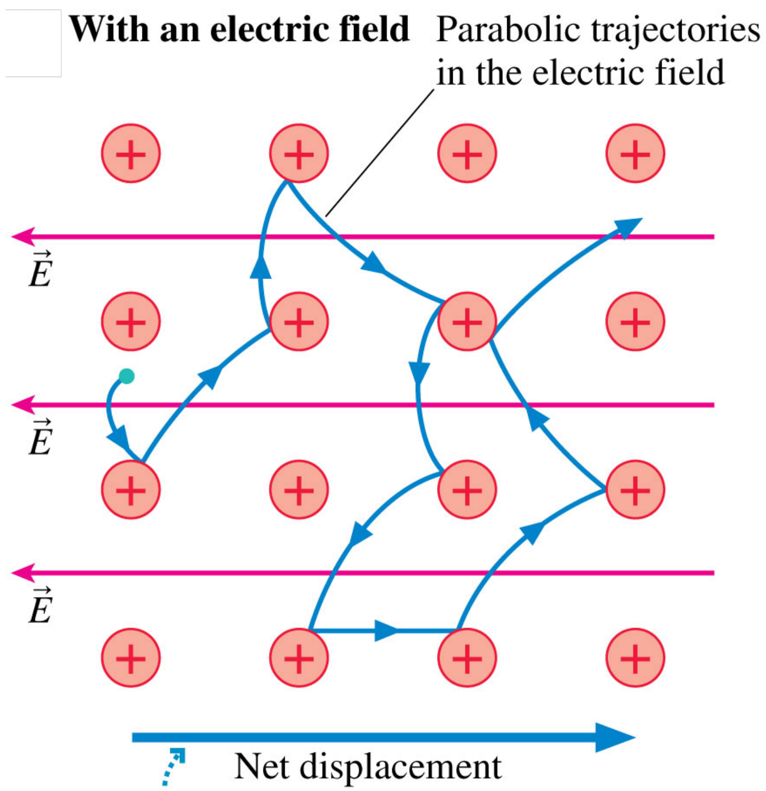
$$I = \frac{dQ}{dt} = \frac{n_e A e^2 E \tau}{m} = \frac{n_e A e^2 \tau}{m} E$$

charge/time

Perform a unit analysis on this expression. What are the units of i_e?

$$J = \frac{I}{A} = \boxed{\frac{n_e e^2 \tau}{m}} E$$

$$= \sigma E$$ conductivity



$$i_e = \frac{n_e A e E \tau}{m}$$

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$$I = \frac{dQ}{dt} = \frac{n_e A e^2 E \tau}{m} = \frac{n_e A e^2 \tau}{m} E$$

charge/time

Perform a unit analysis on this expression. What are the units of i_e?

$$J = \frac{I}{A} = \boxed{\frac{n_e e^2 \tau}{m}} E$$

$$= \sigma E$$

conductivity

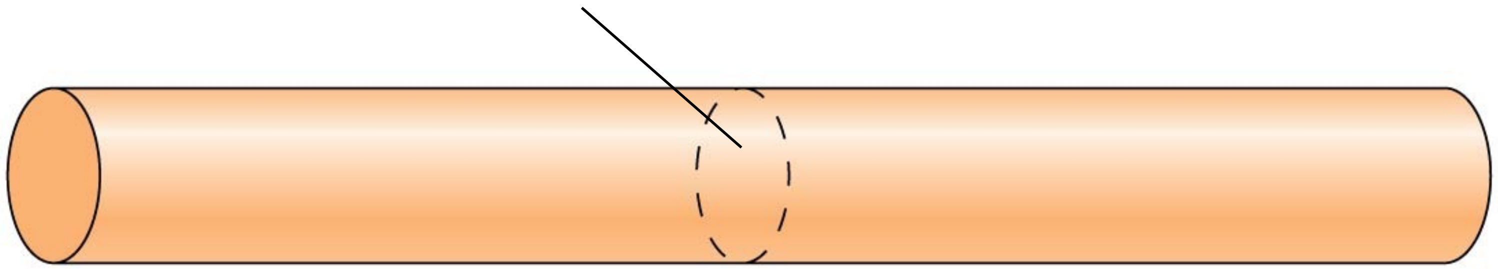
$$= \frac{1}{\rho} E$$

resistivity

Quiz Question

Every minute, 120 C of charge flow through this cross section of the wire.

The wire's current is

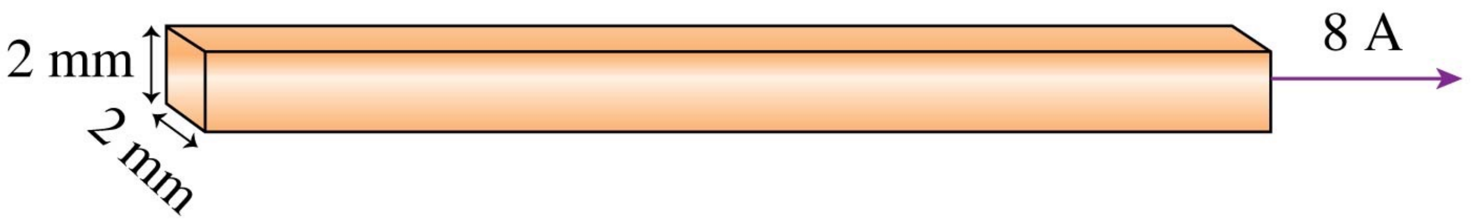


B. 240 A.
C. 120 A.
D. 60 A.
E. 2 A.

Quiz Question

The current density in this wire is

A. 4×10^6 A/m^2.
B. 2×10^6 A/m^2.
C. 4×10^3 A/m^2.
D. 2×10^3 A/m^2.
E. Some other value.

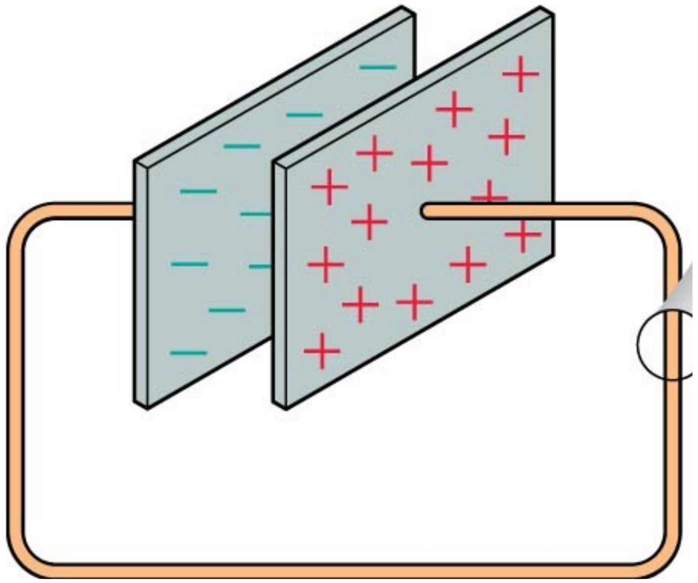


Quiz Question

Which direction is the current?

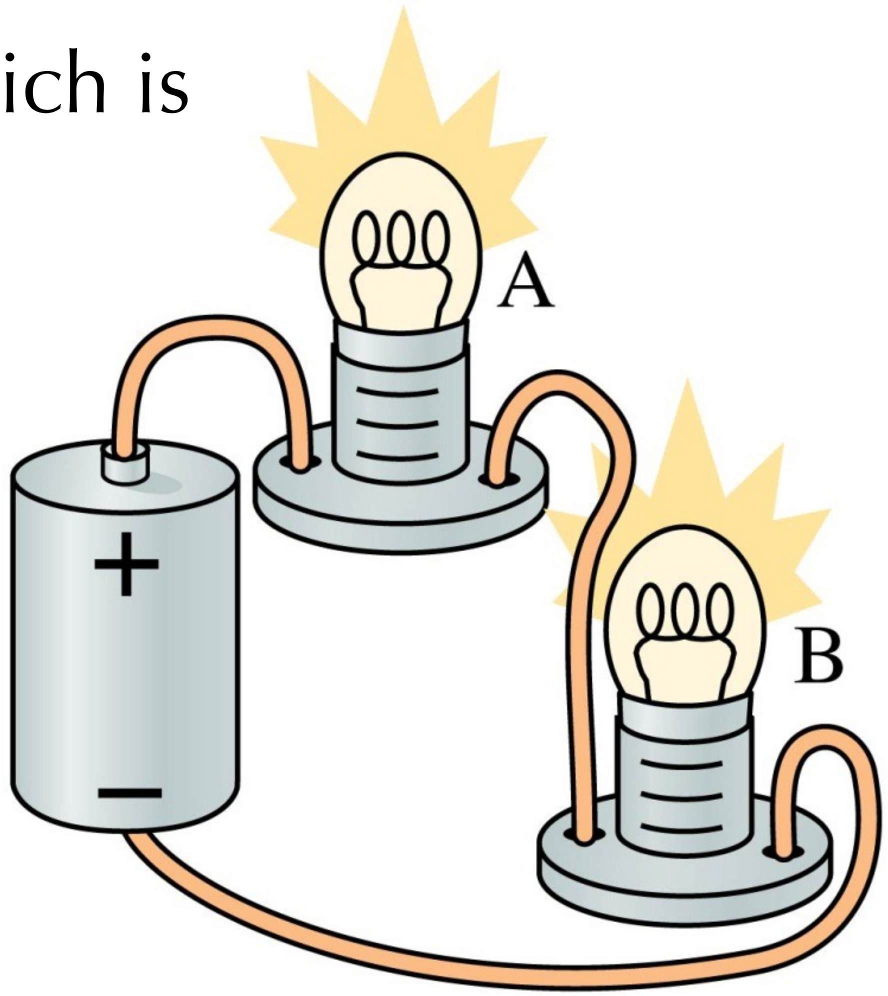
a) counterclockwise

b) clockwise



Quiz Question

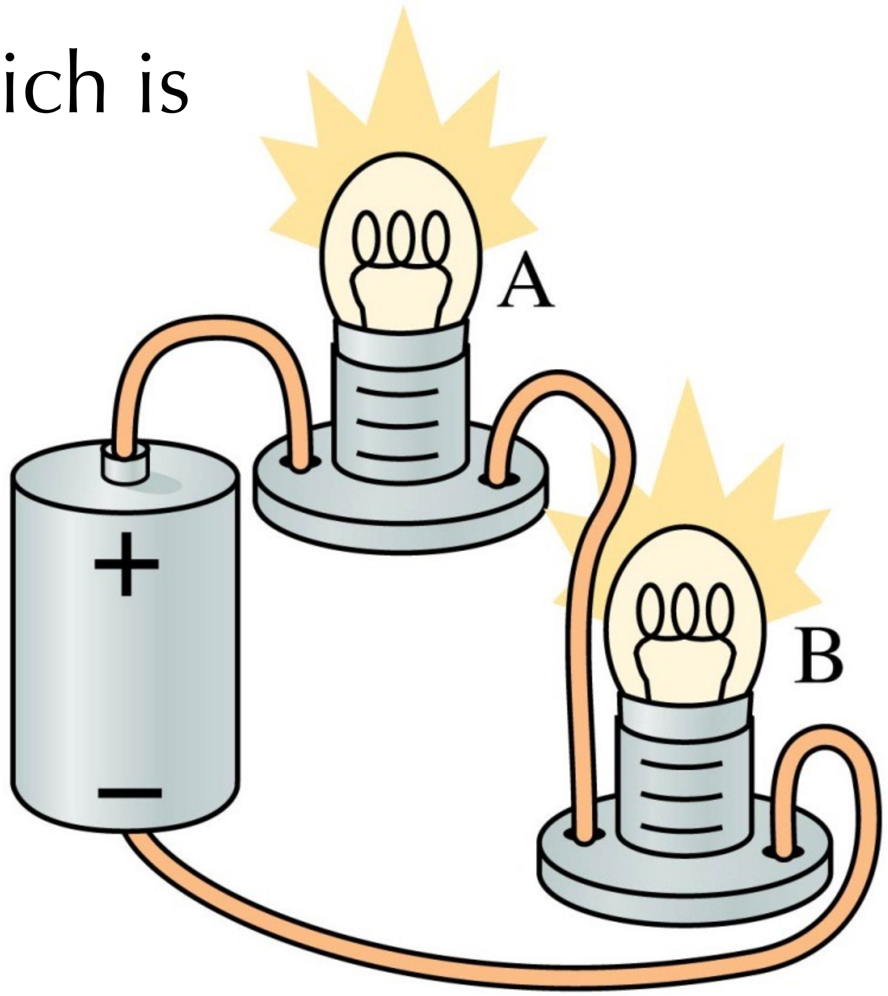
A and B are identical lightbulbs connected to a battery as shown. Which is brighter?



A. Bulb A.
B. Bulb B.
C. The bulbs are equally bright.

Quiz Question

A and B are identical lightbulbs connected to a battery as shown. Which is brighter?

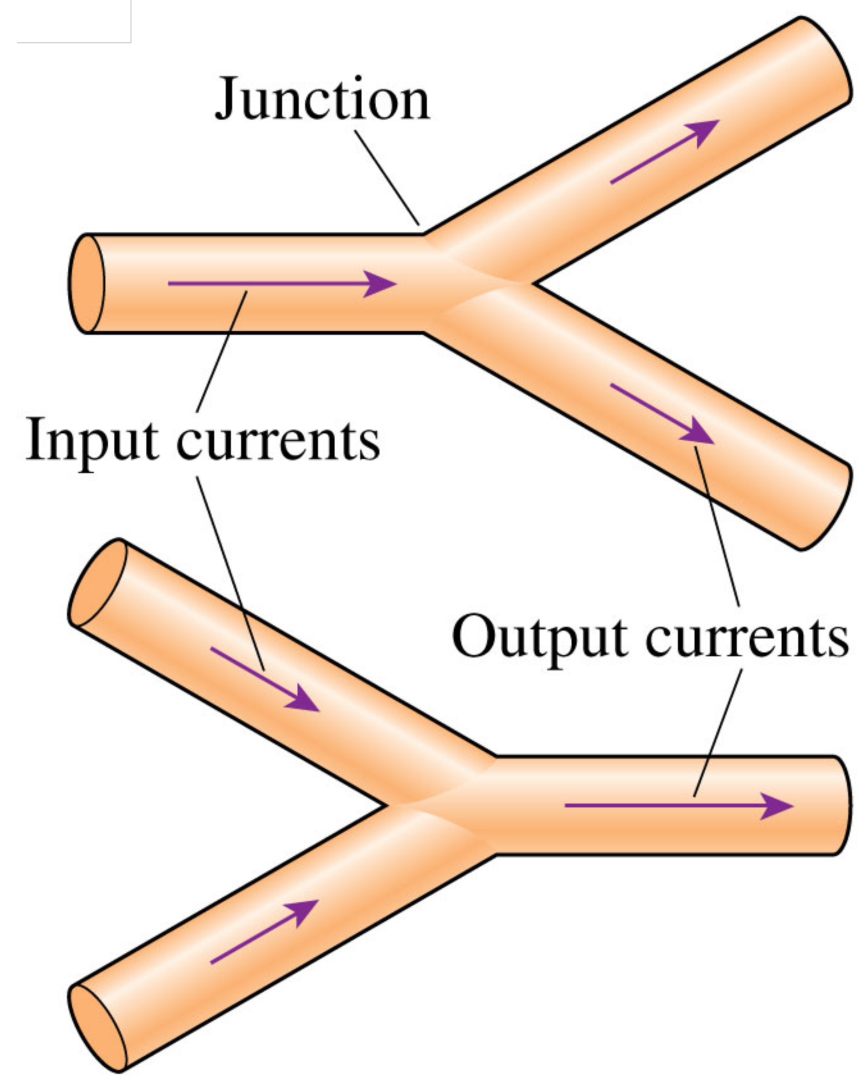


A. Bulb A.
B. Bulb B.
C. The bulbs are equally bright.

conservation of current.

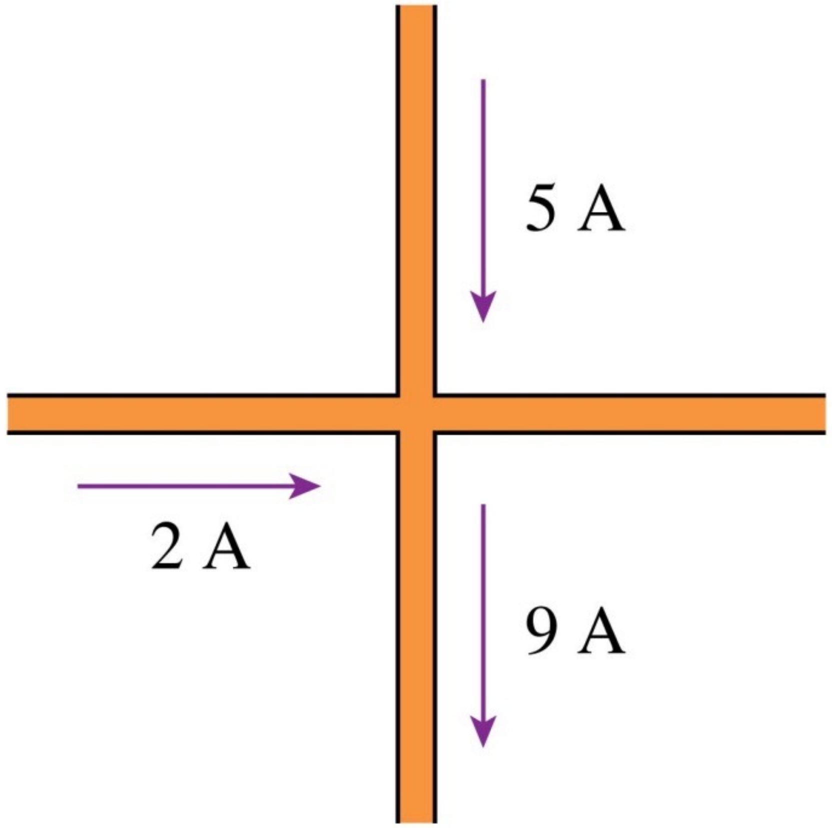
Kirchoff's Junction Law

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



Quiz Question

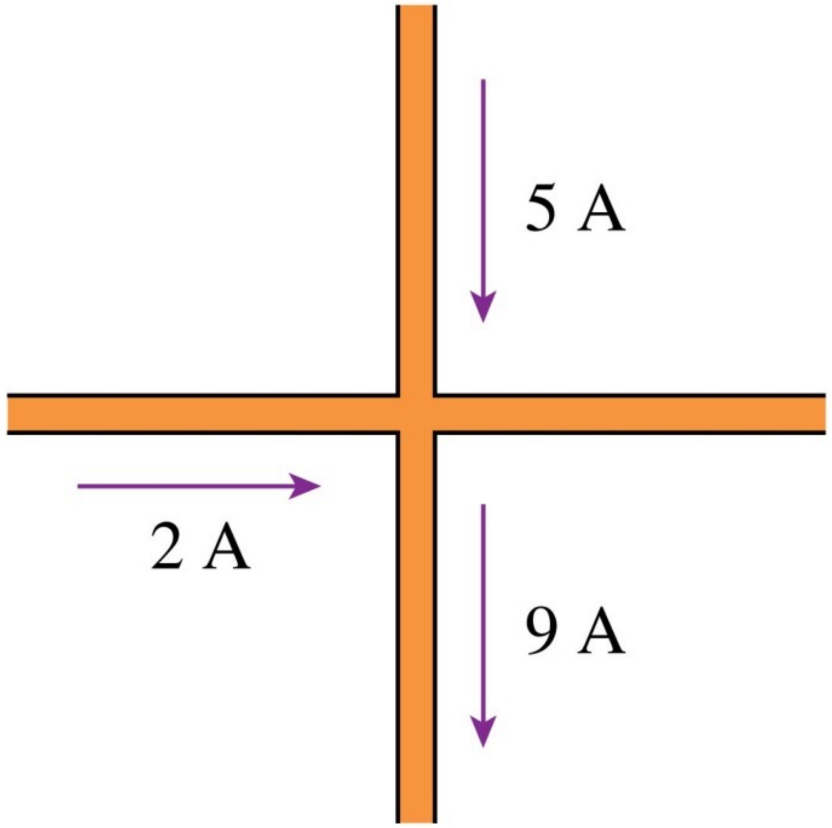
The current in the fourth wire is



A. 2 A to the left.
B. 4 A to the left.
C. 2 A to the right.
D. 16 A to the right.
E. Not enough information to tell.

Quiz Question

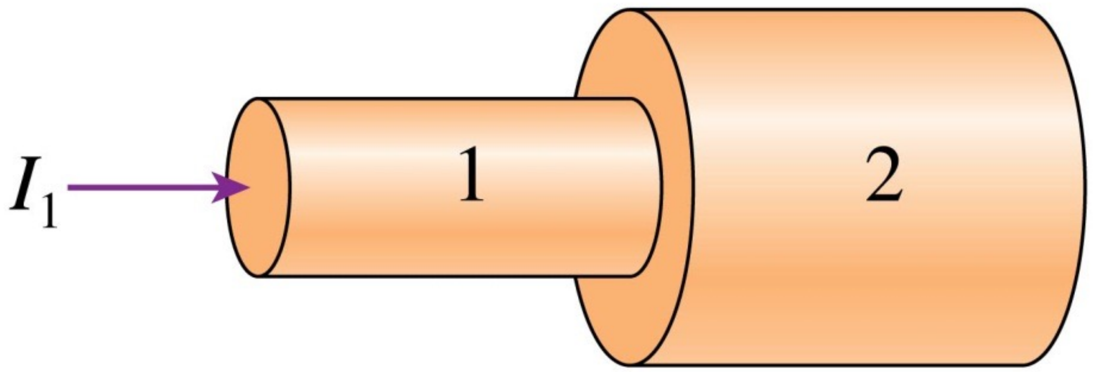
The current in the fourth wire is



A. 2 A to the left.
B. 4 A to the left.
C. 2 A to the right.
D. 16 A to the right.
E. Not enough information to tell.

Quiz Question

Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left. How does current I_1 in segment 1 compare to current I_2 in segment 2?



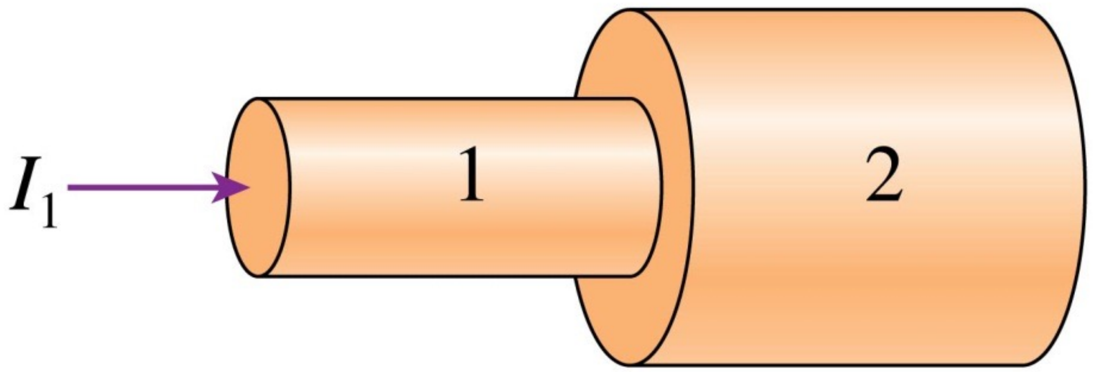
B. $I_1 > I_2$.

C. $I_1 < I_2$.

D. $I_1 = I_2$.

Quiz Question

Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left. How does current density J_1 in segment 1 compare to current density J_2 in segment 2?



B. $J_1 = J_2$.

C. $J_1 < J_2$.

D. $J_1 > J_2$.

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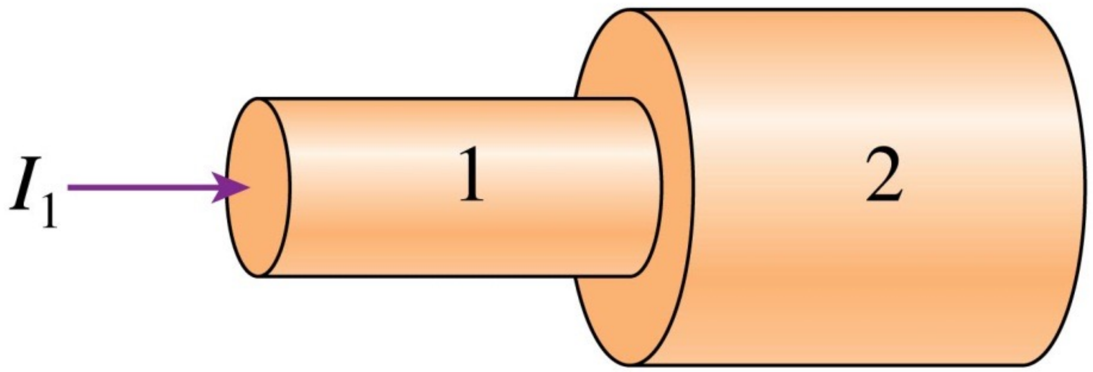


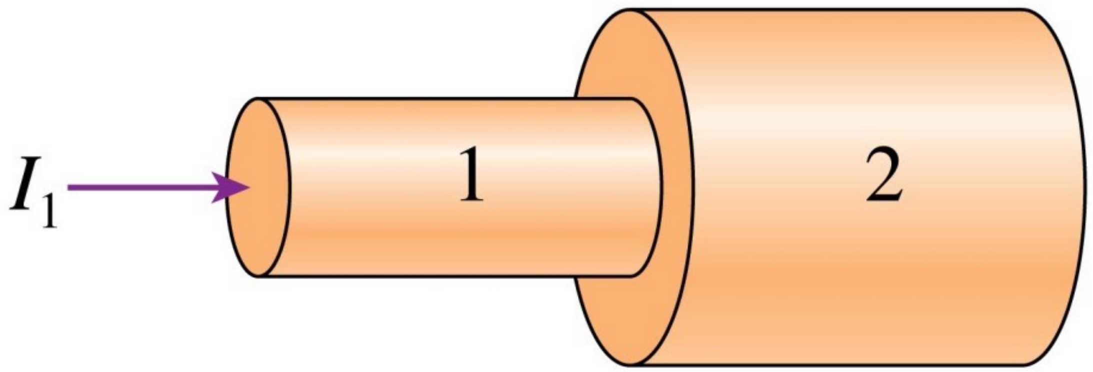
B. $J_1 = J_2$.

C. $J_1 < J_2$.

D. $J_1 > J_2$. smaller cross section

Quiz Question

Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left. How does the electric field E_1 in segment 1 compare to the electric field E_2 in segment 2?



A. $E_1 < E_2$.

B. $E_1 = E_2$ but not zero.

C. $E_1 > E_2$.

D. Both are zero because metal is a conductor.

E. There's not enough information to compare them.

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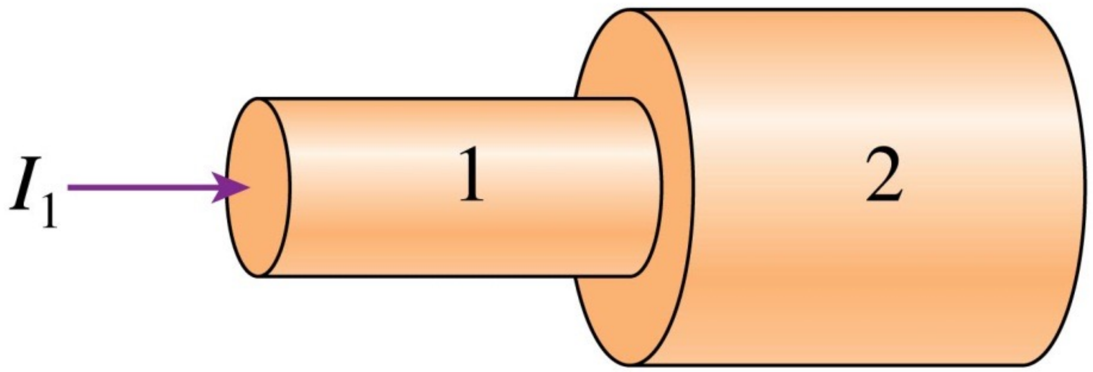


A. $E_1 < E_2$.

B. $E_1 = E_2$ but not zero.

C. $E_1 > E_2$. how is this possible?

D. Both are zero because metal is a conductor.

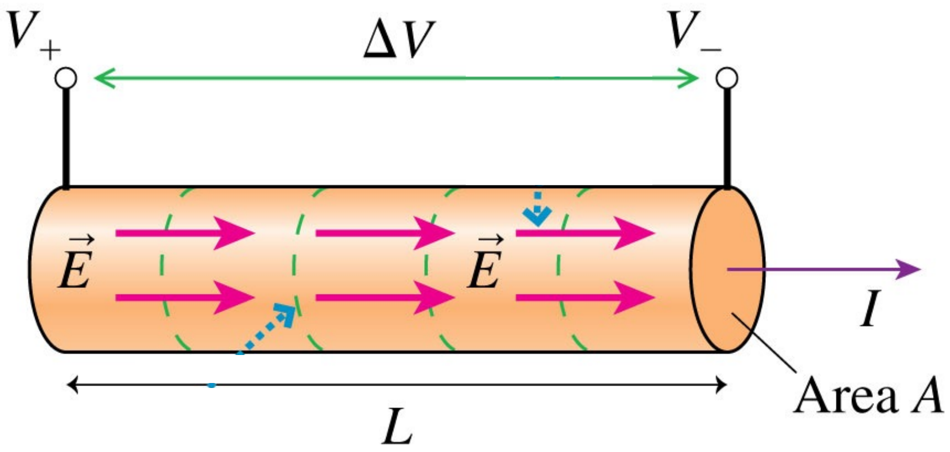
E. There's not enough information to compare them.

Ohm's Law

recall that...

$$J = \frac{I}{A} = \frac{1}{\rho}E$$

$$E = \frac{\Delta V}{L}$$



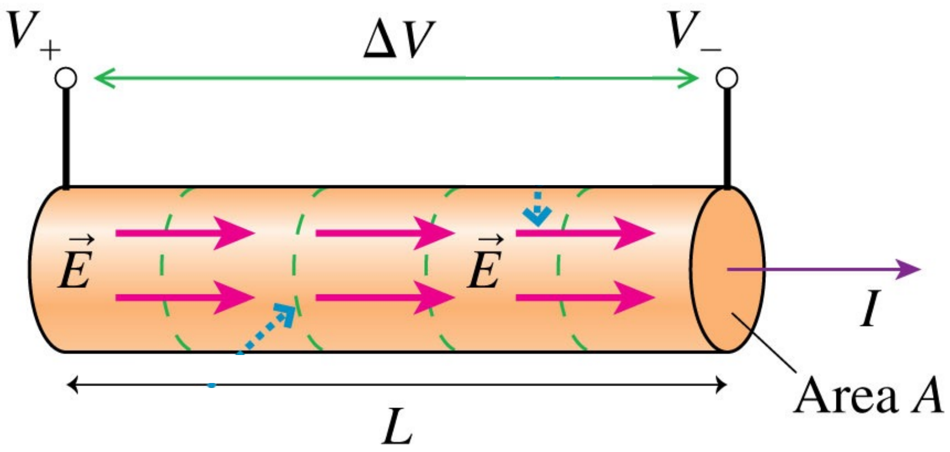
Ohm's Law

recall that…

$$E = \frac{\Delta V}{L}$$

$$J = \frac{I}{A} = \frac{1}{\rho} E$$

rearrange…



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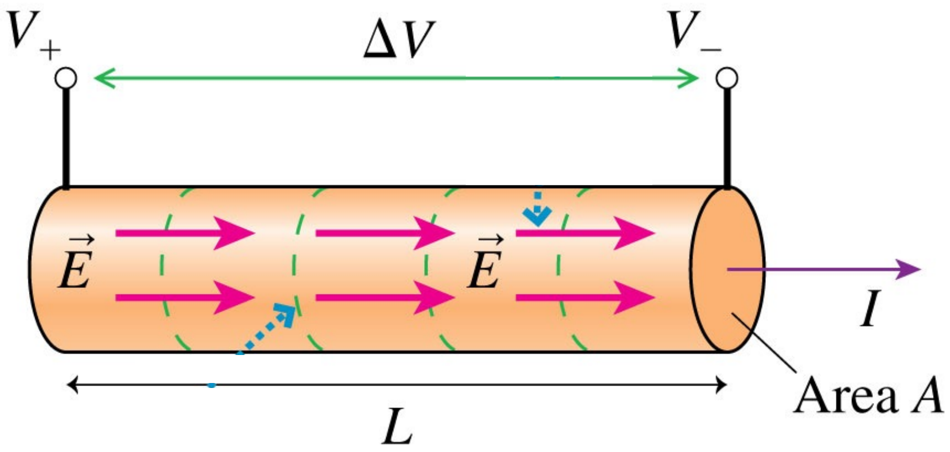

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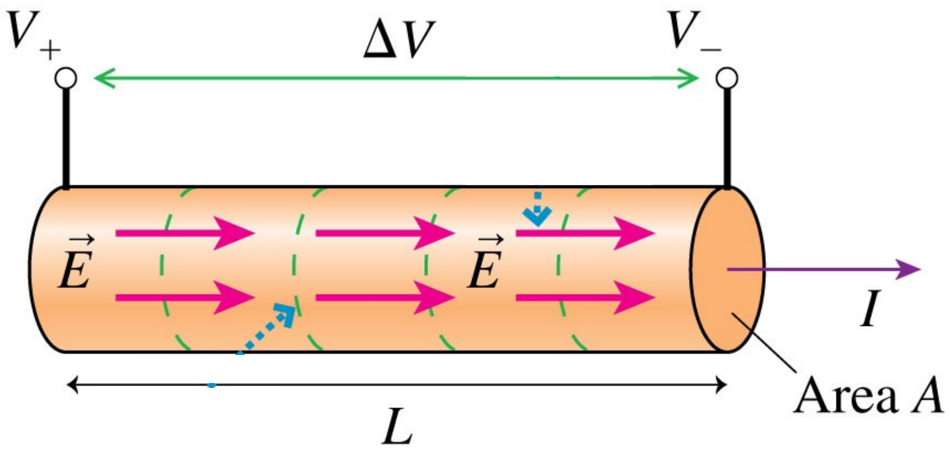

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$$= \frac{A\Delta V}{\rho L}$$

Ohm's Law

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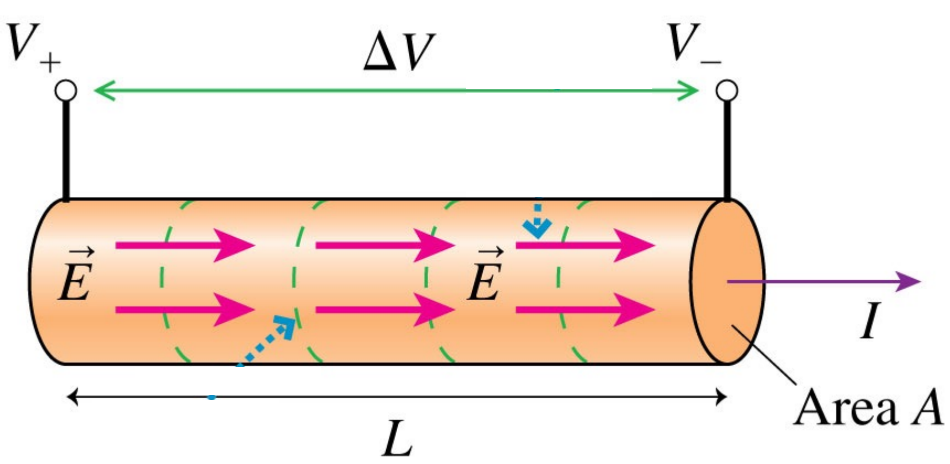


$$J = \frac{I}{A} = \frac{1}{\rho} E$$

rearrange...

$$I = \frac{A}{\rho} E$$

$$= \frac{A \Delta V}{\rho L}$$

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

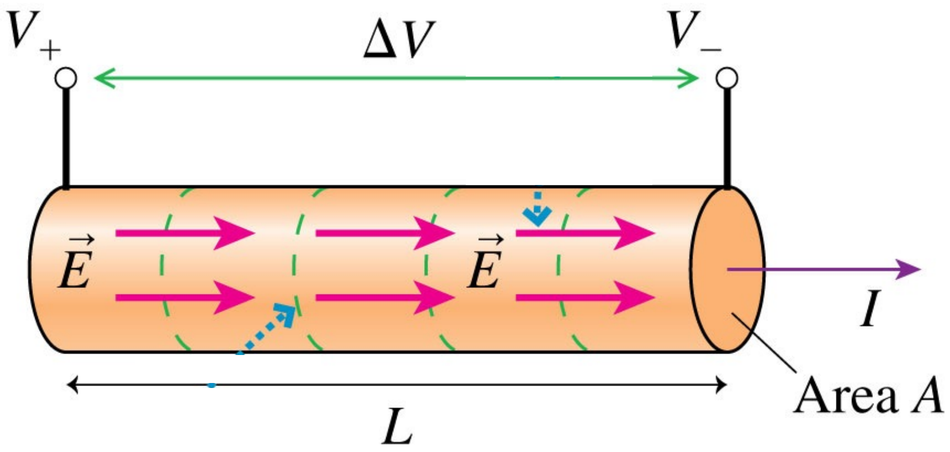
Ohm's Law

recall that...

$$E = \frac{\Delta V}{L}$$

$$J = \frac{I}{A} = \frac{1}{\rho} E$$

rearrange...



$$I = \frac{A}{\rho} E$$

$$= \frac{A \Delta V}{\rho L}$$

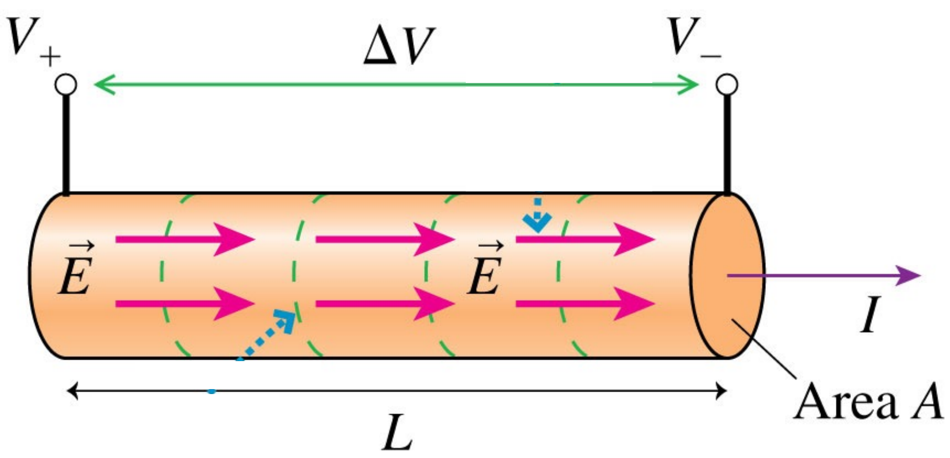
$$= \frac{\Delta V}{R}$$

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

Ohm's Law

recall that...

$$E = \frac{\Delta V}{L}$$



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

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

$$J = \frac{I}{A} = \frac{1}{\rho} E$$

rearrange...

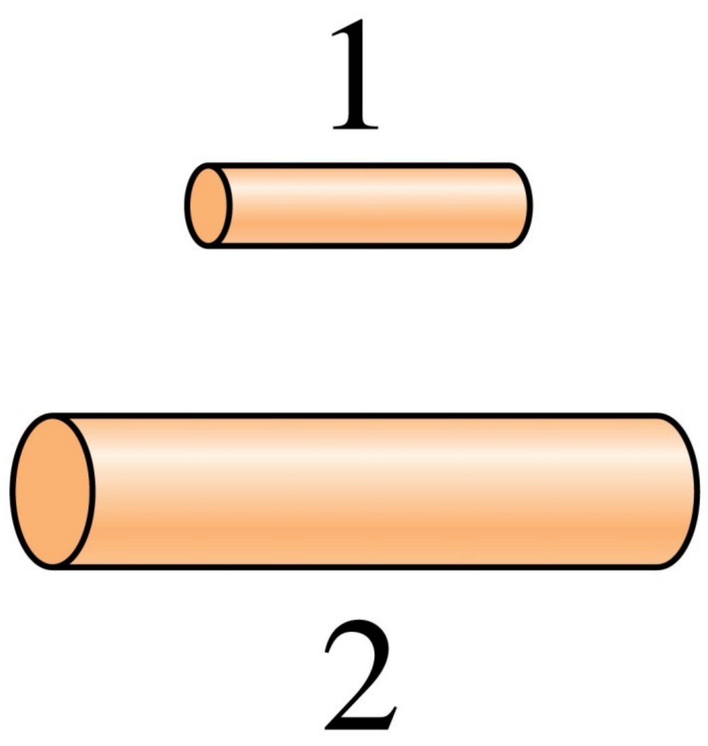
$$I = \frac{A}{\rho} E$$

$$= \frac{A \Delta V}{\rho L}$$

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

Quiz Question

Wire 2 is twice the length **and** twice the diameter of wire 1. What is the ratio R_2/R_1 of their resistances?



A. 1/4.
B. 2.
C. 1.
D. 1/2.
E. 4.

Quiz Question

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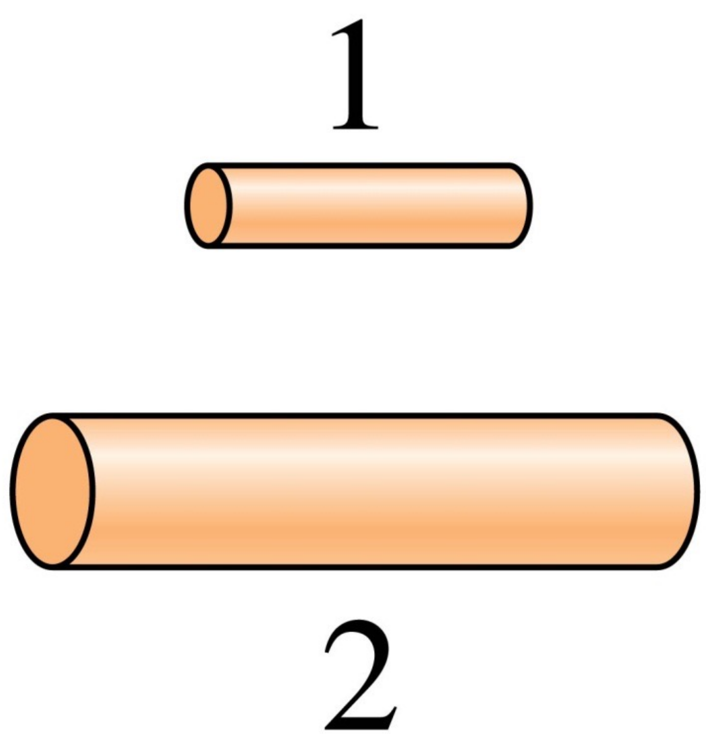
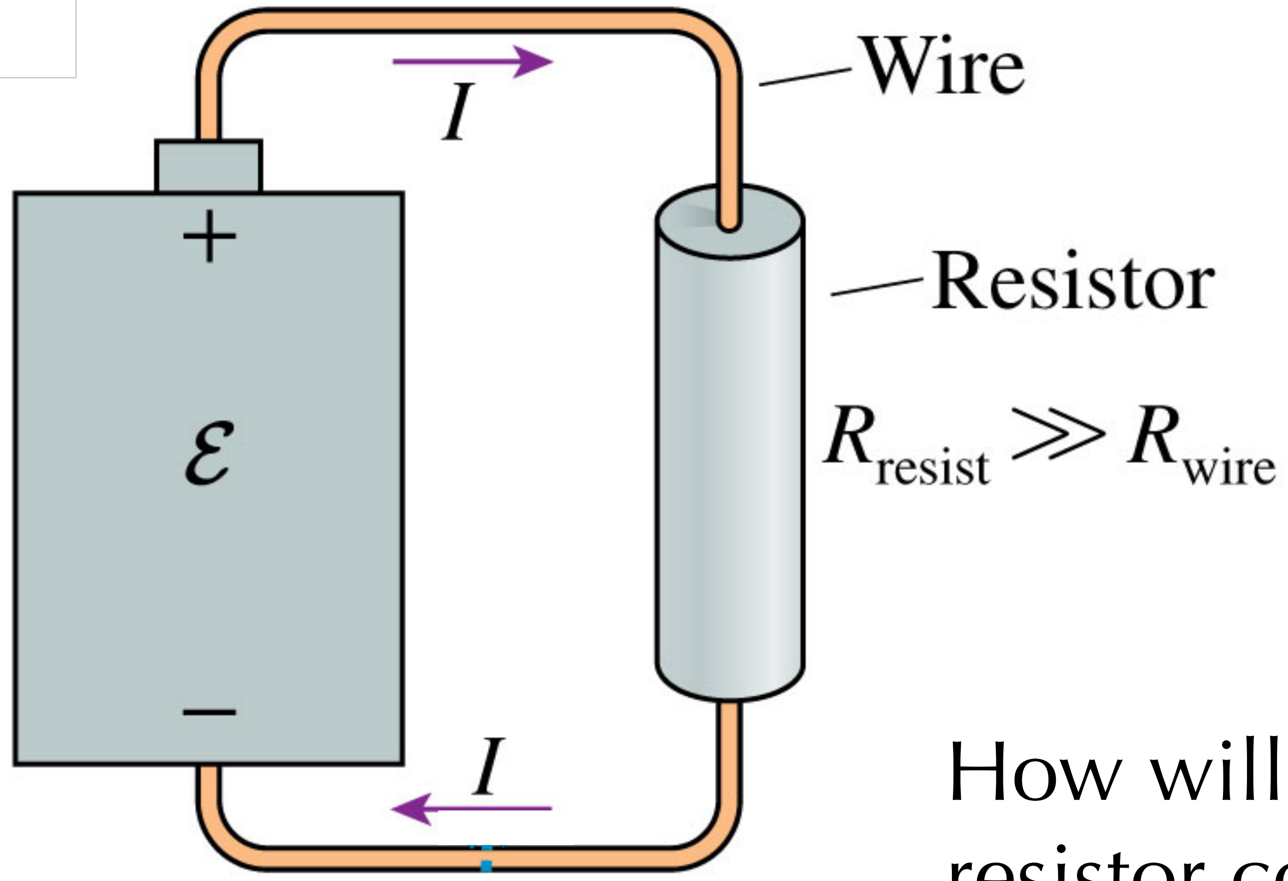


A. 1/4.
B. 2.
C. 1.
D. 1/2.
E. 4.

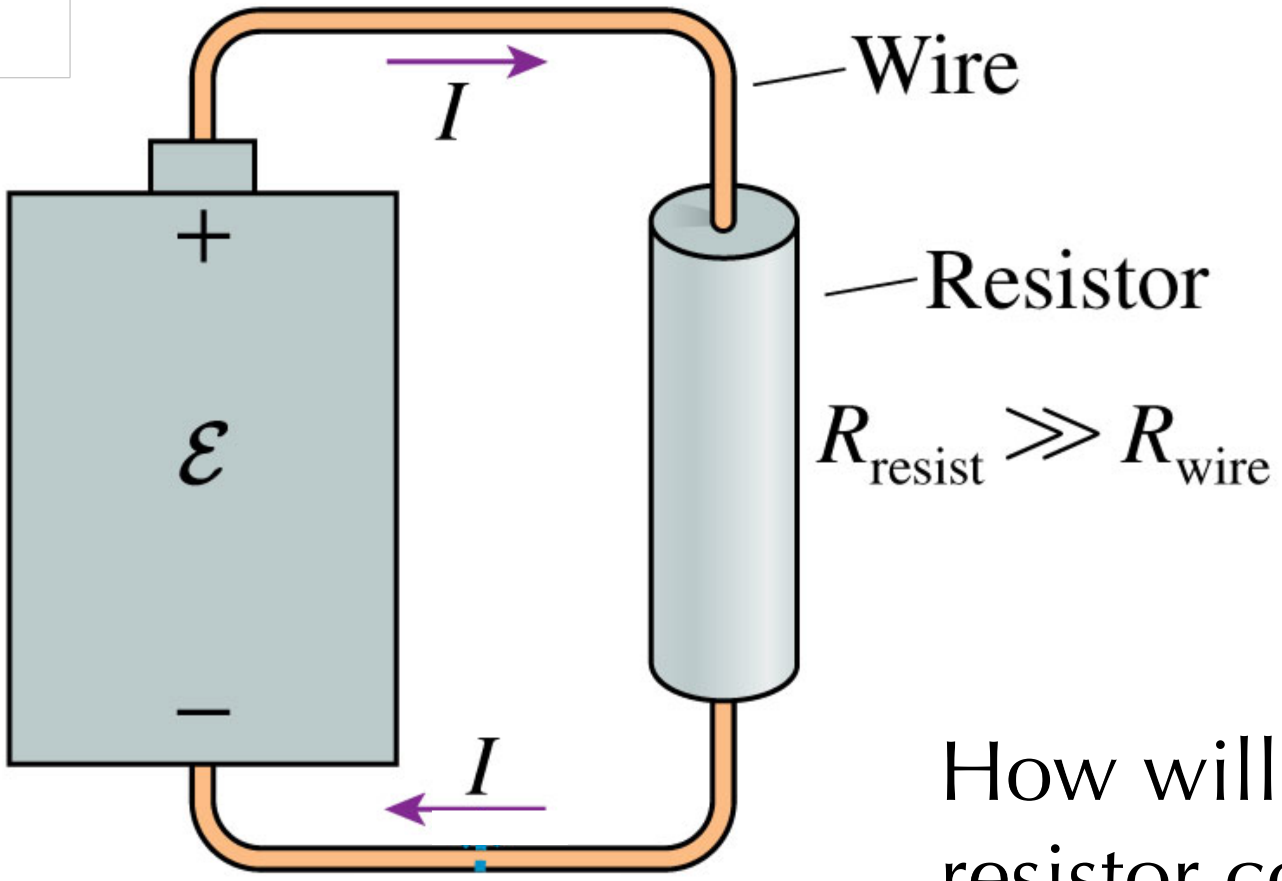
$$R = \frac{\rho L}{A}$$

Resistance is specific to the geometry of the material, not just the type of material.



How will the voltage drop across the resistor compare to the voltage drop across the wire leading to the resistor?

How is this possible?



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

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How is this possible?

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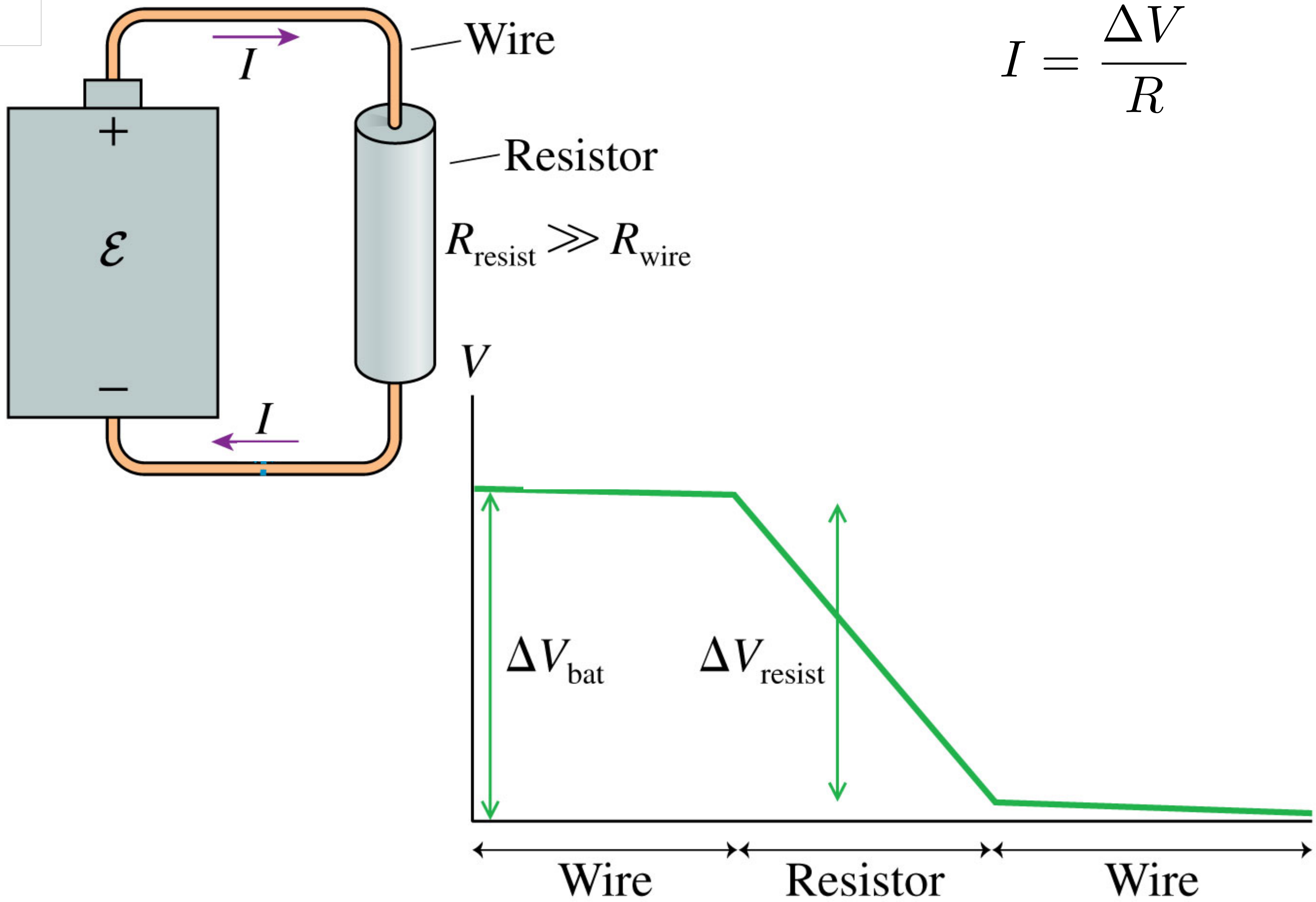

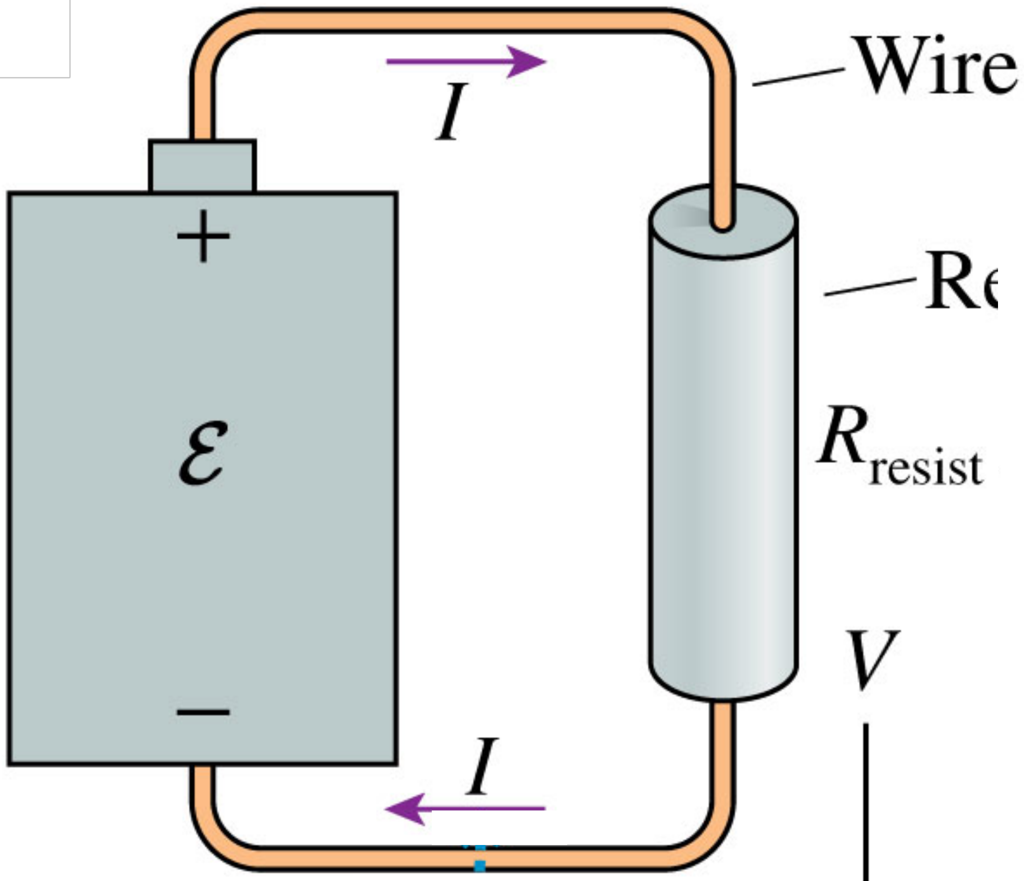

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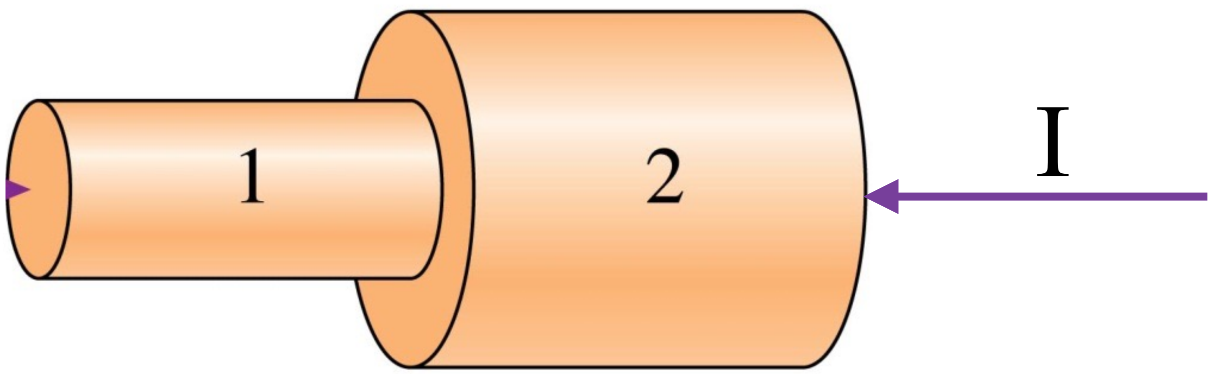

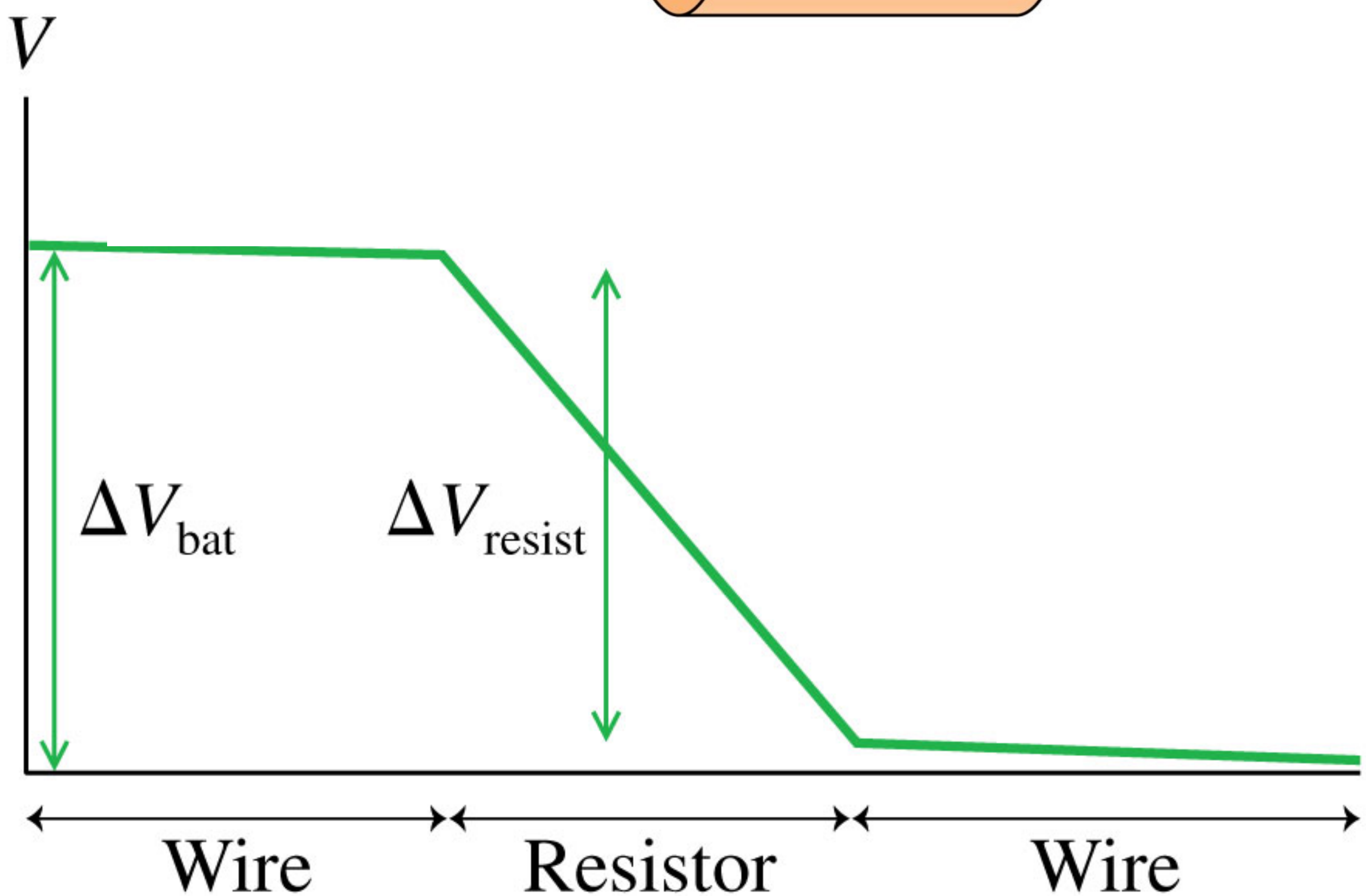

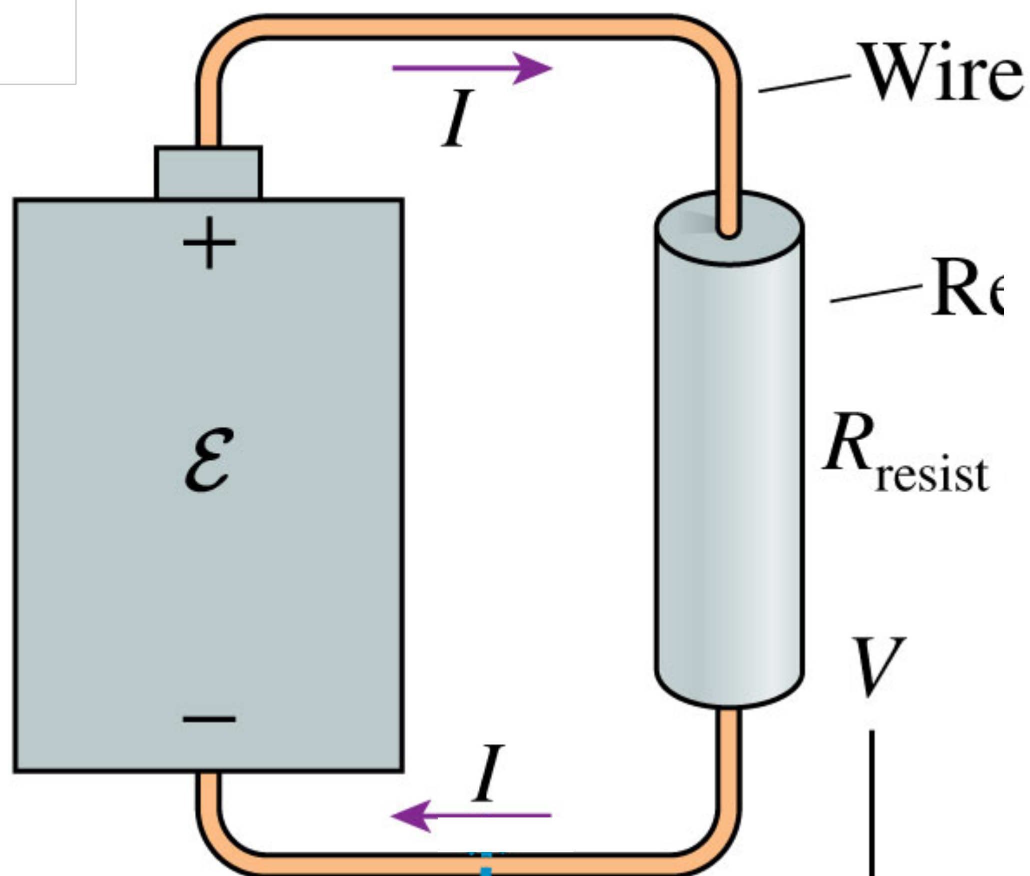

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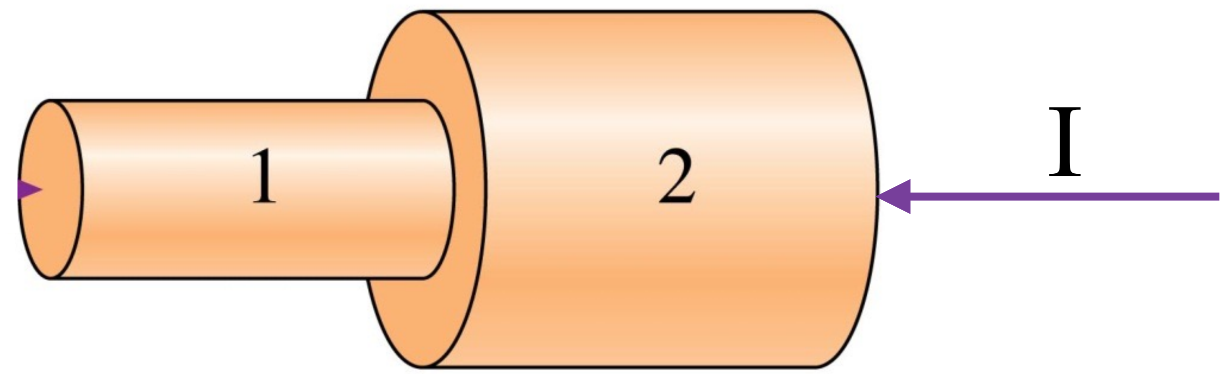
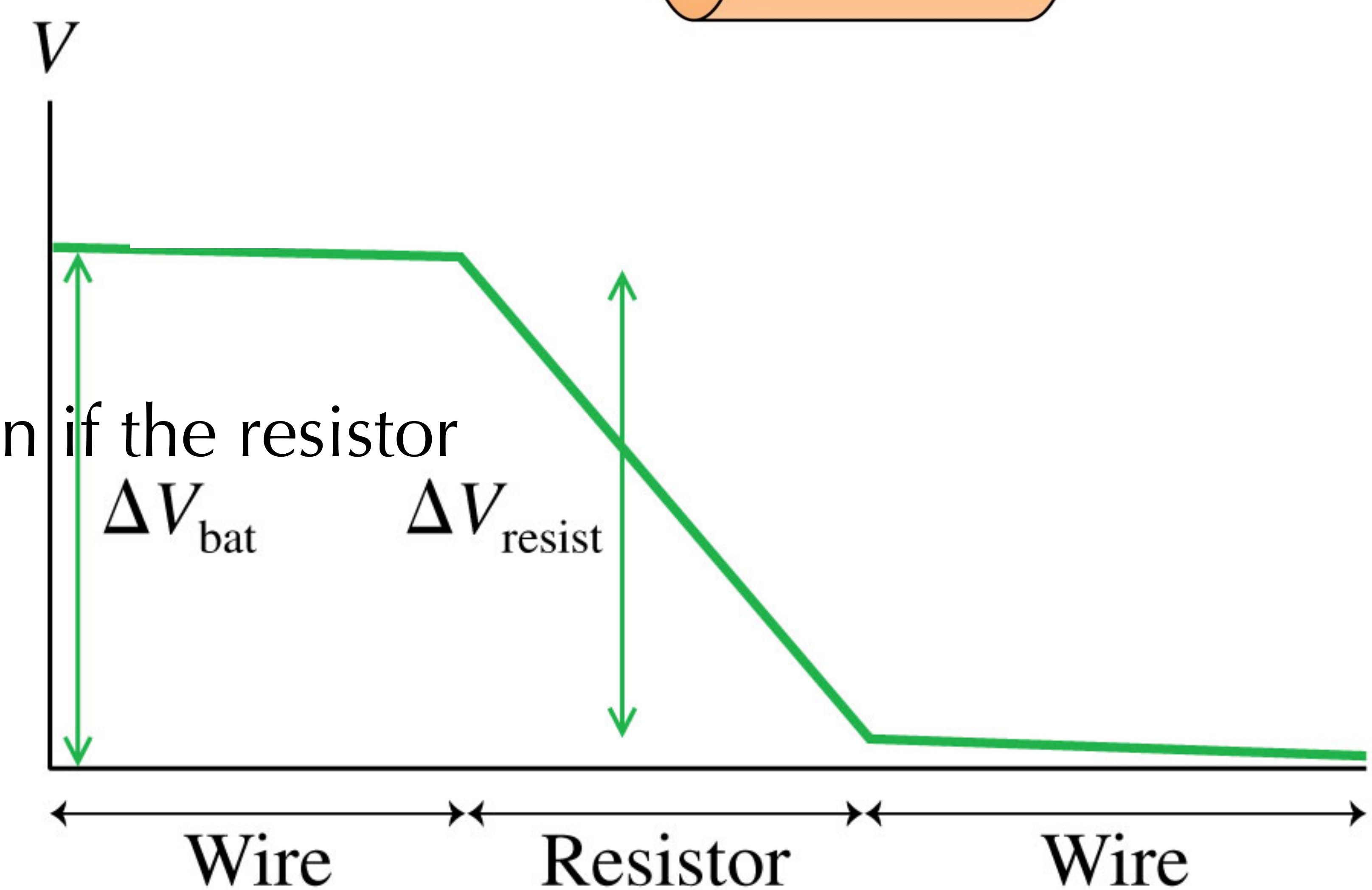
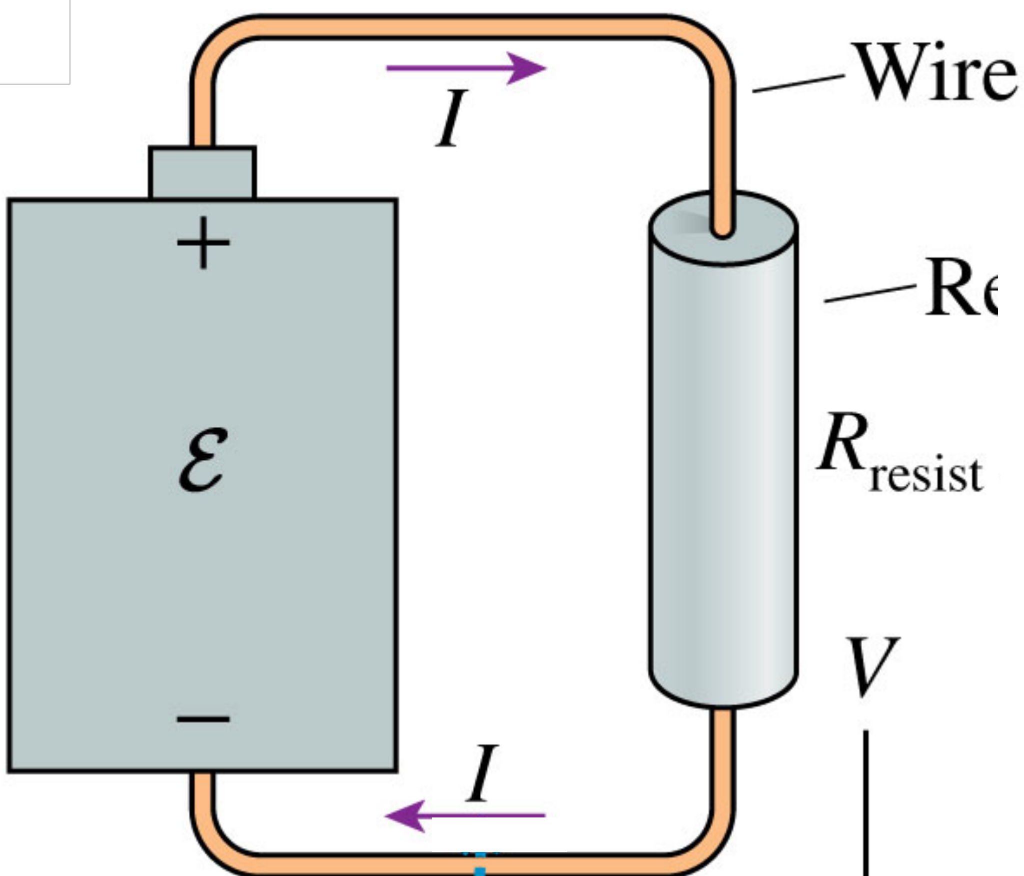
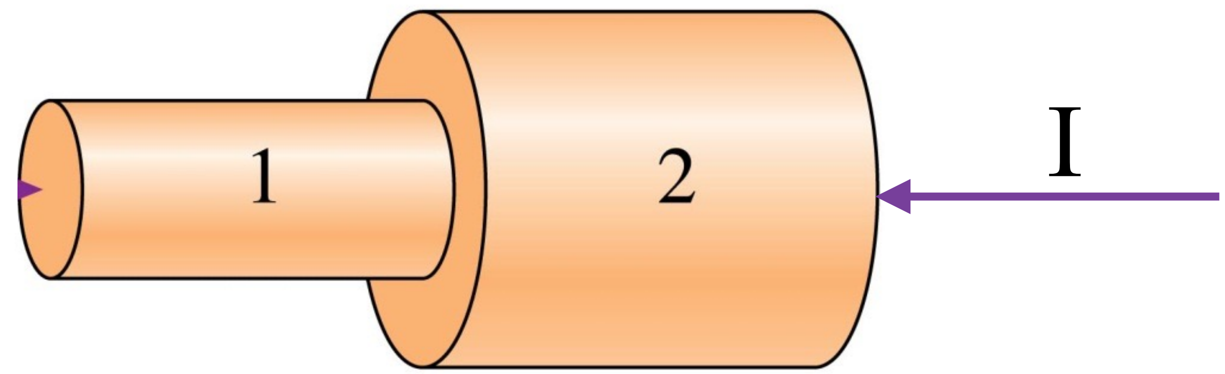


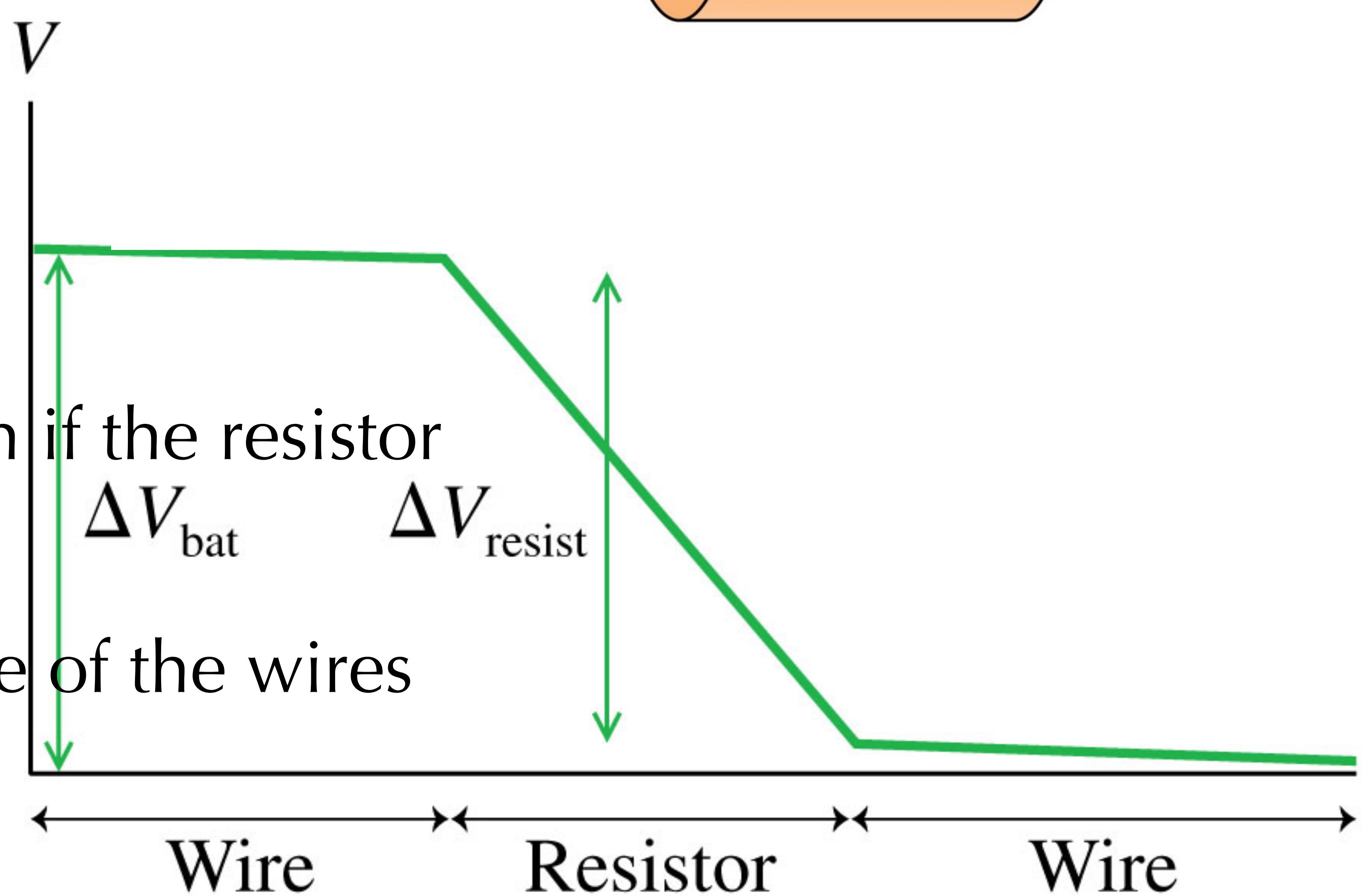
What would happen if the resistor was removed?





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





What would happen if the resistor was removed?

What if the resistance of the wires were not small?

An electric utility company supplies a customer's house from the main power lines (120 V) with two copper wires, each of which is 50.0 m long and has a resistance of 0.108 Ohms per 300 m. Find the voltage at the customer's house for a load current of 110 A.

Draw a circuit diagram for this problem and try to provide a conceptual(no math) description of what is being asked.

Equations so far

$$v_d = \frac{eE}{m}\tau$$

$$C = \frac{\epsilon_0 A}{d}$$

$$i_e = \frac{n_e A e E \tau}{m}$$

$$\boldsymbol{\kappa \equiv \frac{E_0}{E}}$$

$$J = \sigma E$$

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

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

$$C = \frac{Q}{\Delta V_{\text{C}}}$$

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

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

$$U_C = \frac{Q^2}{2C} = \frac{1}{2}C(\Delta V_C)^2$$

$$C_{\text{eq}} = C_1 + C_2 + C_3 + \ldots$$

$$i_e = n_e A v_d$$

Equations so far

$\boxed{1}$
$$i_e = n_e A v_d$$

$\boxed{2}$
$$C_{\text{eq}} = C_1 + C_2 + C_3 + \ldots$$

$\boxed{3}$
$$C = \frac{\epsilon_0 A}{d}$$

$\boxed{4}$
$$J = \sigma E$$

$\boxed{5}$
$$C = \frac{Q}{\Delta V_{\text{C}}}$$

$\boxed{6}$
$$R = \frac{\rho L}{A}$$

$\boxed{7}$
$$I = \frac{\Delta V}{R}$$

$\boxed{8}$
$$\kappa \equiv \frac{E_0}{E}$$

$\boxed{9}$
$$v_d = \frac{eE}{m}\tau$$

$\boxed{10}$
$$i_e = \frac{n_e A e E \tau}{m}$$

$\boxed{11}$
$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

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$\boxed{13}$
$$\sum I_{\text{in}} = \sum I_{\text{out}}$$