PH 220

Lance Nelson

How would you calculate….

Electric Field:

1-

2-

3-

4-

Electric Potential:

1-

2-

3-

4-

Flux:

1-

2-

3-

4-

Electric Potential Energy:

1-

2-

3-

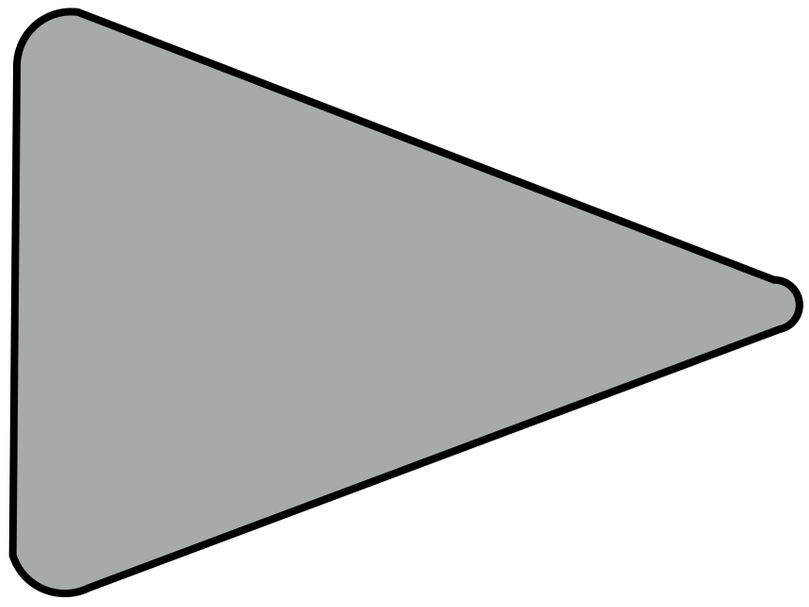
4-

Well if the situation was _____, then I could do _____!

Tell your neighbor everything you know about a conductor in equilibrium

Be sure to discuss the following:

- electric potential
- electric field (inside and out)
- charge
- charge density



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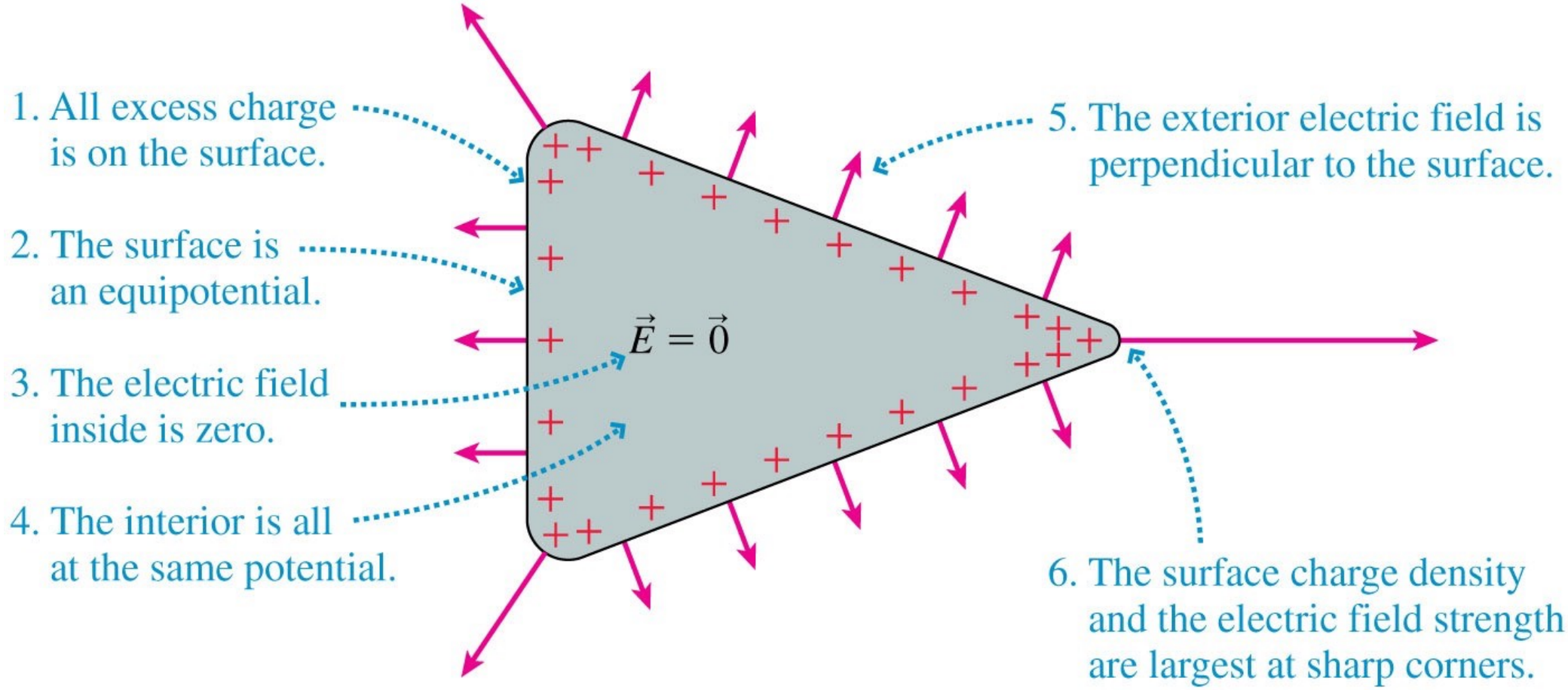
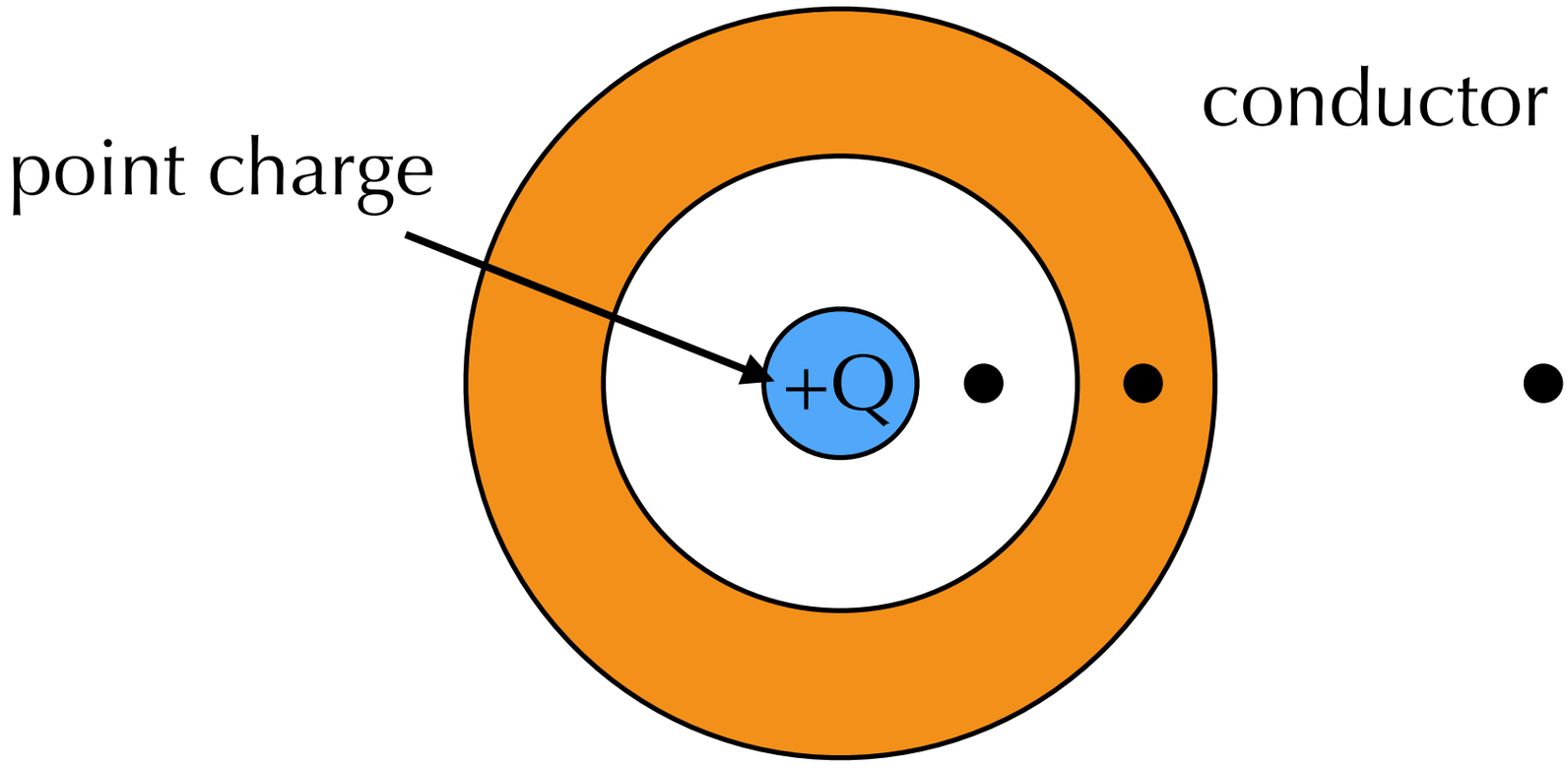
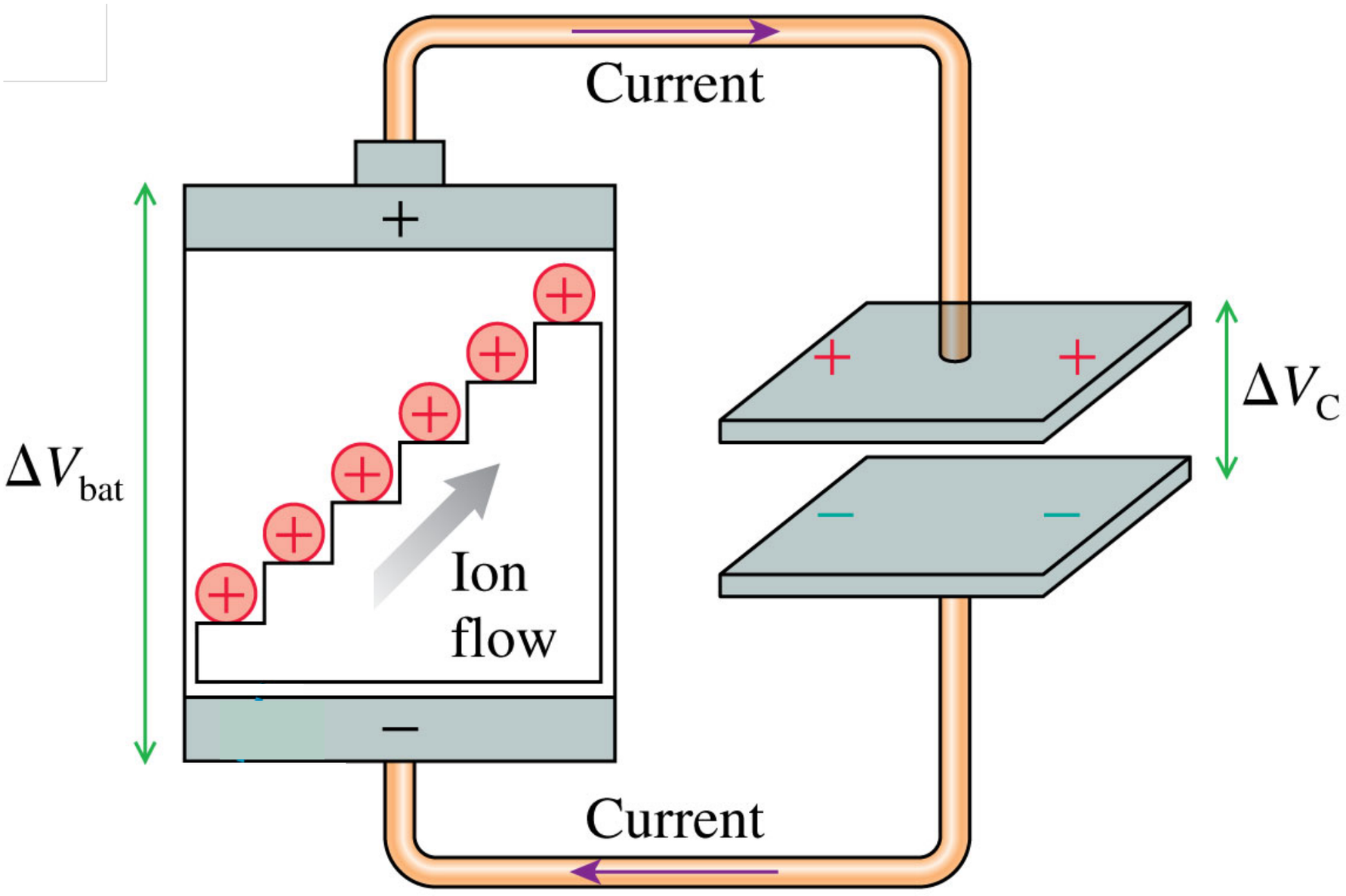


At which dot is the electric potential greatest.



Capacitance



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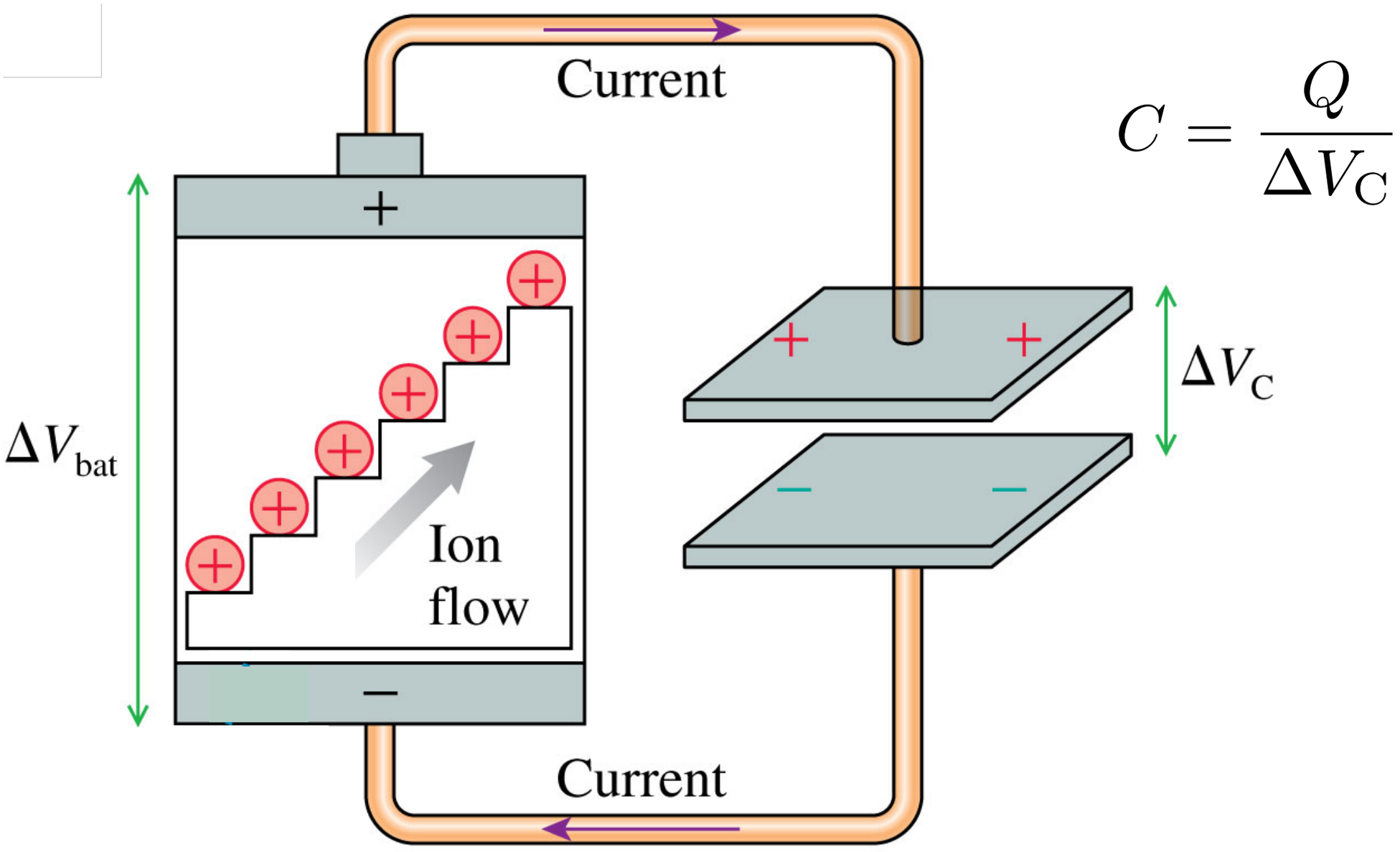
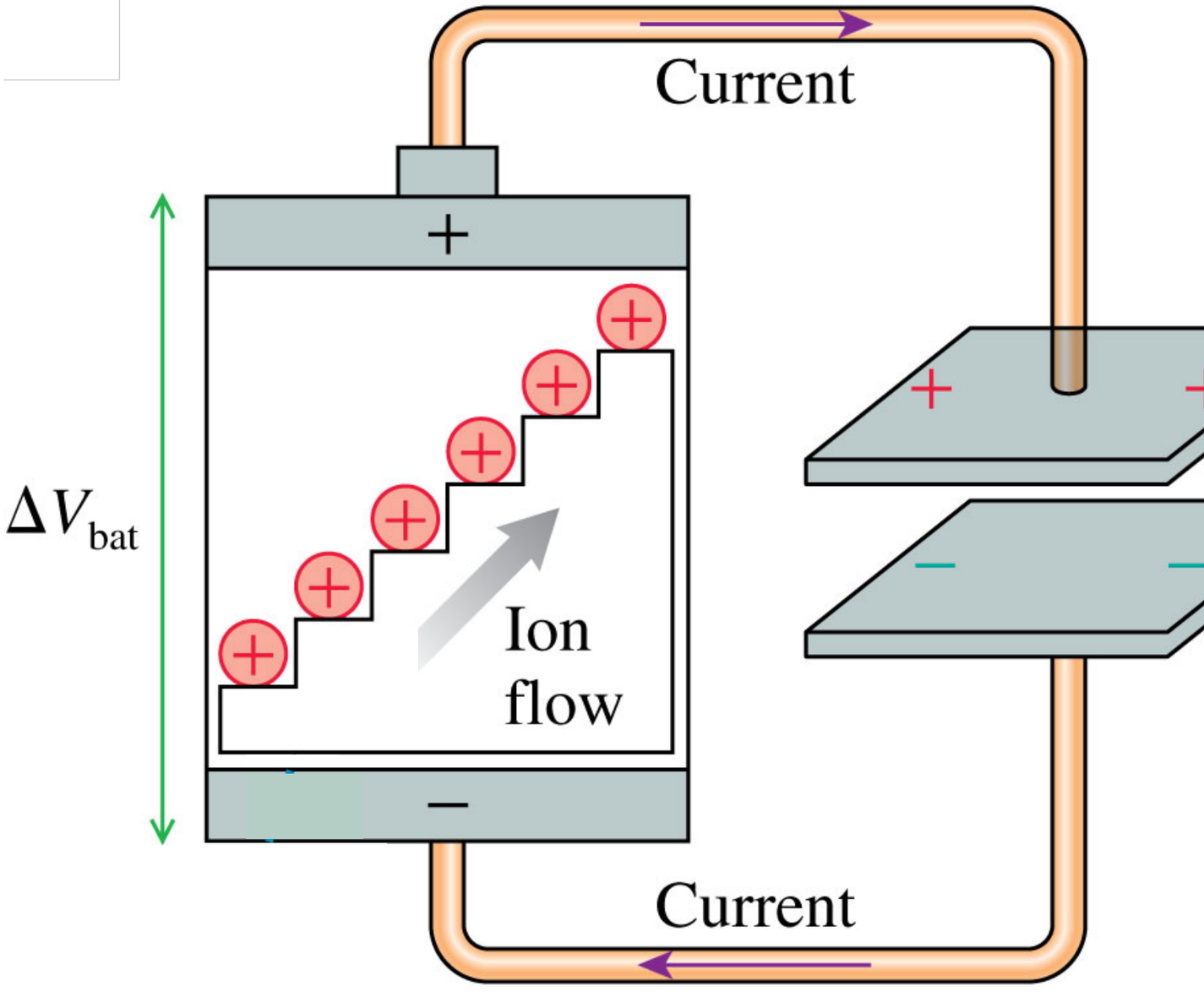


$$C = \frac{Q}{\Delta V_C}$$

Capacitance



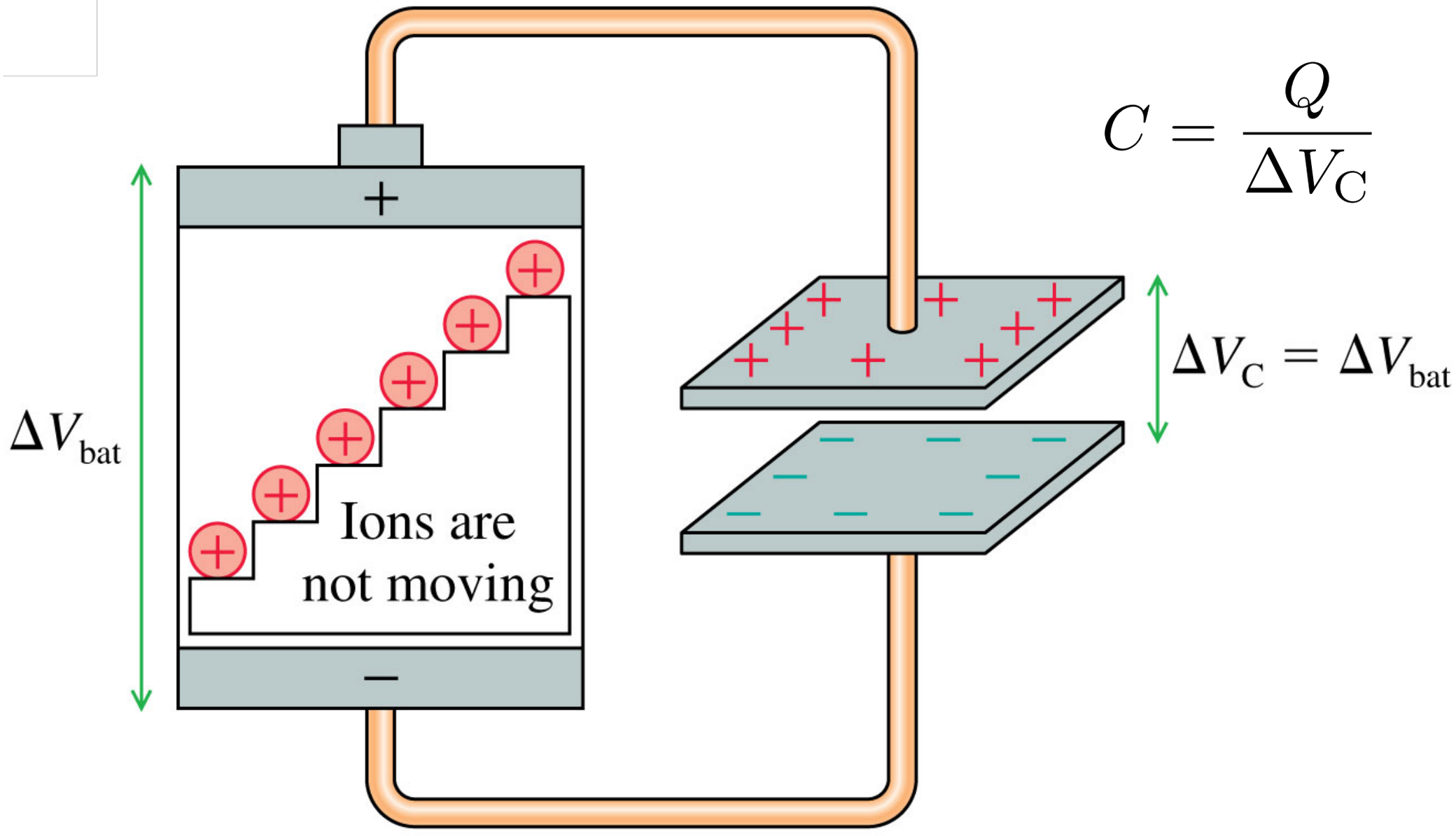
$$C = \frac{Q}{\Delta V_C}$$

When does the flow of electrons stop?

How would the capacitance change if the area of the plates got smaller?

How would the capacitance change if the distance between the plates got smaller?

Capacitance



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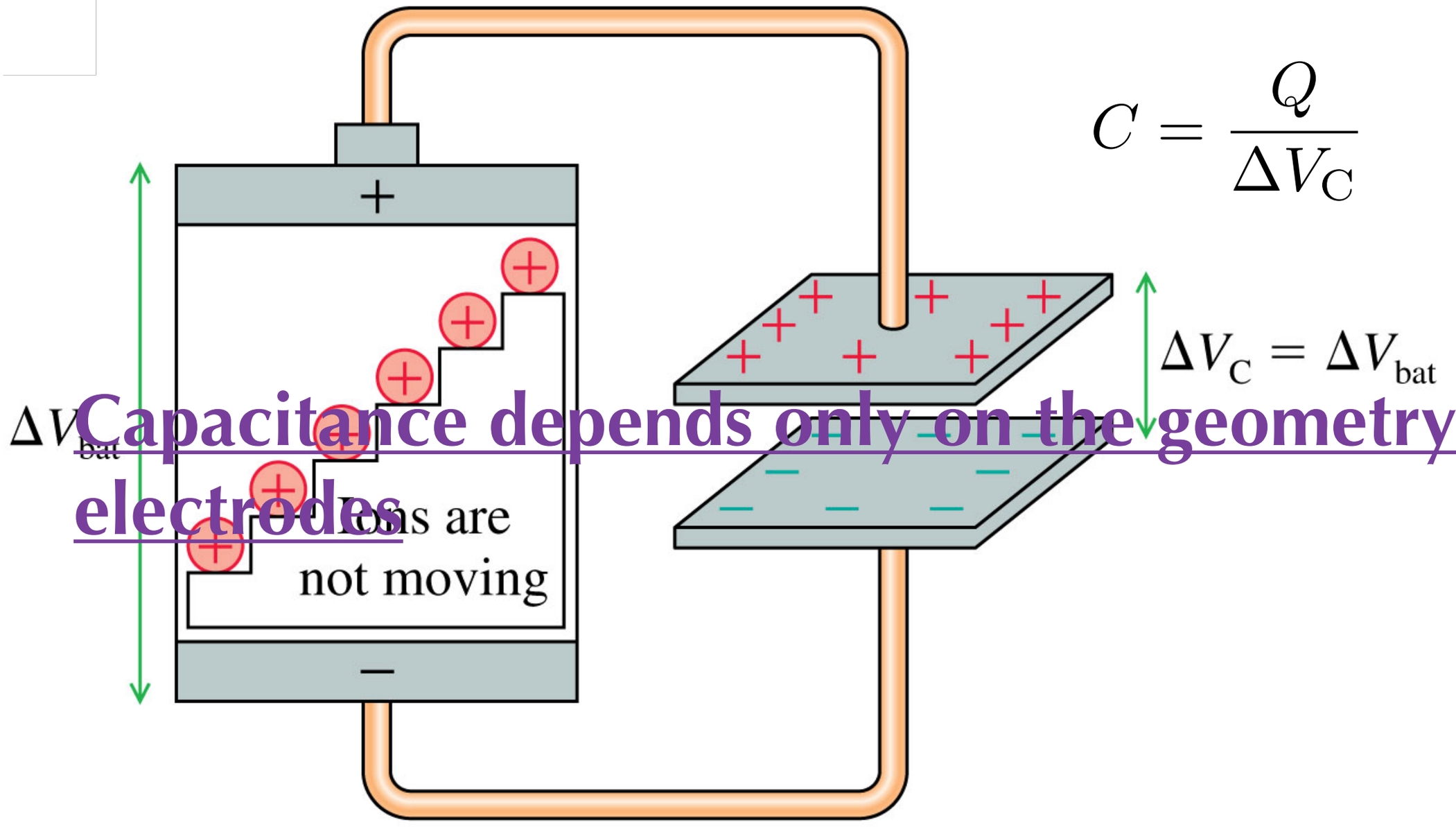

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Capacitance depends only on the geometry of the electrodes

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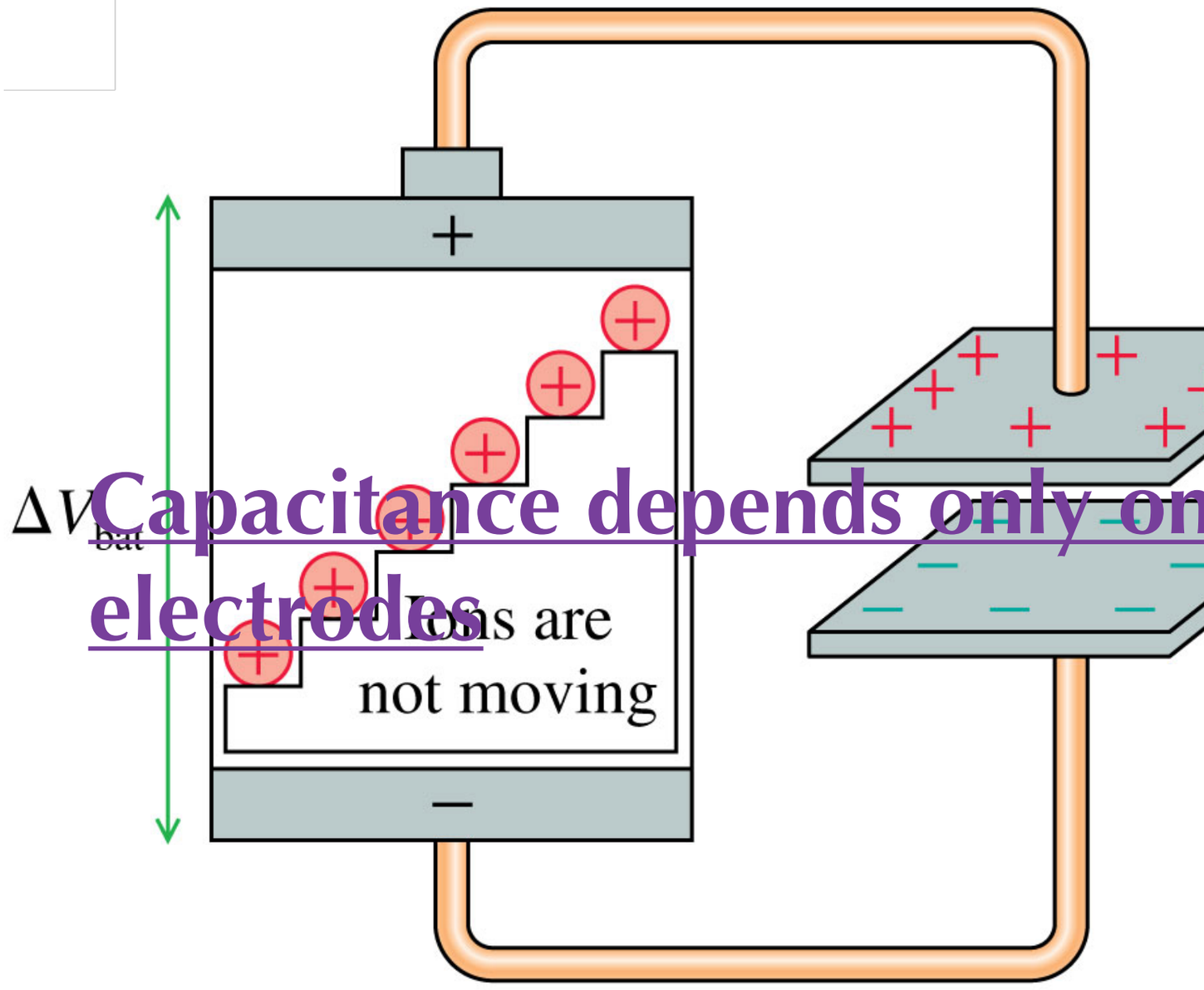
Capacitance



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

Capacitance depends only on the geometry of the electrodes

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

When does the flow of electrons stop?

How would the capacitance change if the area of the plates got smaller?

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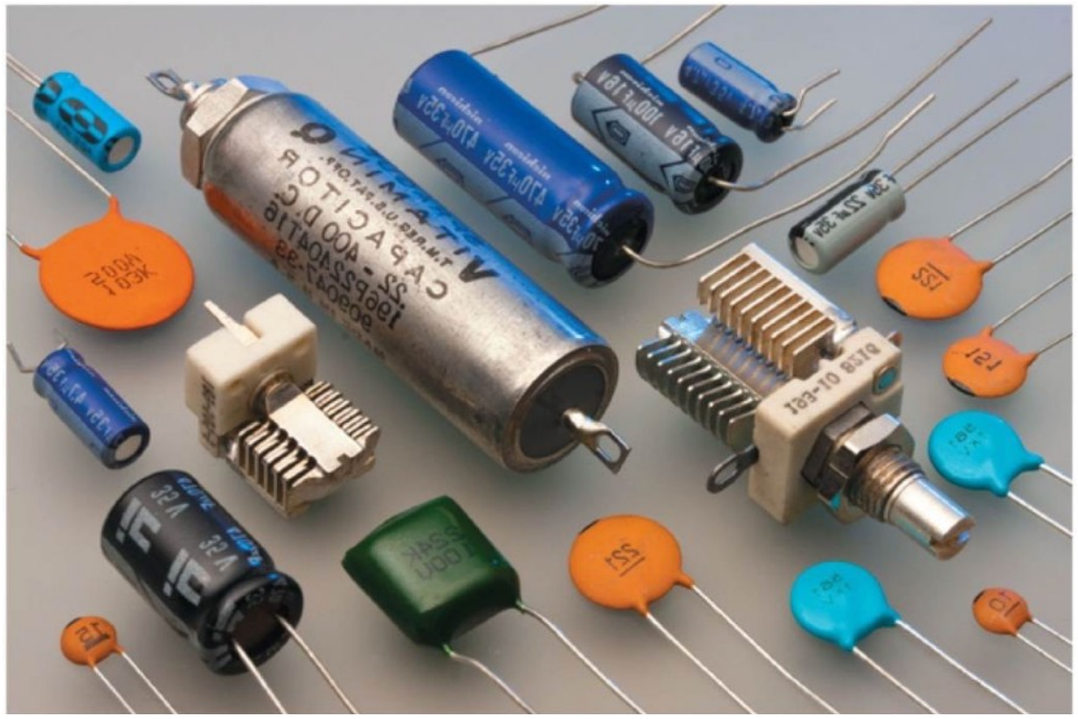
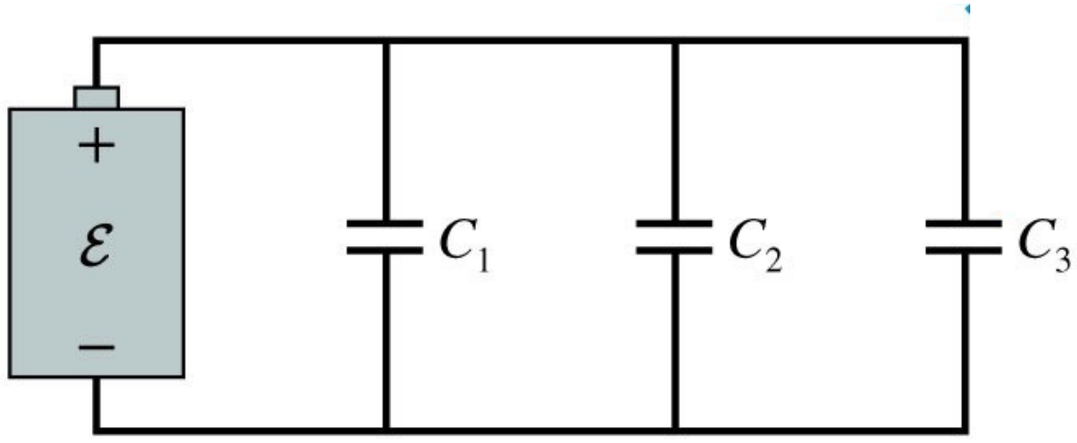

CAPACITOR

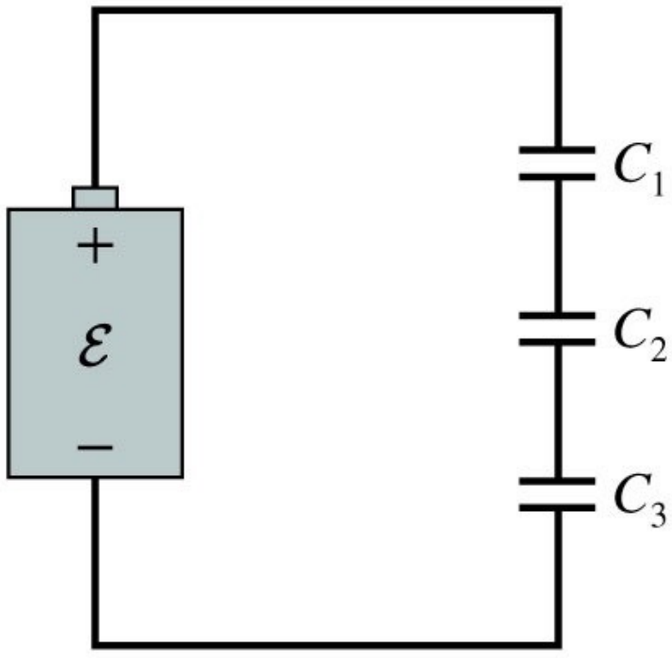

Shift
Enter

Beginning of Circuits

parallel

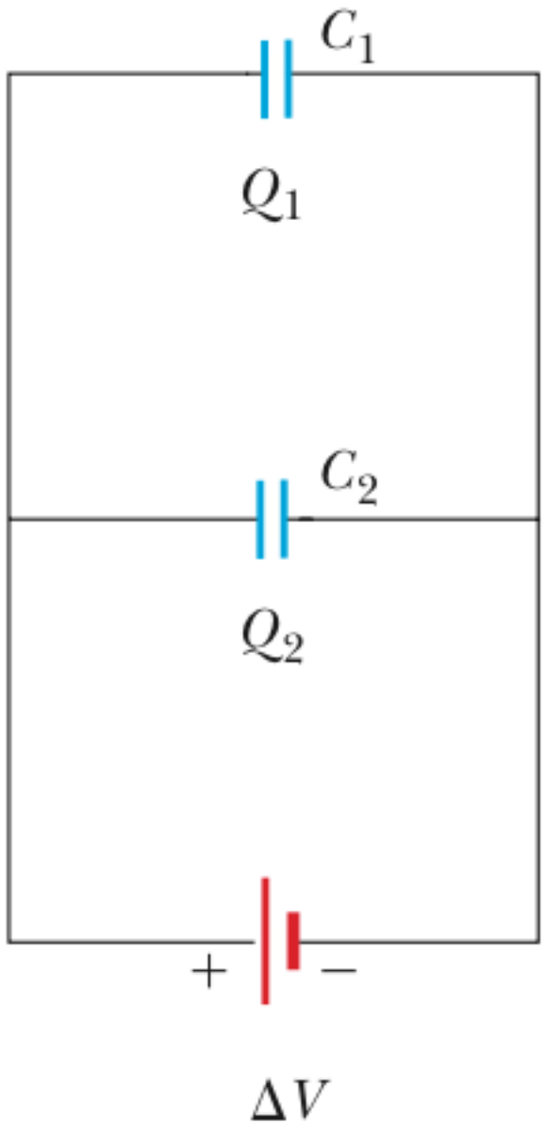


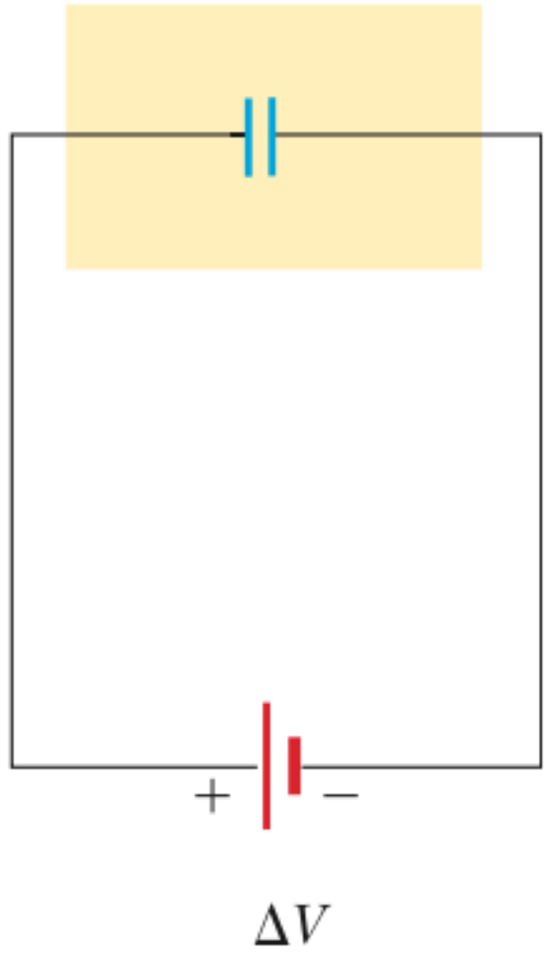
series



Parallel

Is the potential difference across capacitor 1 greater than, less than or equal to the potential difference across capacitor 2?





a) greater
b) less
c) equal

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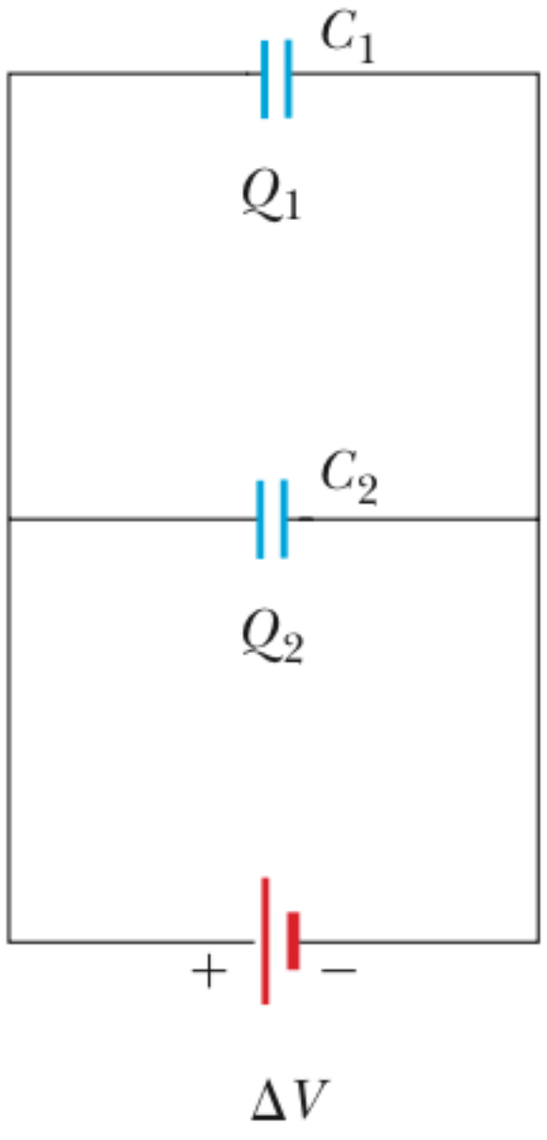
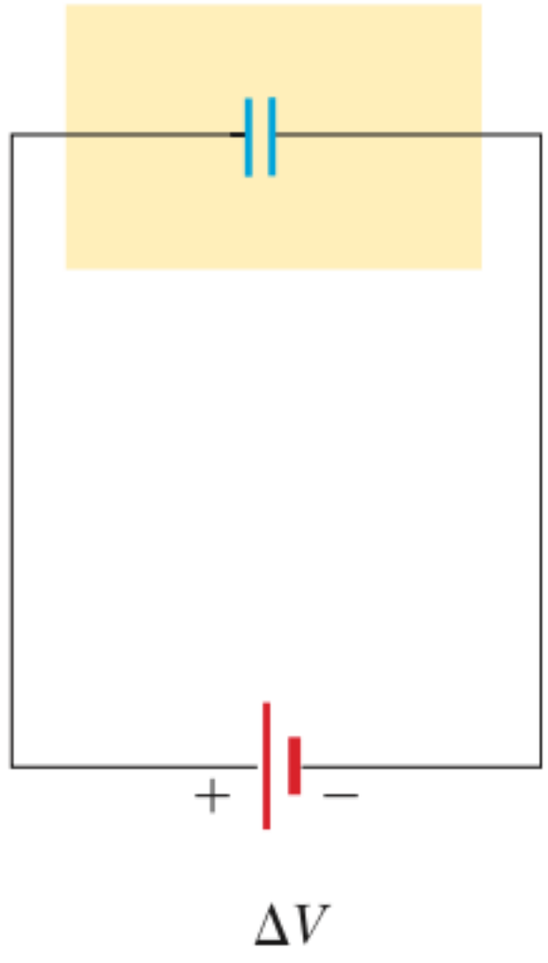


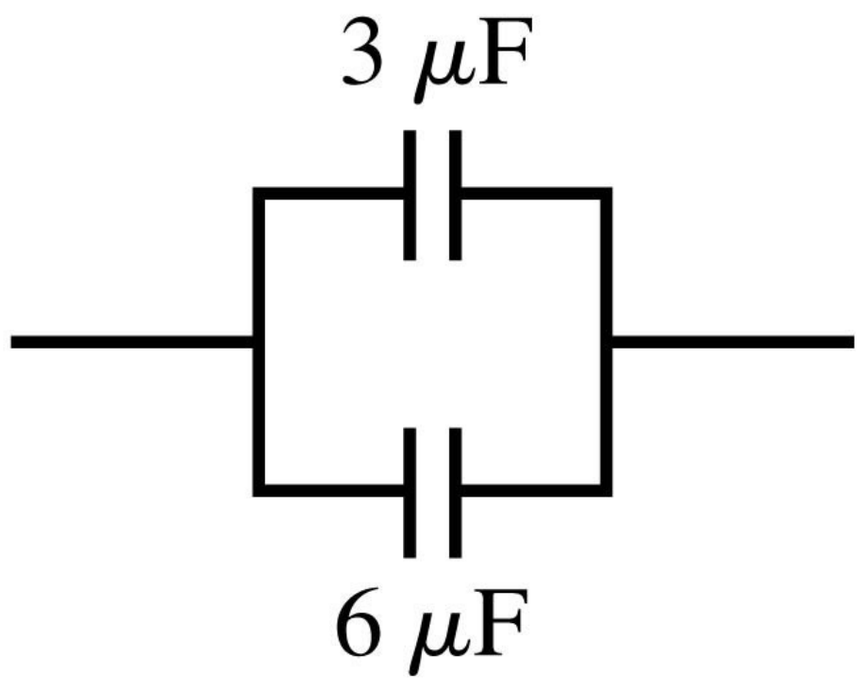


a) greater
b) less
c) equal

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

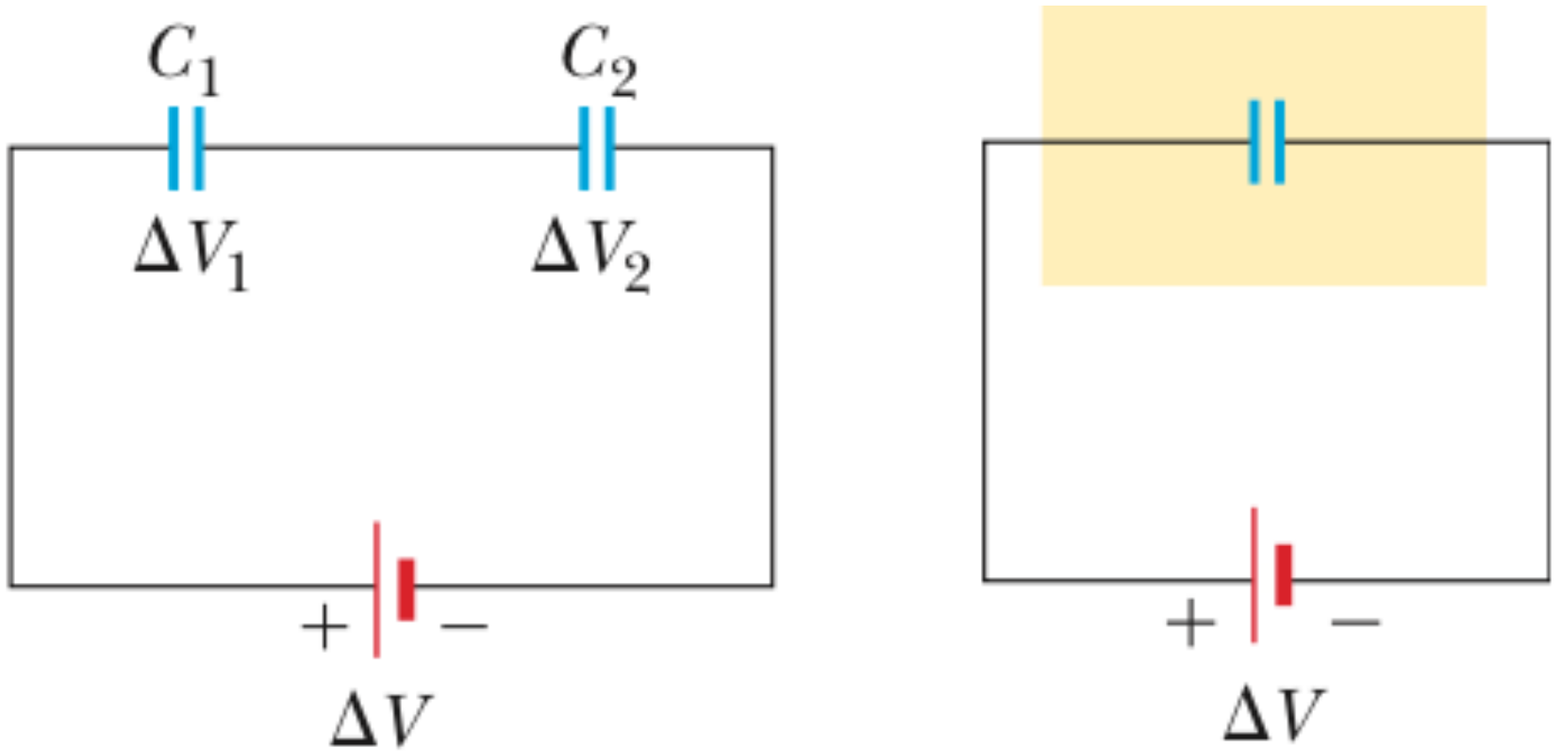
The equivalent capacitance is

A. 9 μF.
B. 6 μF.
C. 3 μF.
D. 2 μF.
E. 1 μF.



Series

Is the charge on capacitor 1 greater than, less than or equal to the charge on capacitor 2?



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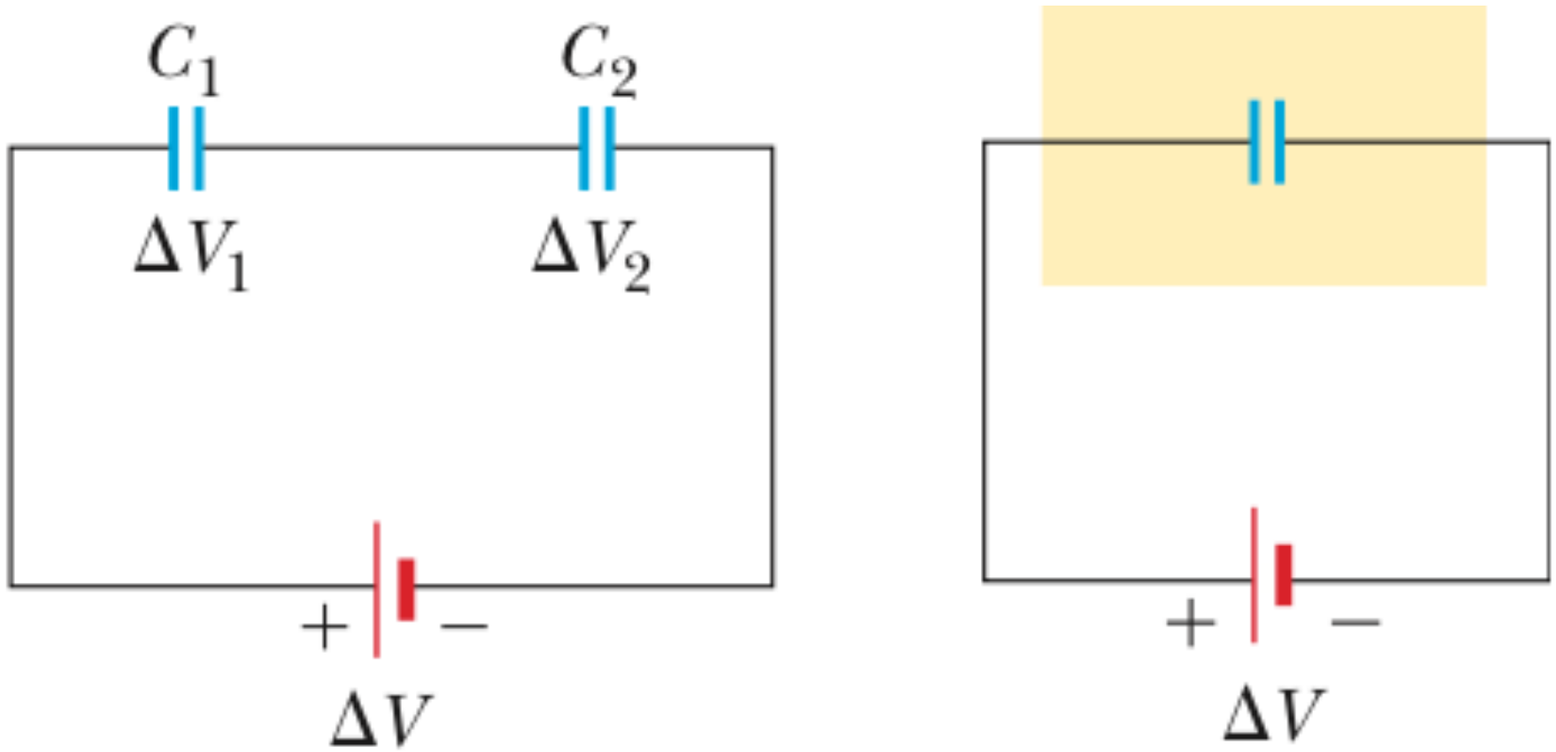
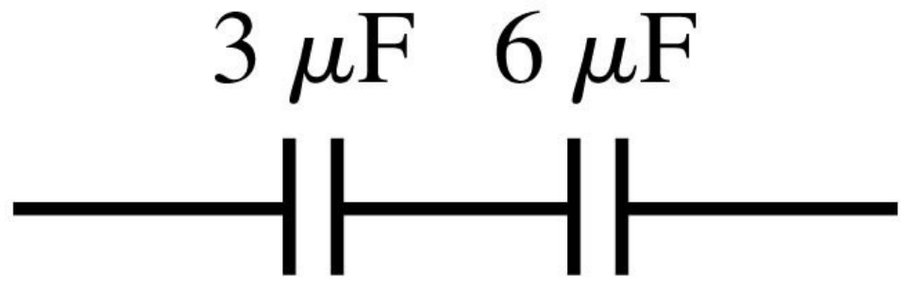
Is the charge on capacitor 1 greater than, less than or equal to the charge on capacitor 2?



a) greater
b) less
c) equal

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

The equivalent capacitance is



A. 9 μF.

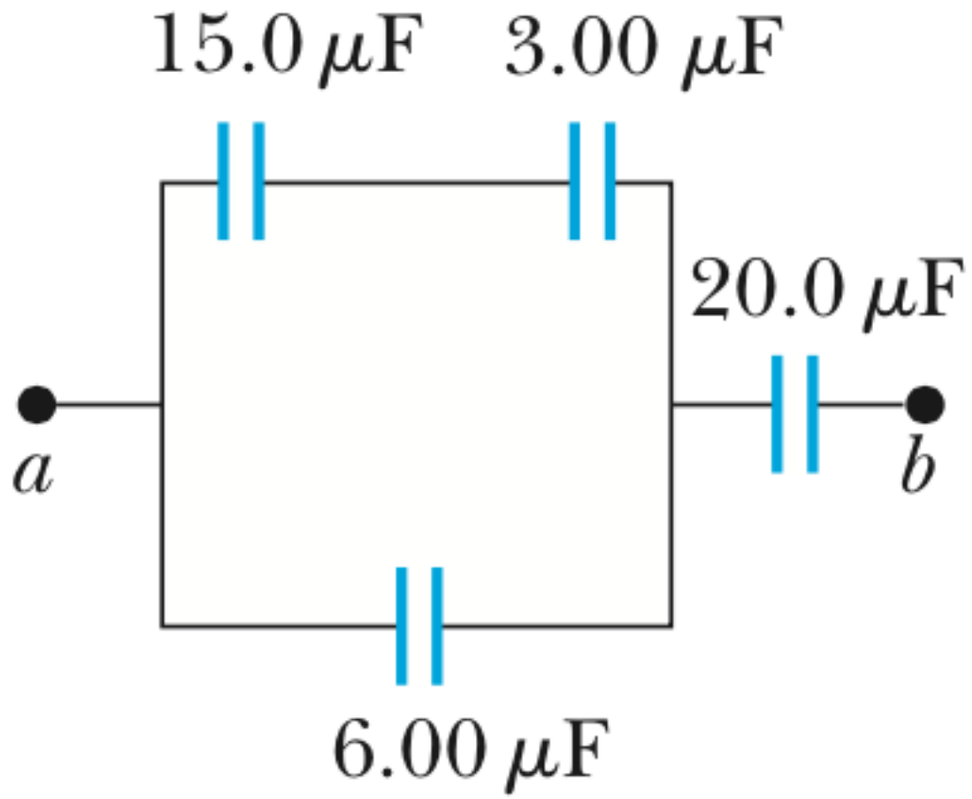
B. 6 μF.

C. 3 μF.

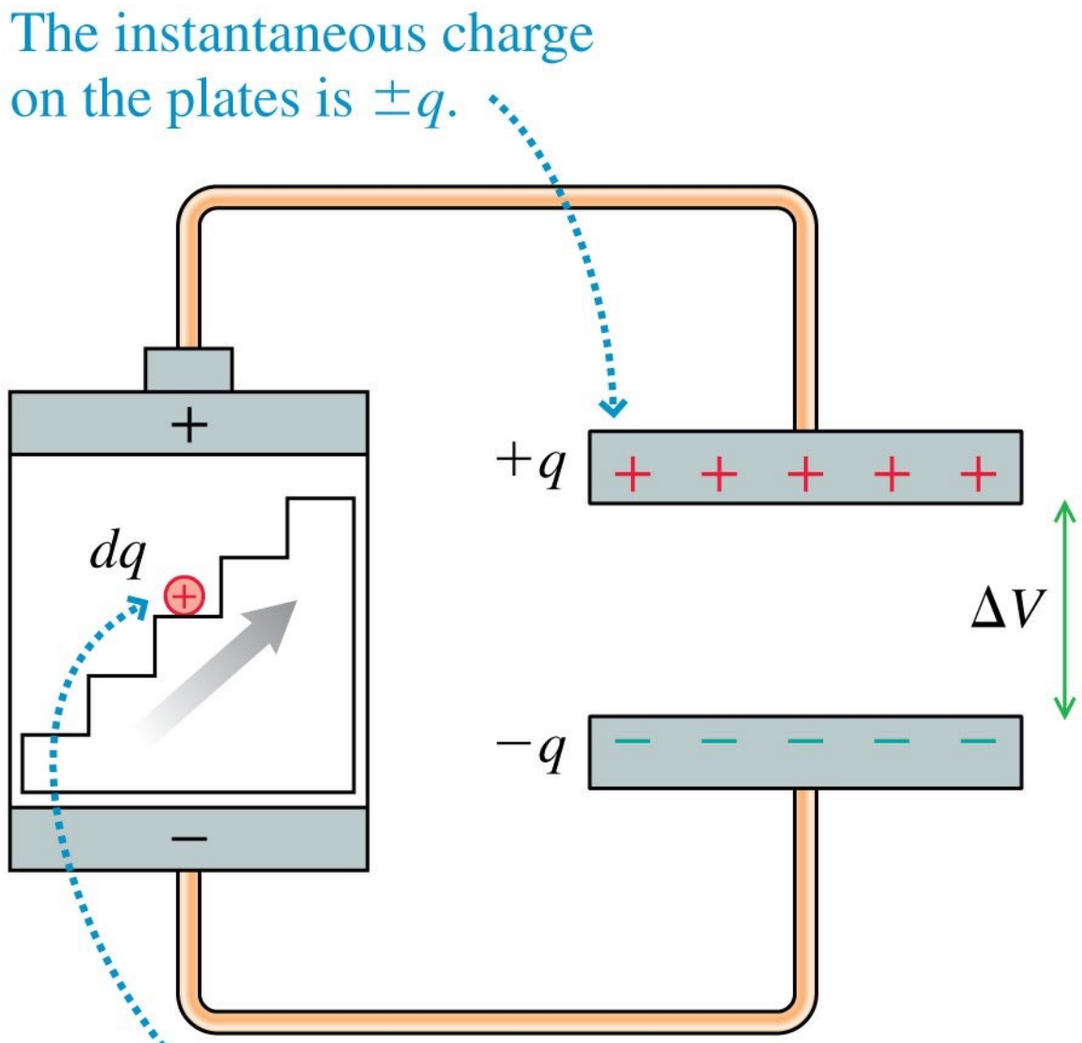
D. 2 μF.

E. 1 μF.

Find the equivalent capacitance between points a and b

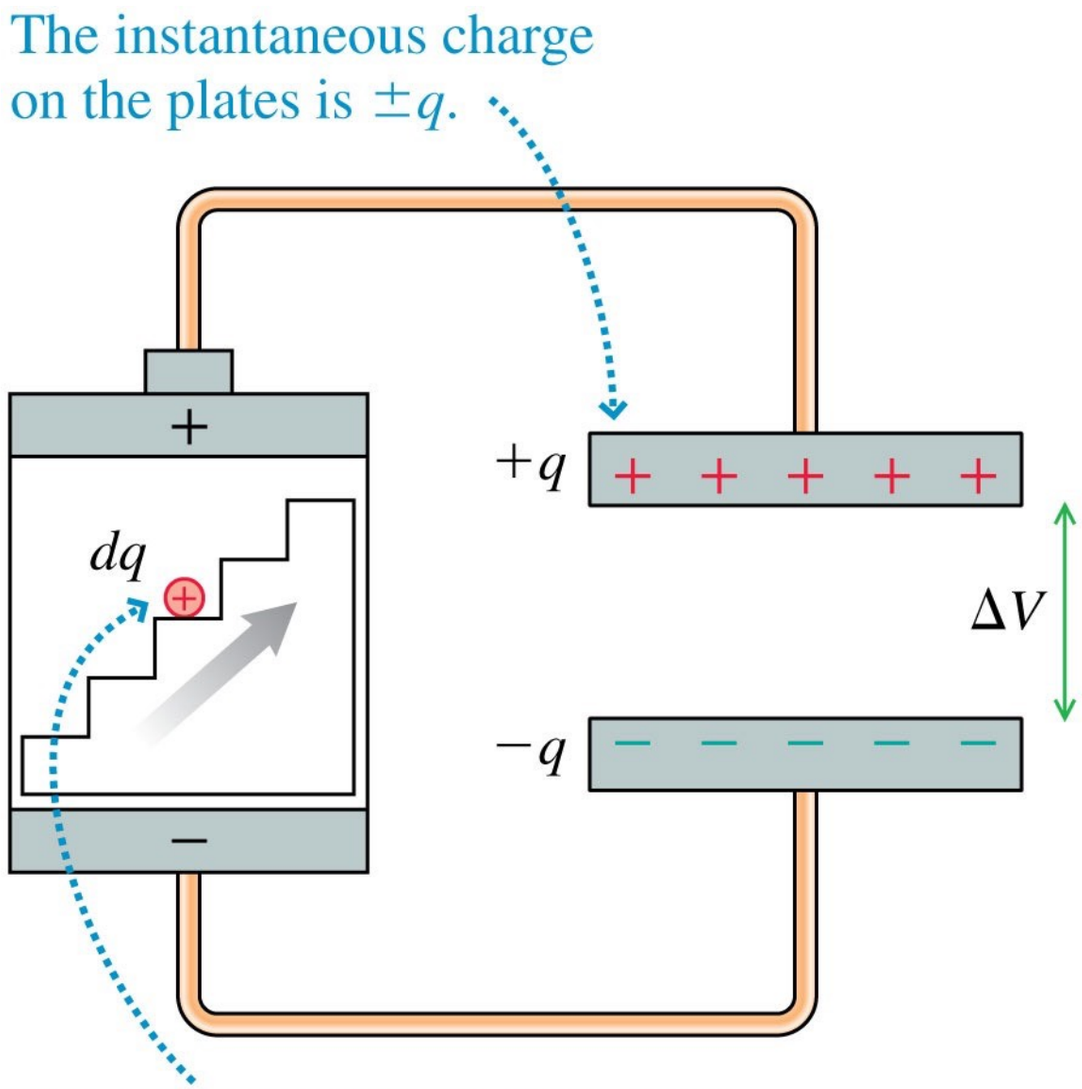


Energy stored in a capacitor



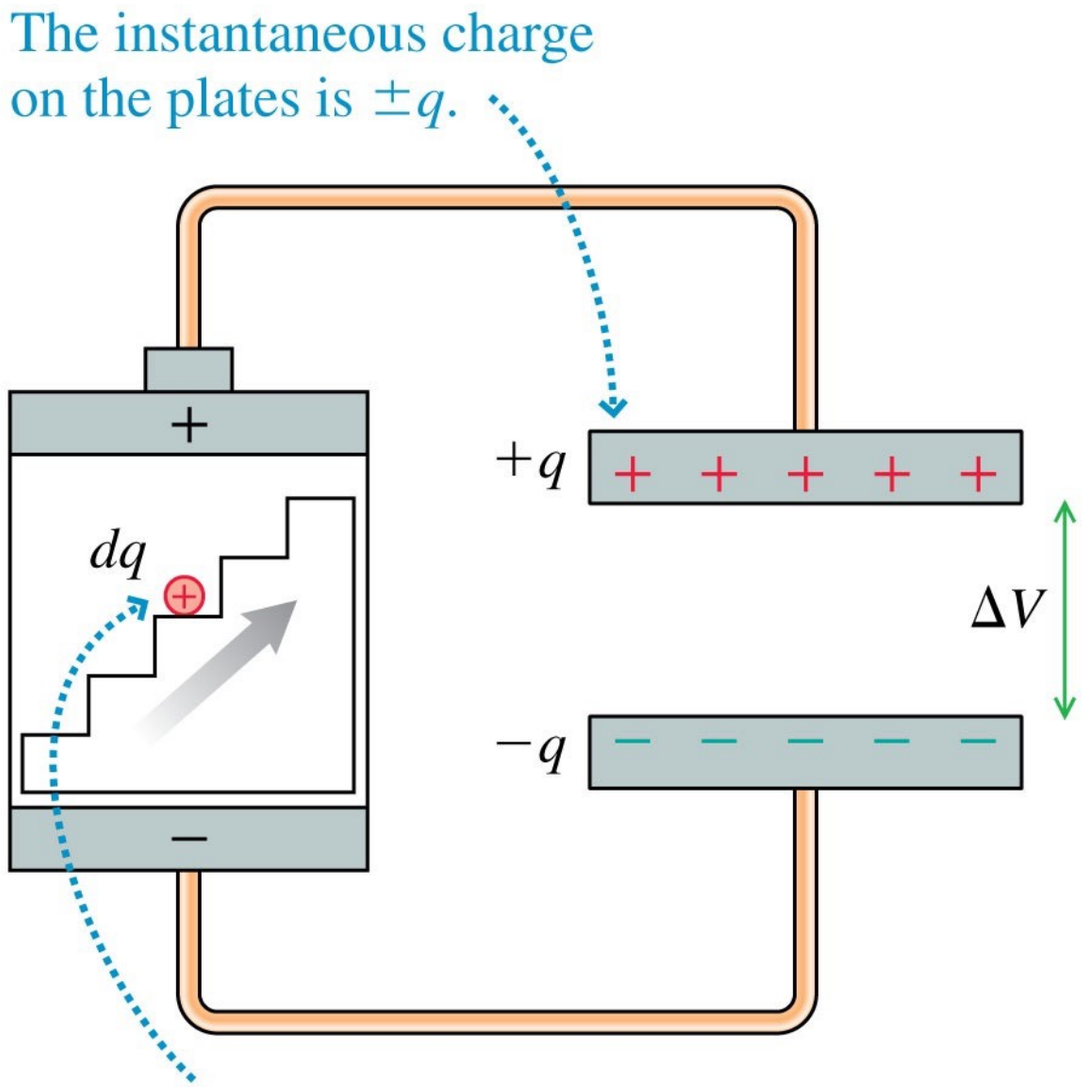
Energy stored in a capacitor

$$U_C = \frac{1}{C}\int_0^Q q\,dq = \frac{Q^2}{2C}$$



The charge escalator does work $dq\,\Delta V$ to move charge dq from the negative plate to the positive plate.

Energy stored in a capacitor



The charge escalator does work $dq\,\Delta V$ to move charge dq from the negative plate to the positive plate.

$$U_C = \frac{1}{C}\int_0^Q q\,dq = \frac{Q^2}{2C}$$

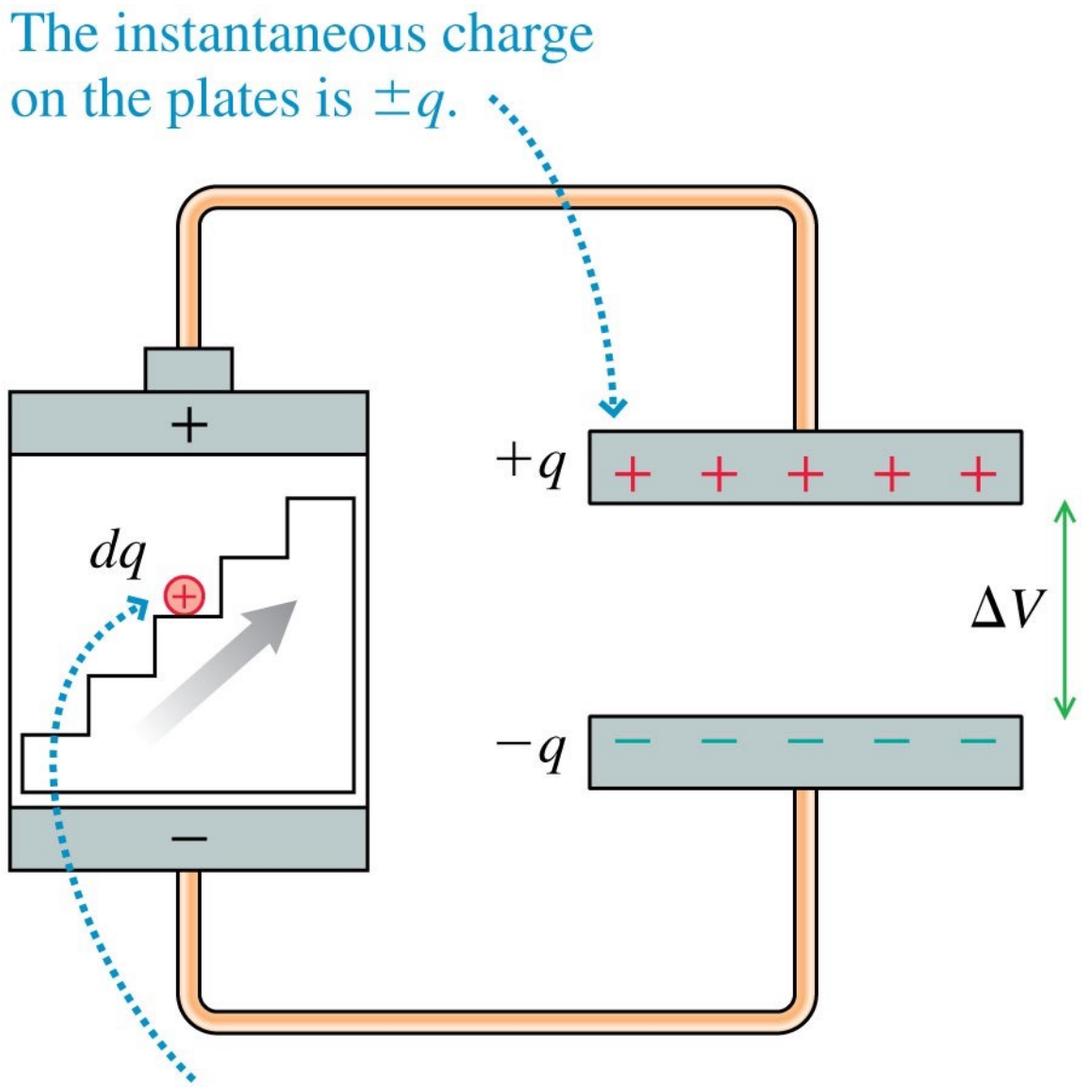
$$= \frac{1}{2}C(\Delta V_C)^2$$

Energy stored in a capacitor

$$dU = dq\,\Delta V = \frac{q\,dq}{C}$$

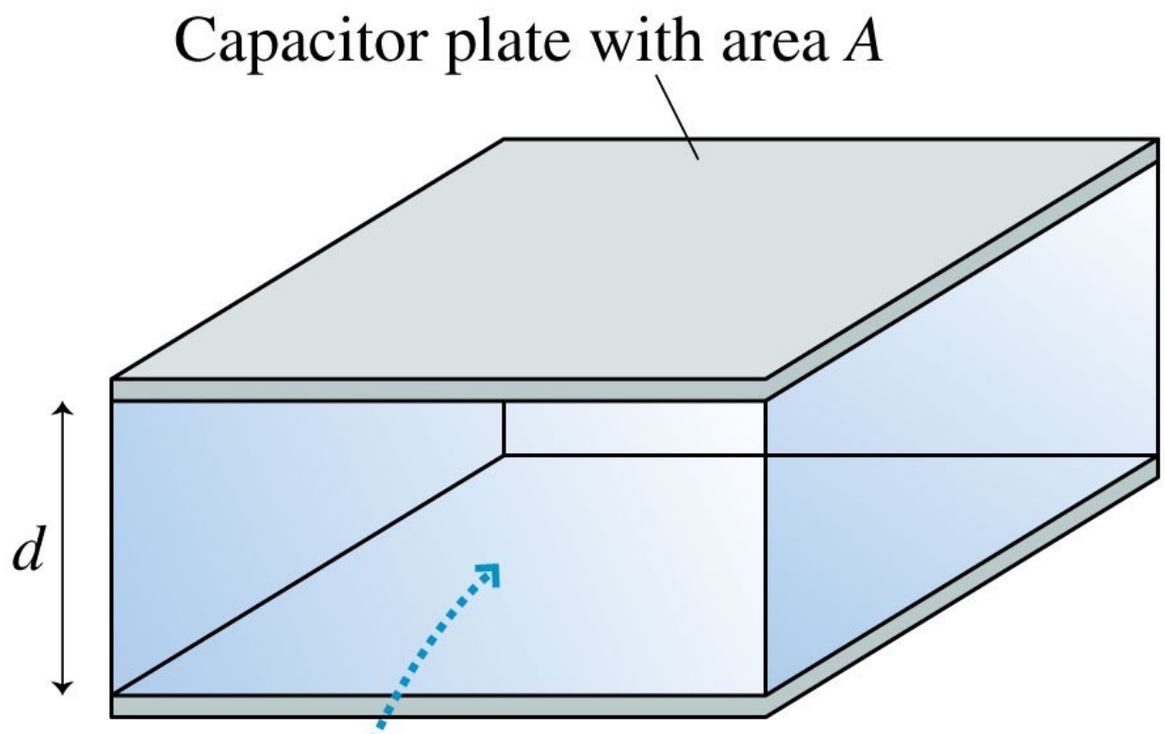
$$U_C = \frac{1}{C}\int_0^Q q\,dq = \frac{Q^2}{2C}$$

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



The charge escalator does work $dq\,\Delta V$ to move charge dq from the negative plate to the positive plate.

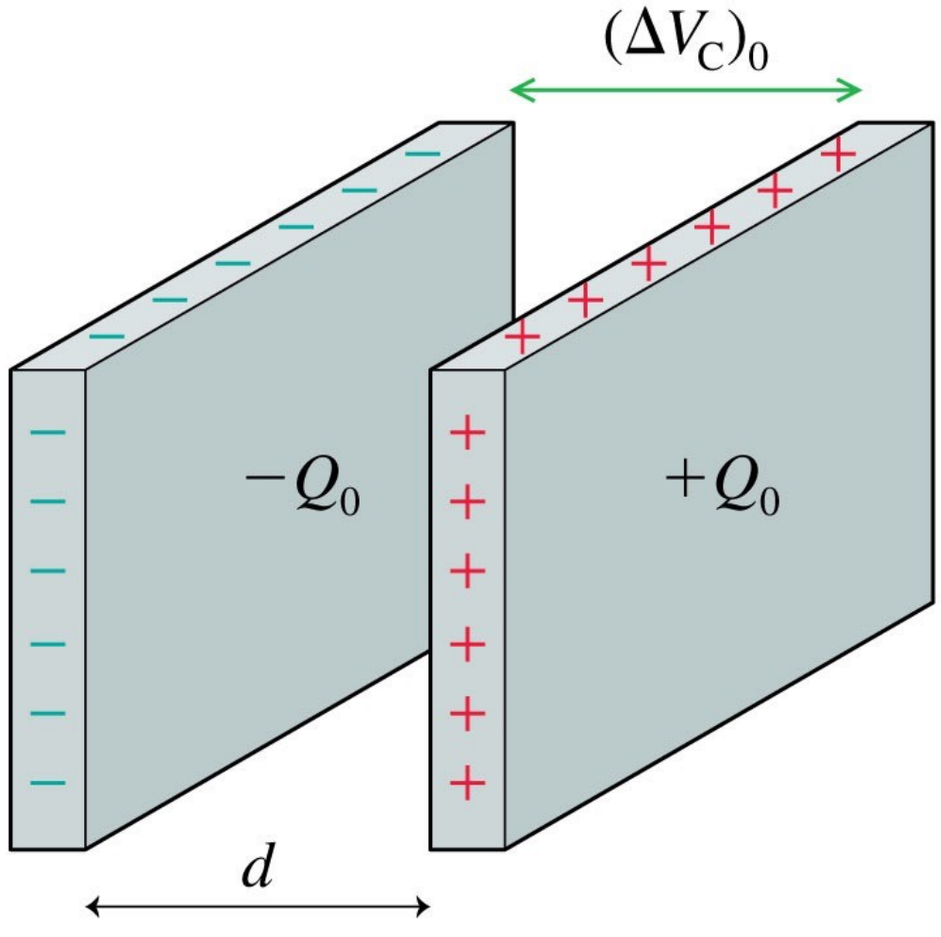
$$u_{\mathrm{E}} = \frac{\text{energy stored}}{\text{volume in which it is stored}} = \frac{U_{\mathrm{C}}}{Ad} = \frac{\epsilon_0}{2}E^2$$



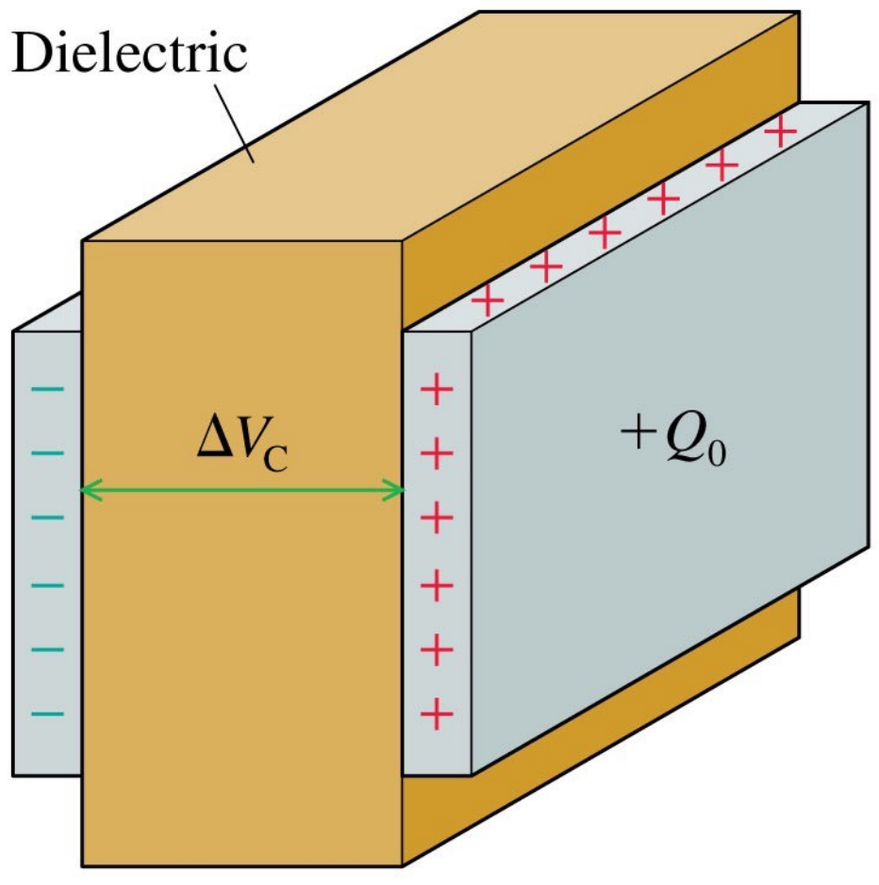
The capacitor's energy is stored in the electric field in volume Ad between the plates.

Dielectrics

What will happen to the E field in between the plates if I insert a dielectric material?



Capacitance C_0 in vacuum



Capacitance $C > C_0$

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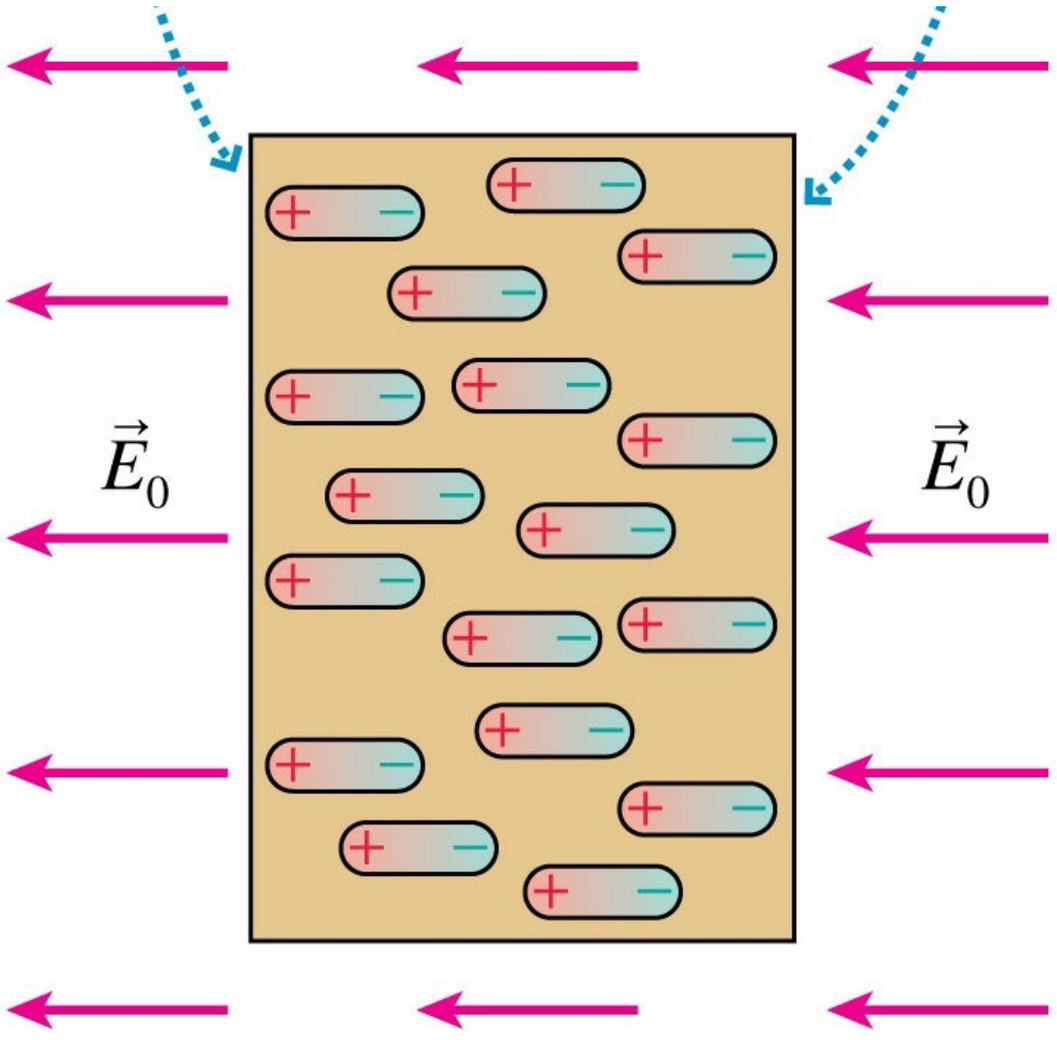
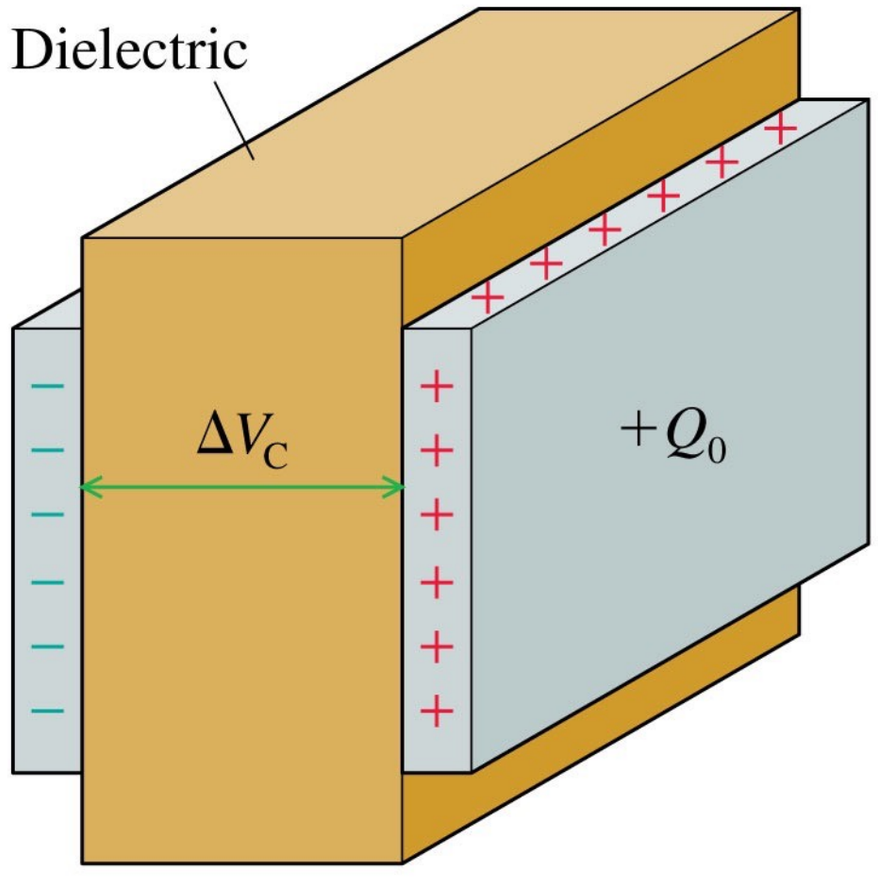


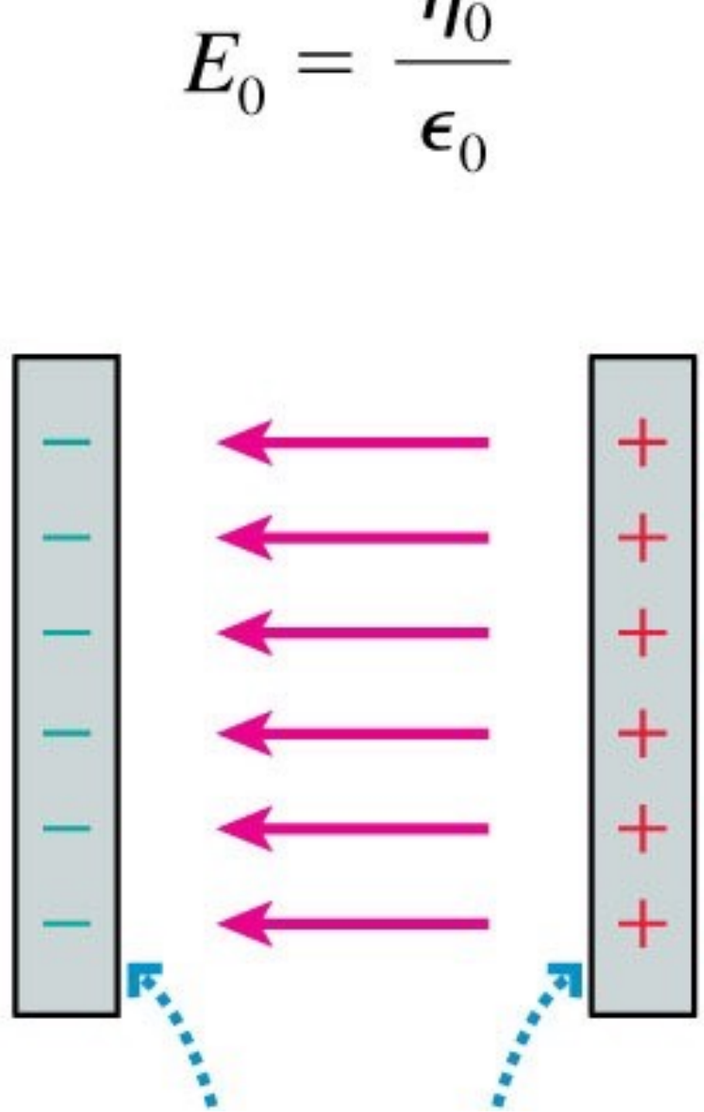


Capacitance $C > C_0$

Dielectrics

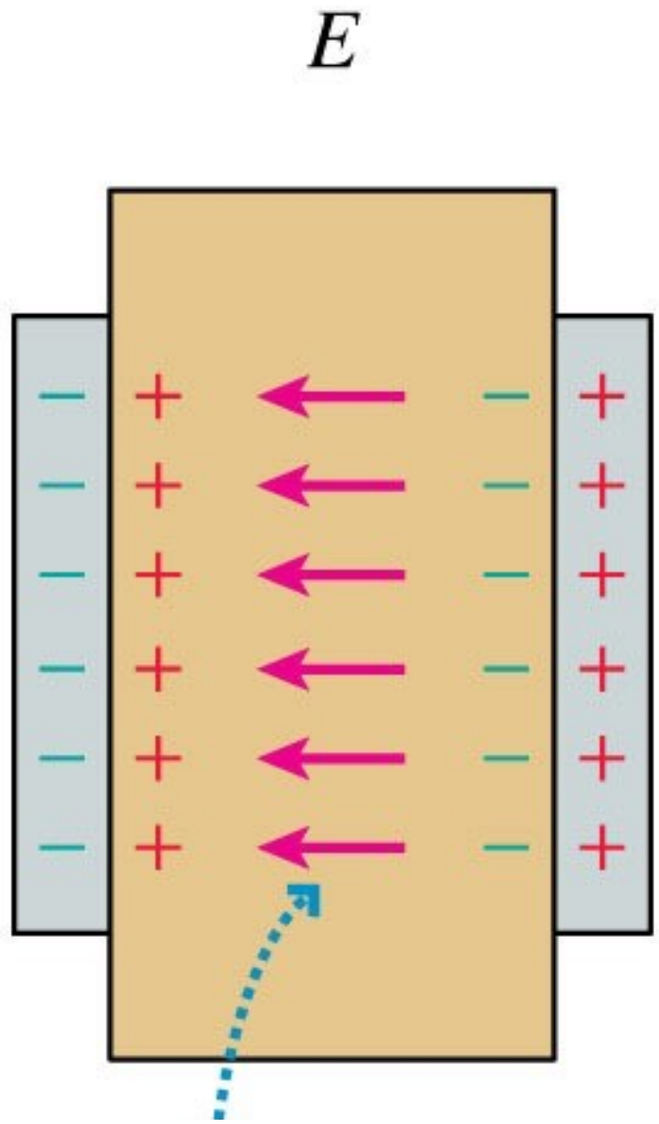
What will happen to the E field in between the plates if I insert a dielectric material?

$$E_0 = \frac{\eta_0}{\epsilon_0}$$



Before

E



After

Dielectric Constant

Dielectric Constant

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

Dielectric Constant

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

$$C = \frac{Q}{\Delta V_C} = \frac{Q_0}{(\Delta V_C)_0/\kappa} = \kappa \frac{Q_0}{(\Delta V_C)_0} = \kappa C_0$$

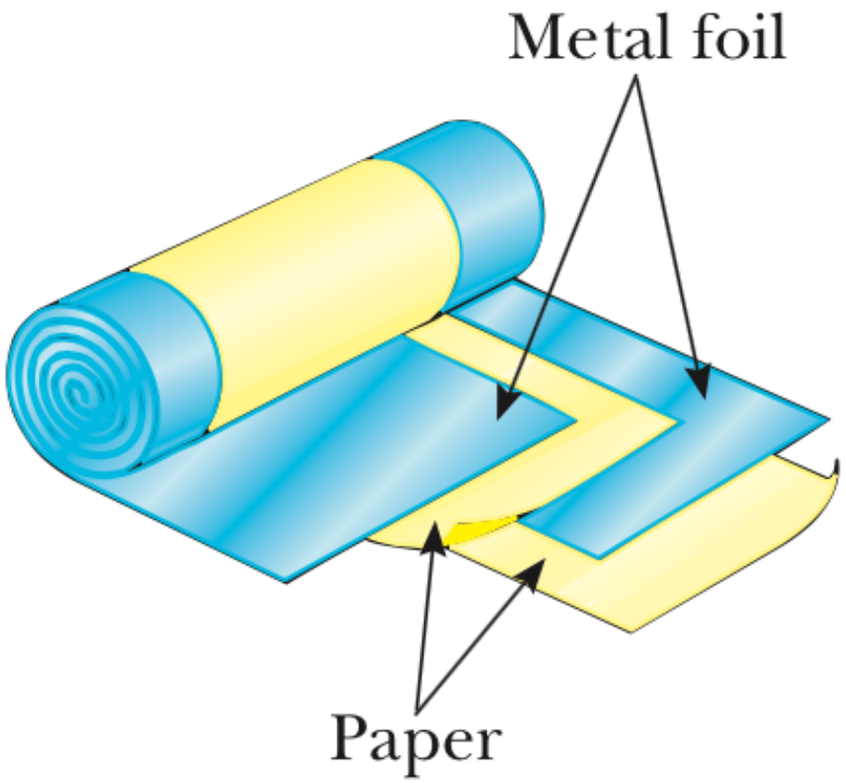
Dielectric Constant

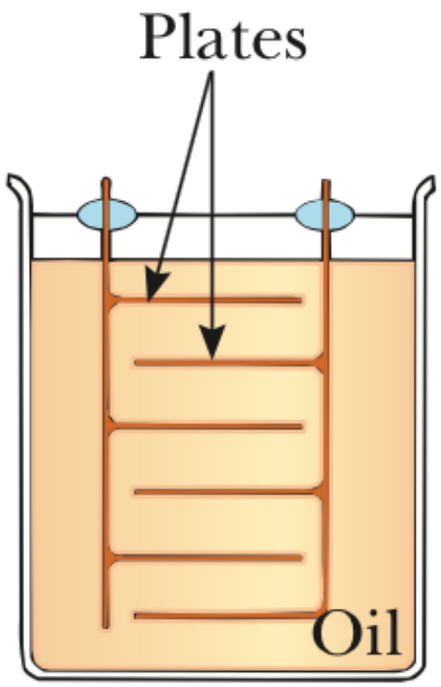
TABLE 29.1 Properties of dielectrics

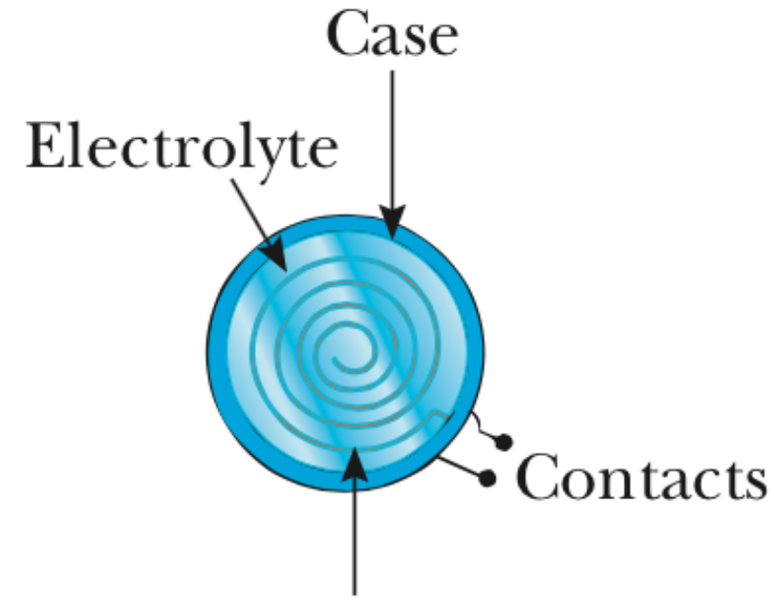
Material	Dielectric constant κ	Dielectric strength E_{max} (10^6 V/m)
Vacuum	1	—
Air (1 atm)	1.0006	3
Teflon	2.1	60
Polystyrene plastic	2.6	24
Mylar	3.1	7
Paper	3.7	16
Pyrex glass	4.7	14
Pure water (20°C)	80	—
Titanium dioxide	110	6
Strontium titanate	300	8

$$C \qquad \frac{Q_0}{\Delta V_C)_0} = \kappa C_0$$

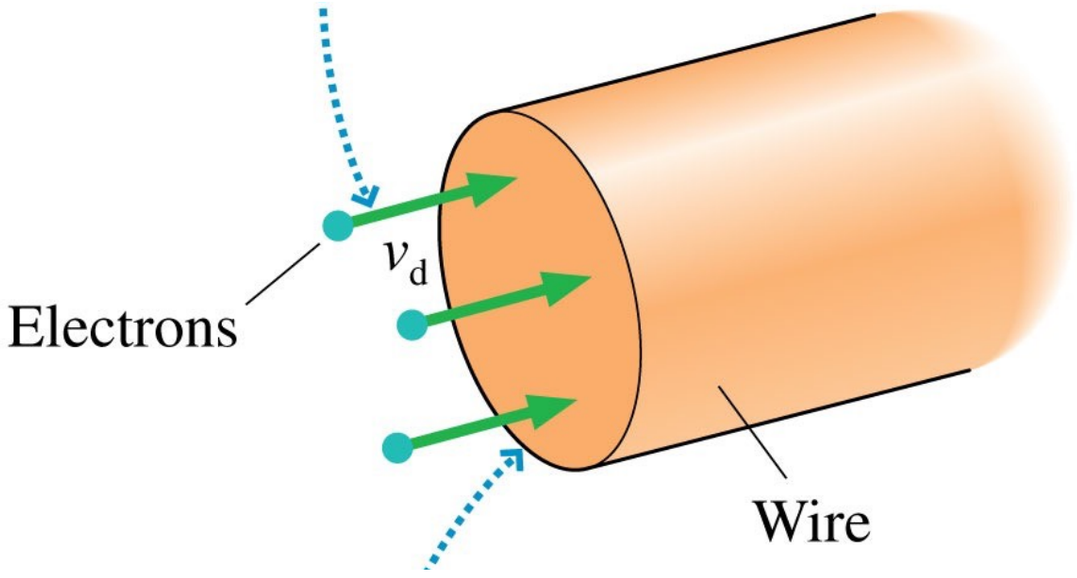
Real capacitors





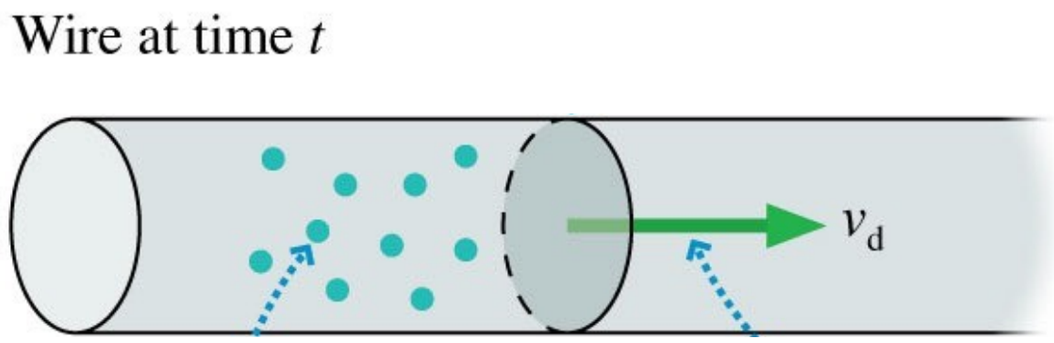


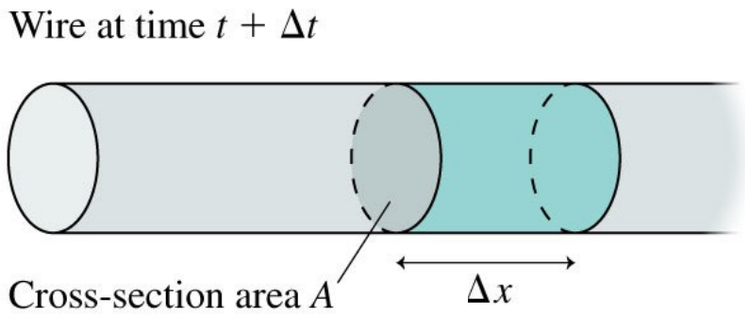
Current



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

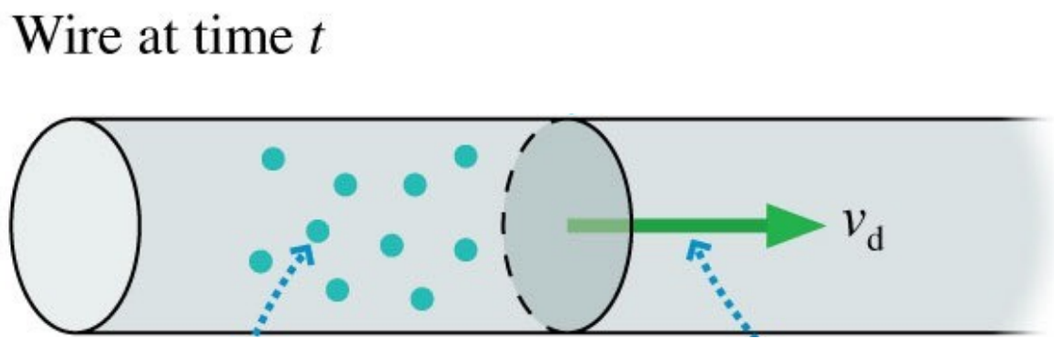
$$N_e = i_e \Delta t$$

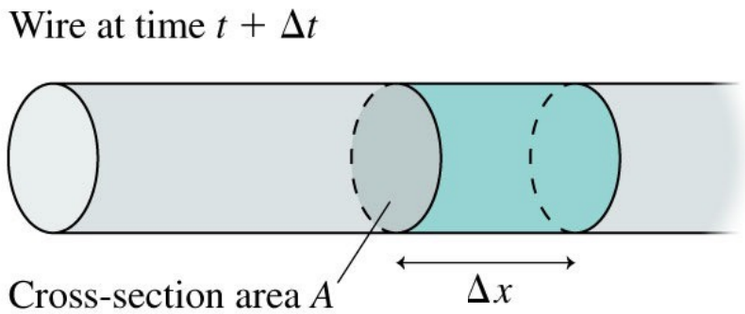

Wire at time t
v_d


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

$$N_{\mathrm{e}} = i_{\mathrm{e}}\,\Delta t$$

$$N_e = n_e V$$





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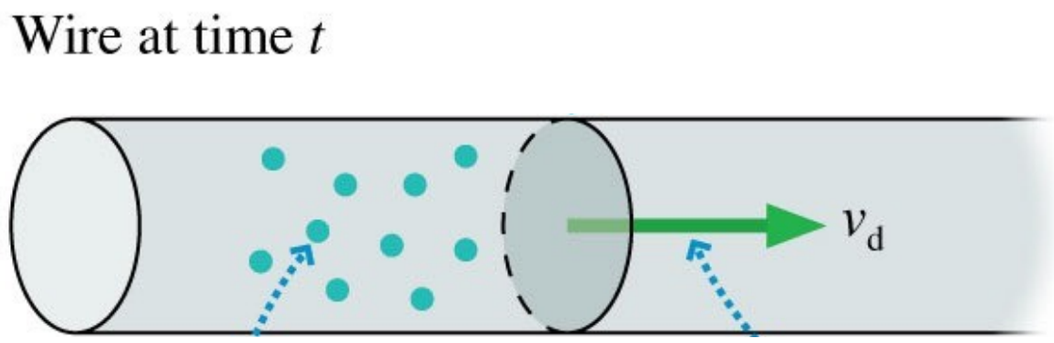
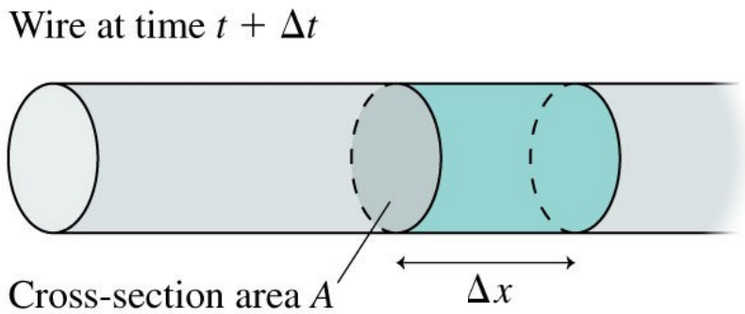
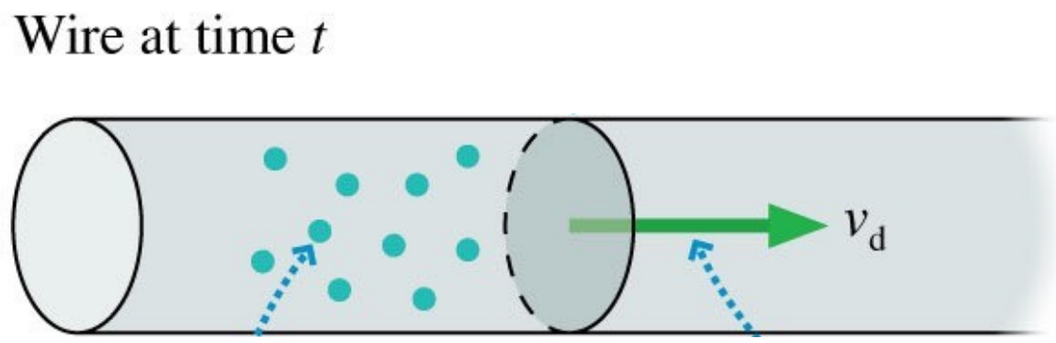


$$N_e = n_e V$$

$$= n_e A \Delta x$$



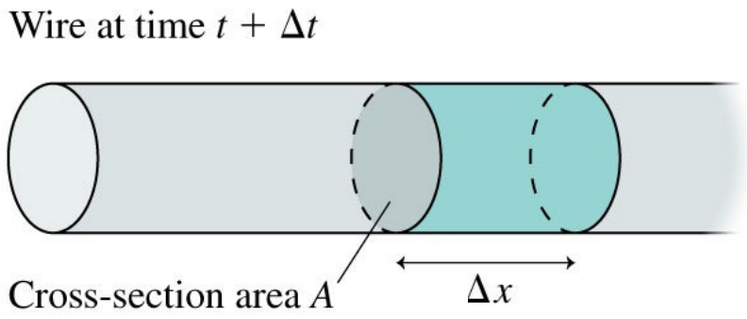
$$N_{\mathrm{e}} = i_{\mathrm{e}}\,\Delta t$$



$$N_e = n_e V$$

$$= n_e A \Delta x$$

$$= n_e A v_d \Delta t$$



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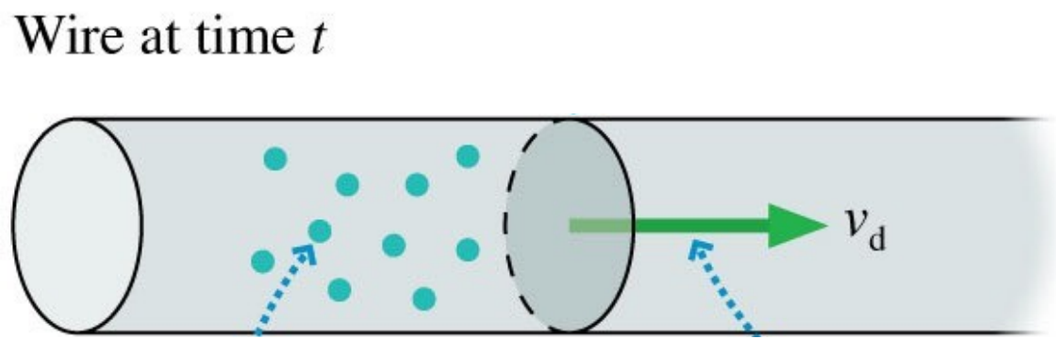

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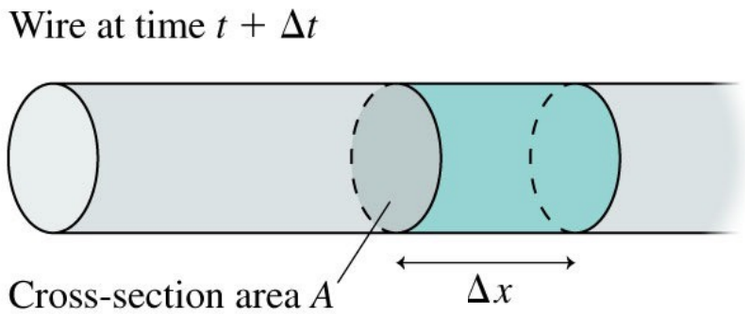


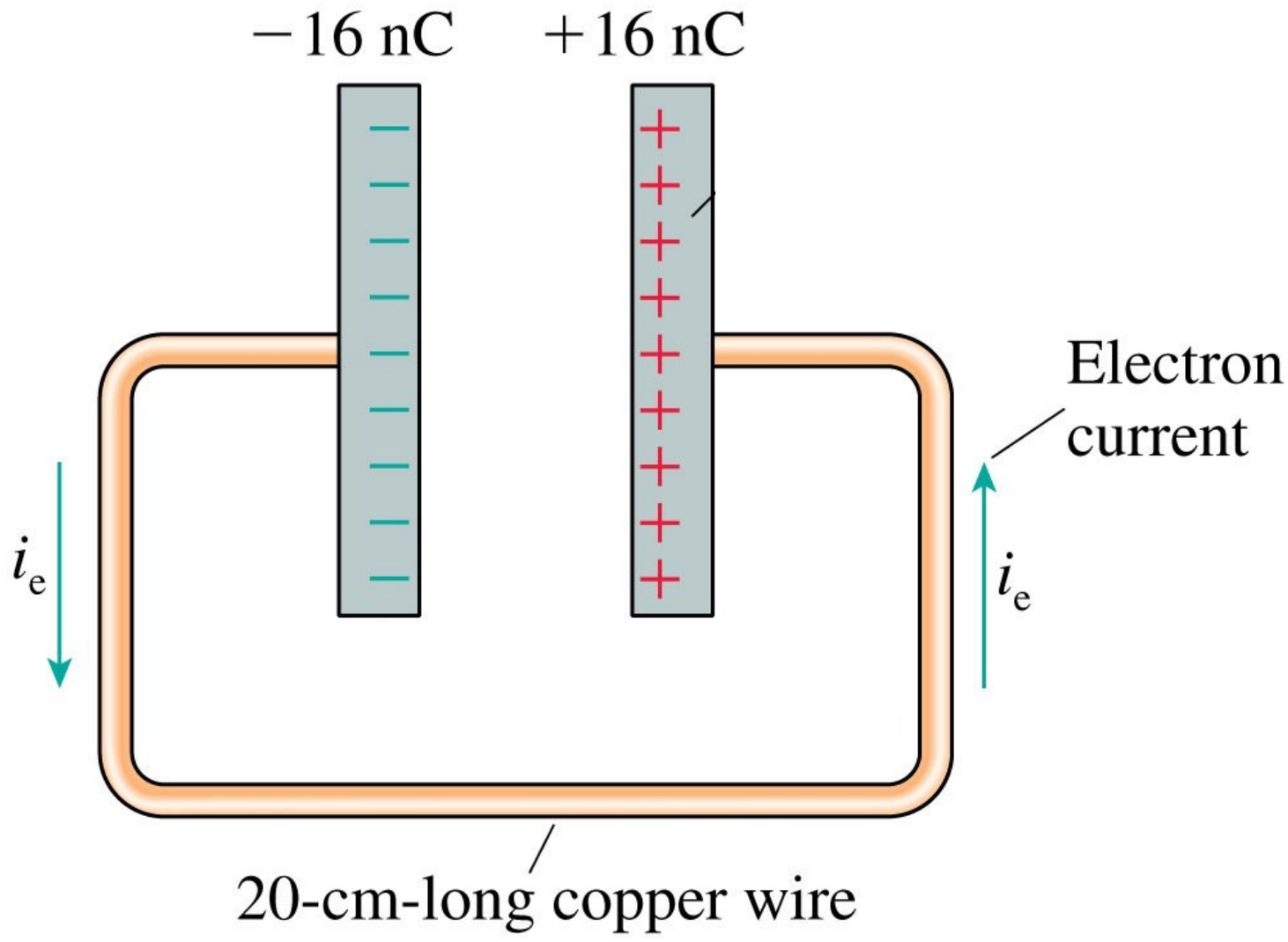
$$i_e = n_e A v_d$$

Discharging a capacitor

Typical drift velocities are on the order:

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

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



Animation

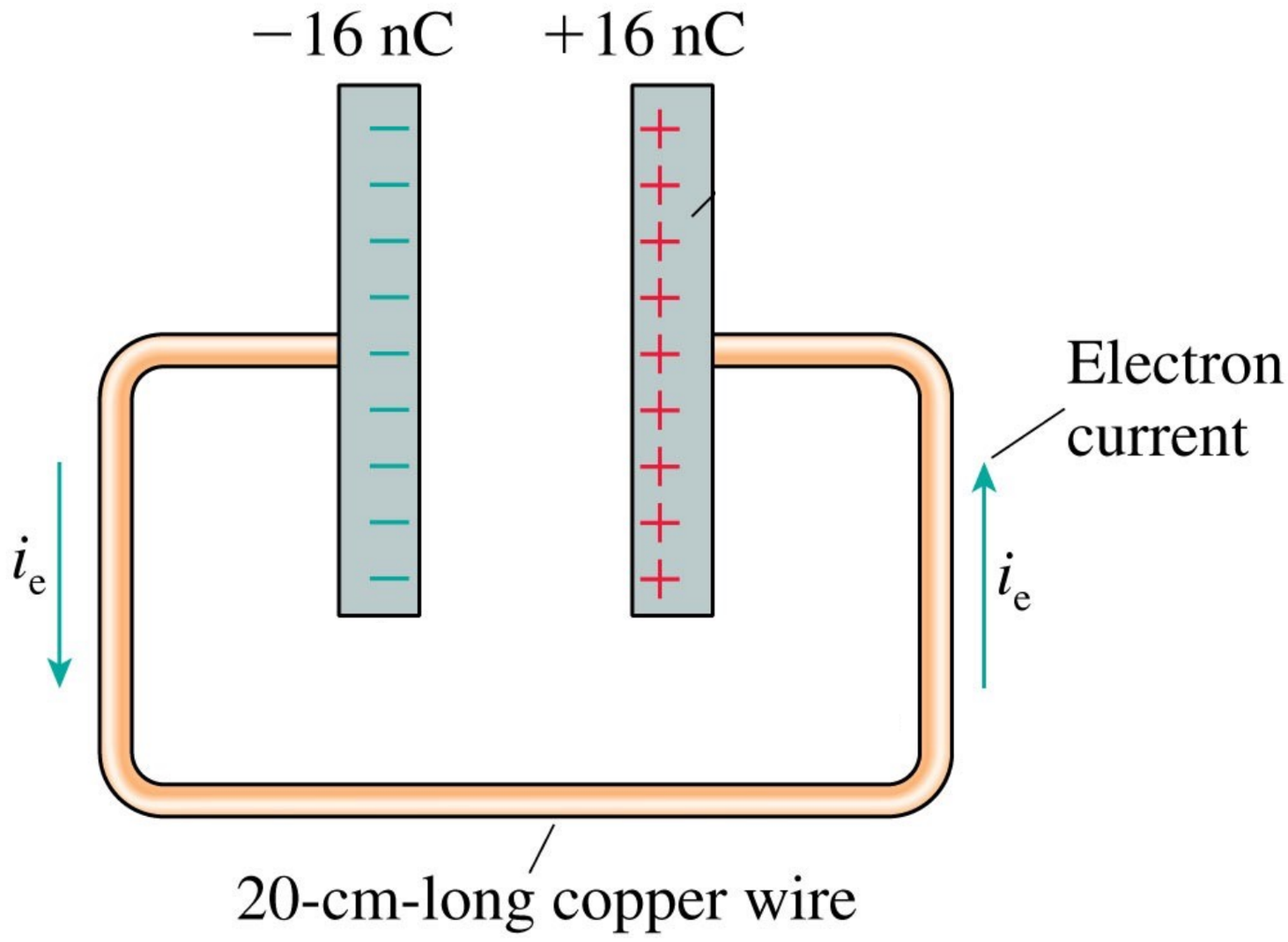
Discharging a capacitor

Typical drift velocities are on the order:

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

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

2000 s



Animation

Discharging a capacitor

Typical drift velocities are on the order:

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

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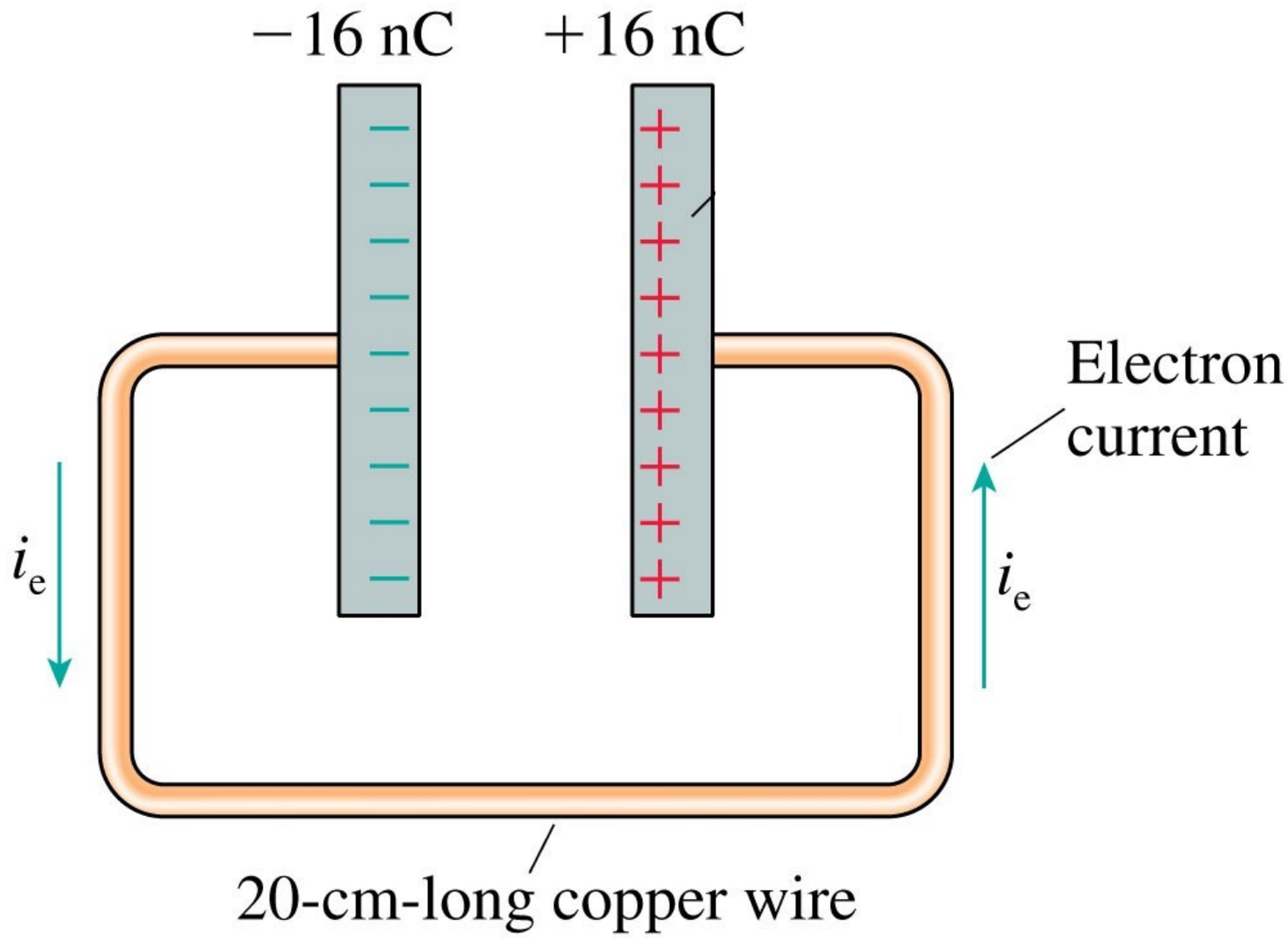

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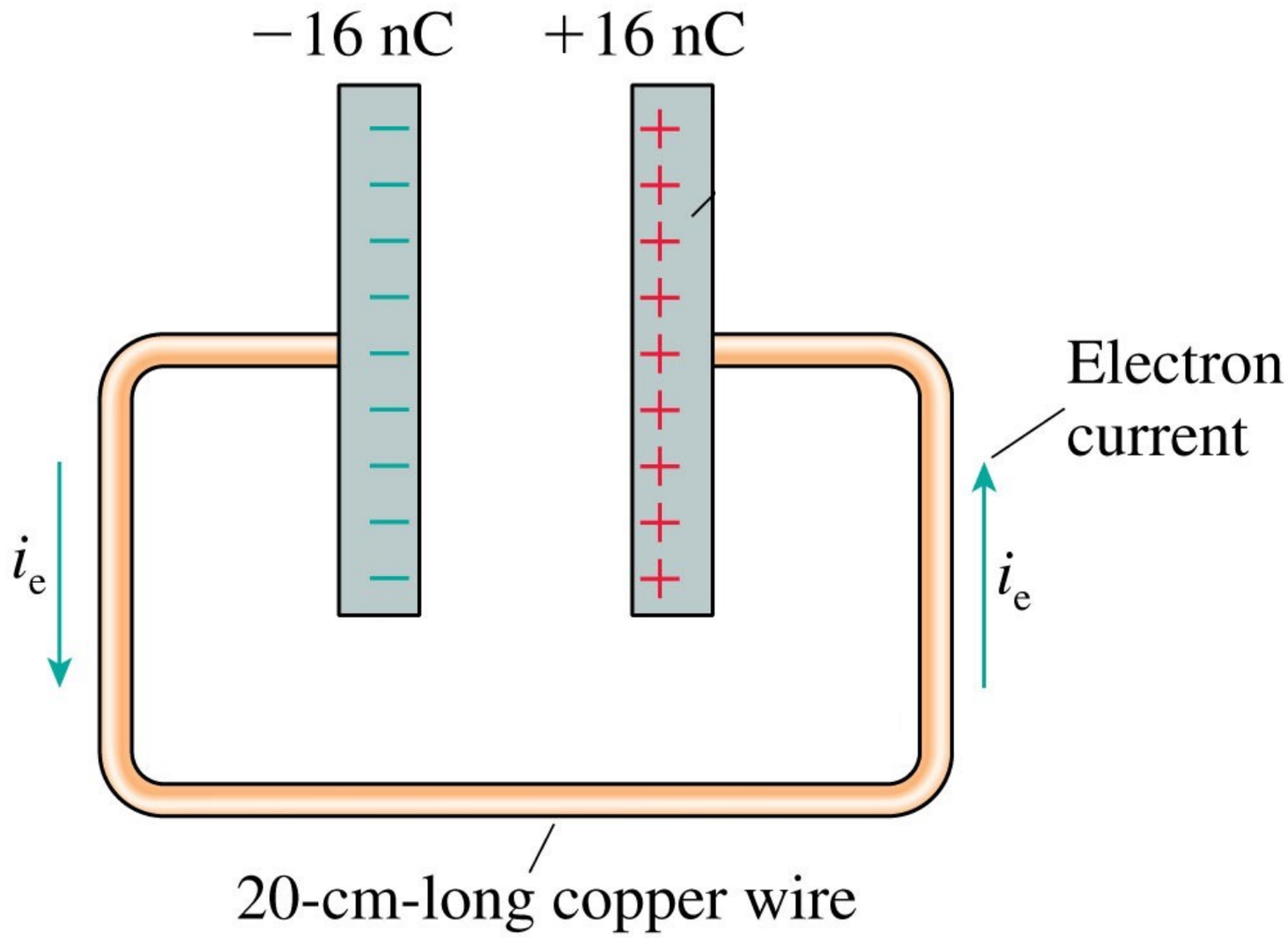

Capacitors discharge nearly instantaneously!

Animation

Water-in-pipe analogy

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

Water-in-pipe analogy

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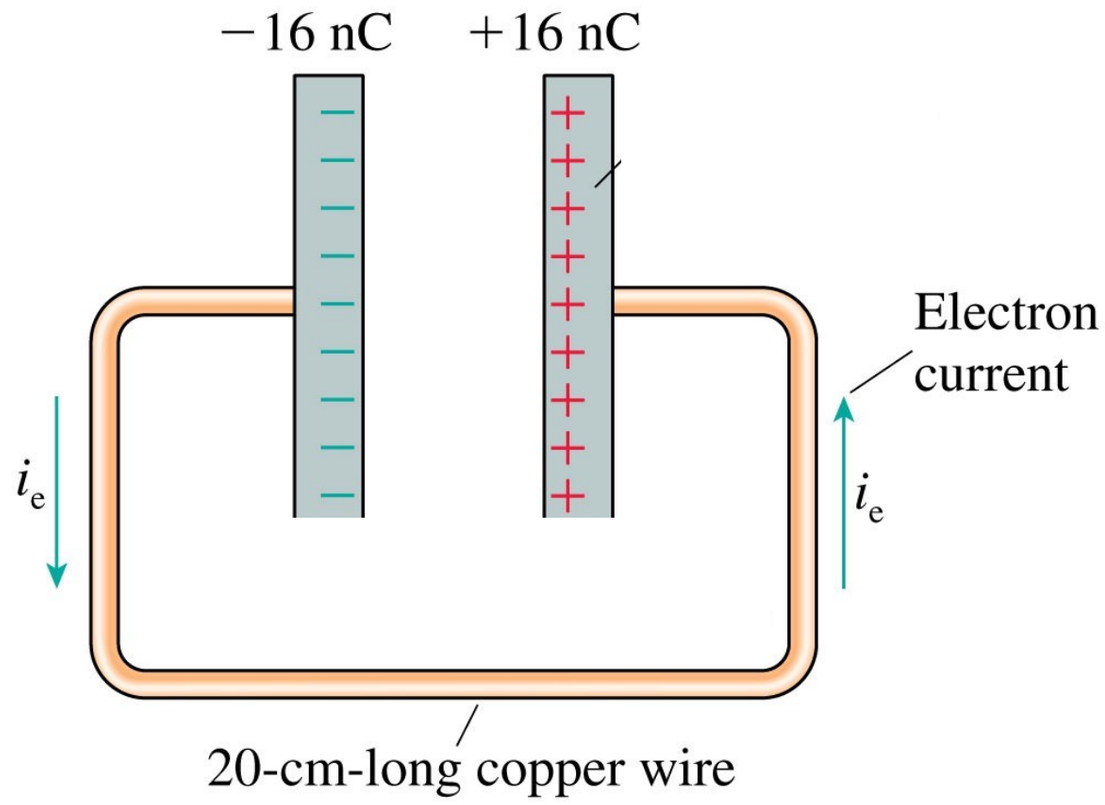
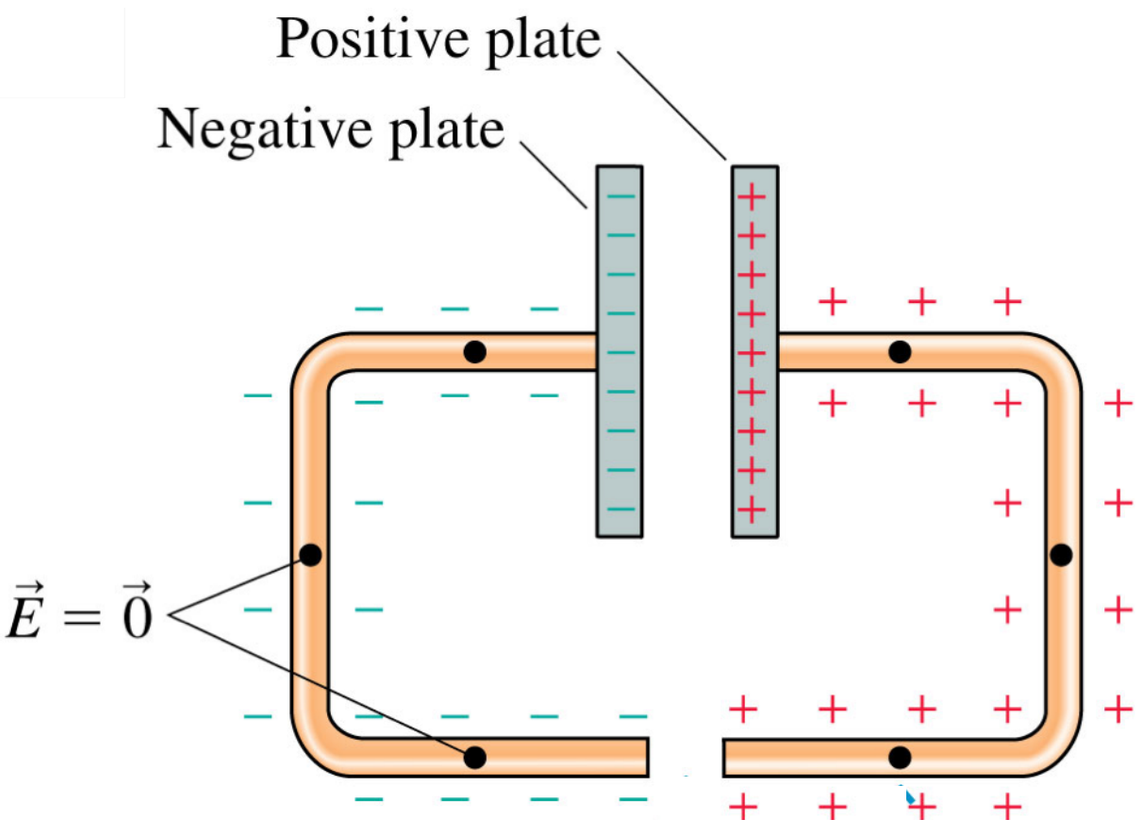
5×10^{22}

10^{11}



Conceptualizing Current



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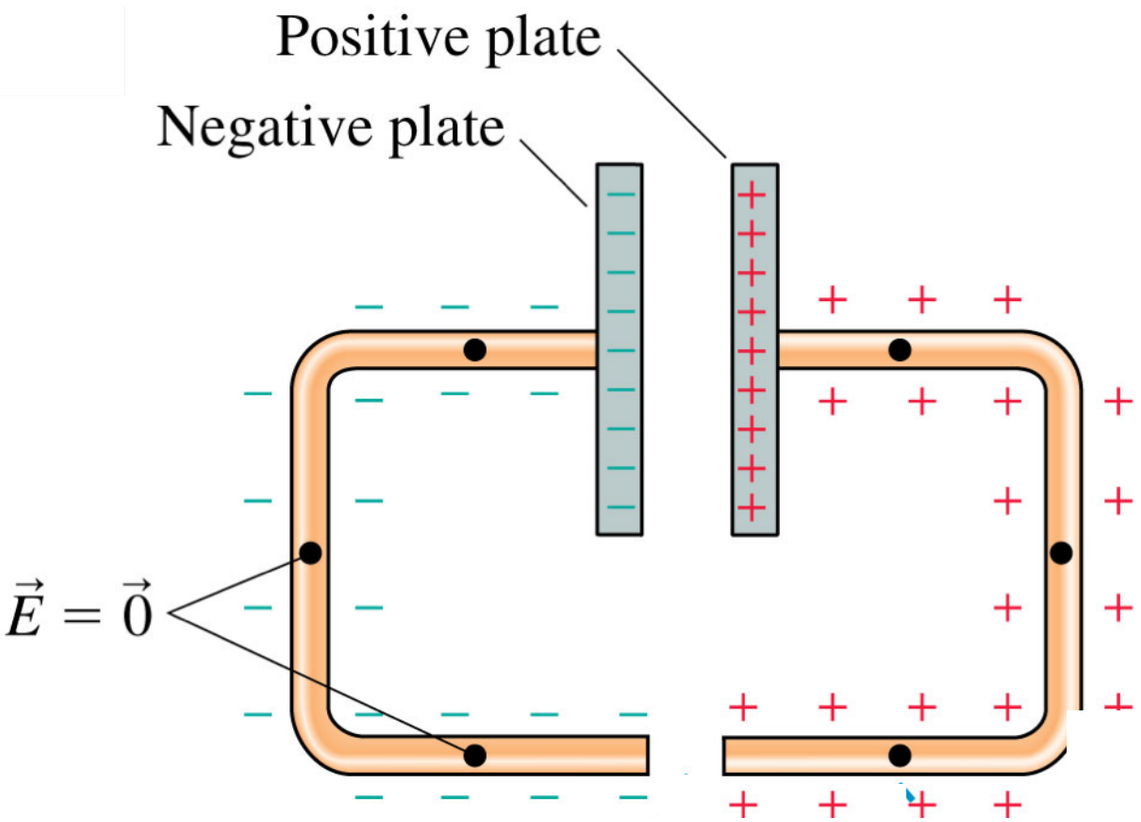

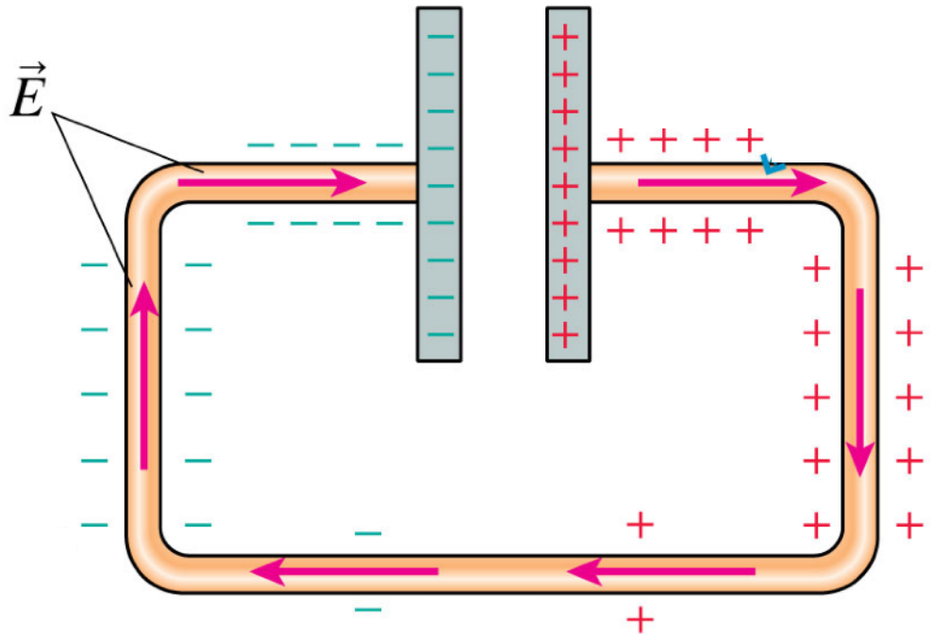

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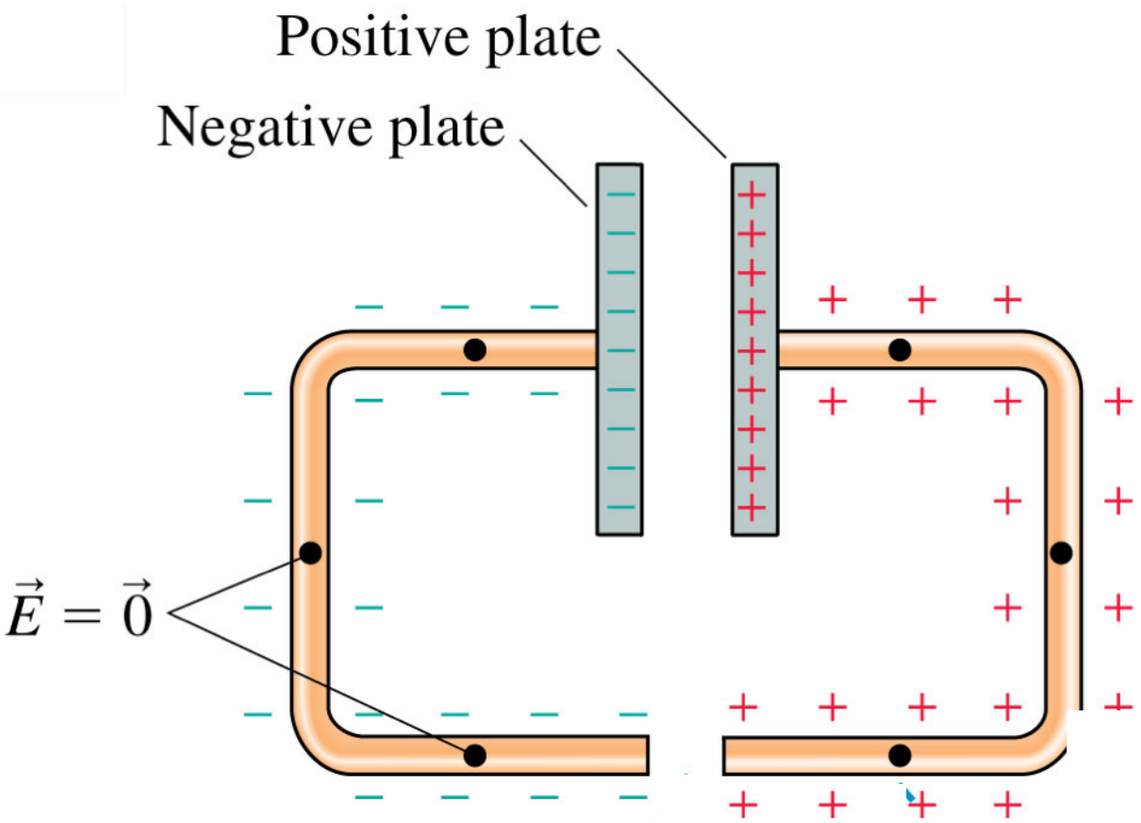
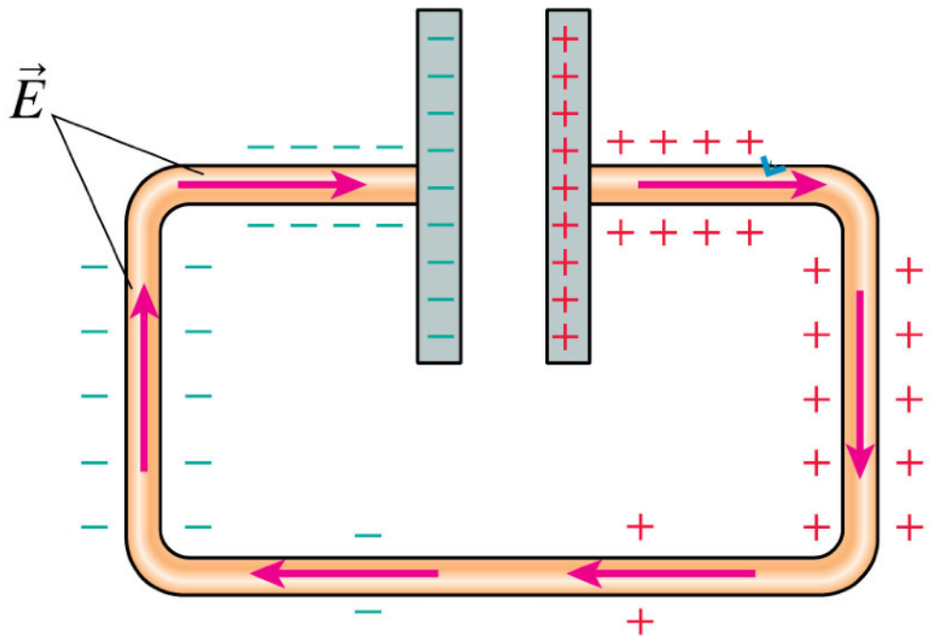
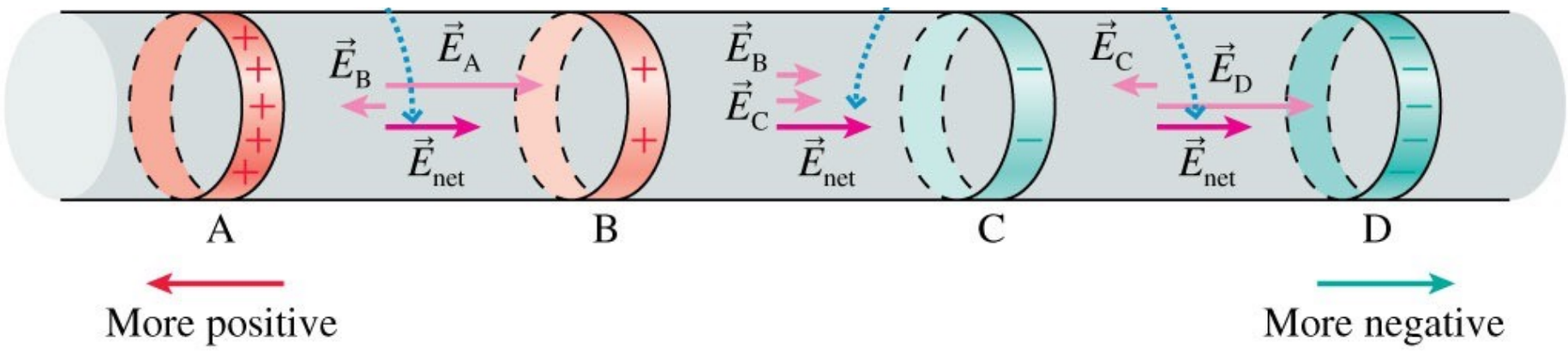
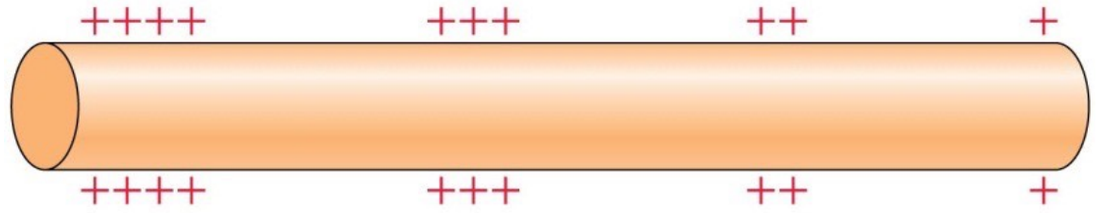




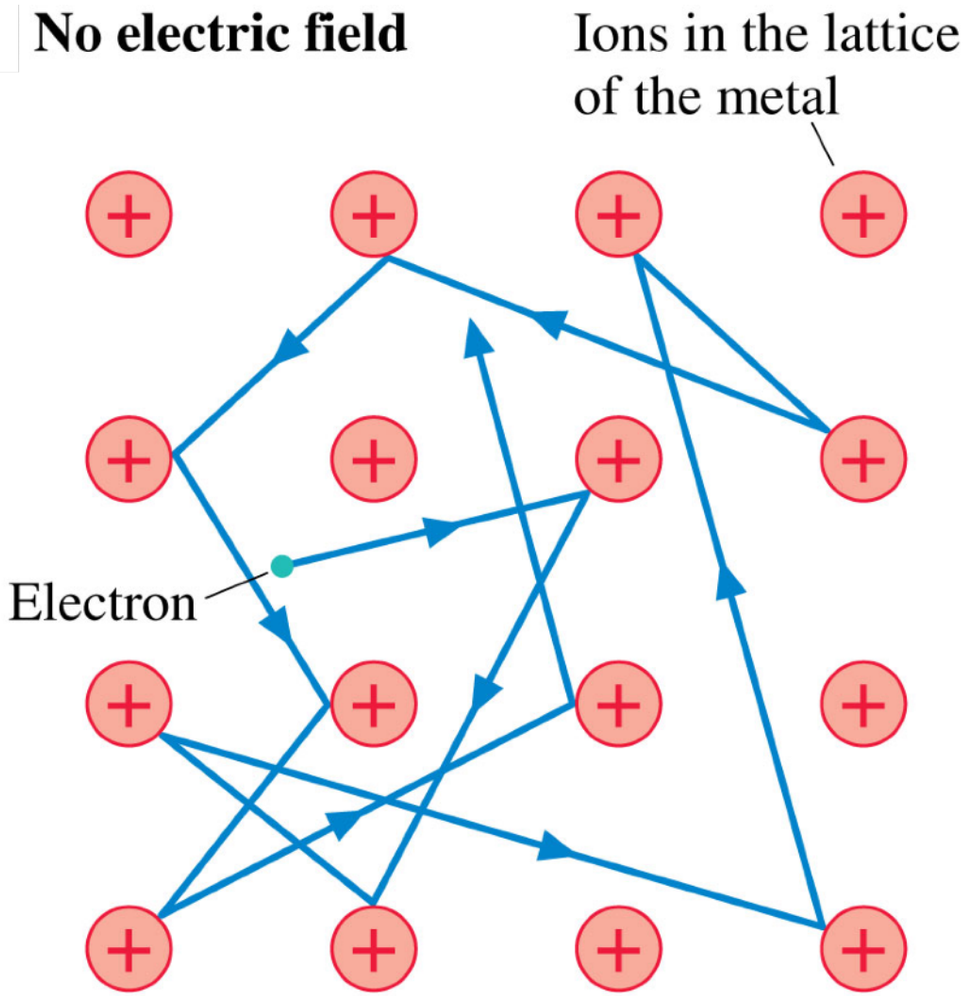


Surface charge is distributed on a wire as shown.
Electrons in the wire



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

Model of Conduction



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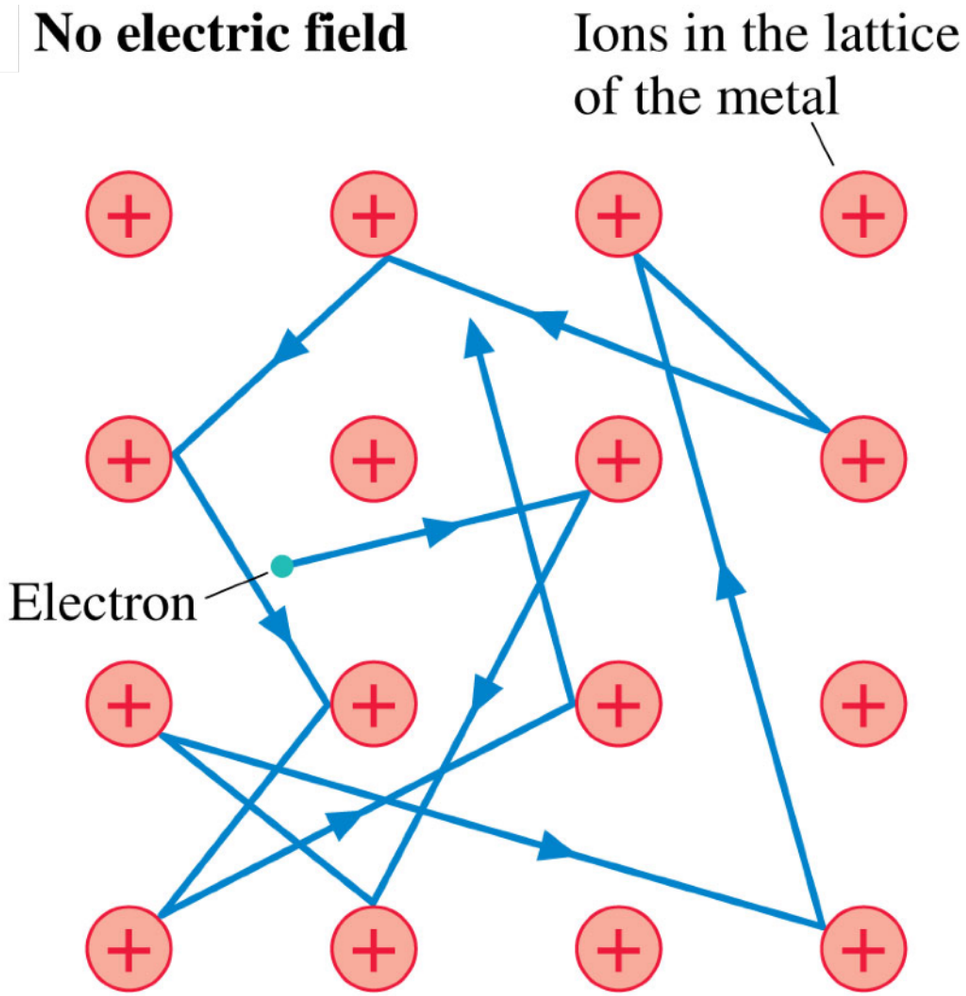
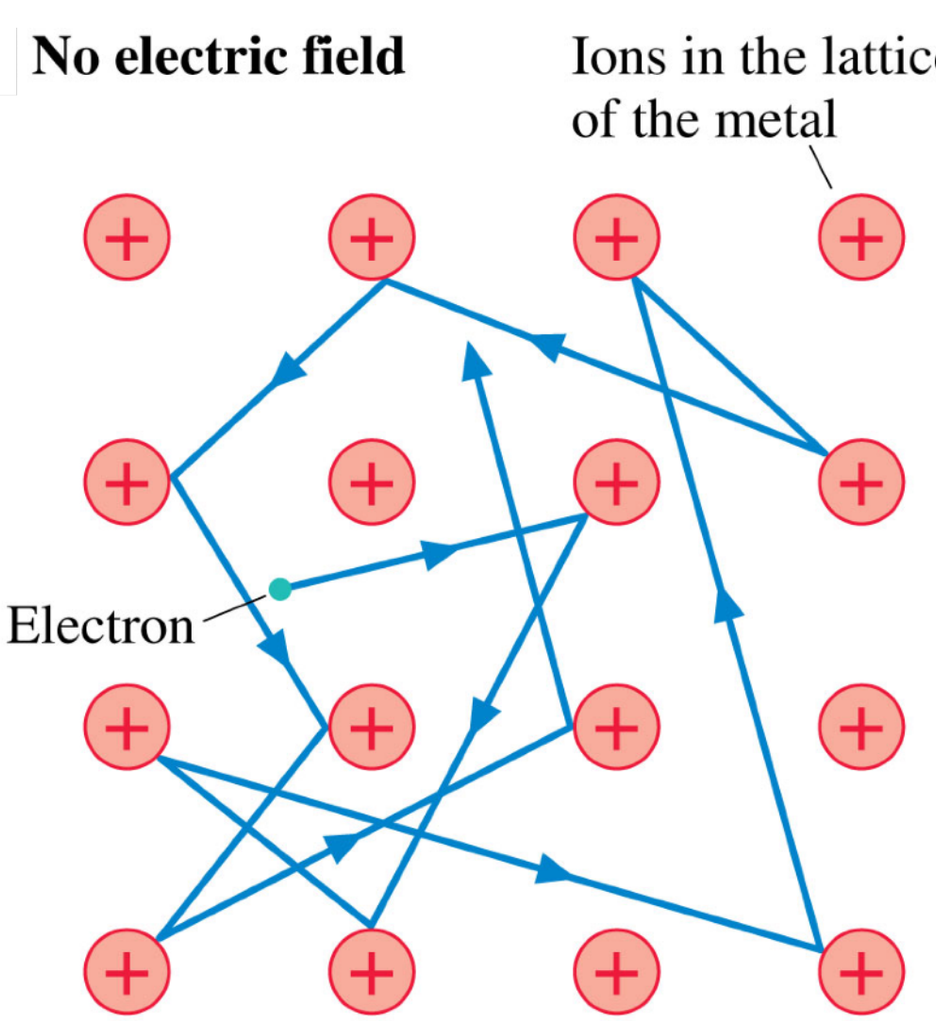
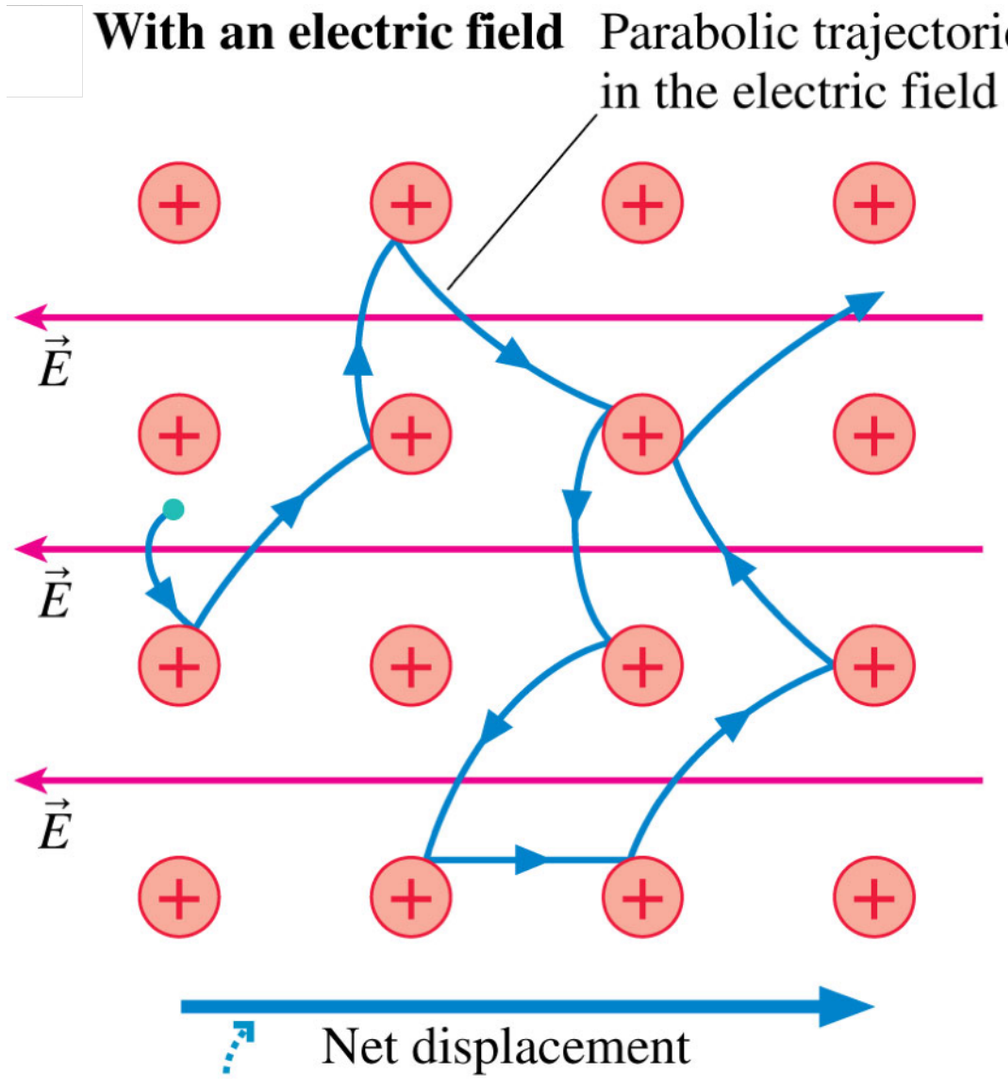


What will the trajectories look like when an E field is present?

Model of Conduction





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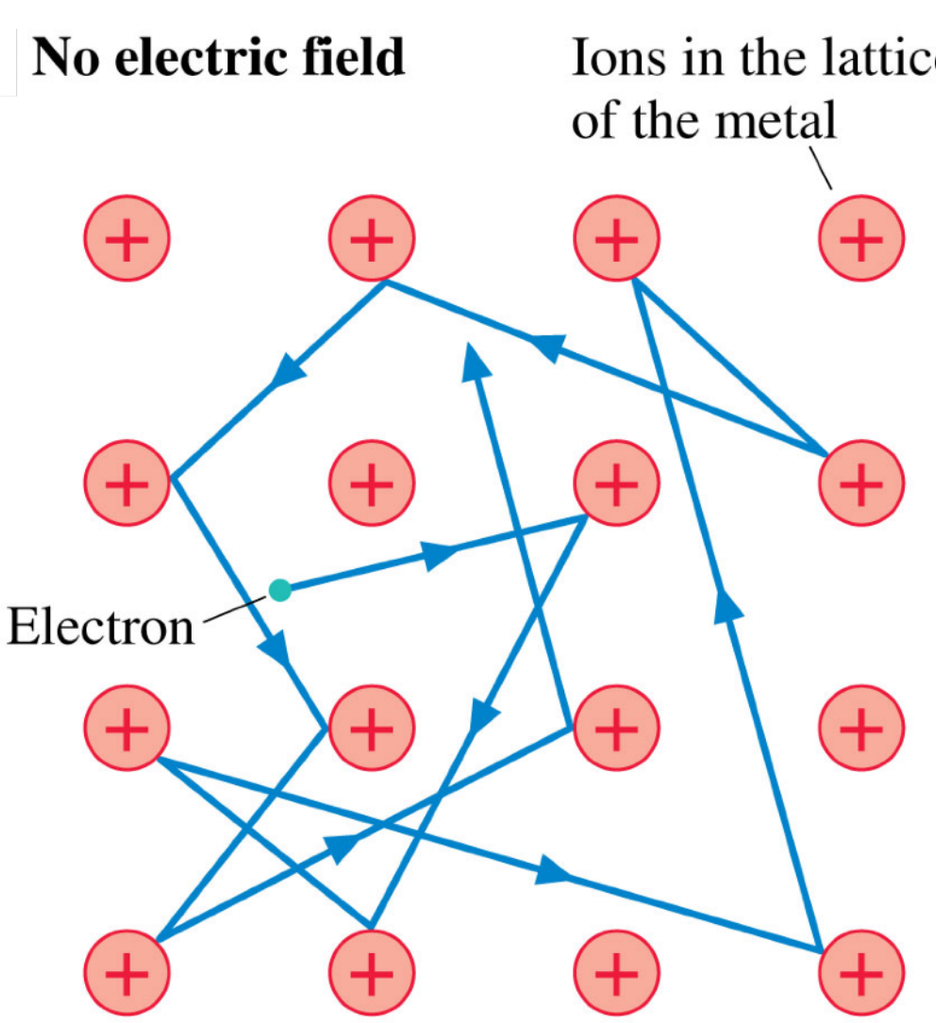

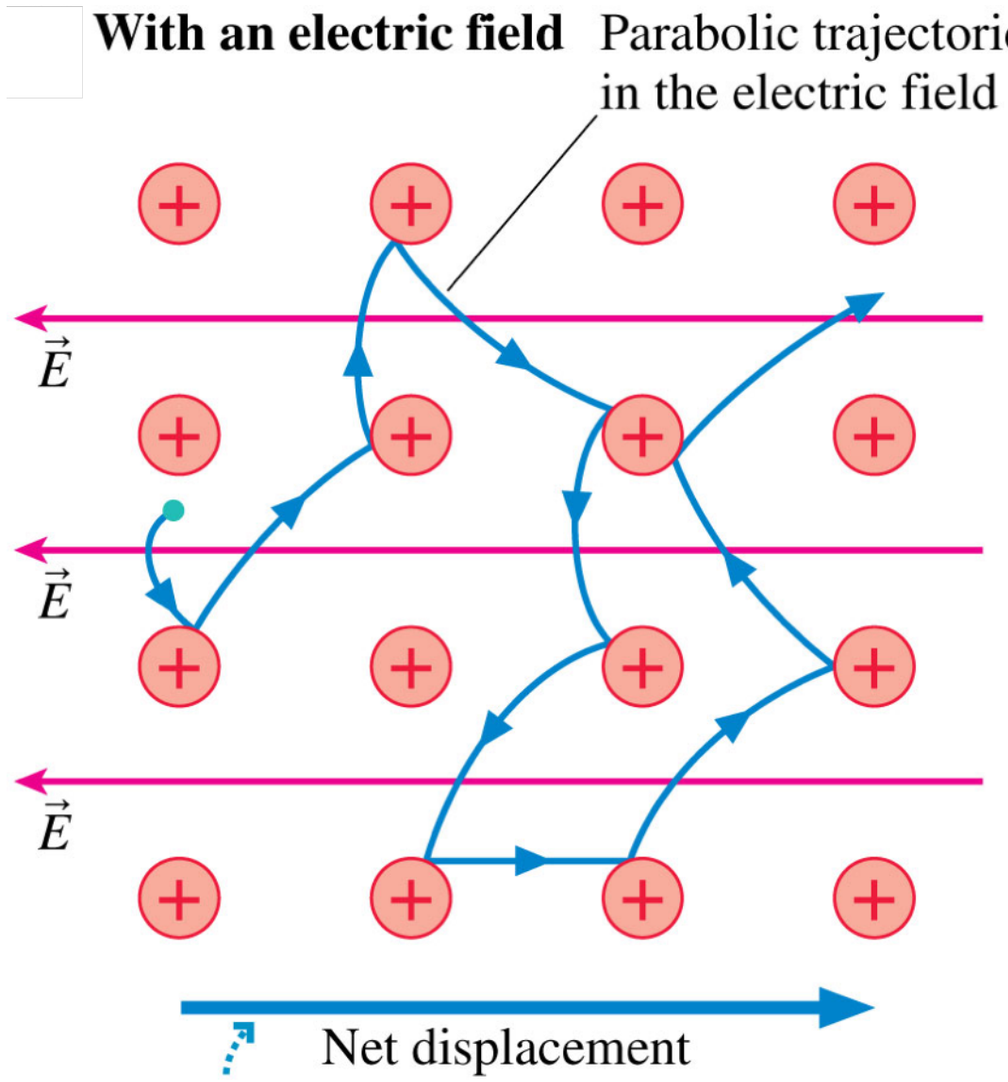

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Write an expression for the acceleration of the electrons in between collisions

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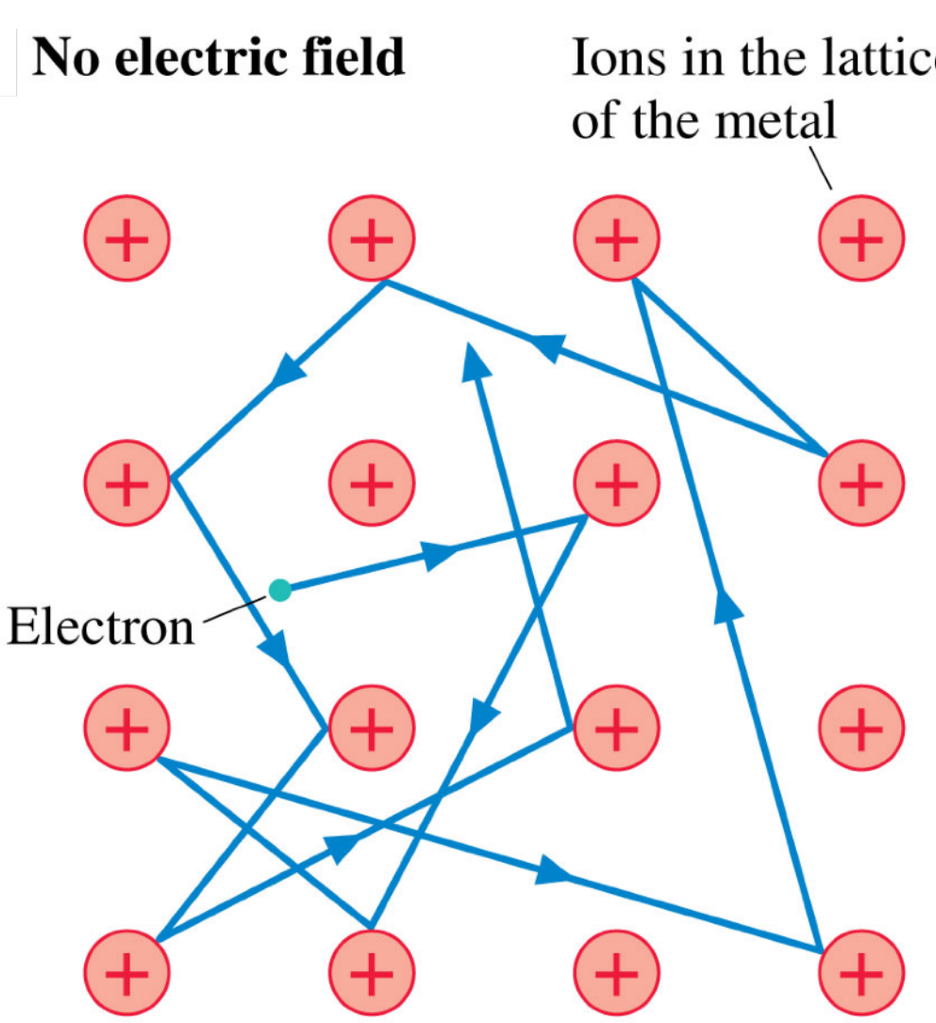

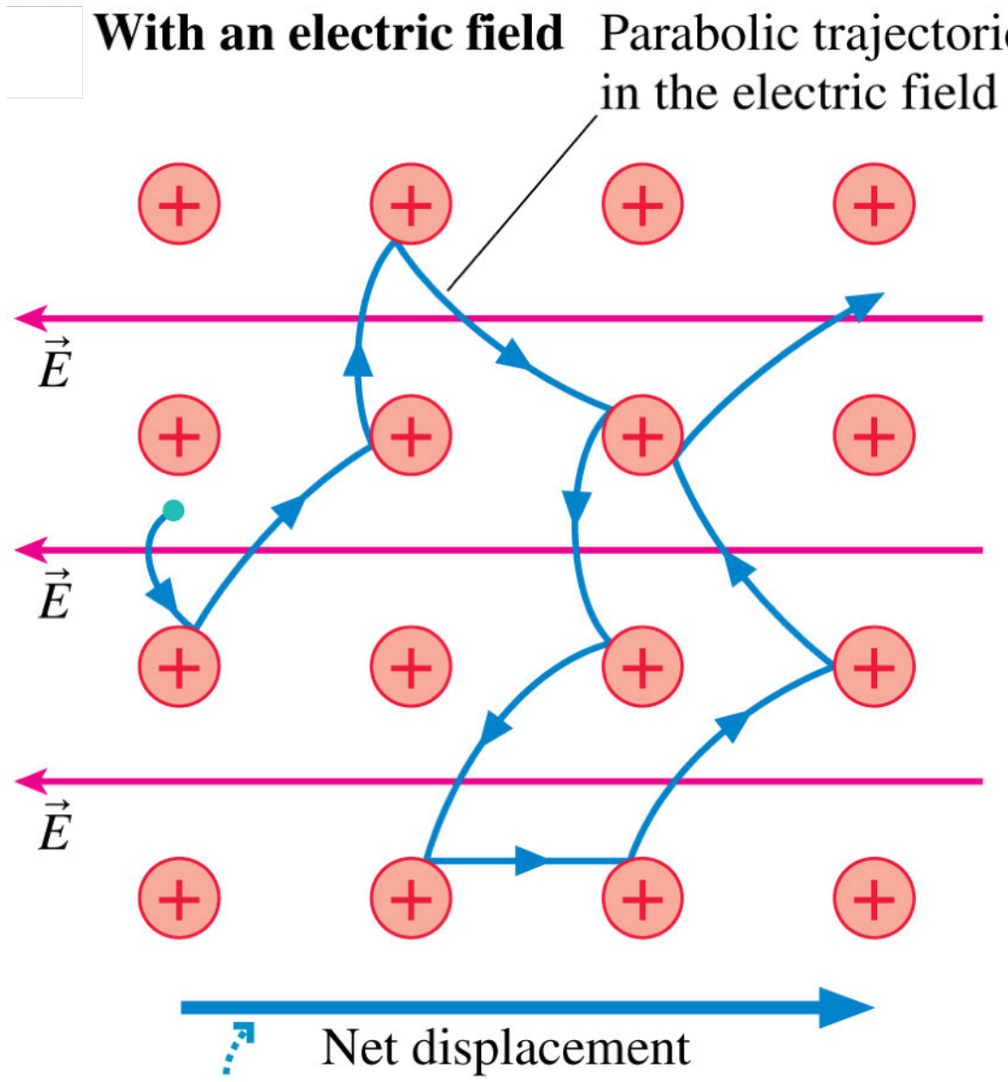

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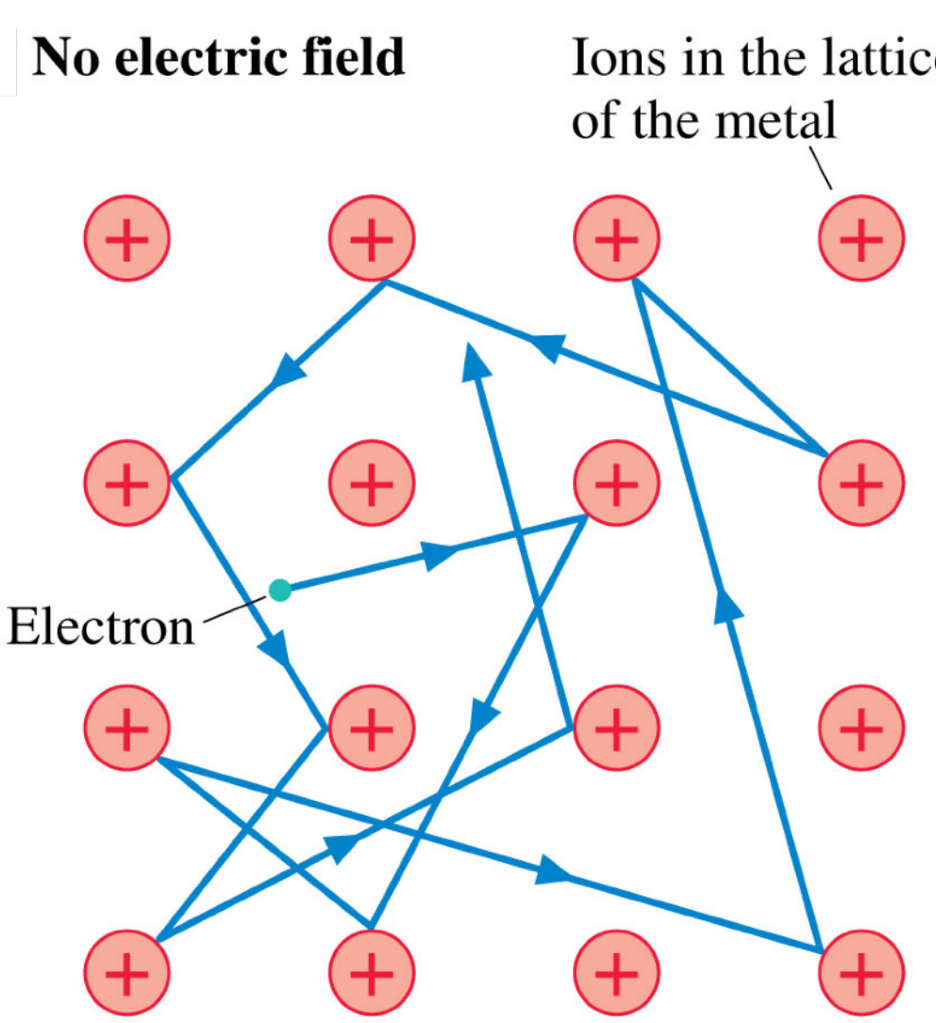

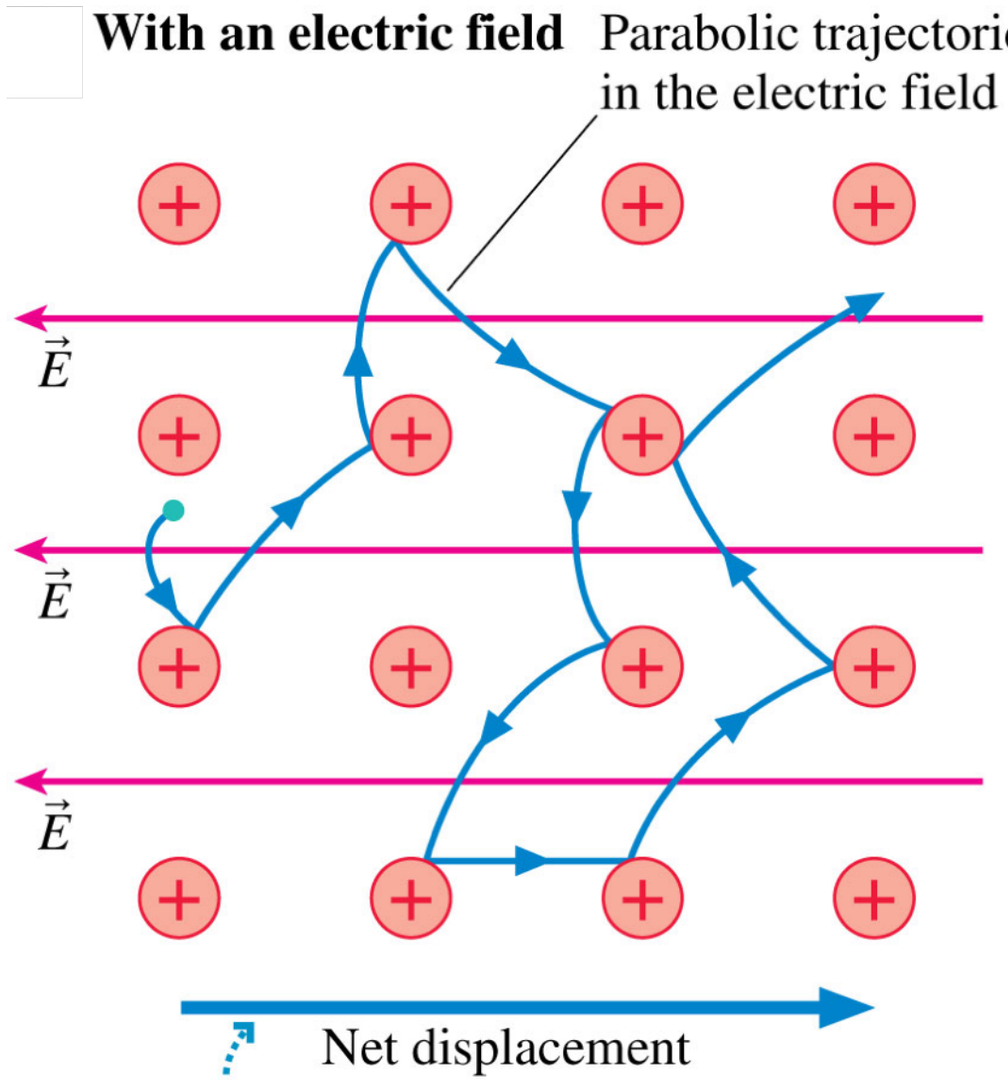

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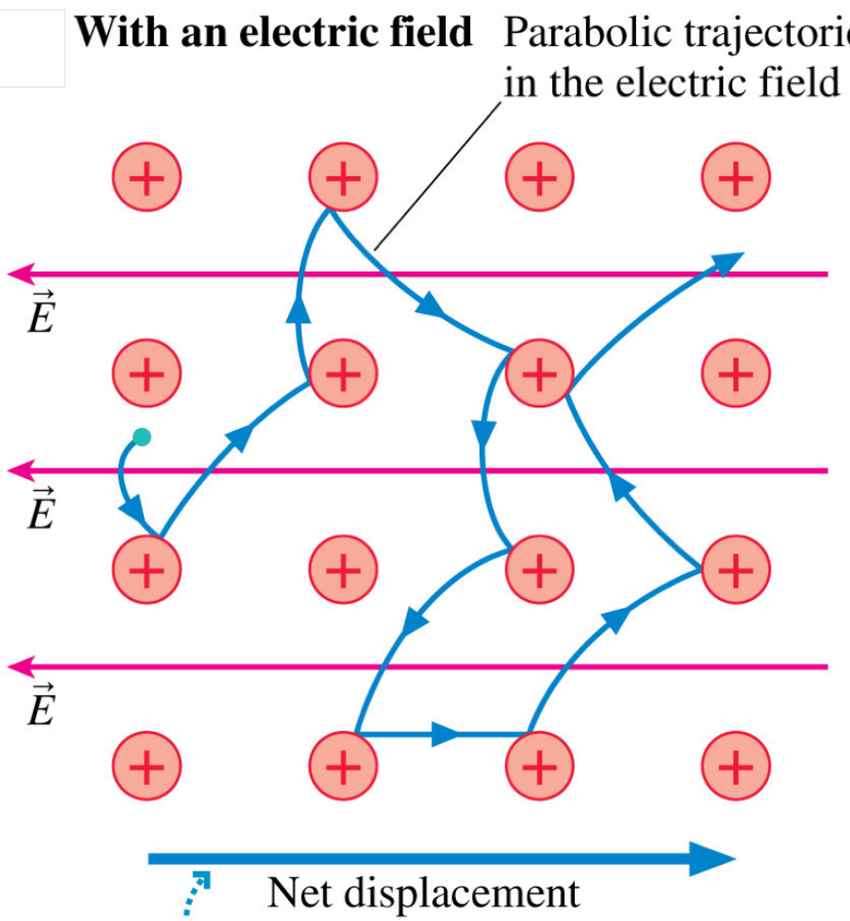

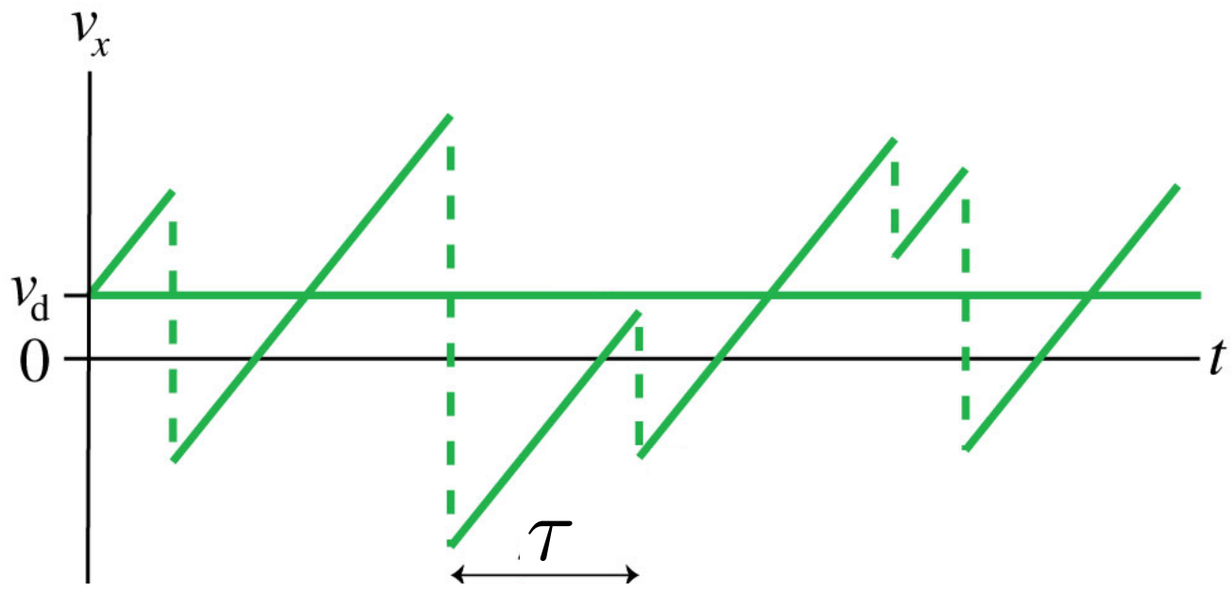

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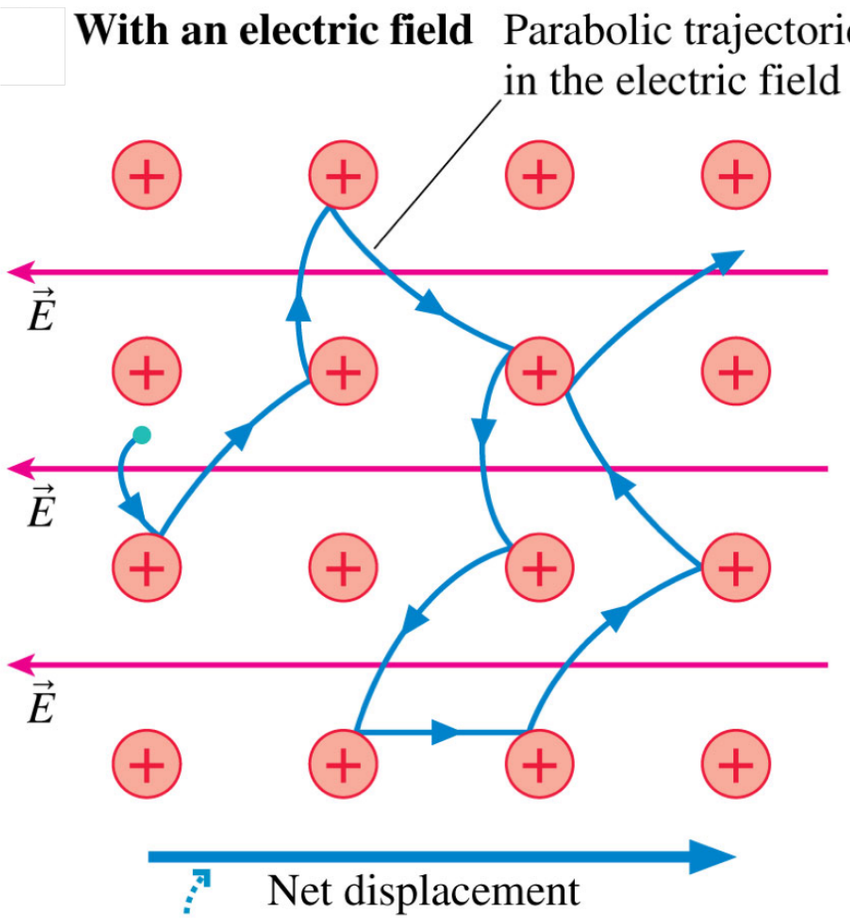

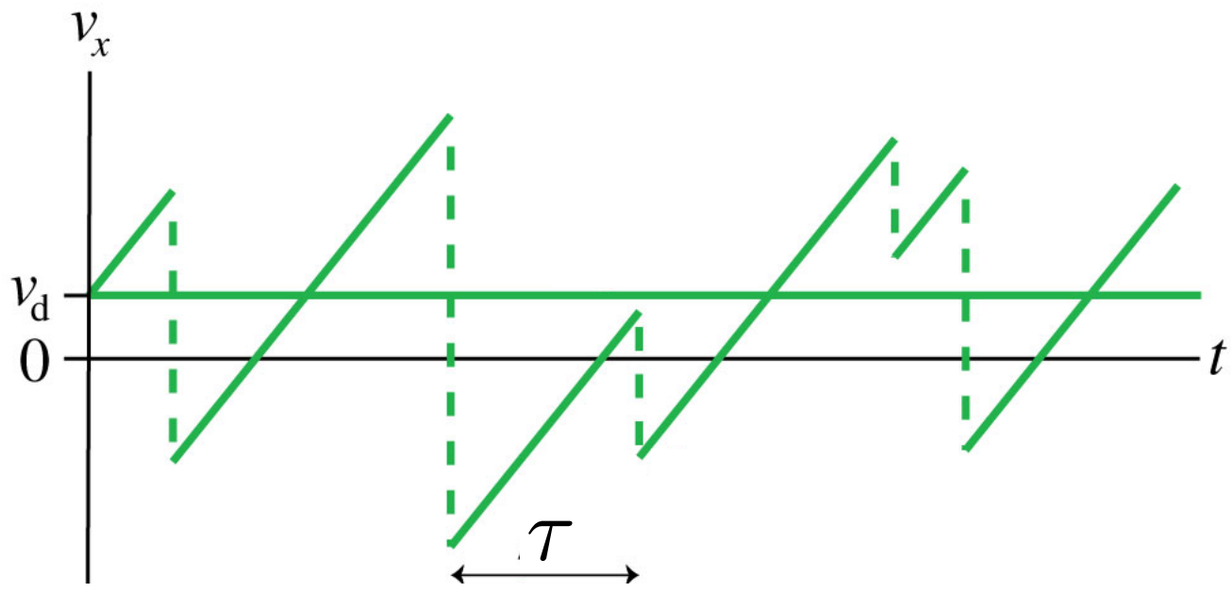

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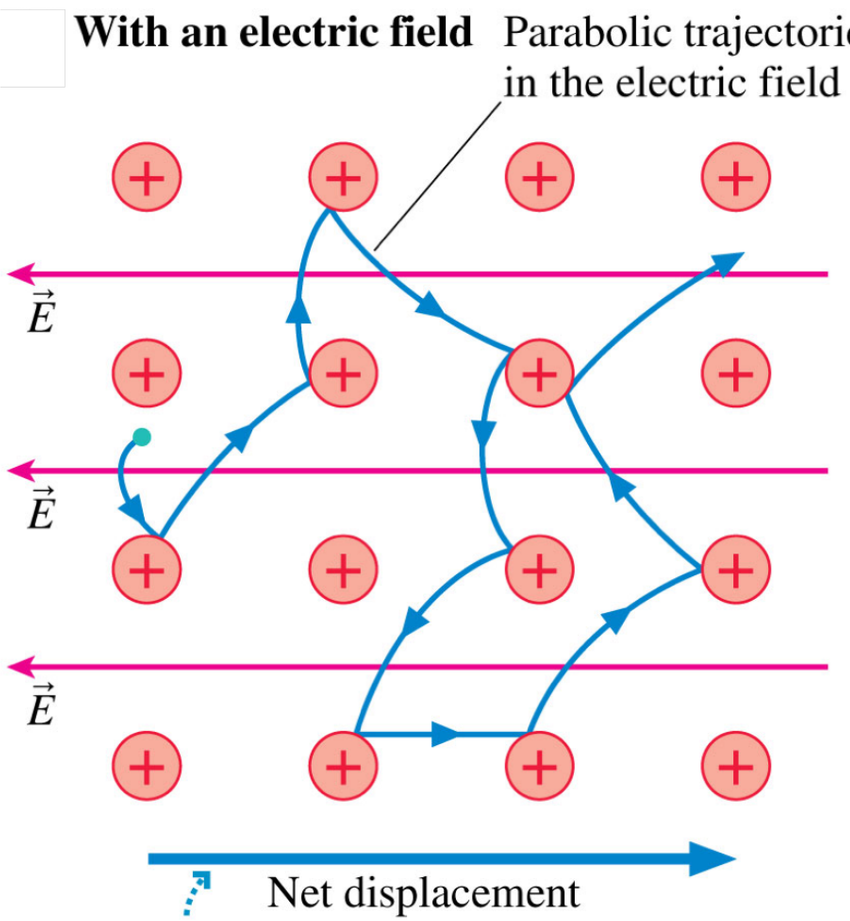

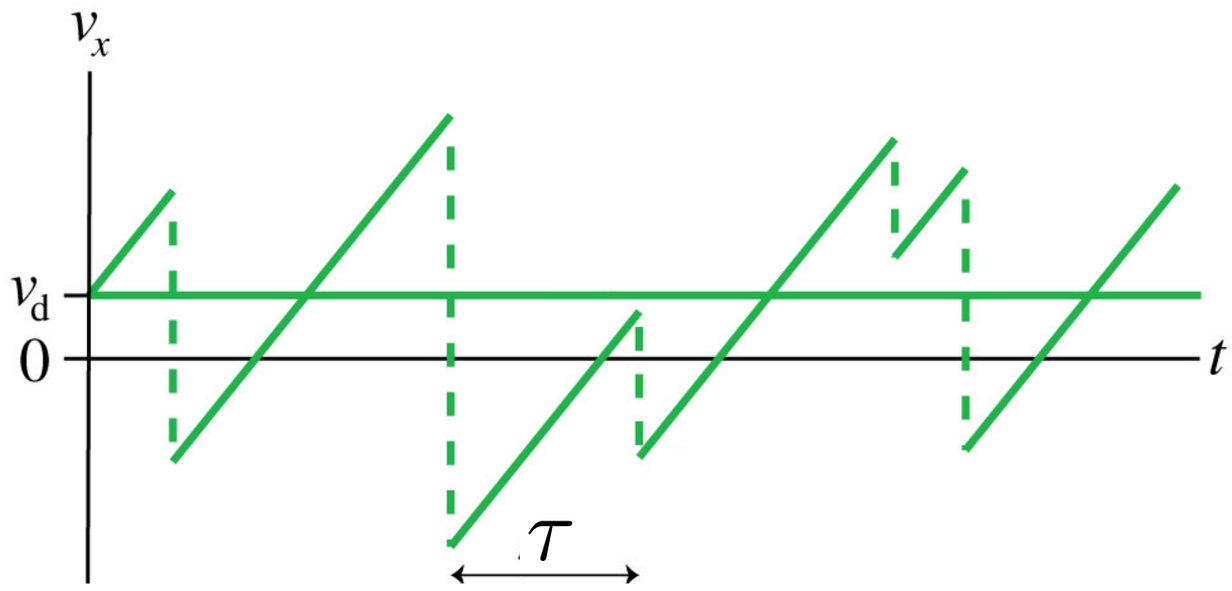

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