



PH 220

Lance Nelson

How would you calculate....

Electric Field:

- 1-
- 2-
- 3-

Electric Potential:

- 1-
- 2-

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

Flux:

- 1-
- 2-

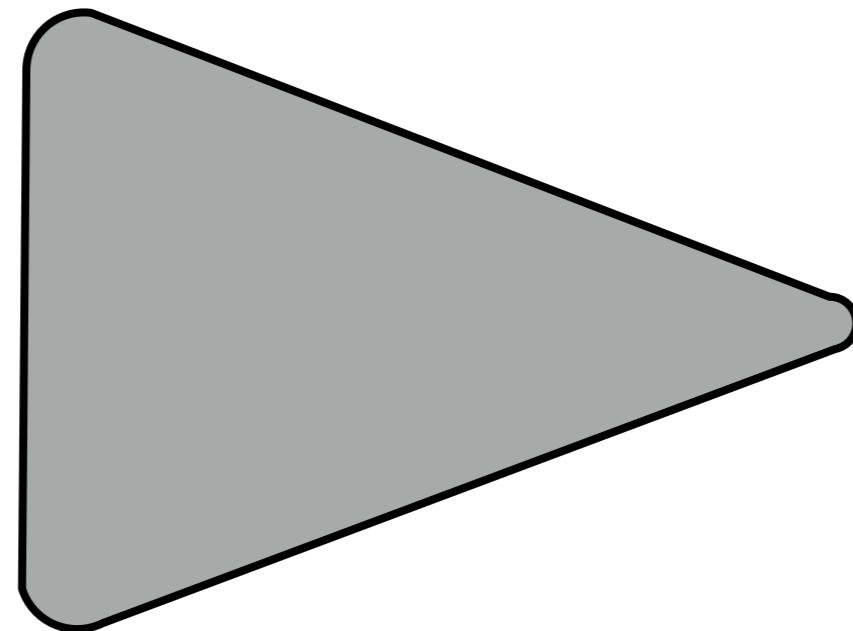
Electric Potential Energy:

- 1-
- 2-

Tell your neighbor everything you know about a conductor in equilibrium

Be sure to discuss the following:

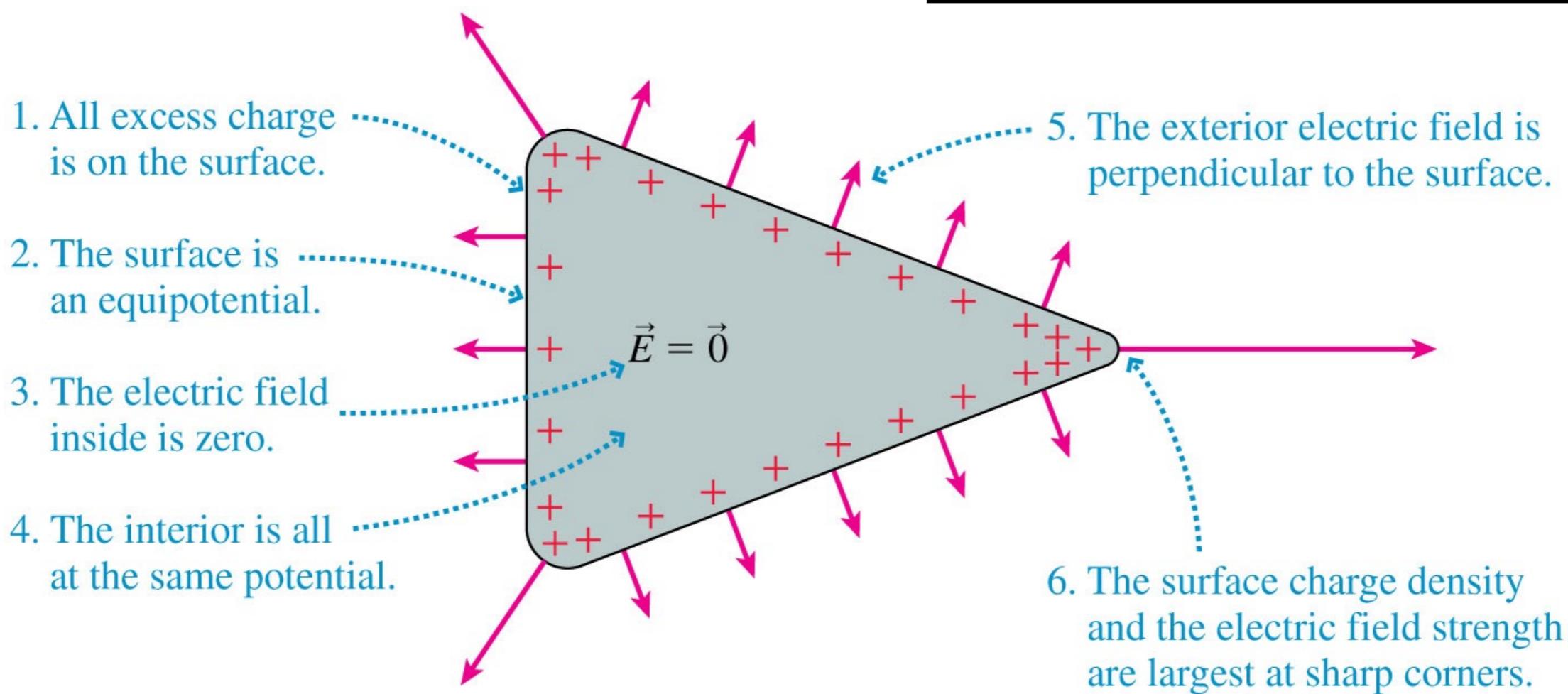
- electric potential
- electric field (inside and out)
- charge
- charge density



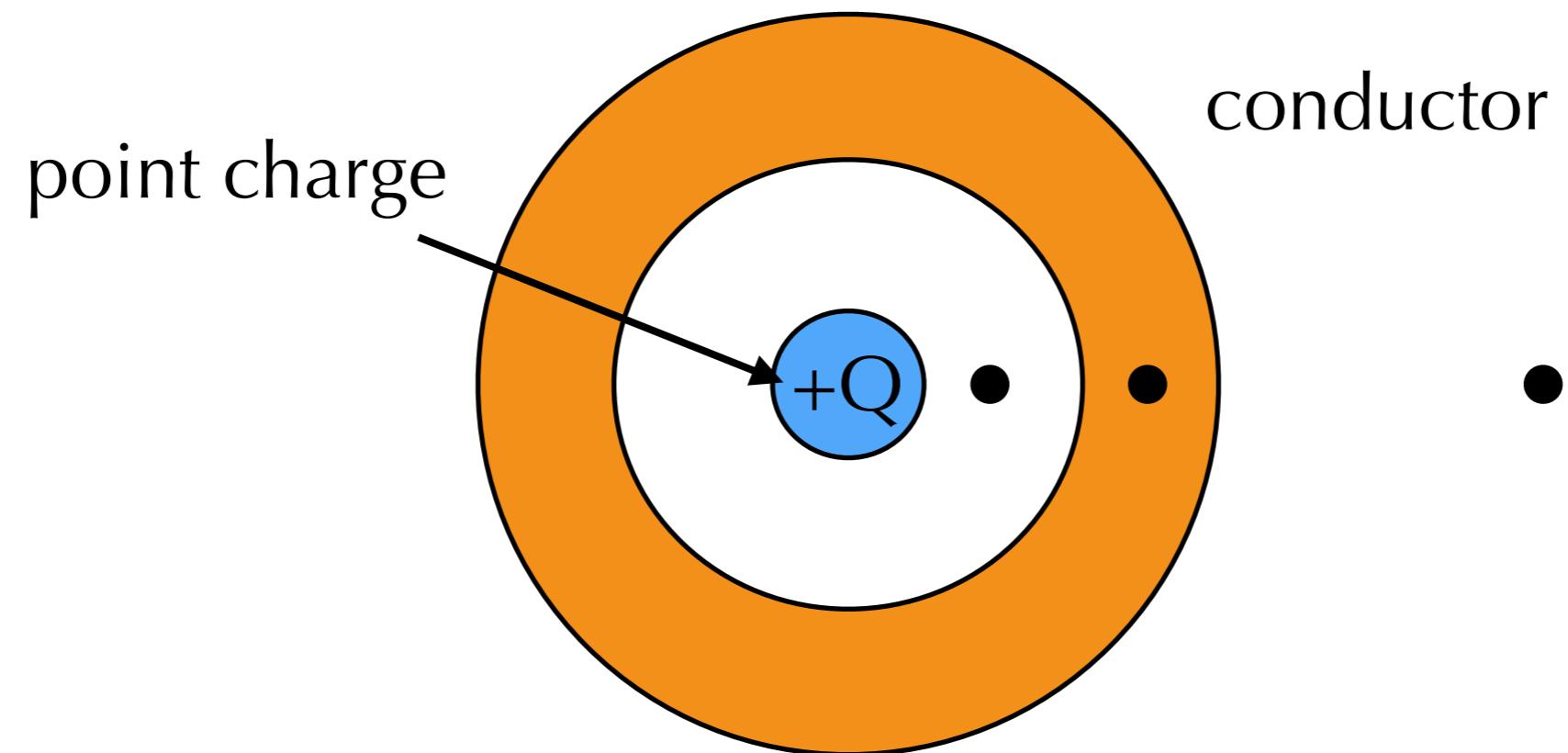
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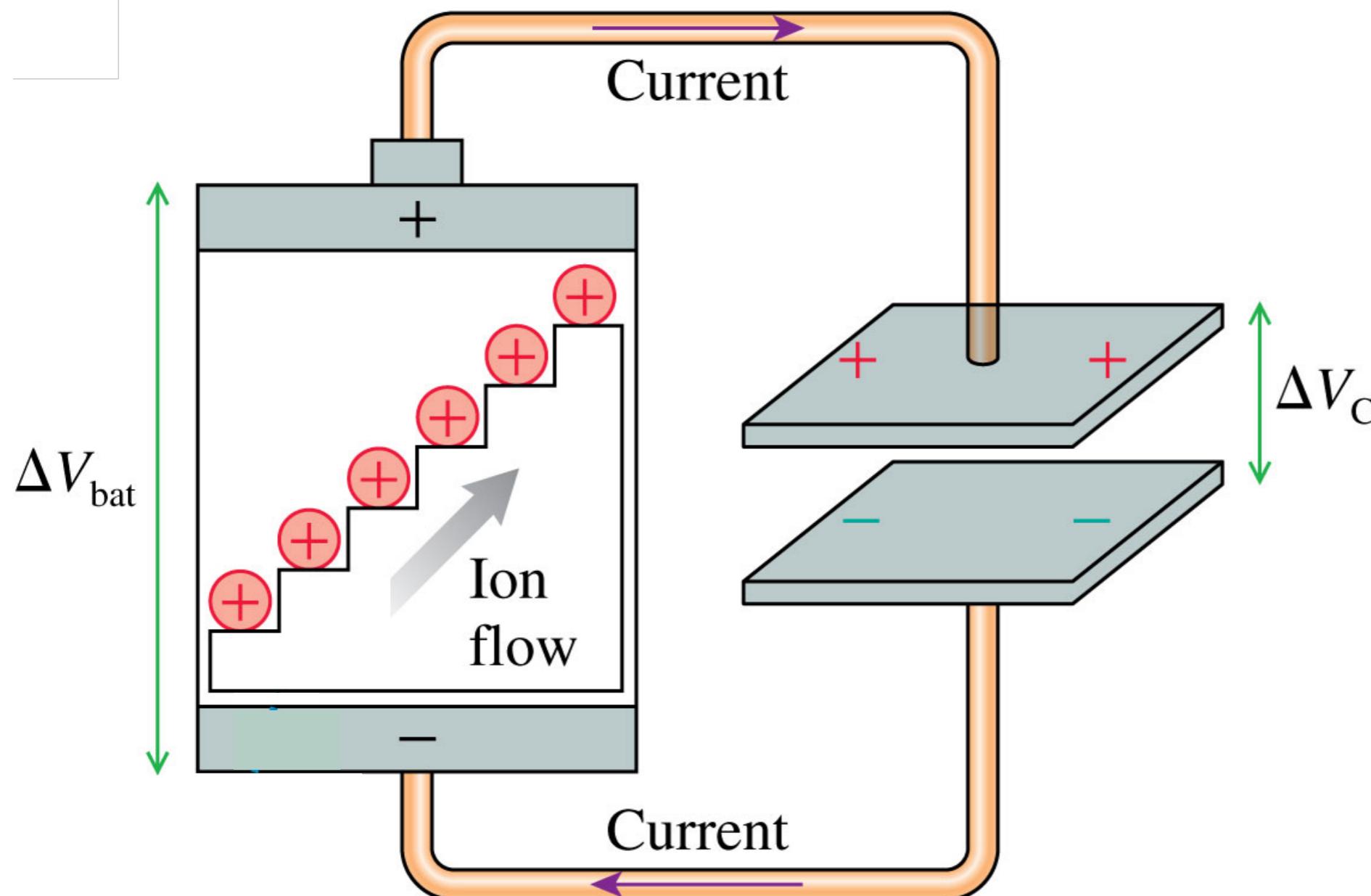
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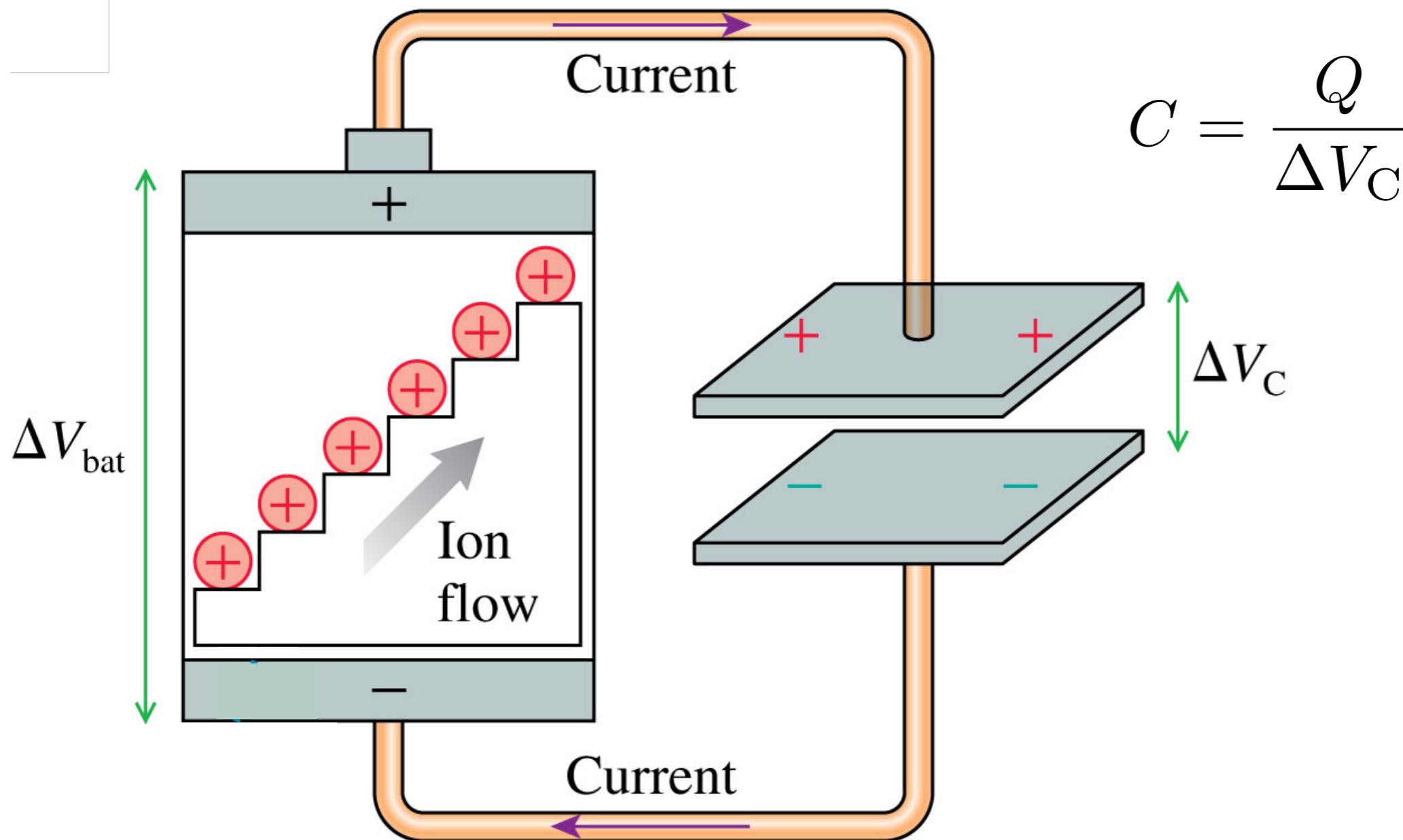
At which dot is the electric potential greatest.



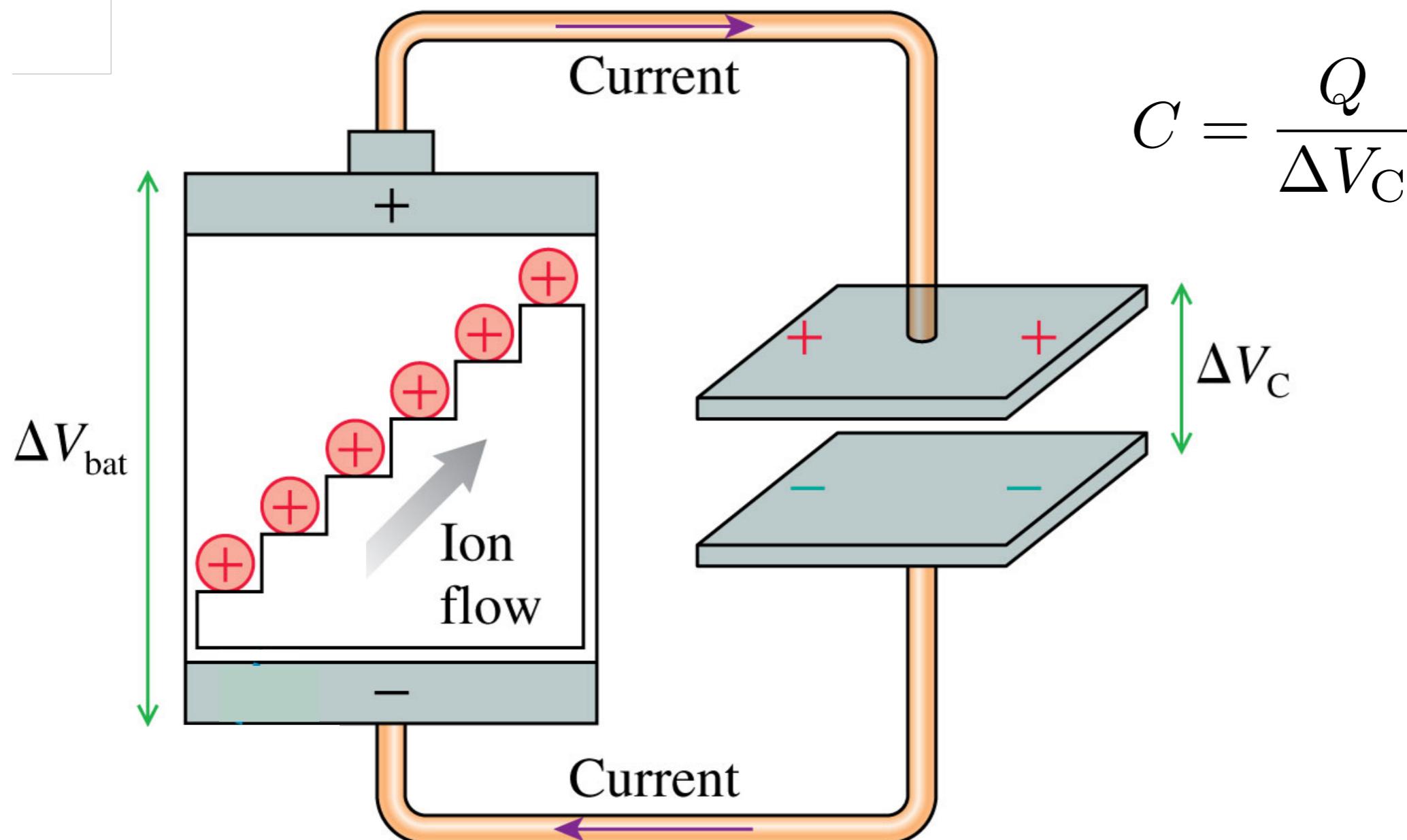
Capacitance



Capacitance



Capacitance

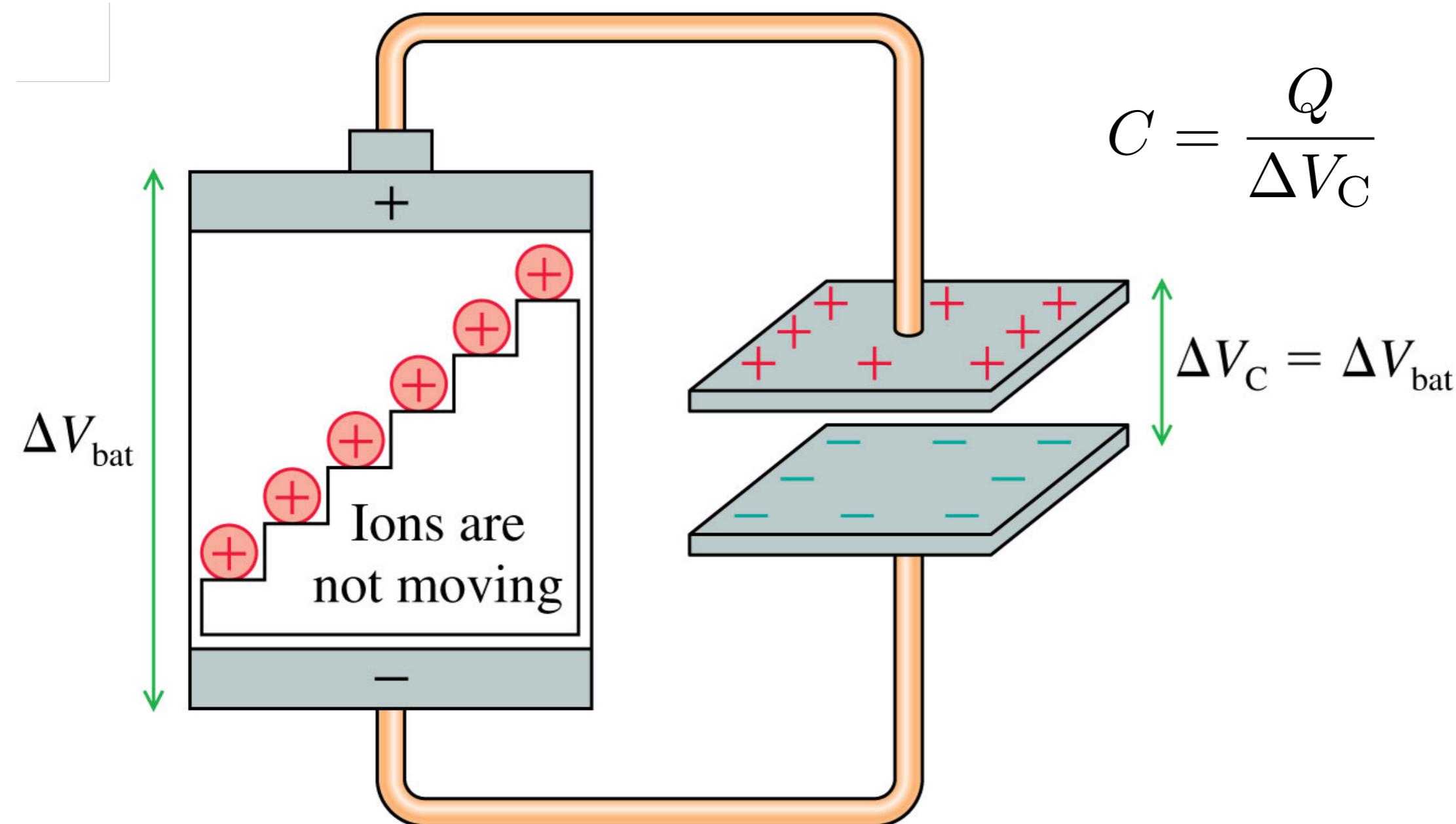


When does the flow of electrons stop?

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



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

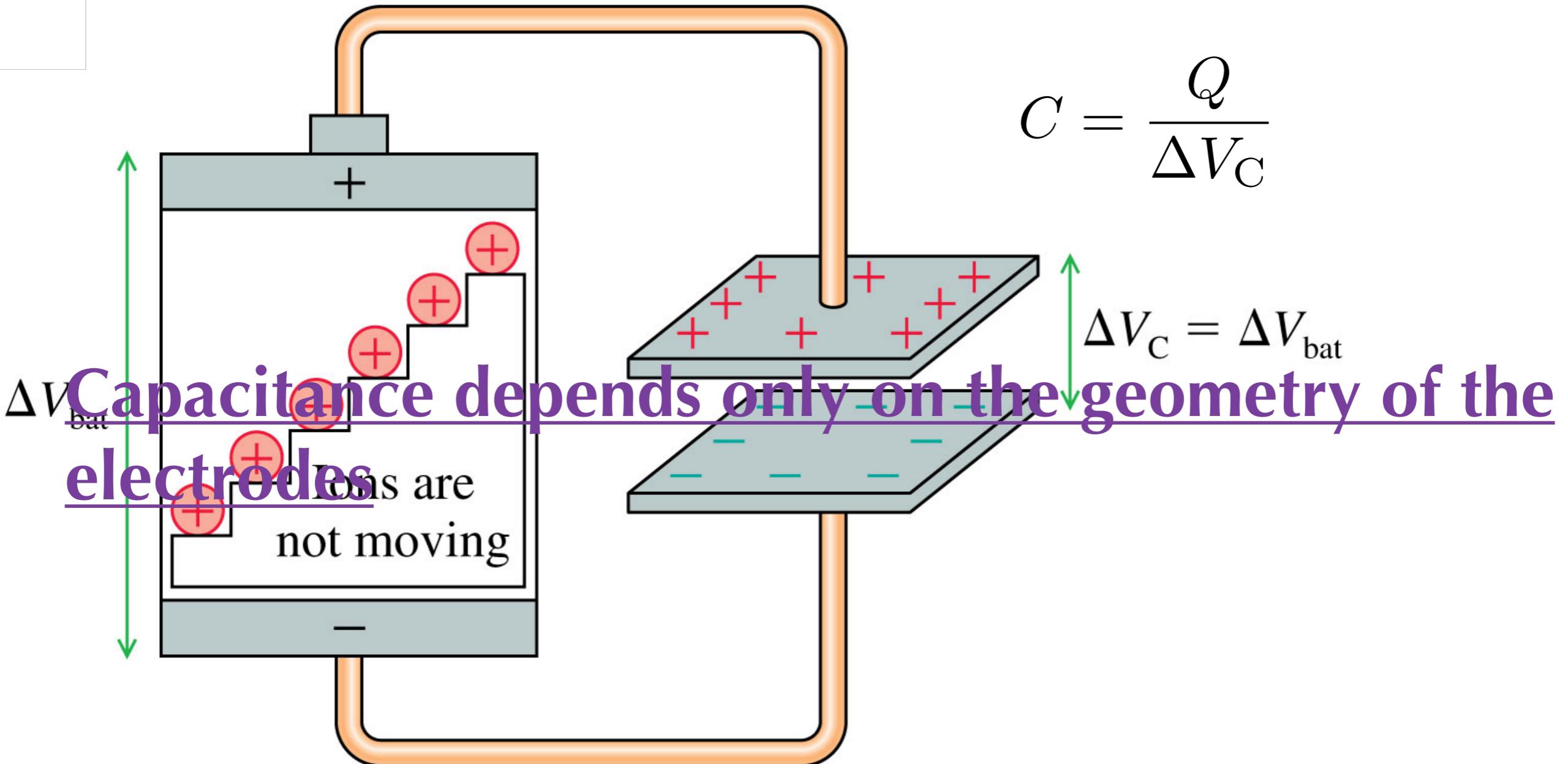
$$\Delta V_C = \Delta V_{\text{bat}}$$

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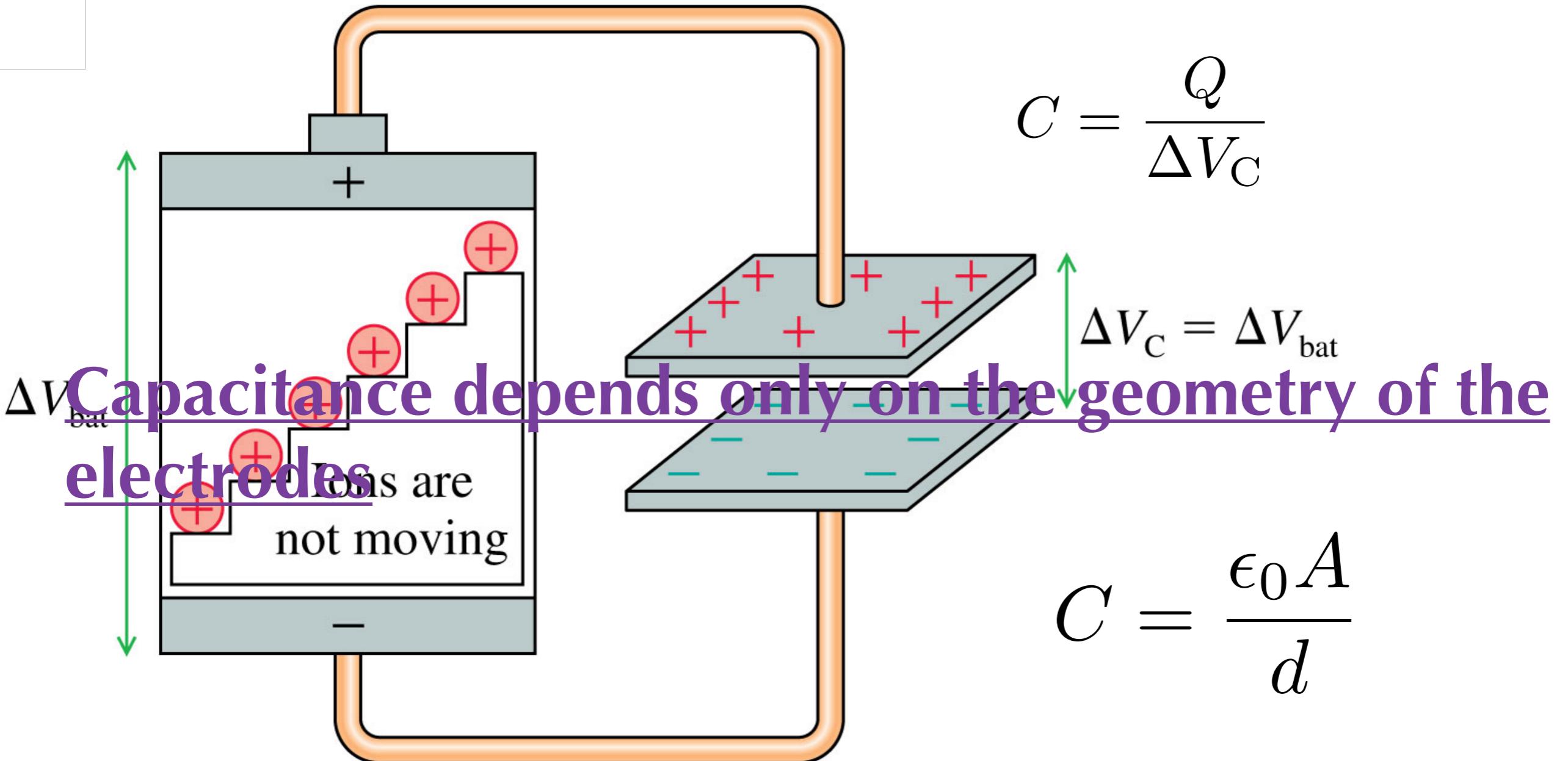
Capacitance depends only on the geometry of the electrodes
ions are not moving

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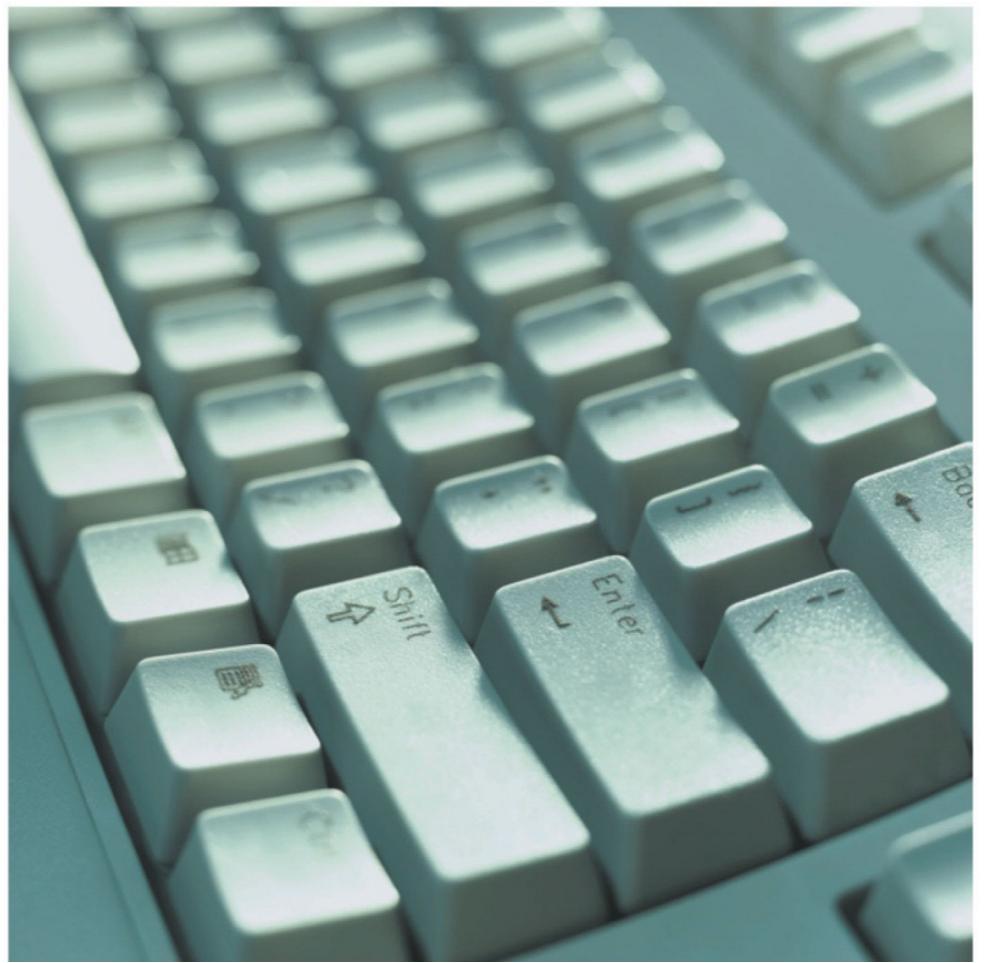
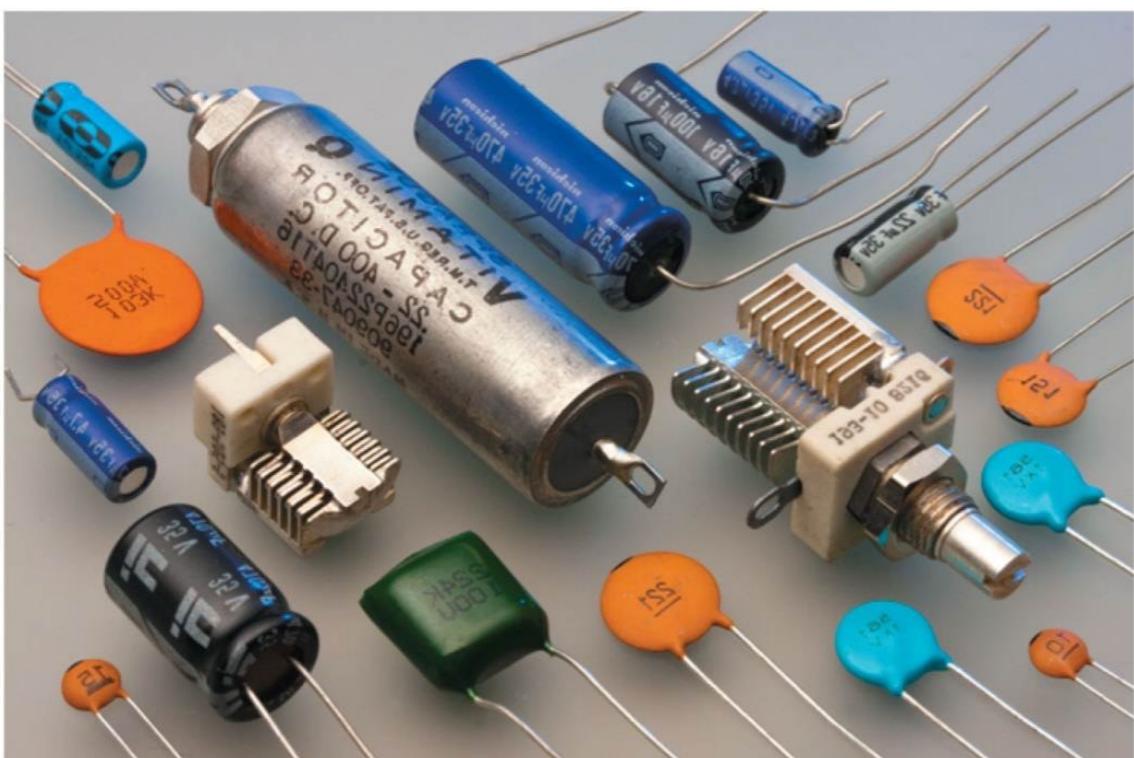
Capacitance



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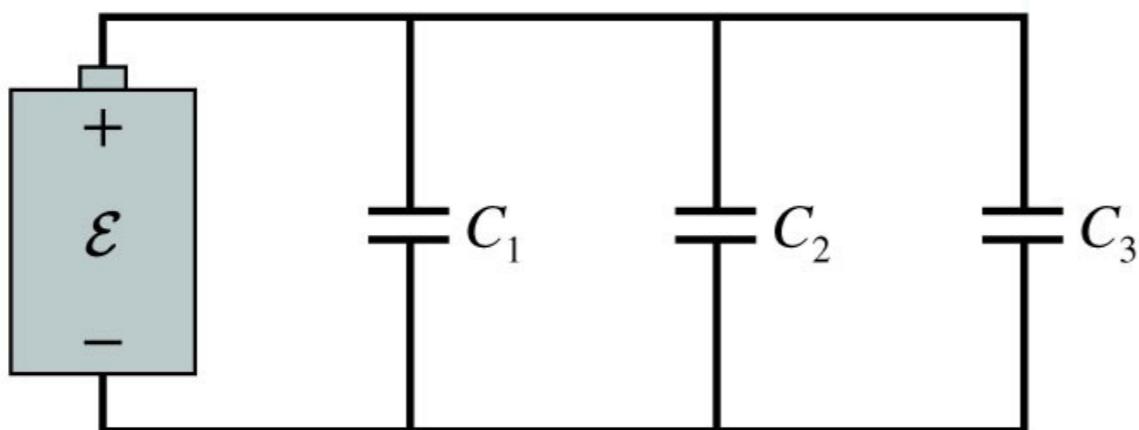
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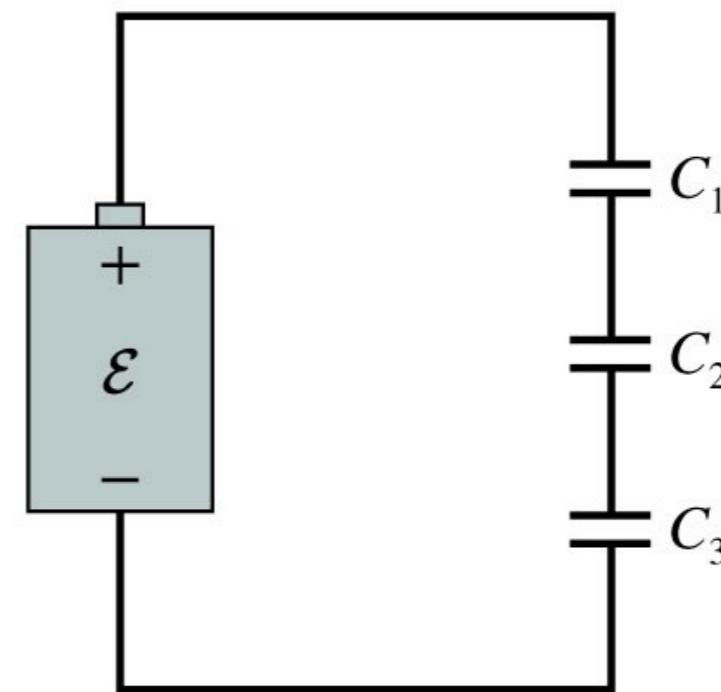


Beginning of Circuits

parallel

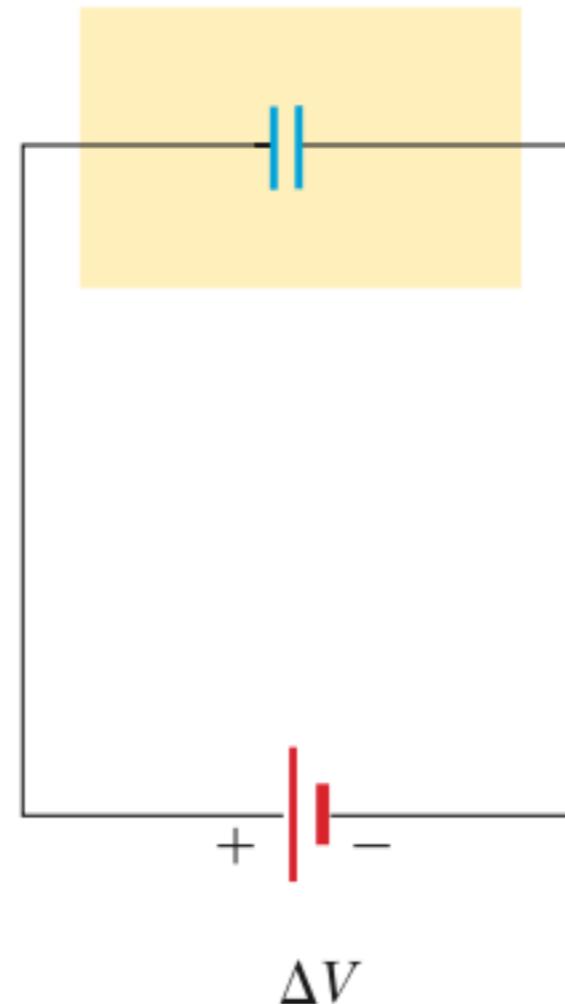
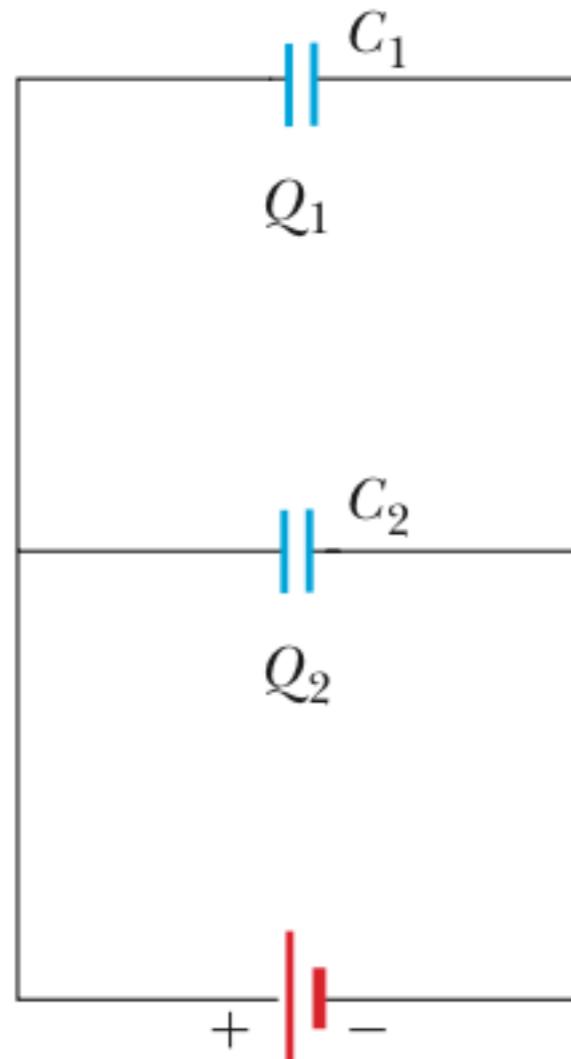


series



Parallel

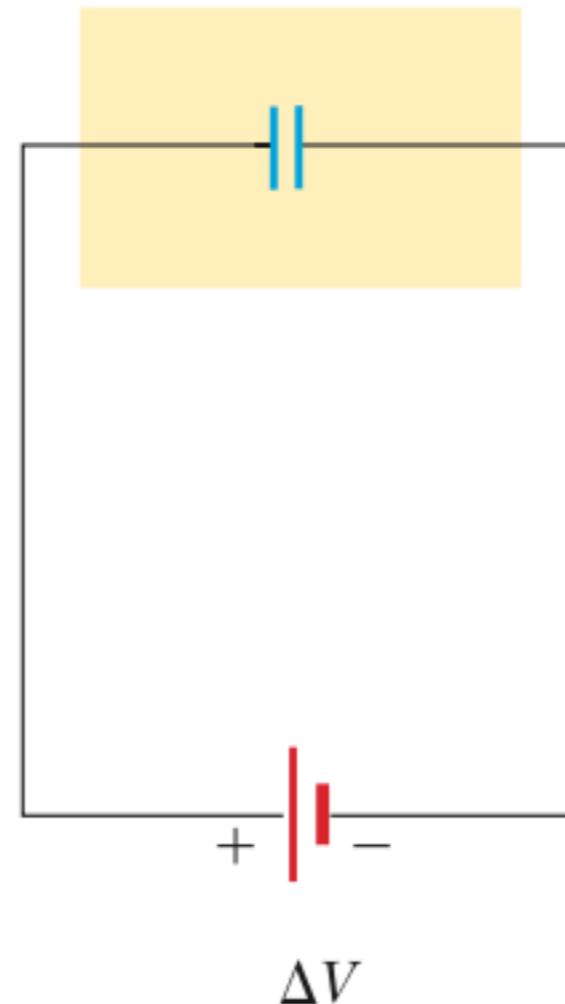
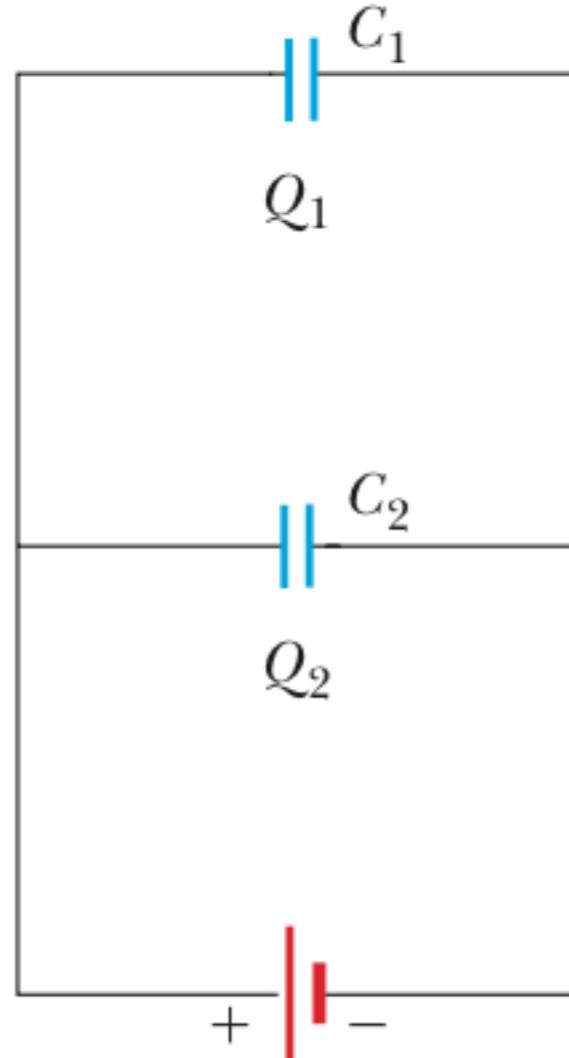
Is the potential difference across capacitor 1 greater than, less than or equal to the potential difference across capacitor 2?



- a) greater
- b) less
- c) equal

Parallel

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

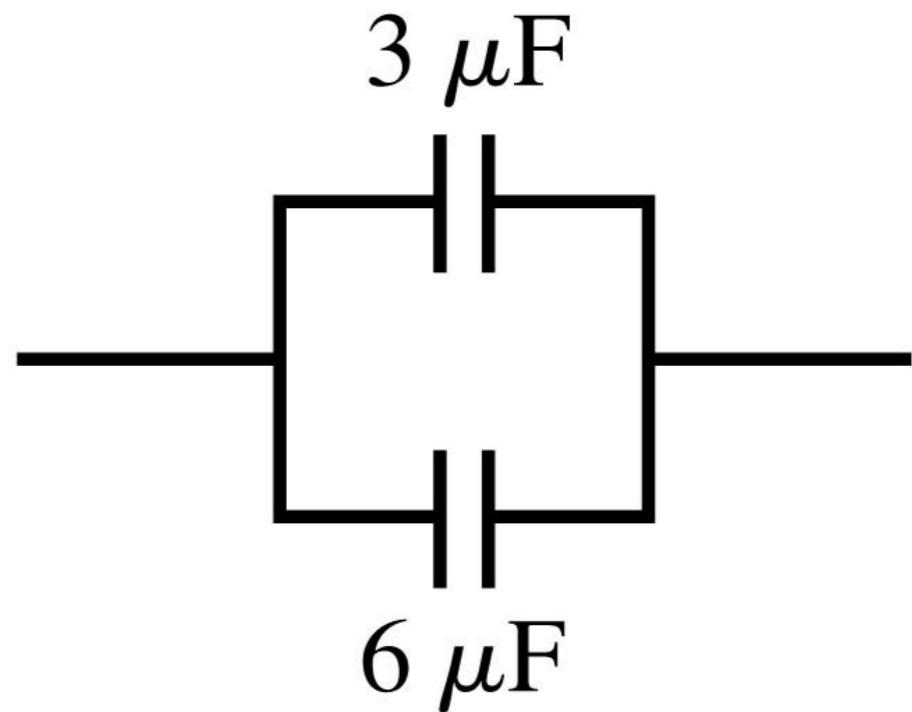


- a) greater
- b) less
- c) equal

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

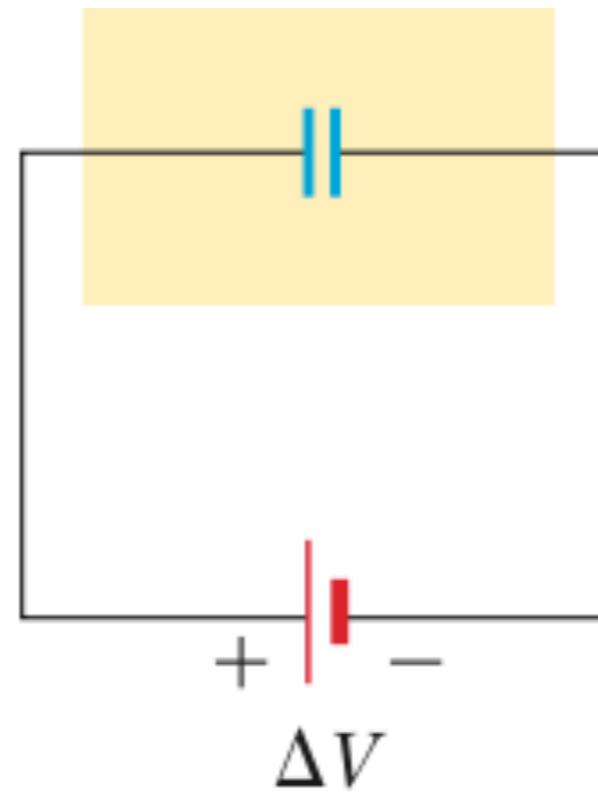
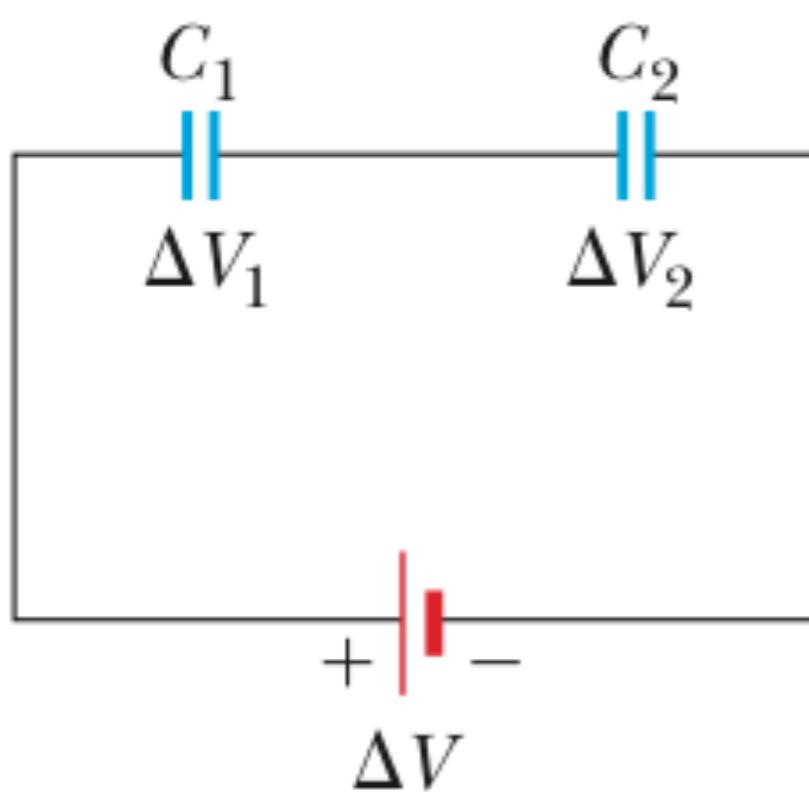
The equivalent capacitance is

- A. $9 \mu\text{F}$.
- B. $6 \mu\text{F}$.
- C. $3 \mu\text{F}$.
- D. $2 \mu\text{F}$.
- E. $1 \mu\text{F}$.



Series

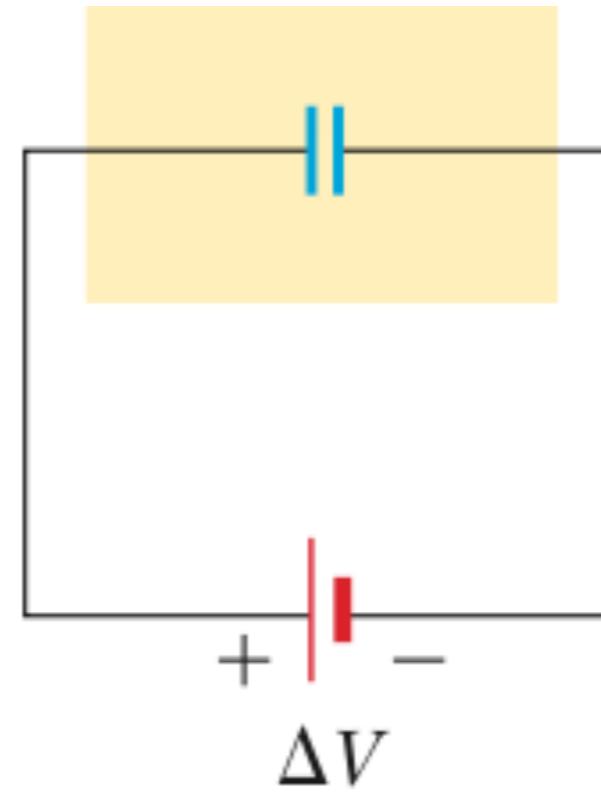
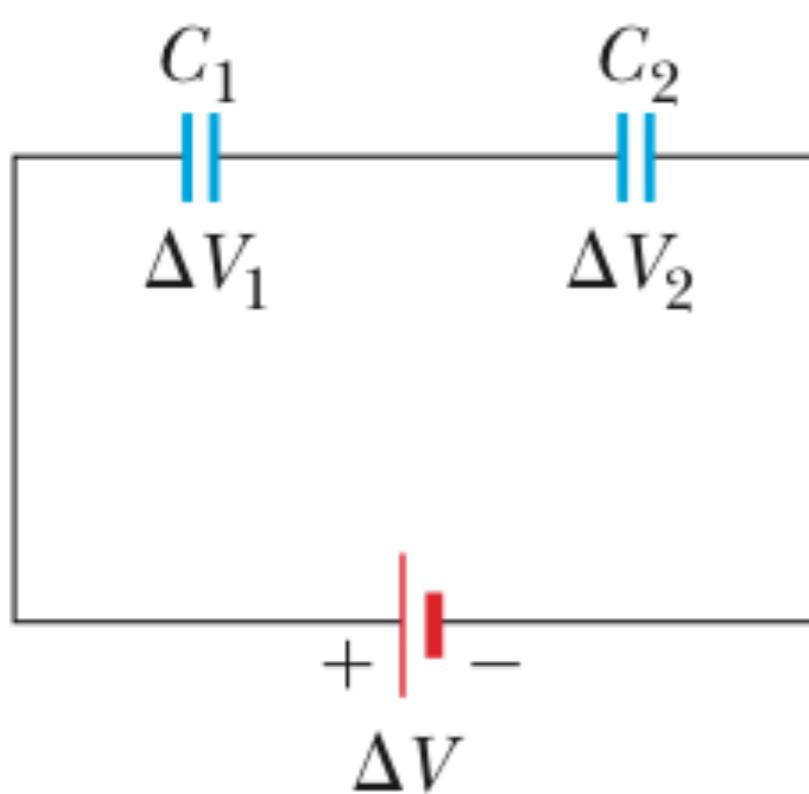
Is the charge on capacitor 1 greater than, less than or equal to the charge on capacitor 2?



- a) greater
- b) less
- c) equal

Series

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



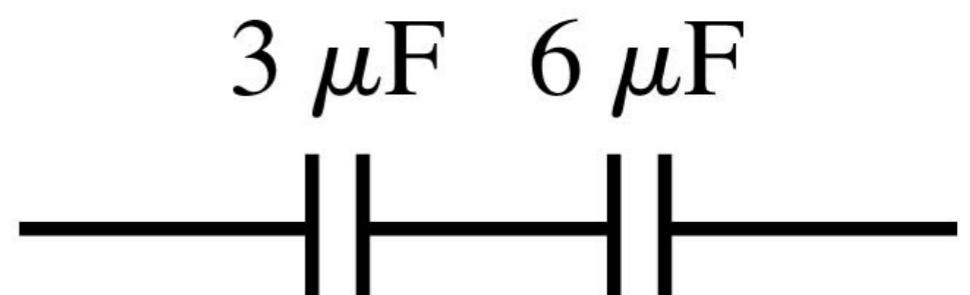
- a) greater
- b) less
- c) equal

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

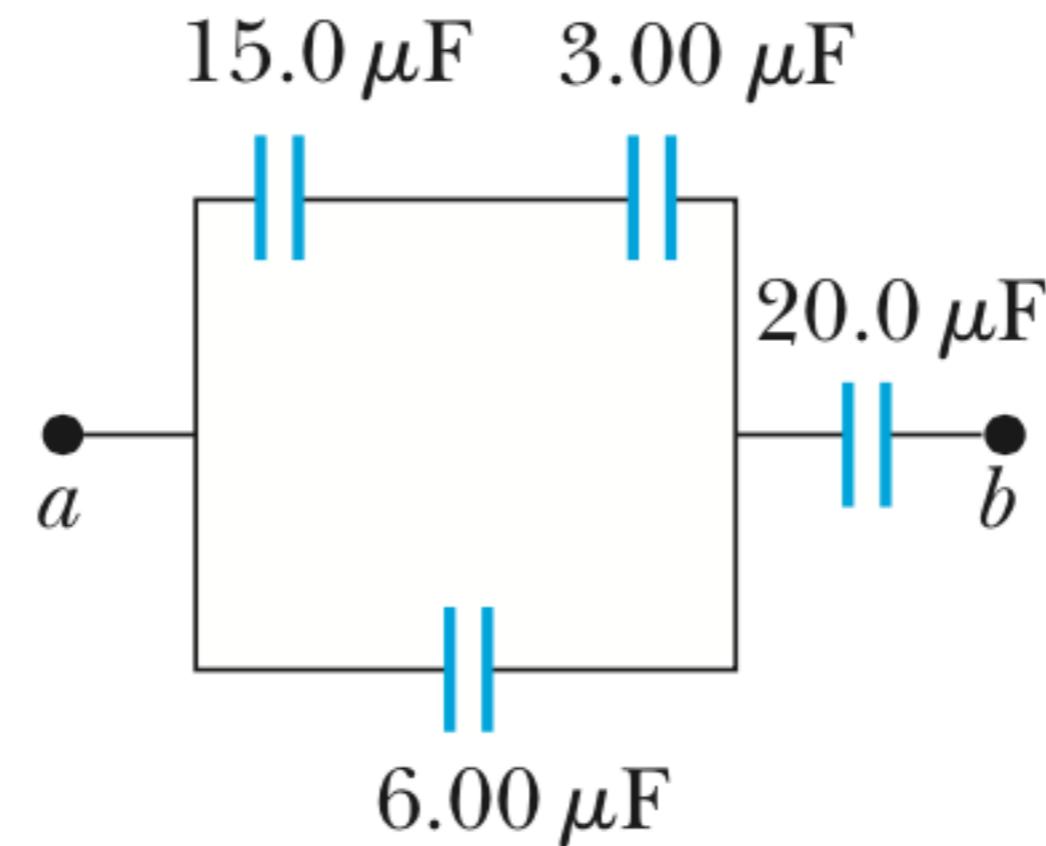
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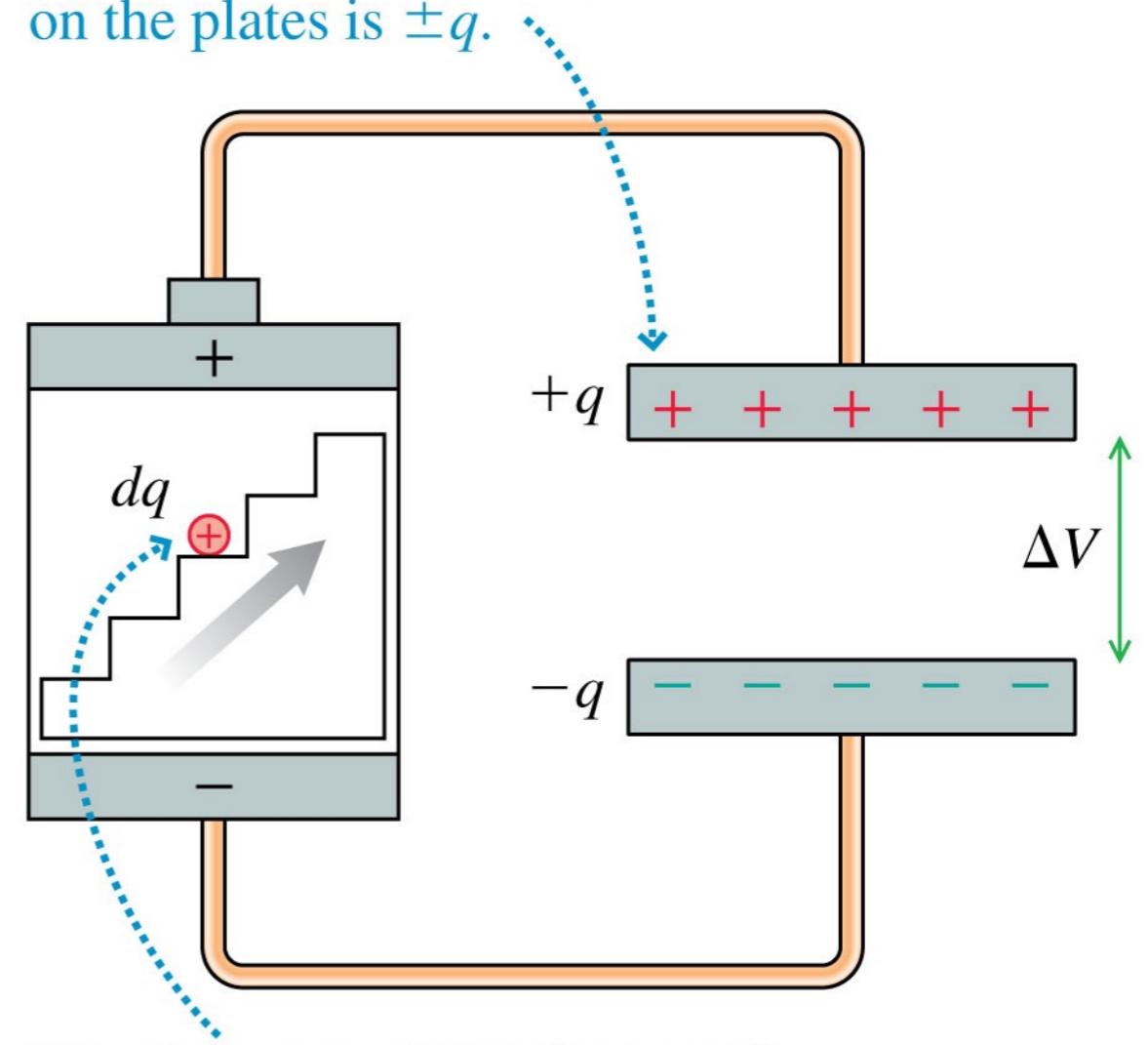


Find the equivalent capacitance between points a and b



Energy stored in a capacitor

The instantaneous charge on the plates is $\pm q$.

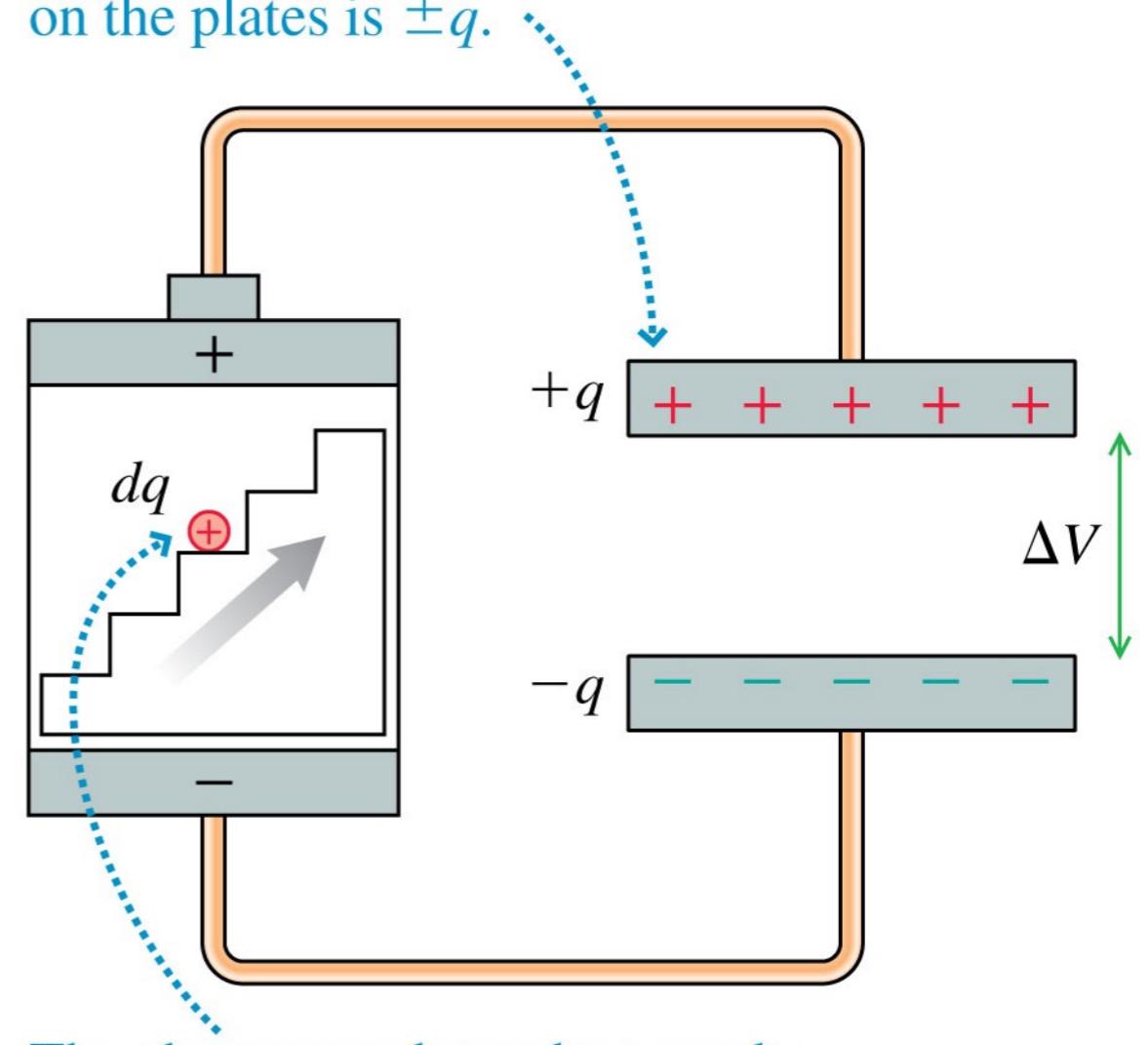


The charge escalator does work $dq \Delta V$ to move charge dq from the negative plate to the positive plate.

Energy stored in a capacitor

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

The instantaneous charge on the plates is $\pm q$.



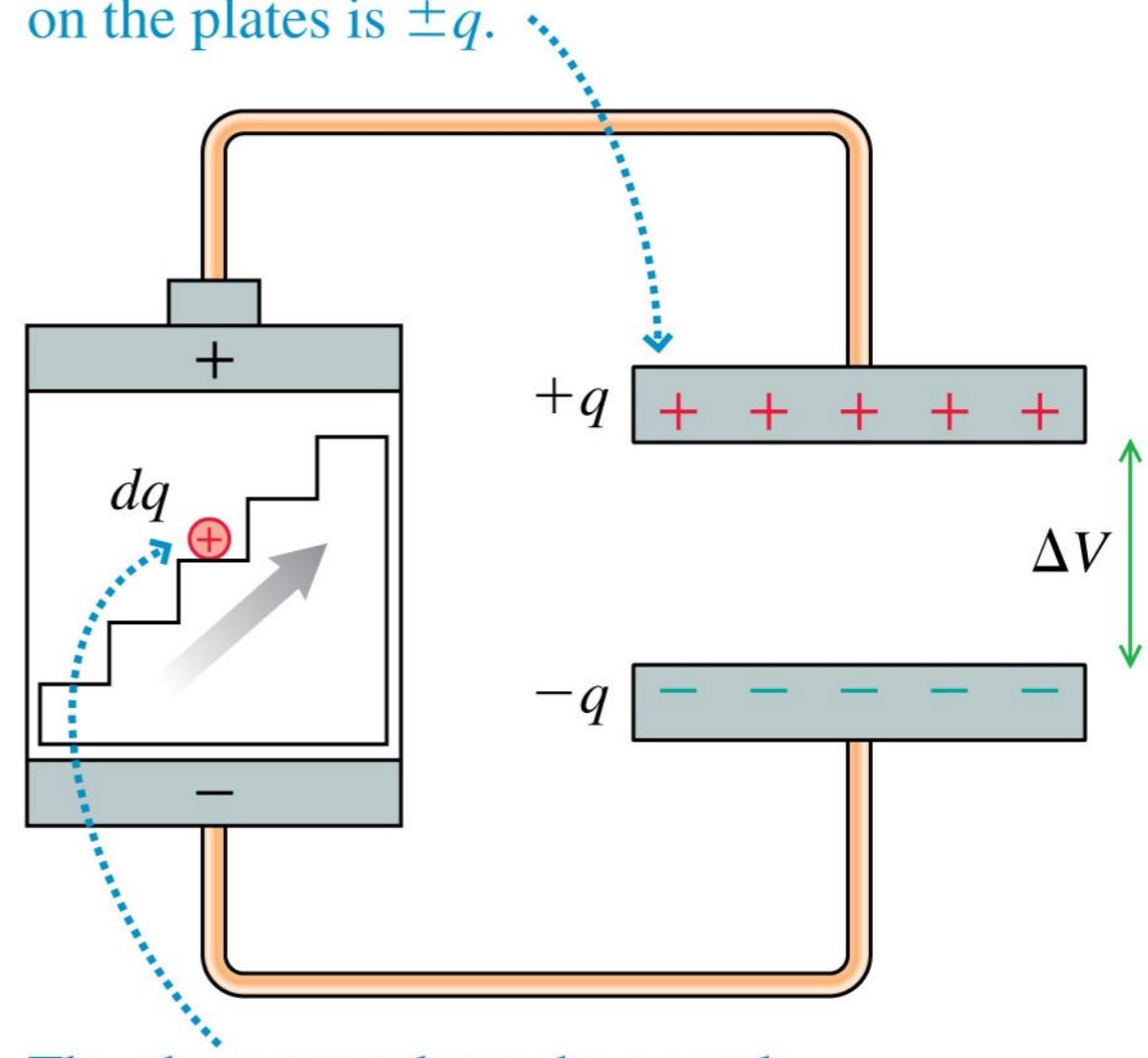
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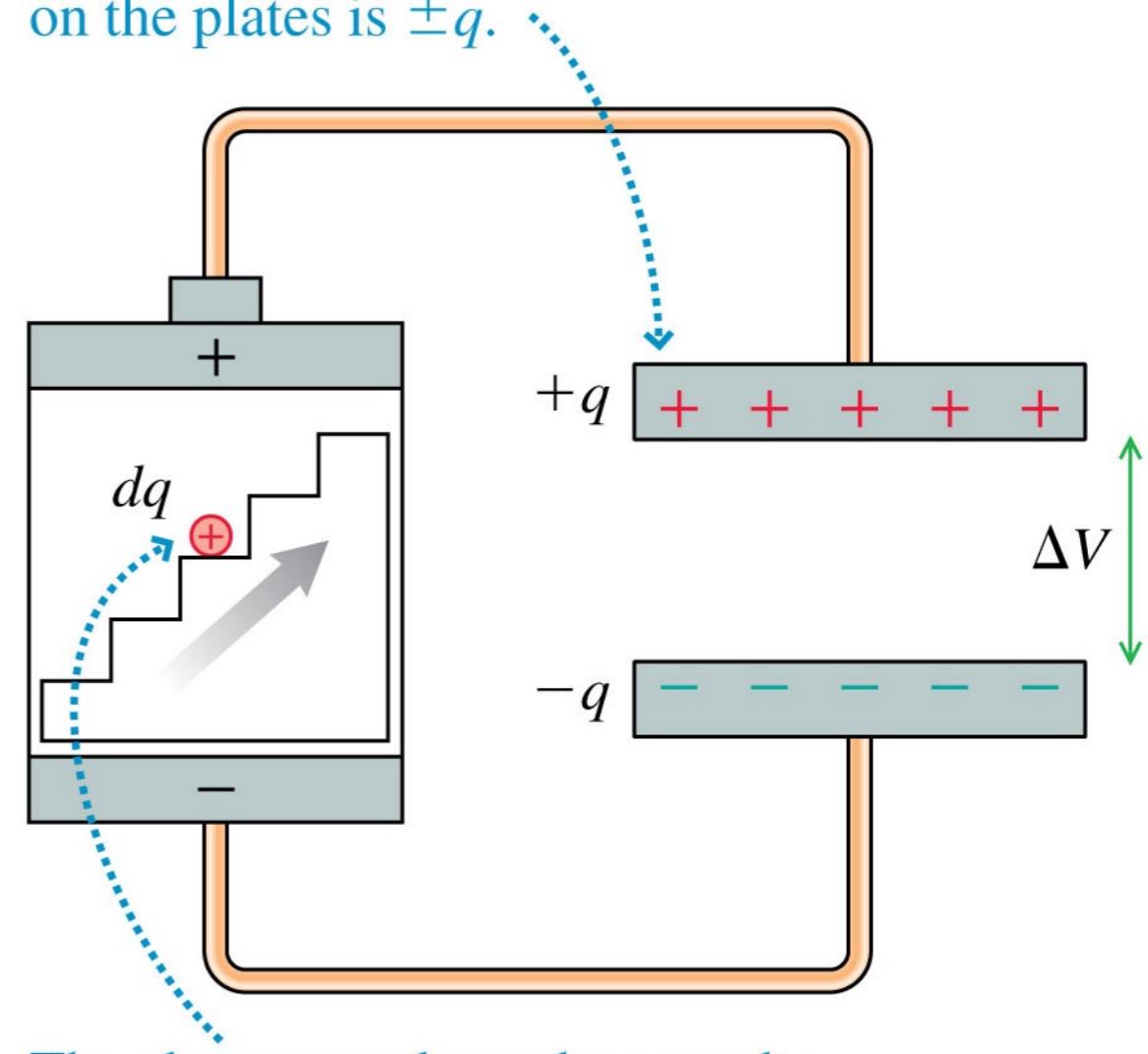
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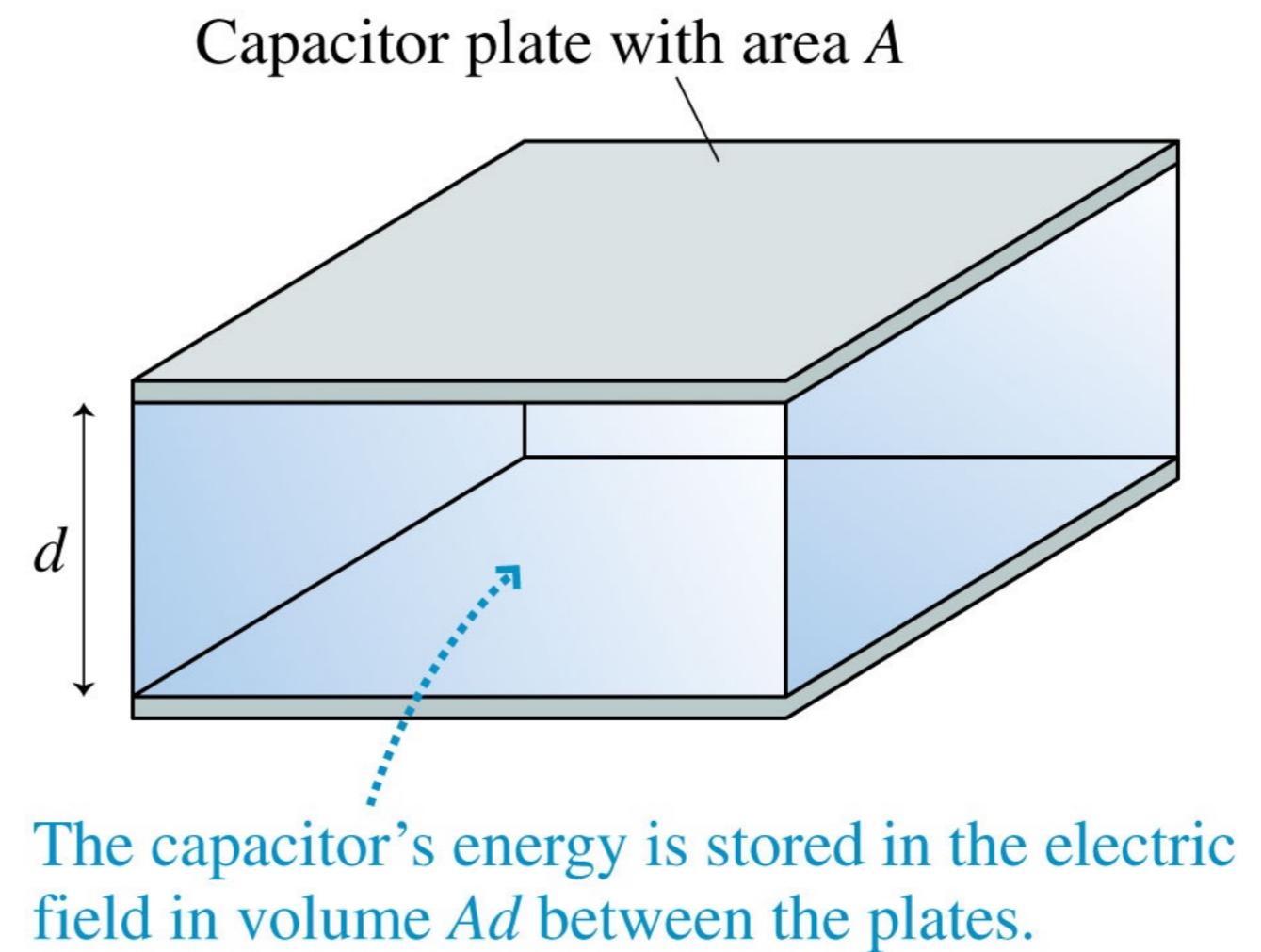
$$= \frac{1}{2} C (\Delta V_C)^2$$

The instantaneous charge on the plates is $\pm q$.



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

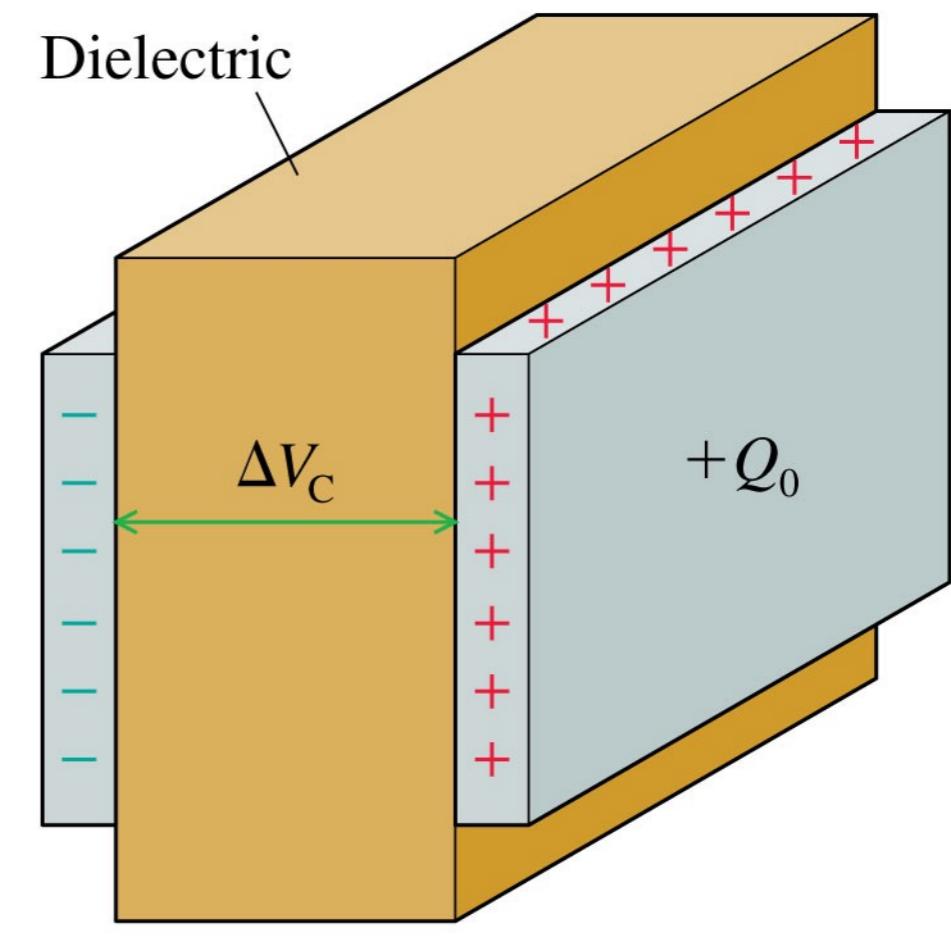
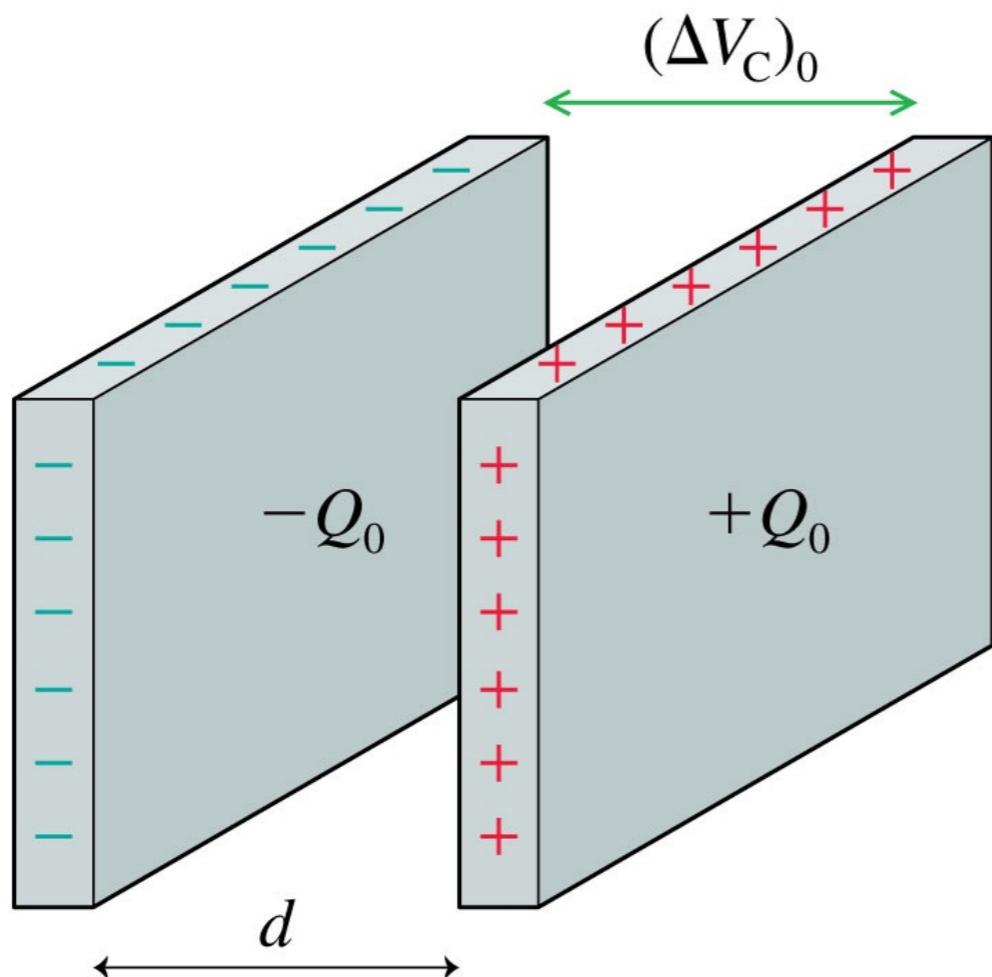
$$u_E = \frac{\text{energy stored}}{\text{volume in which it is stored}} = \frac{U_C}{Ad} = \frac{\epsilon_0}{2} E^2$$



Dielectrics

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

- A. Electric Field strength decreases
- B. Electric Field strength increases
- C. Electric Field strength stays the same

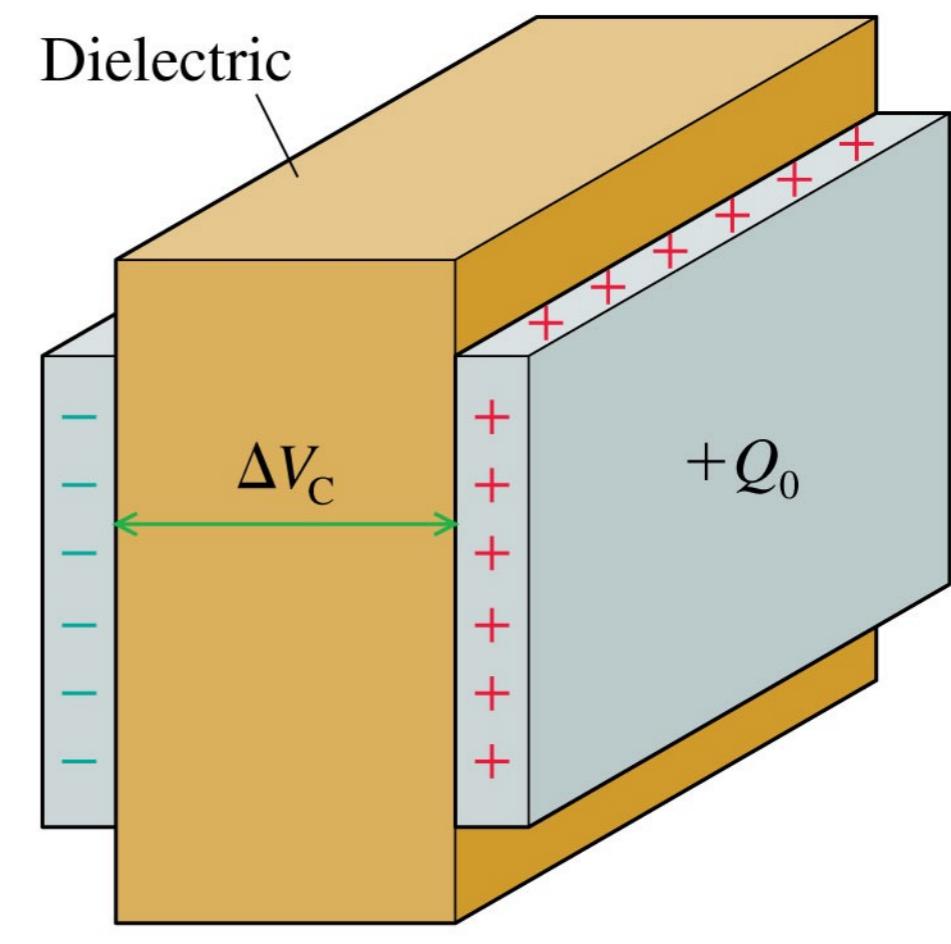
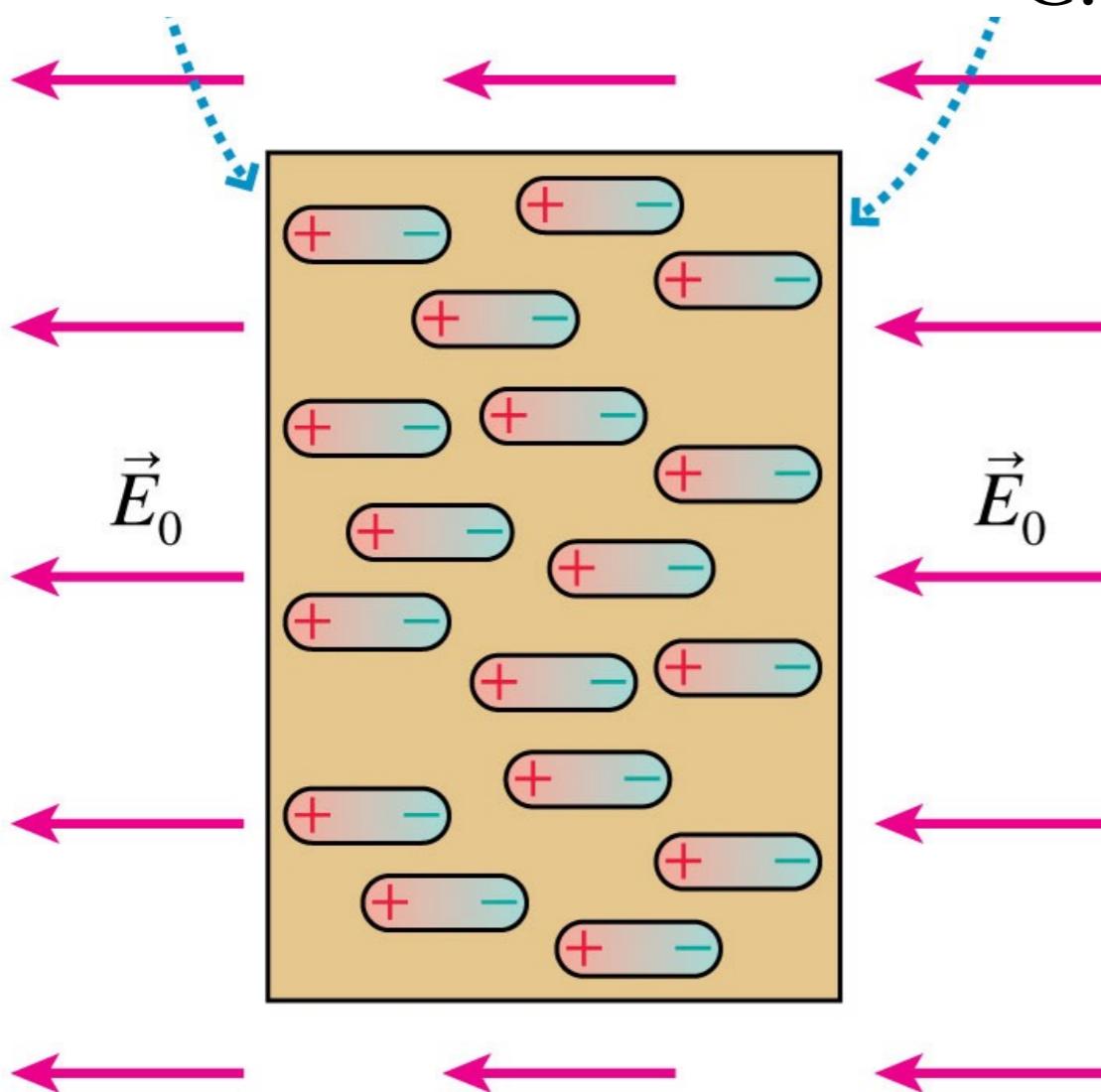


$$\text{Capacitance } C > C_0$$

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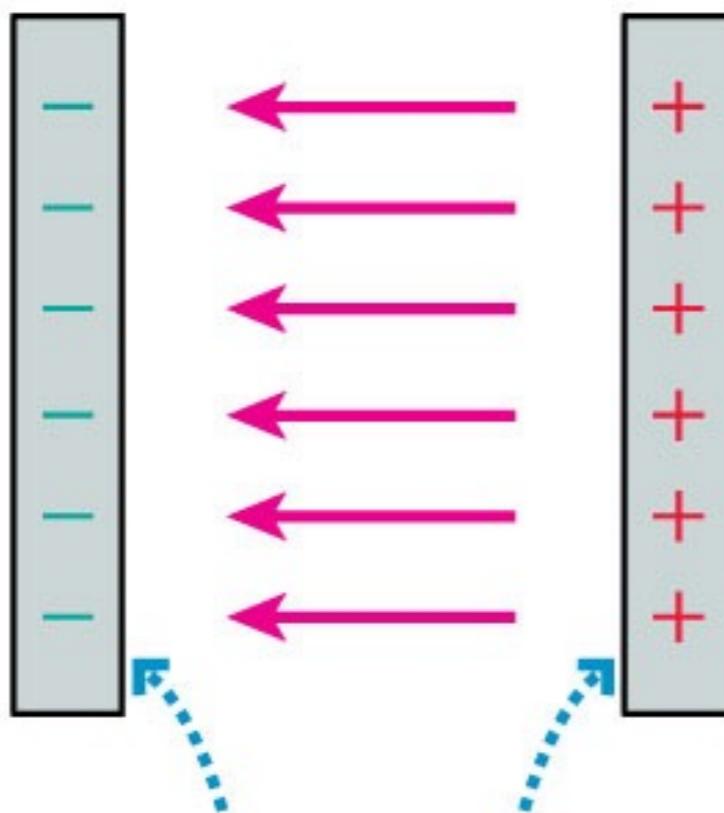
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Dielectrics

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

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

- A. Electric field stays the same
- B. Electric field is reduced
- C. Electric field is increased



Before



After

Dielectric Constant

Dielectric Constant

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

Dielectric Constant

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

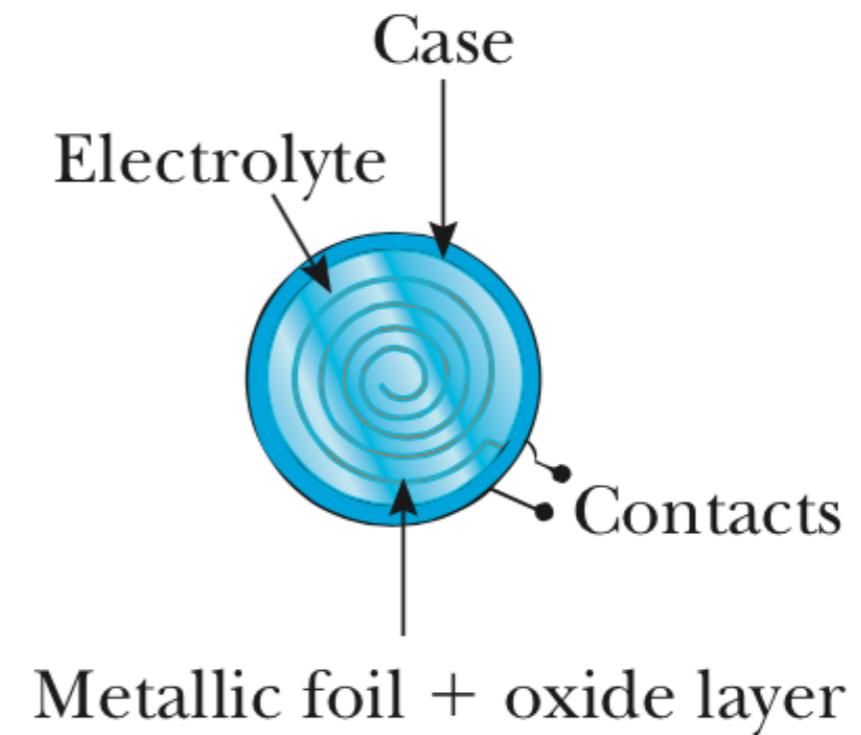
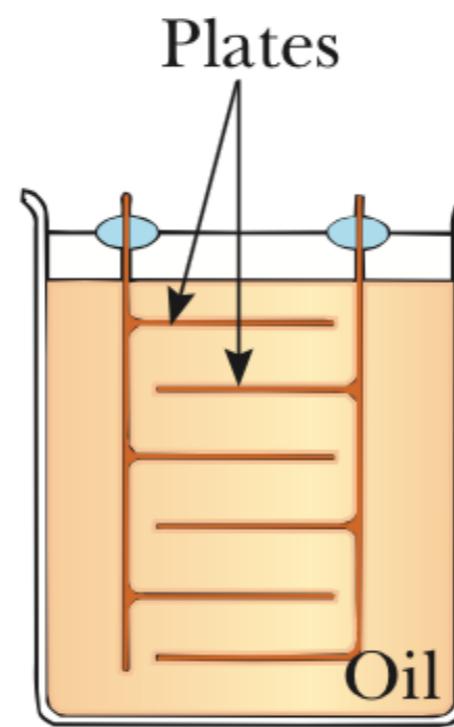
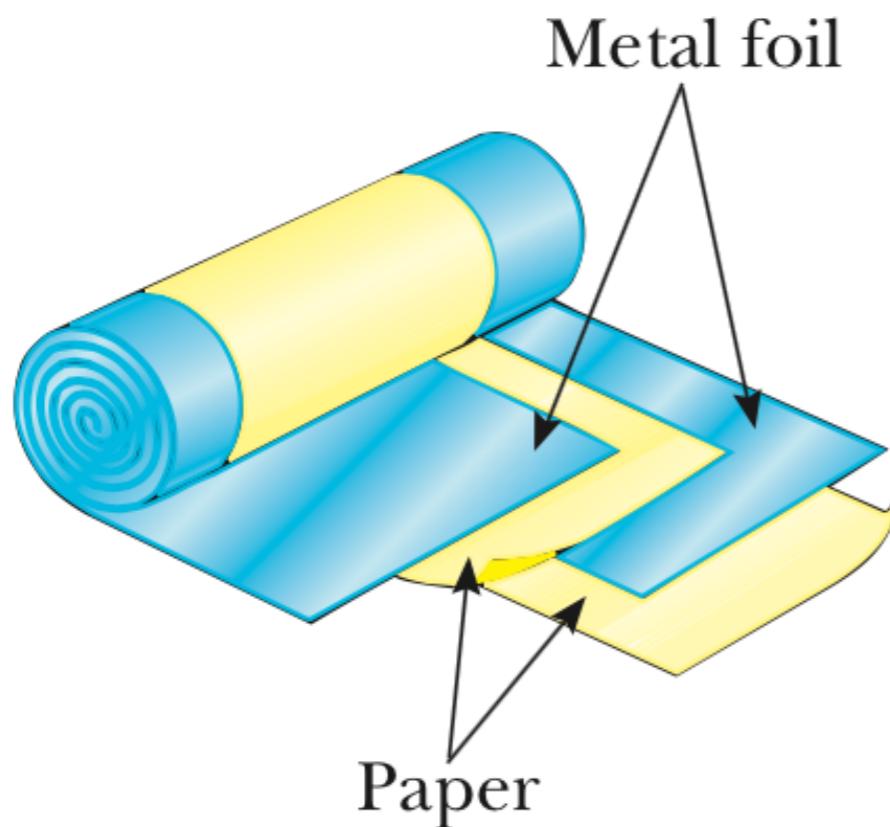
$$C = \frac{Q}{\Delta V_C} = \frac{Q_0}{(\Delta V_C)_0 / \kappa} = \kappa \frac{Q_0}{(\Delta V_C)_0} = \kappa C_0$$

Dielectric Constant

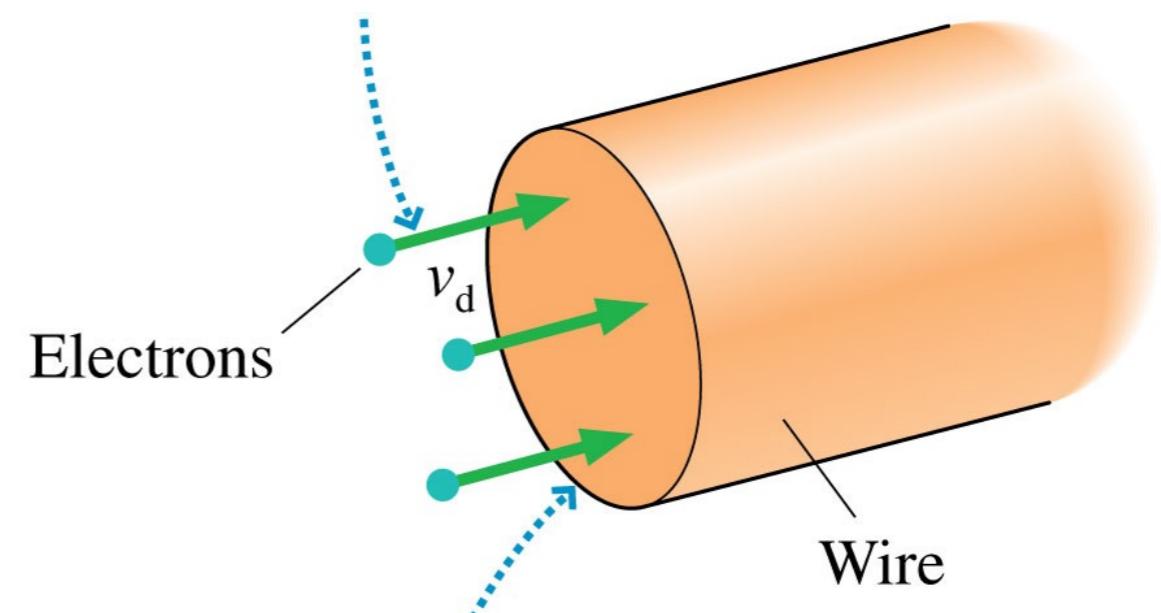
TABLE 29.1 Properties of dielectrics

Material	Dielectric constant κ	Dielectric strength $E_{\max}(10^6 \text{ V/m})$	
Vacuum	1	—	
Air (1 atm)	1.0006	3	
Teflon	2.1	60	
Polystyrene plastic	2.6	24	
C Mylar	3.1	7	$\frac{Q_0}{\Delta V_C} = \kappa C_0$
Paper	3.7	16	
Pyrex glass	4.7	14	
Pure water (20°C)	80	—	
Titanium dioxide	110	6	
Strontium titanate	300	8	

Real capacitors



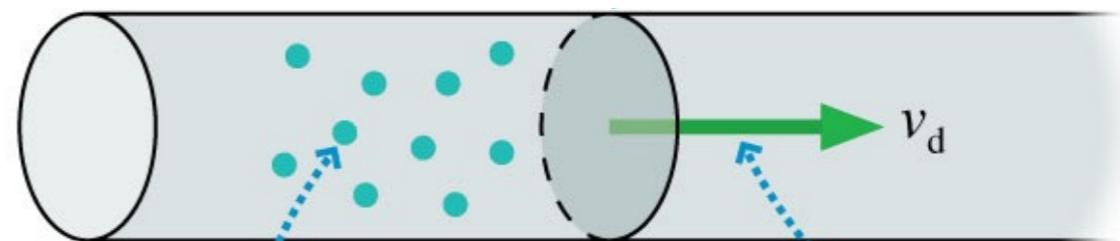
Current



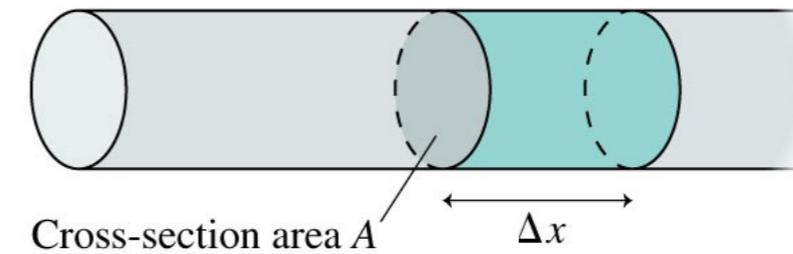
$$i_e = \frac{N_e}{\Delta t}$$

$$N_e = i_e \Delta t$$

Wire at time t



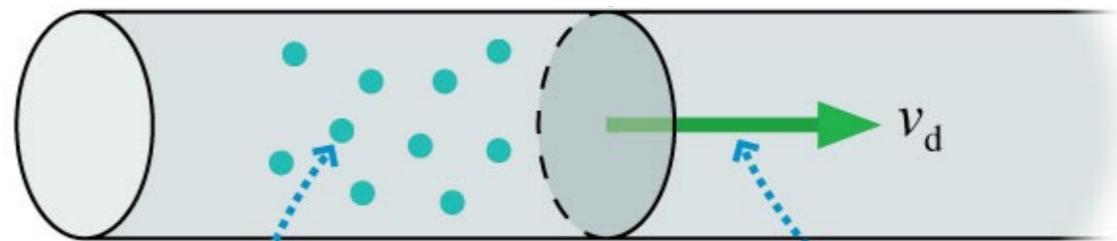
Wire at time $t + \Delta t$



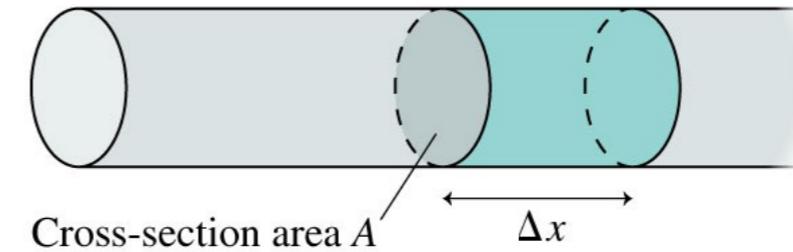
$$N_e = i_e \Delta t$$

$$N_e = n_e V$$

Wire at time t



Wire at time $t + \Delta t$

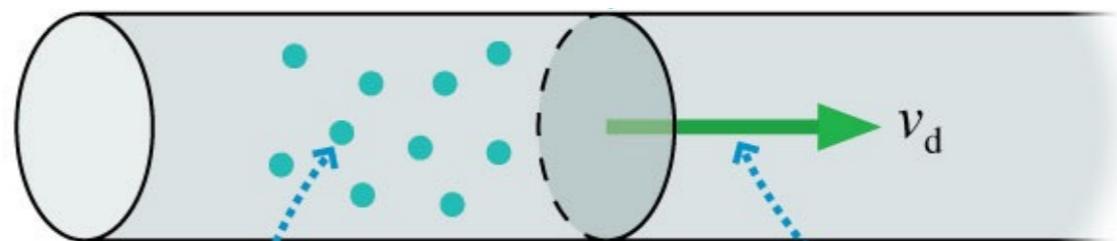


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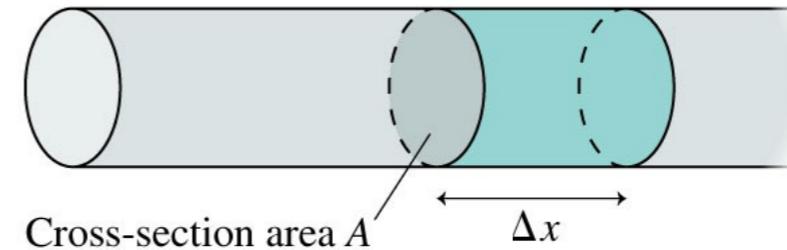
$$N_e = n_e V$$

$$= n_e A \Delta x$$

Wire at time t



Wire at time $t + \Delta t$



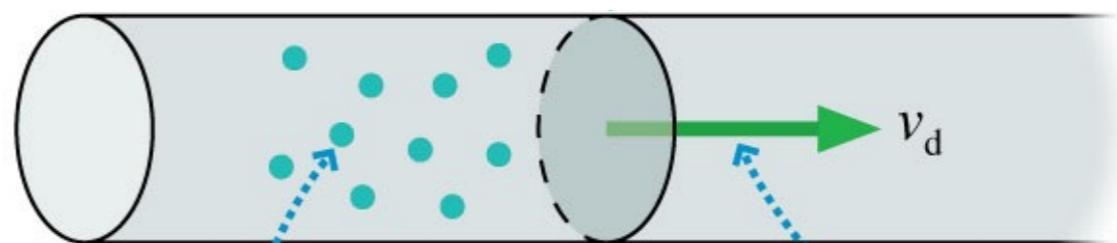
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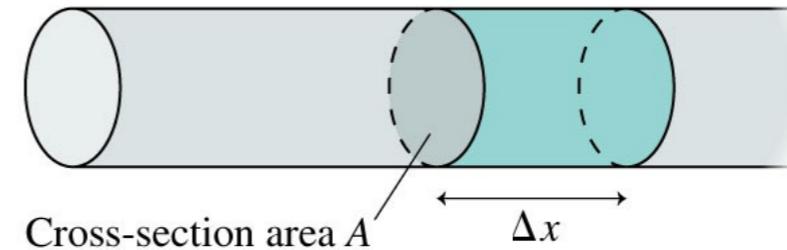
$$= n_e A \Delta x$$

$$= n_e A v_d \Delta t$$

Wire at time t



Wire at time $t + \Delta t$



$$N_e = i_e \Delta t$$

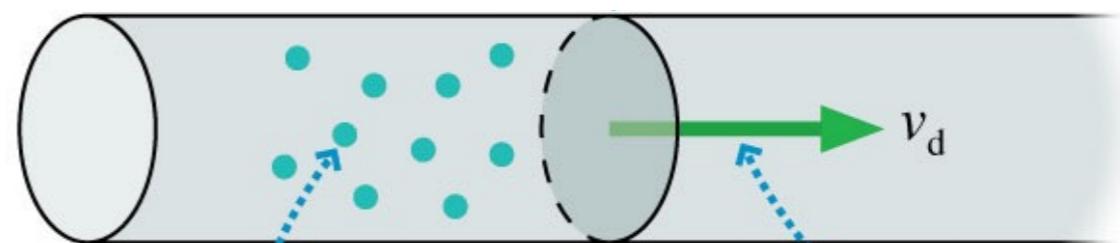
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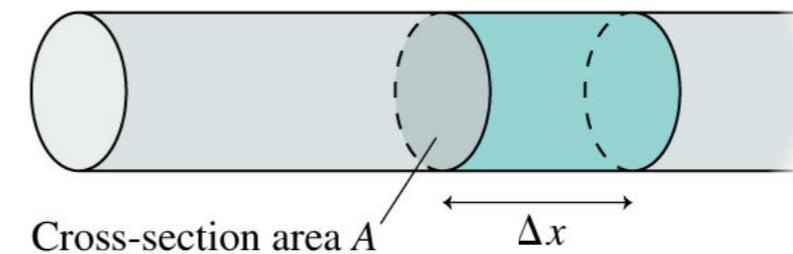
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Wire at time t



Wire at time $t + \Delta t$

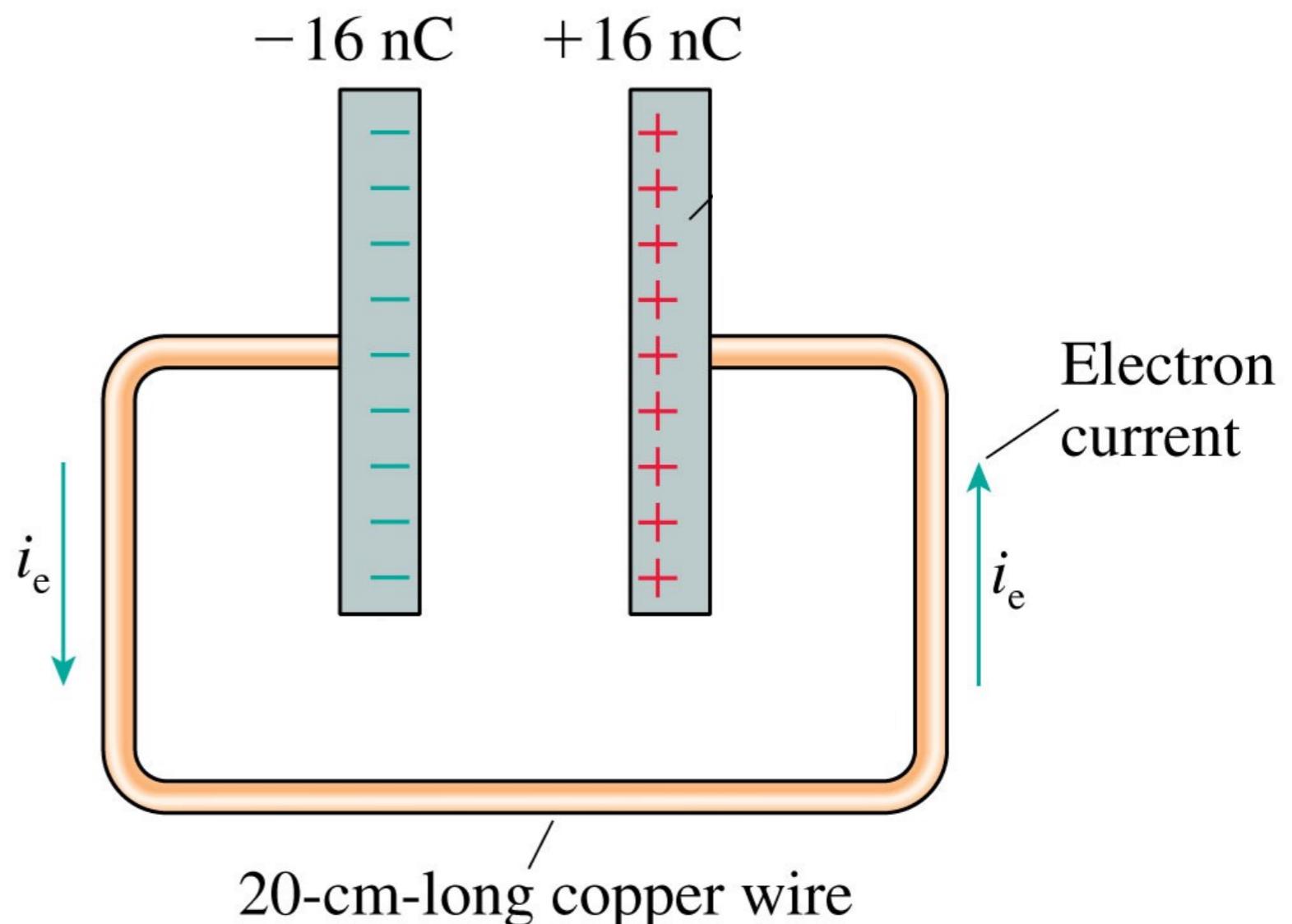


Discharging a capacitor

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?



Animation

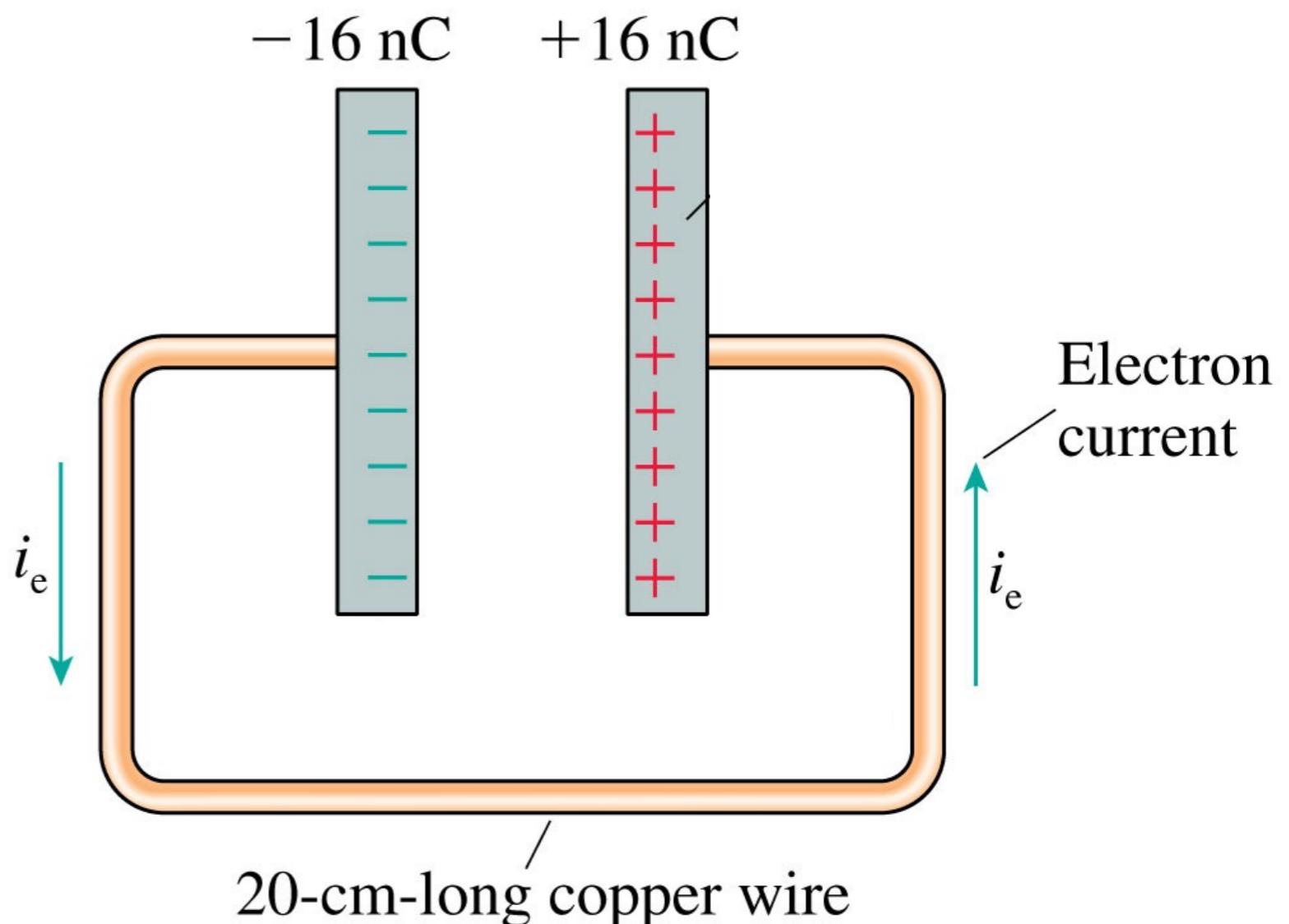
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Animation

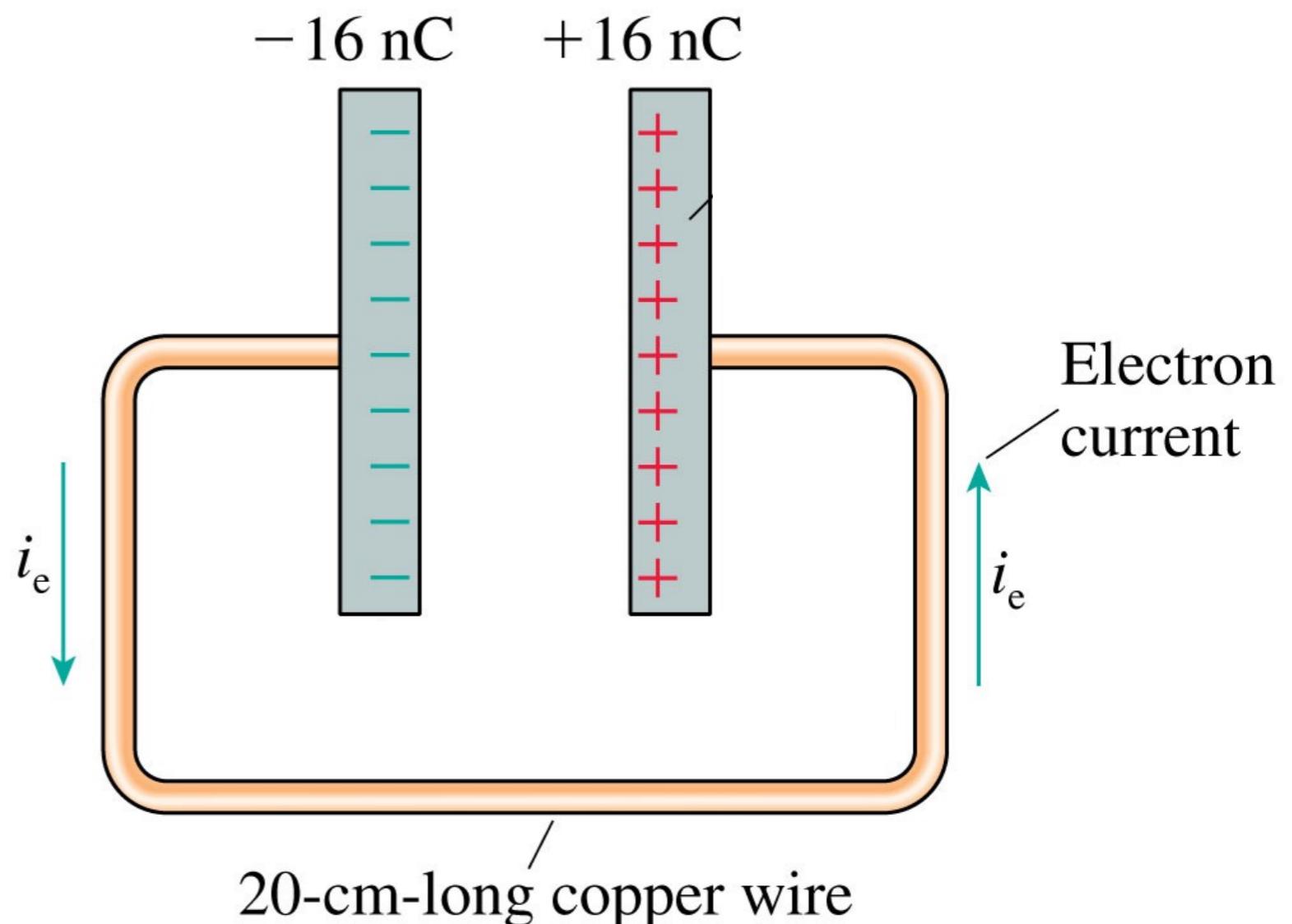
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2000 s What???



Animation

Discharging a capacitor

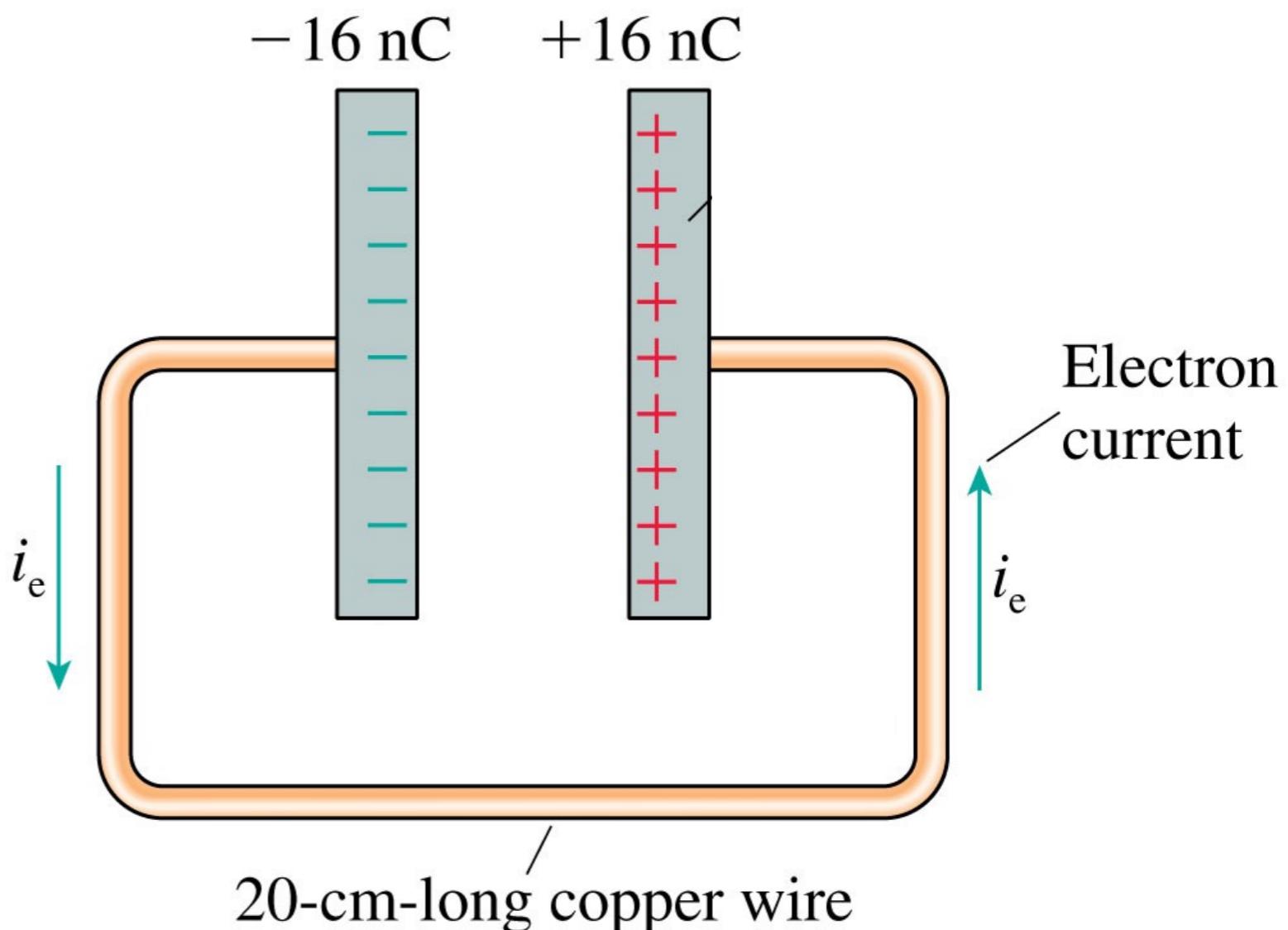
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2000 s What???

Capacitors discharge nearly
instantaneously!



Animation

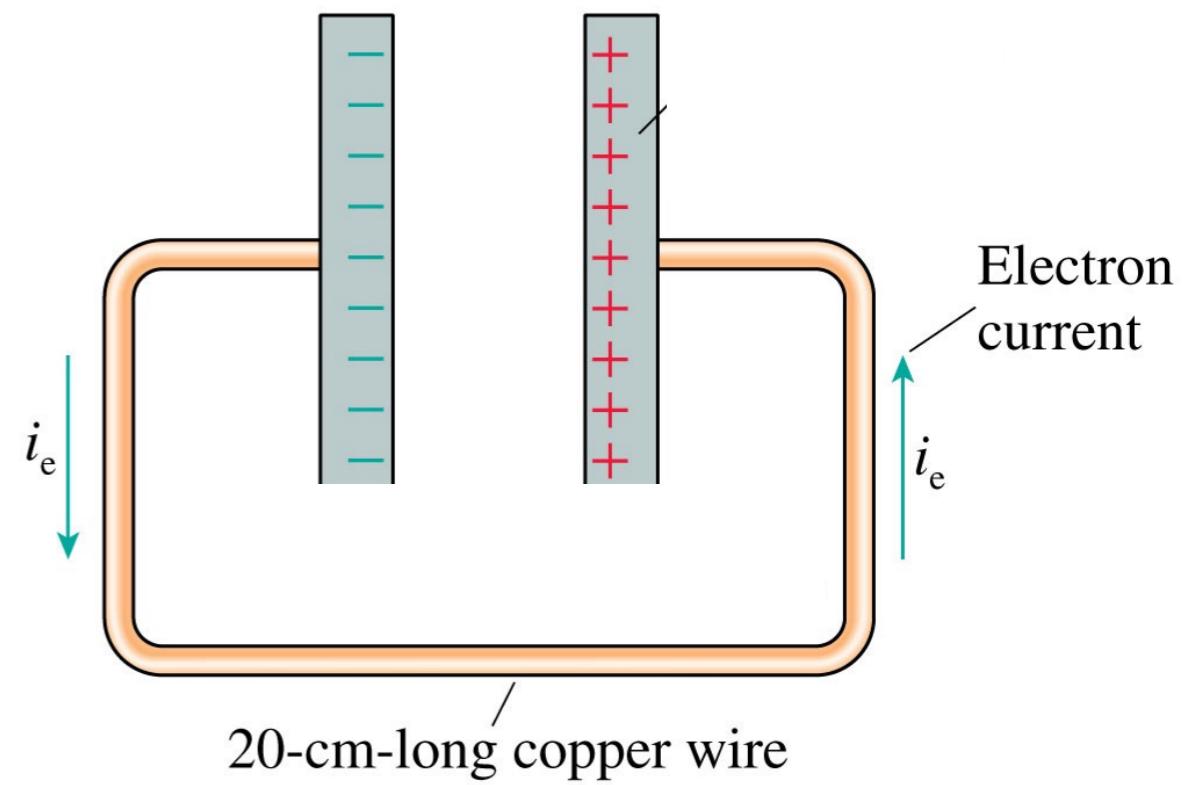
$$5 \times 10^{22}$$



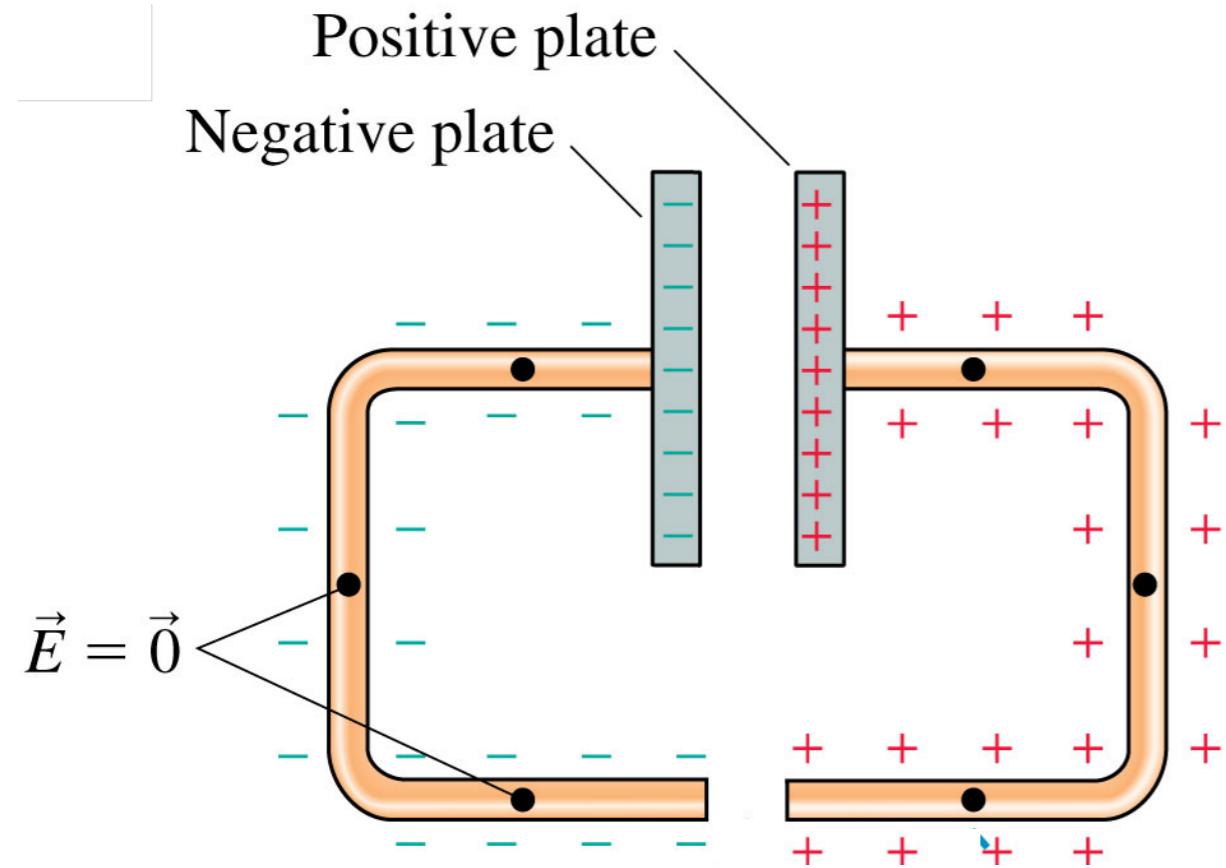
$$10^{11}$$

—

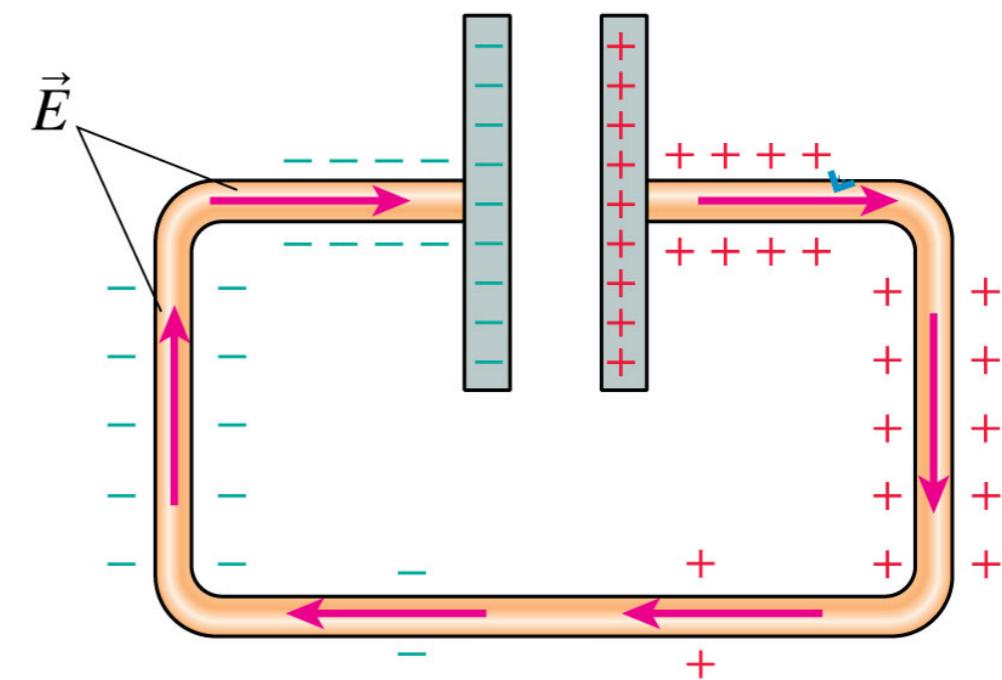
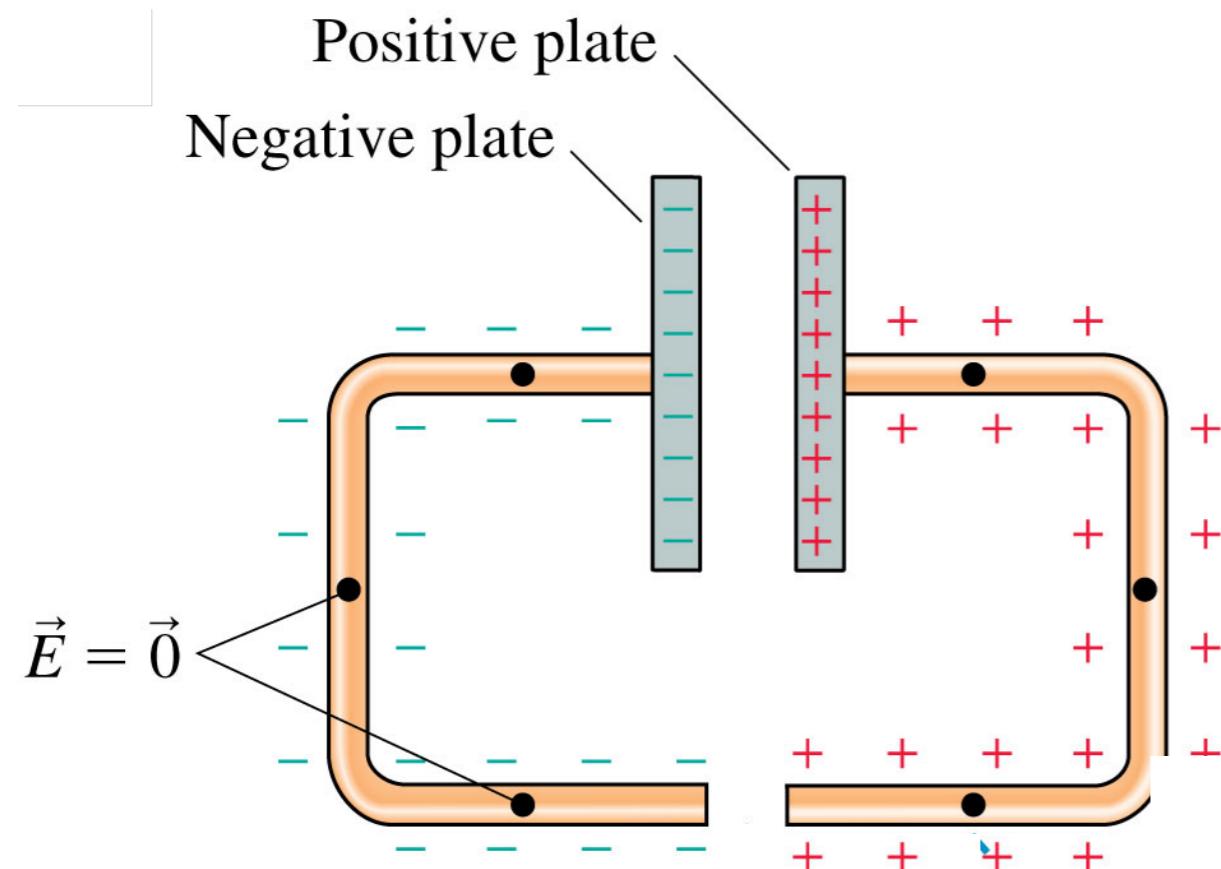
$$-16 \text{ nC} \quad +16 \text{ nC}$$



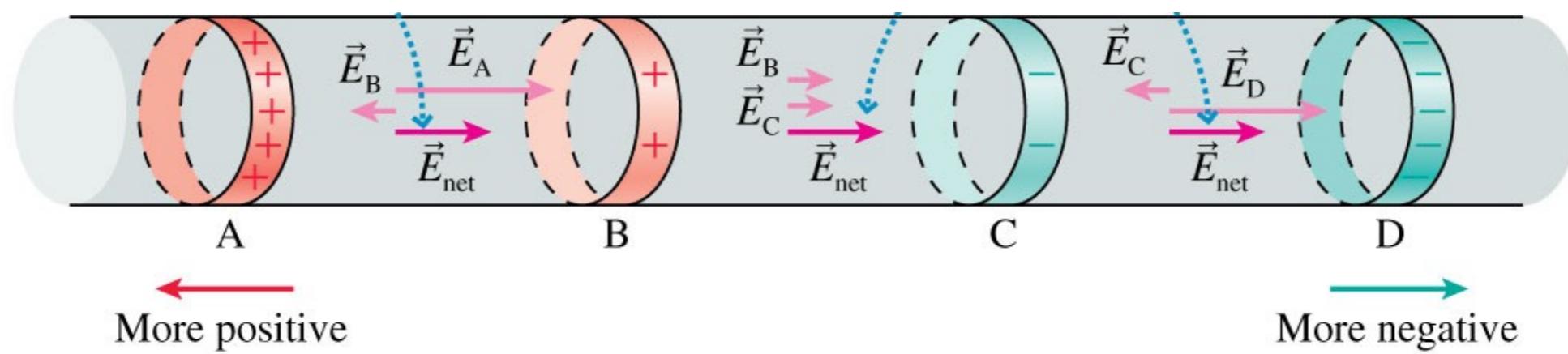
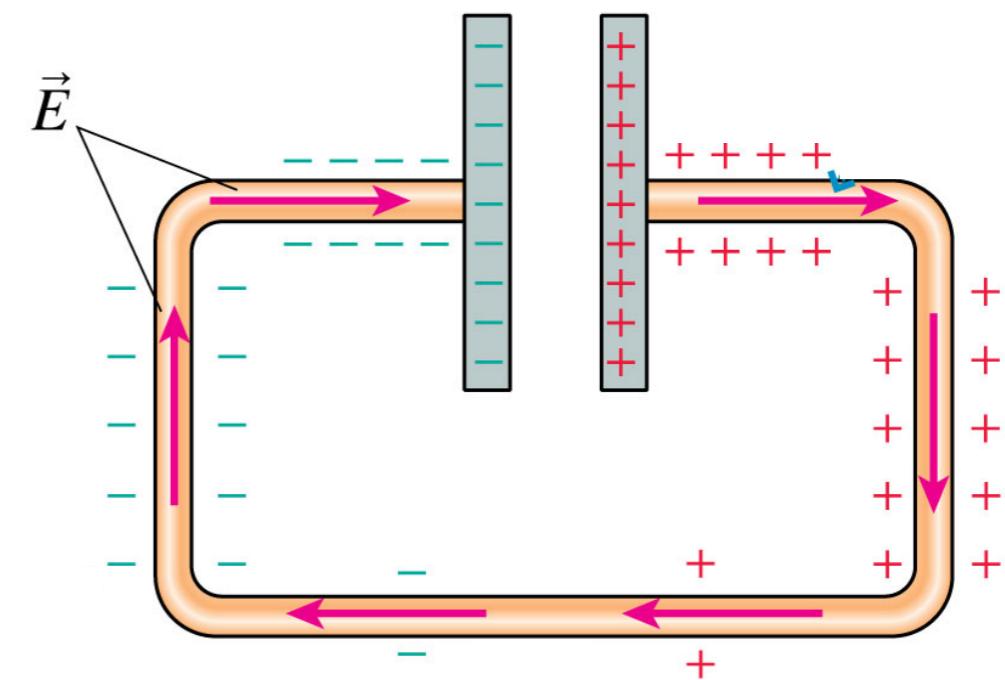
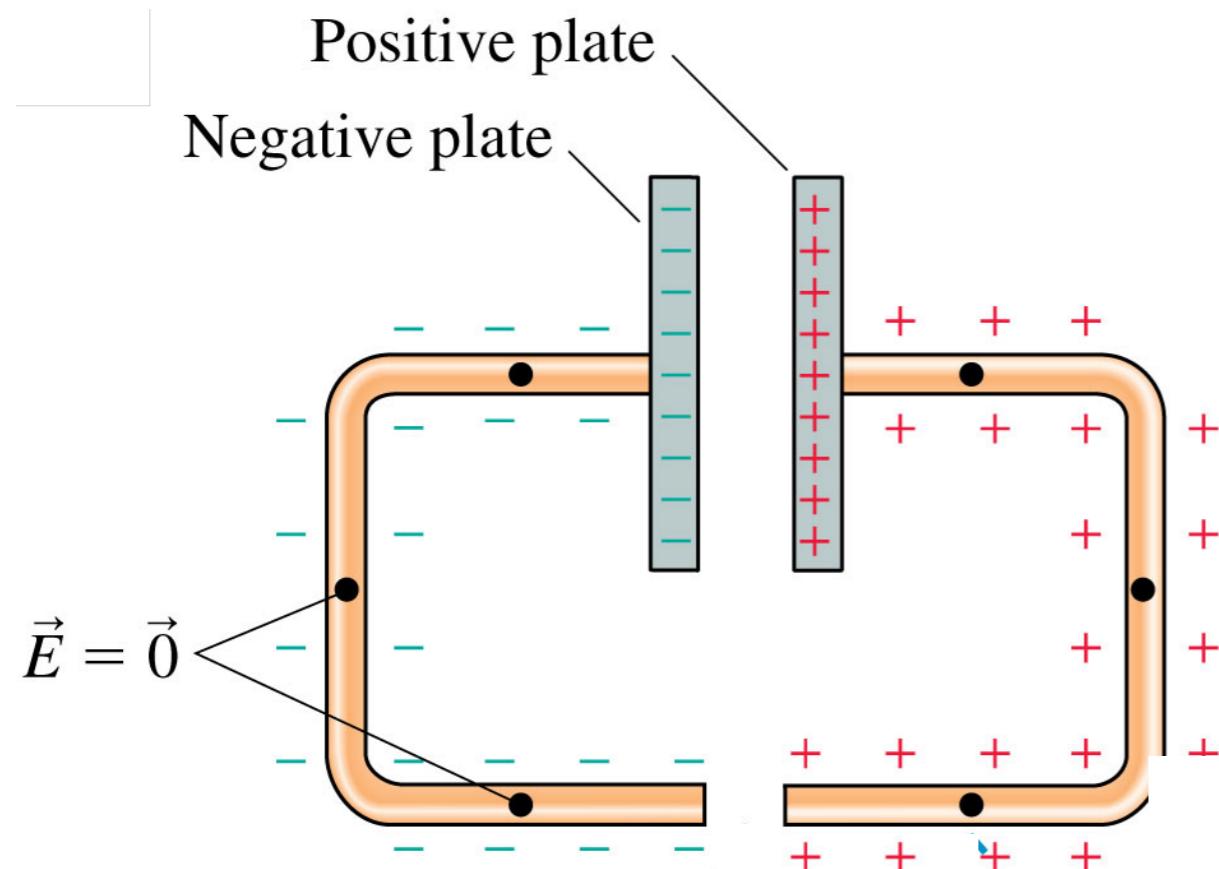
Conceptualizing Current



Conceptualizing Current

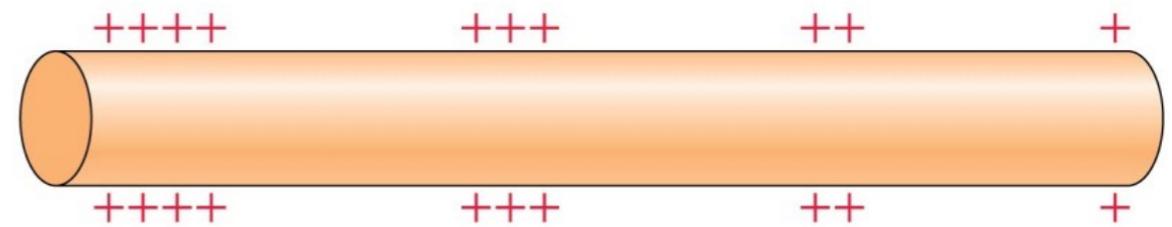


Conceptualizing Current



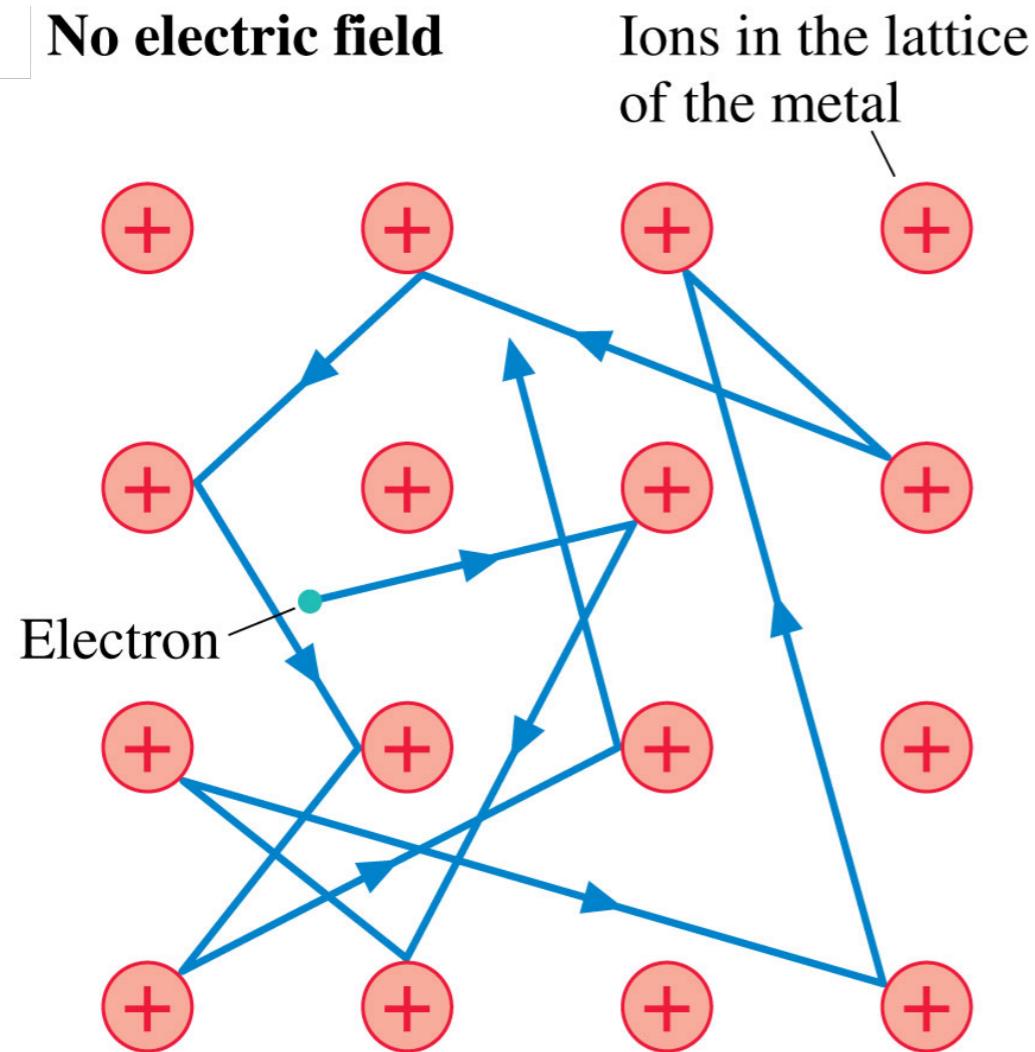
Surface charge is distributed on a wire as shown.
Electrons in the wire

- 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

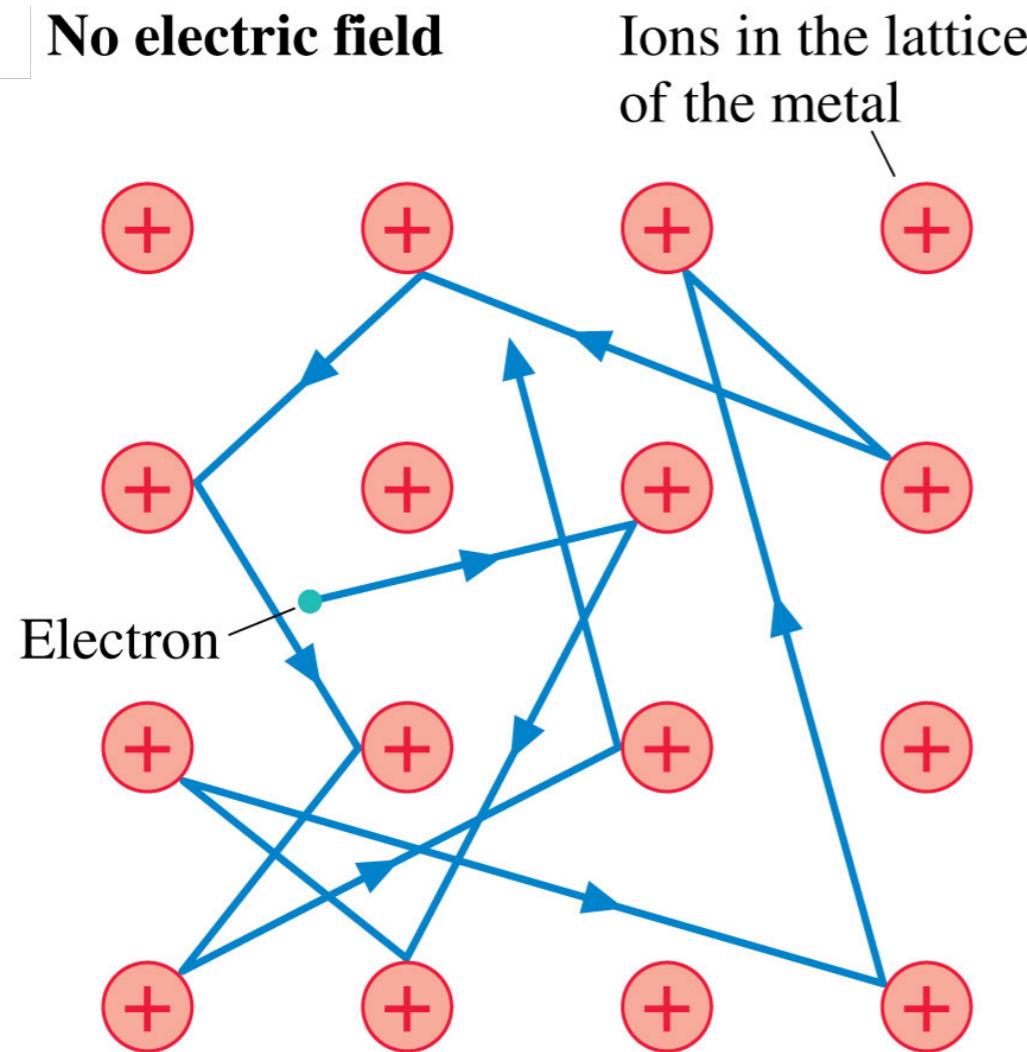
No electric field



Ions in the lattice
of the metal

Model of Conduction

No electric field

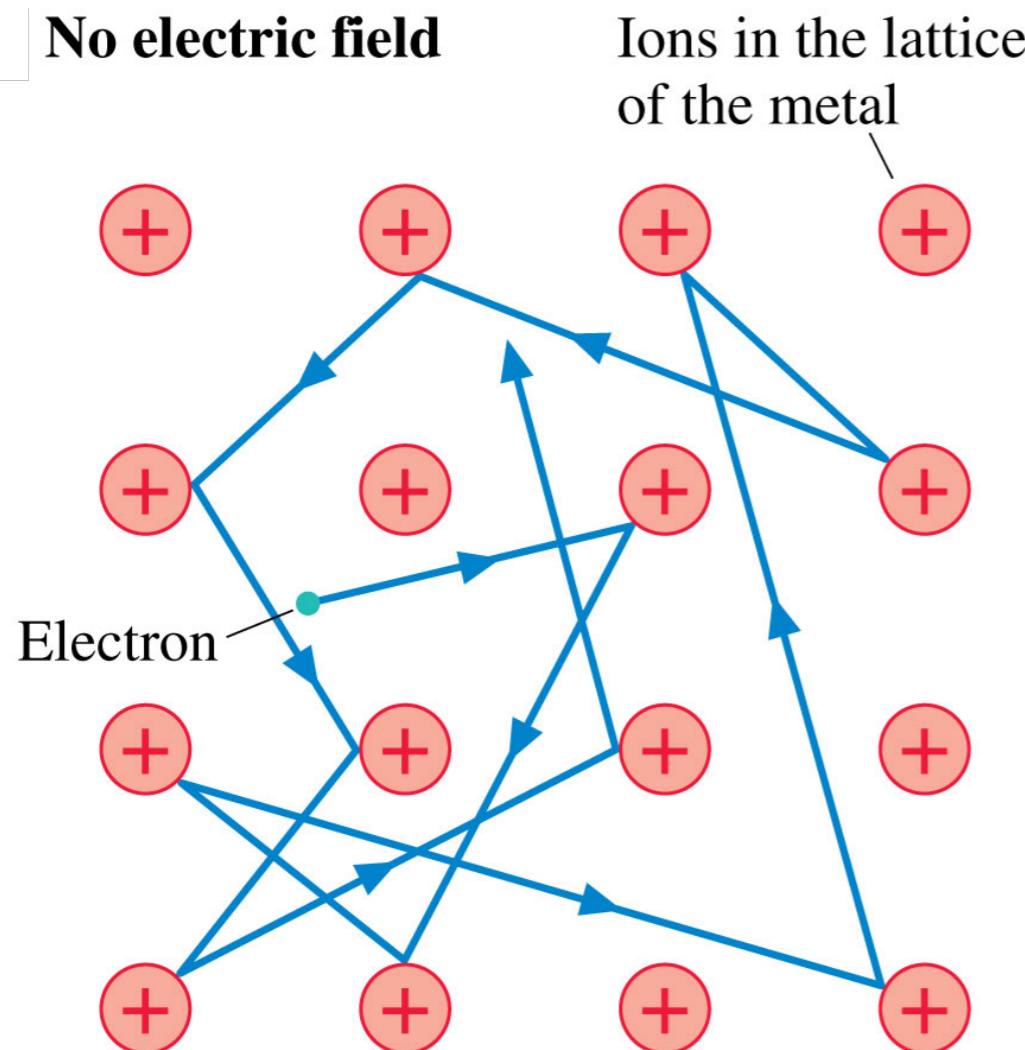


Ions in the lattice
of the metal

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

Model of Conduction

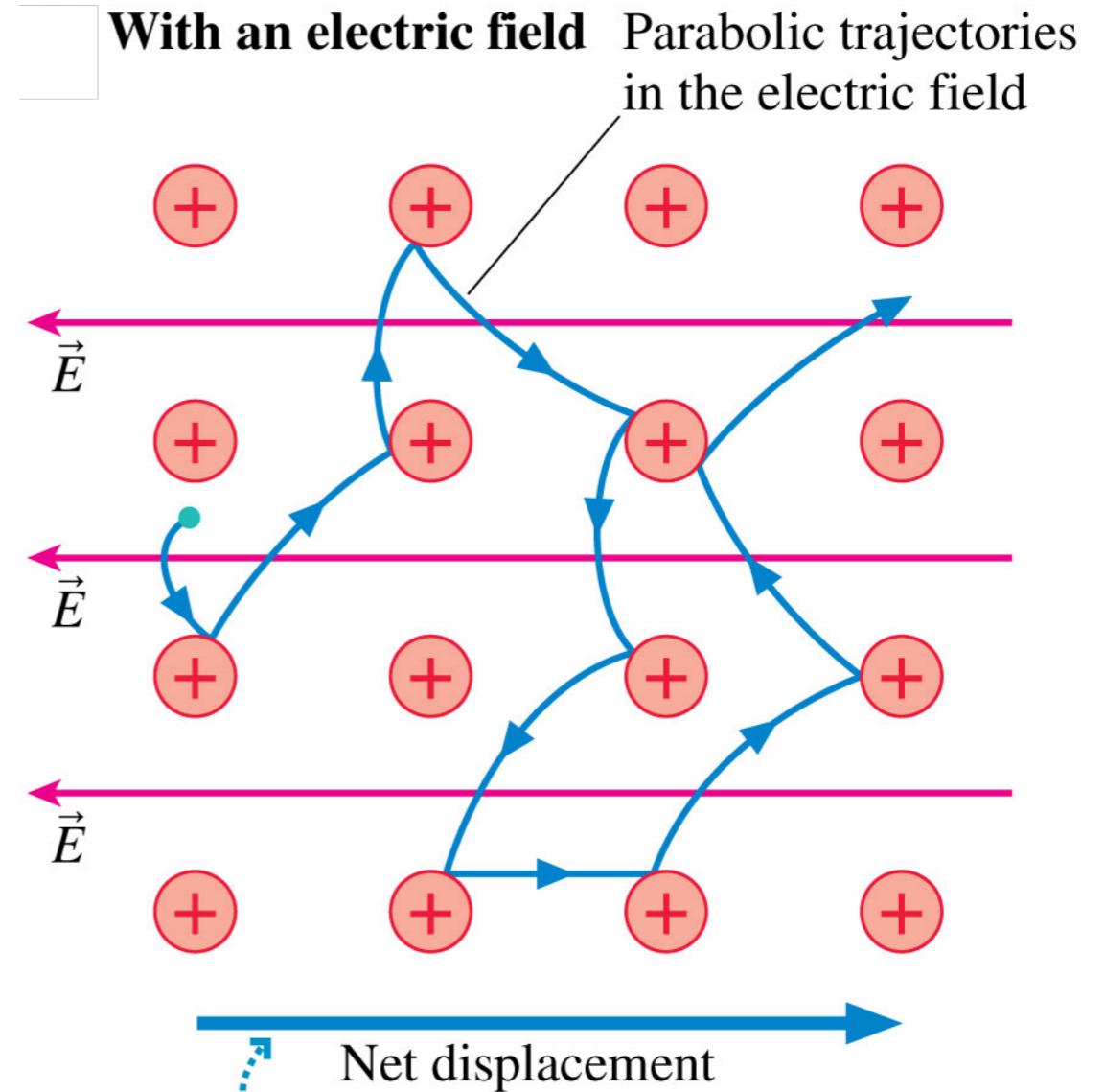
No electric field



Ions in the lattice
of the metal

Electron

With an electric field

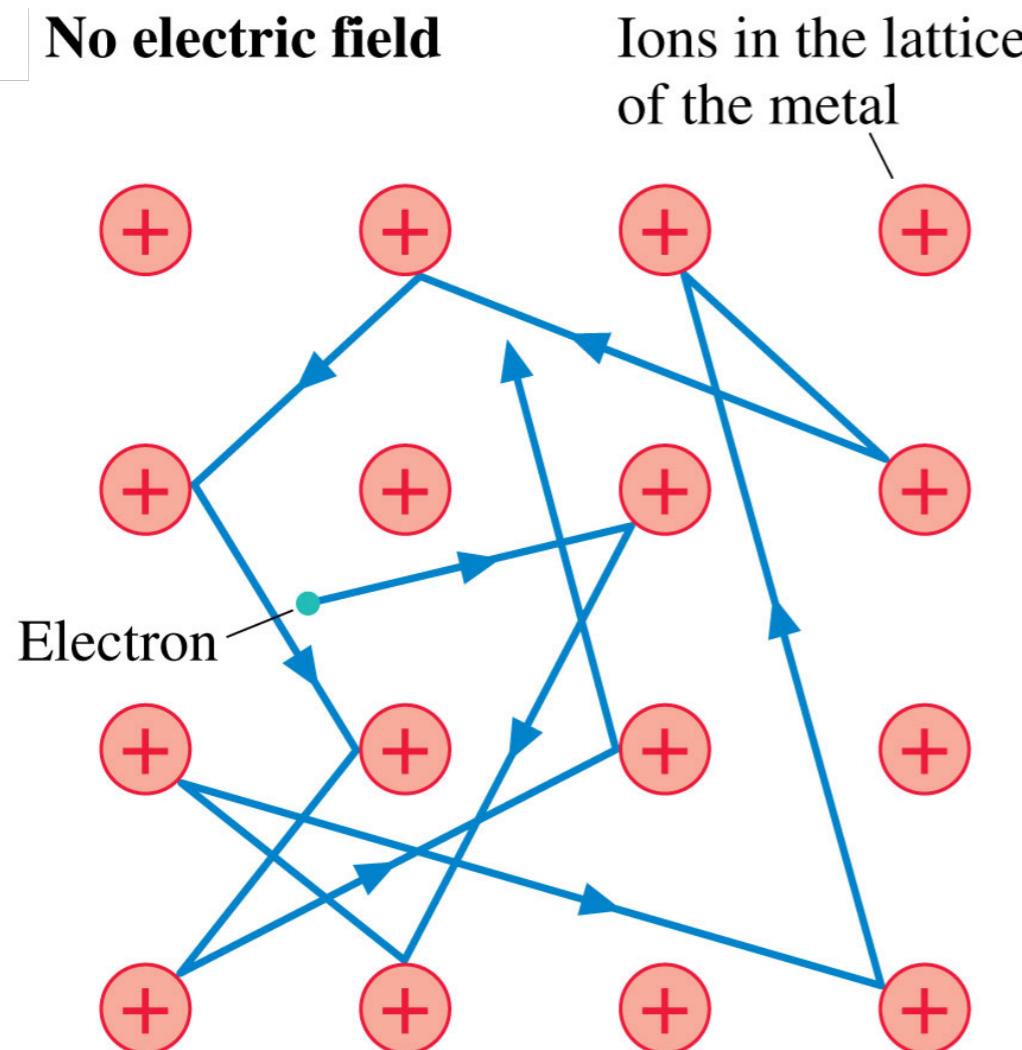


Parabolic trajectories
in the electric field

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

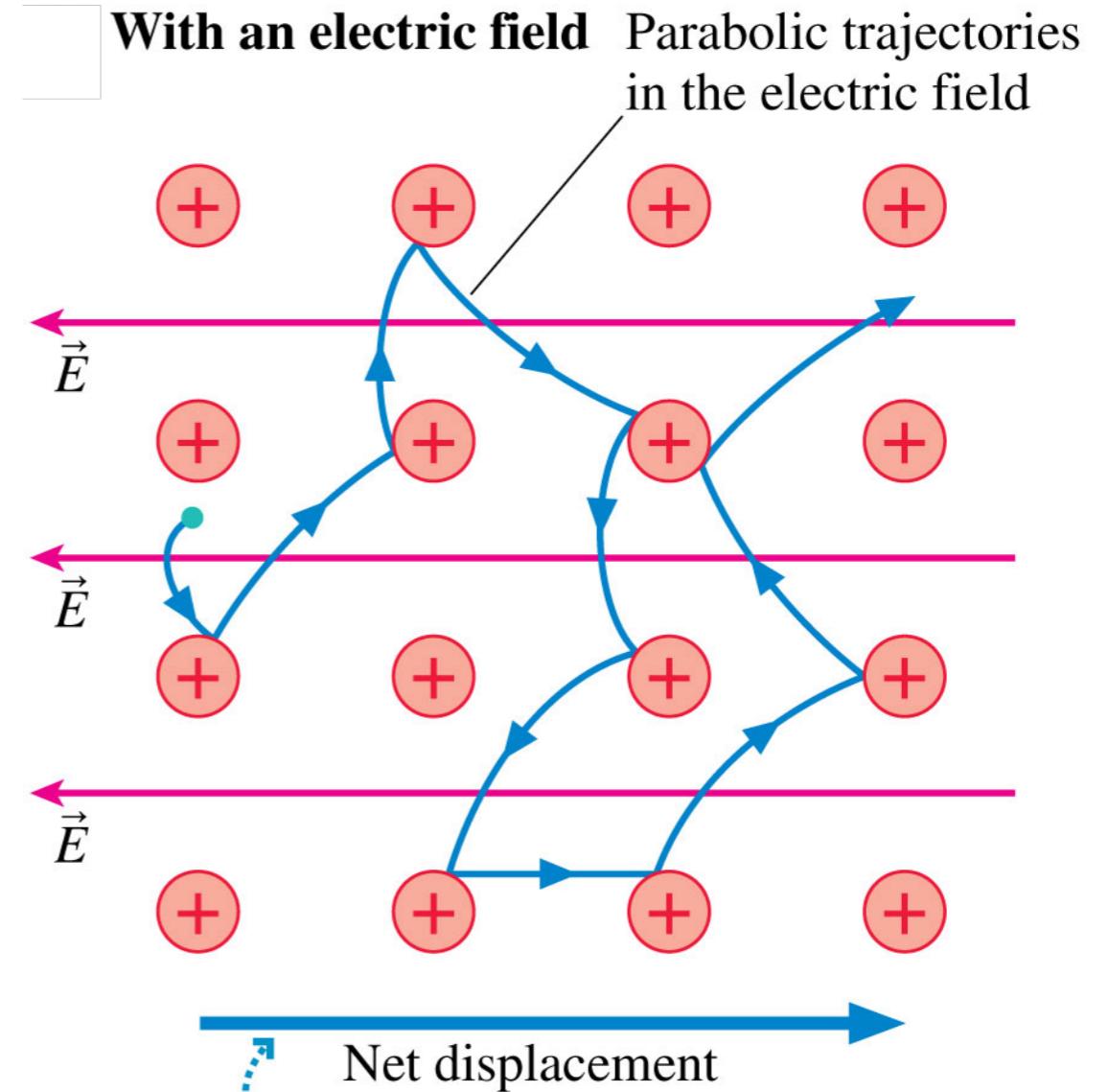
Model of Conduction

No electric field



Ions in the lattice of the metal

With an electric field



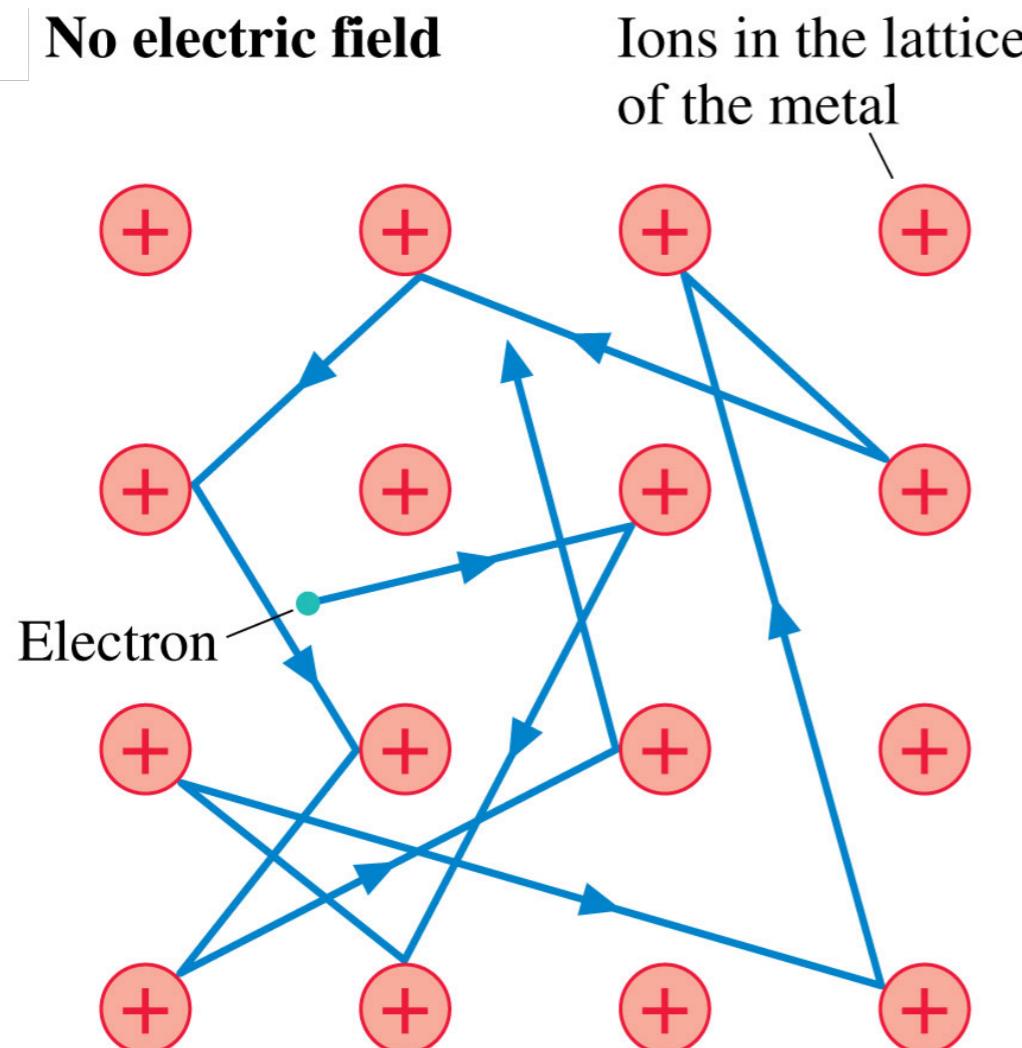
Parabolic trajectories in the electric field

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

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

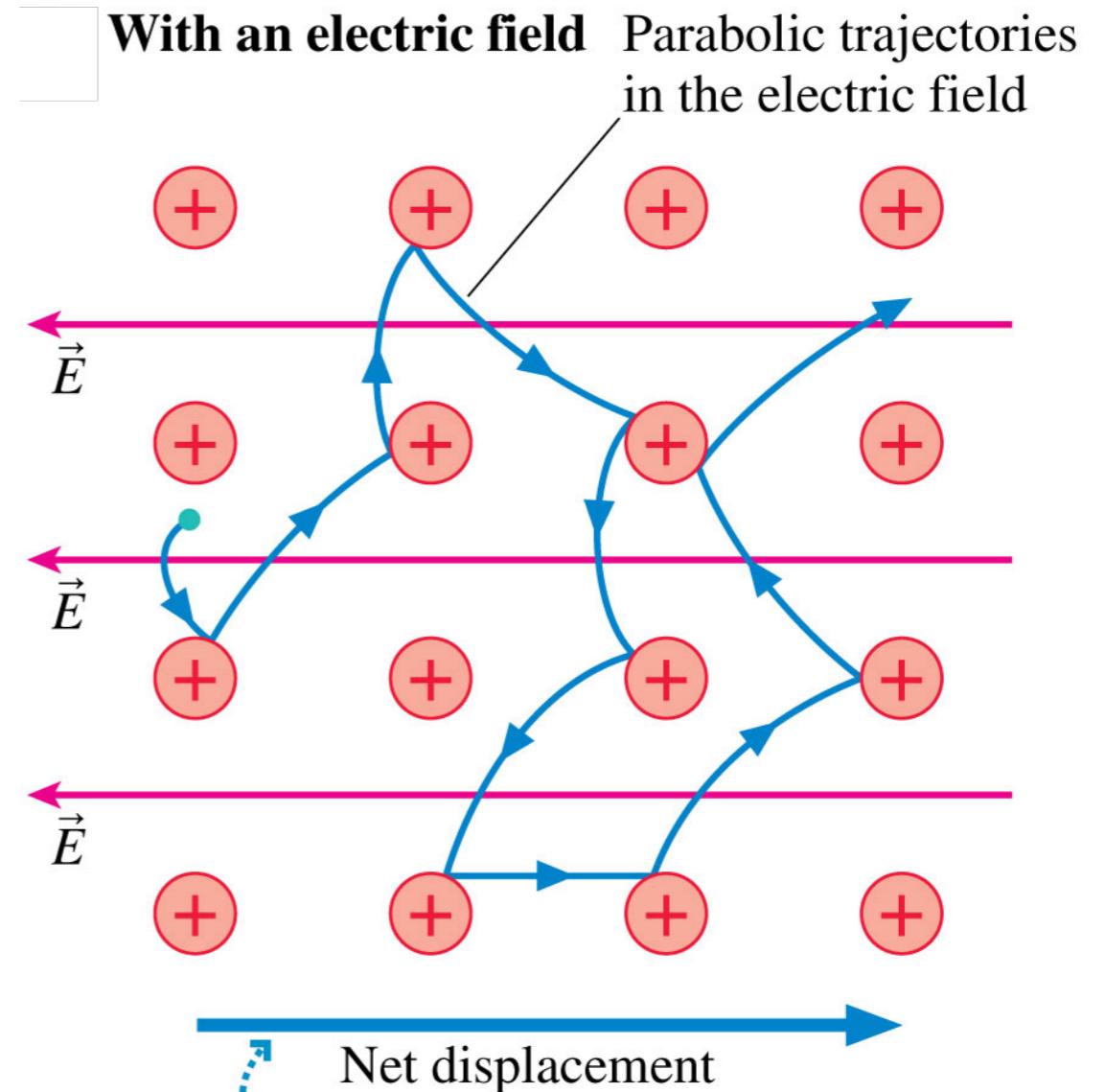
Model of Conduction

No electric field



Ions in the lattice
of the metal

With an electric field



Parabolic trajectories
in the electric field

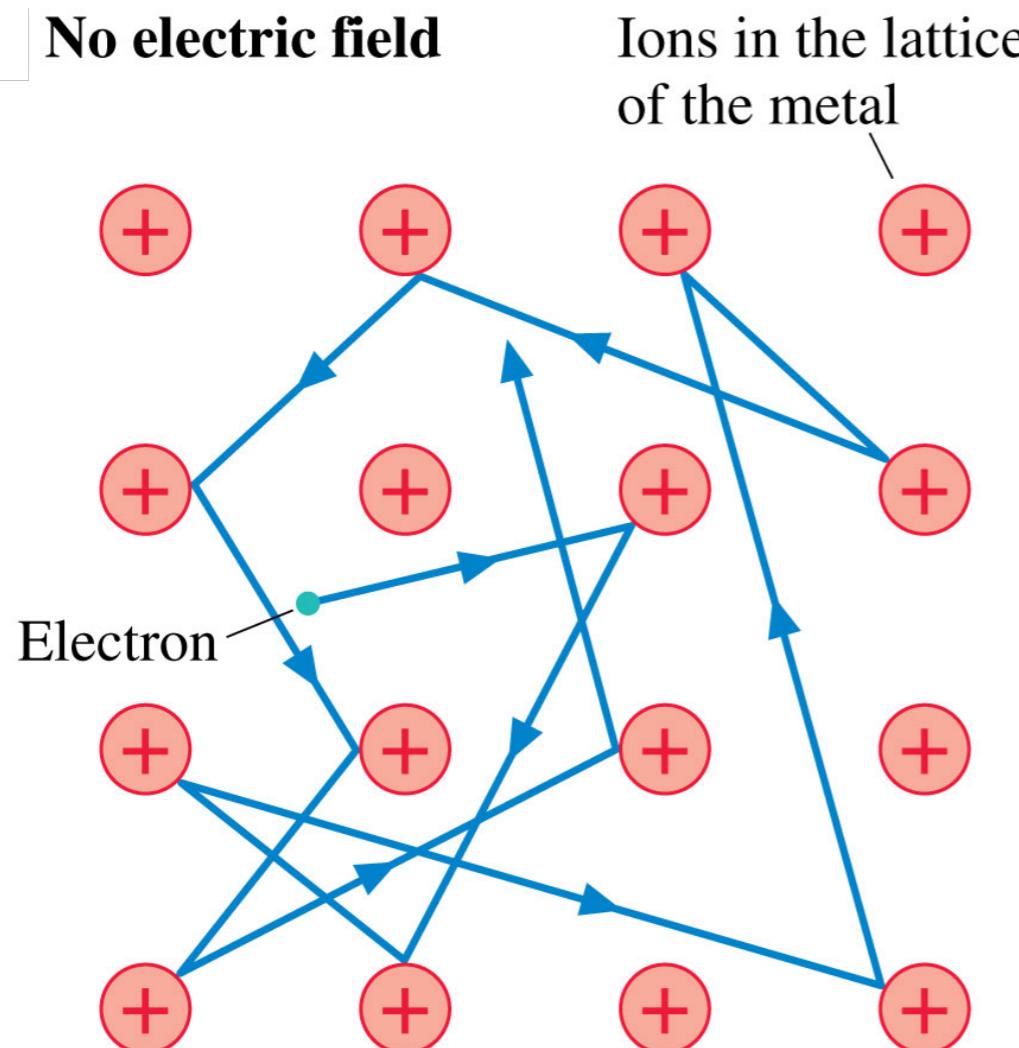
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$$a = \frac{eE}{m}$$

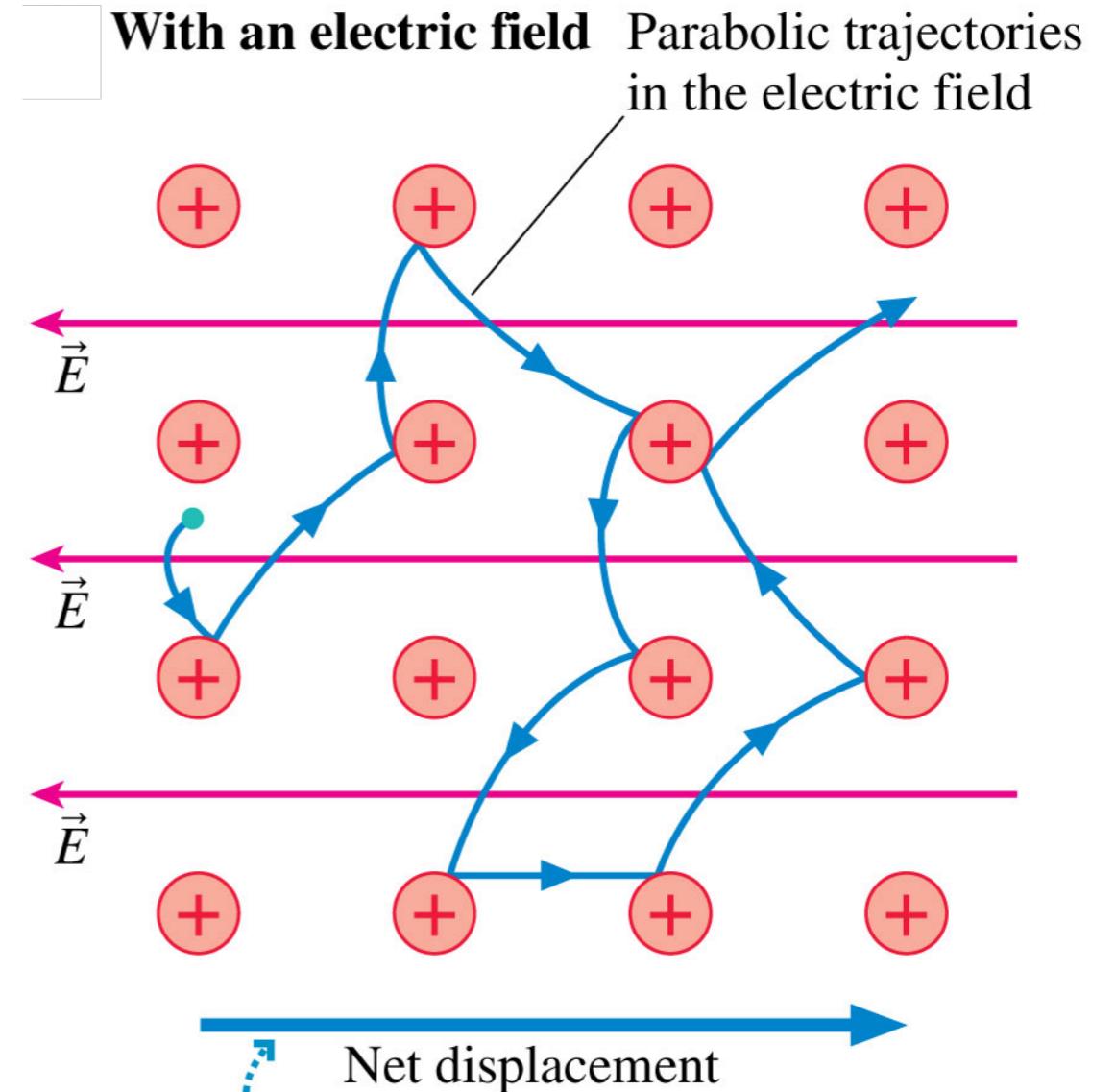
Model of Conduction

No electric field



Ions in the lattice of the metal

With an electric field



Parabolic trajectories in the electric field

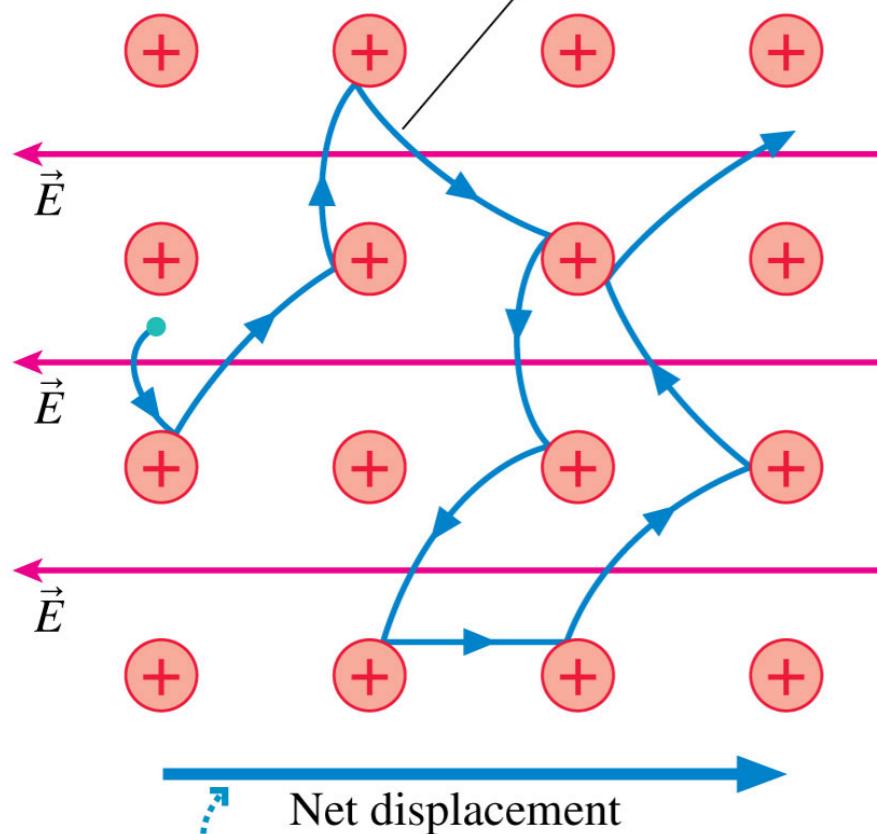
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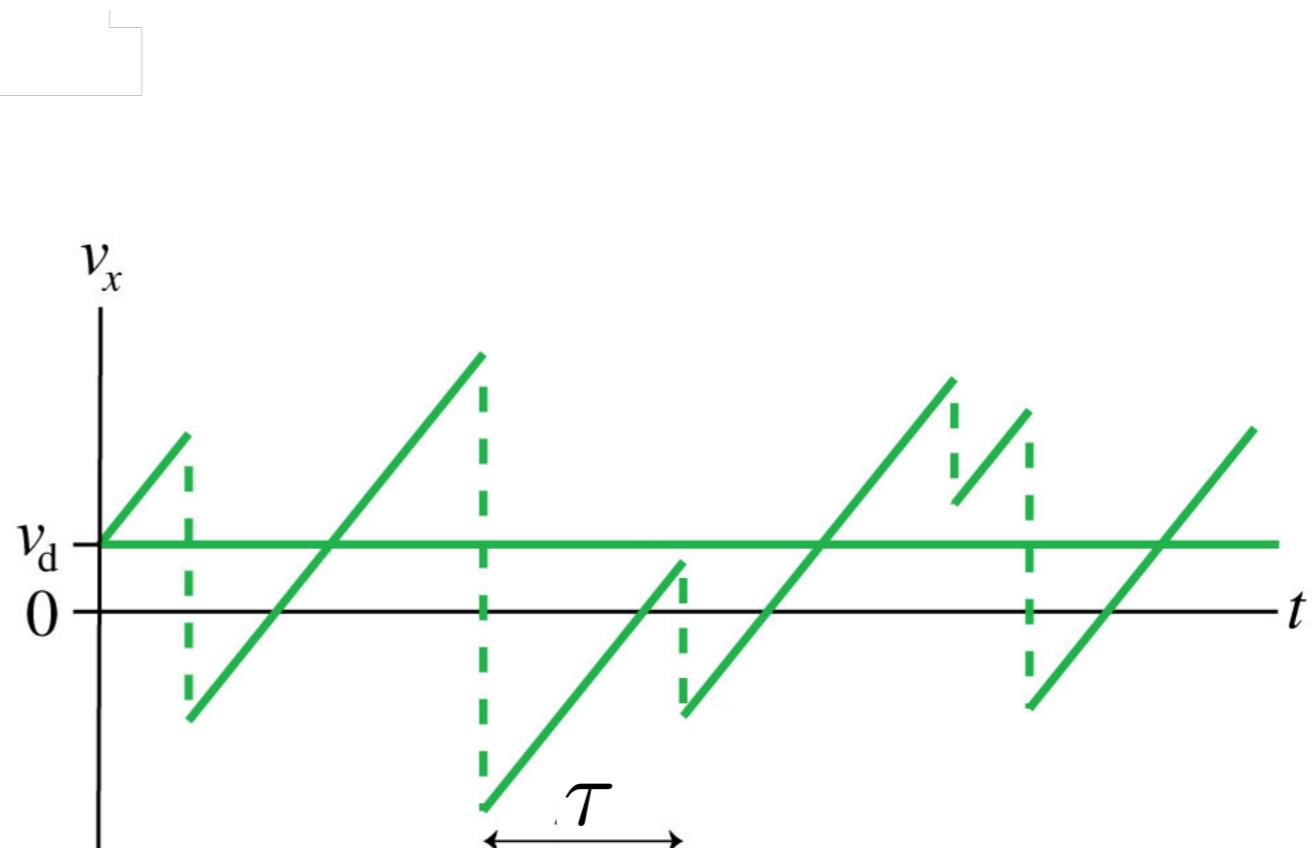
$$a = \frac{eE}{m}$$

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

With an electric field

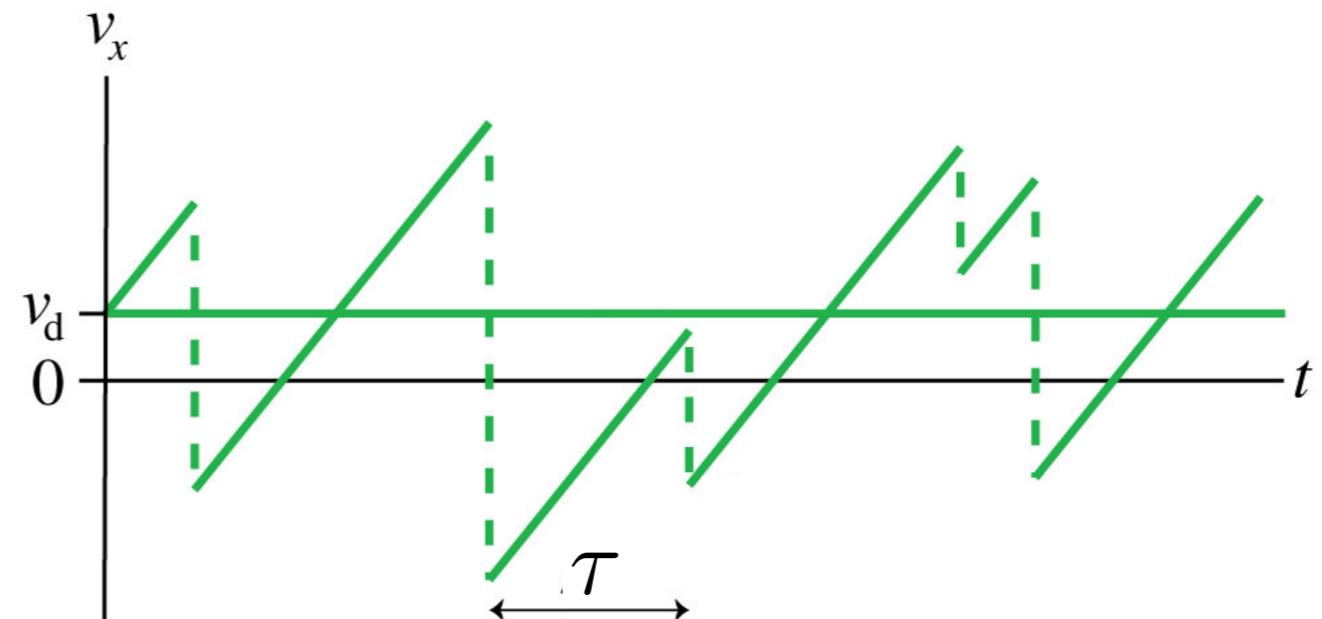
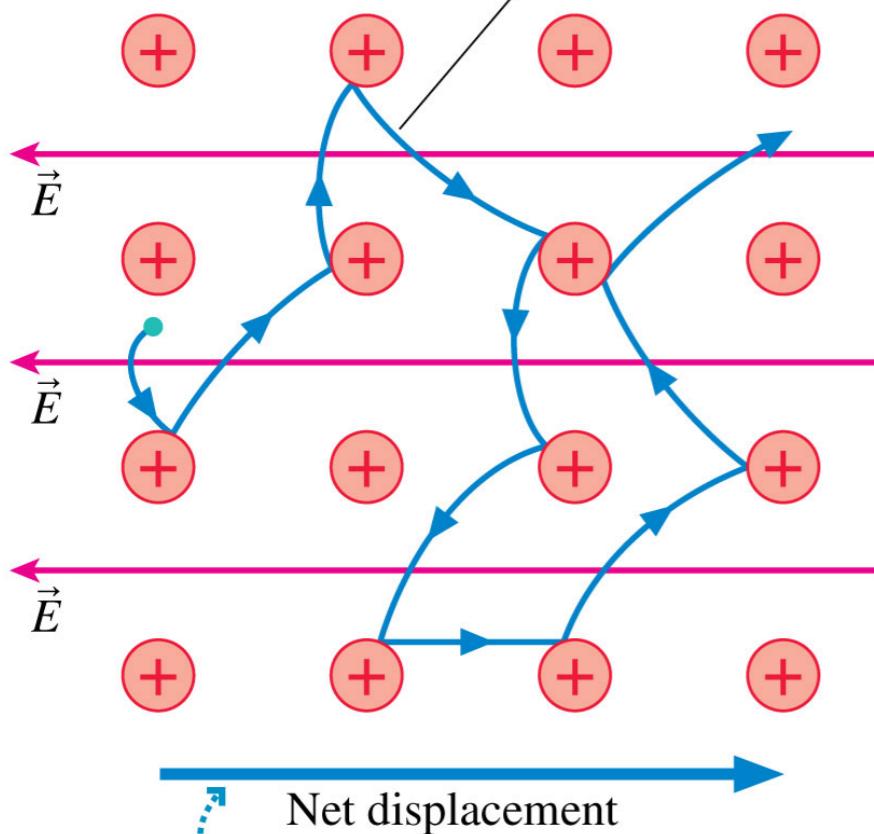


Parabolic trajectories
in the electric field



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

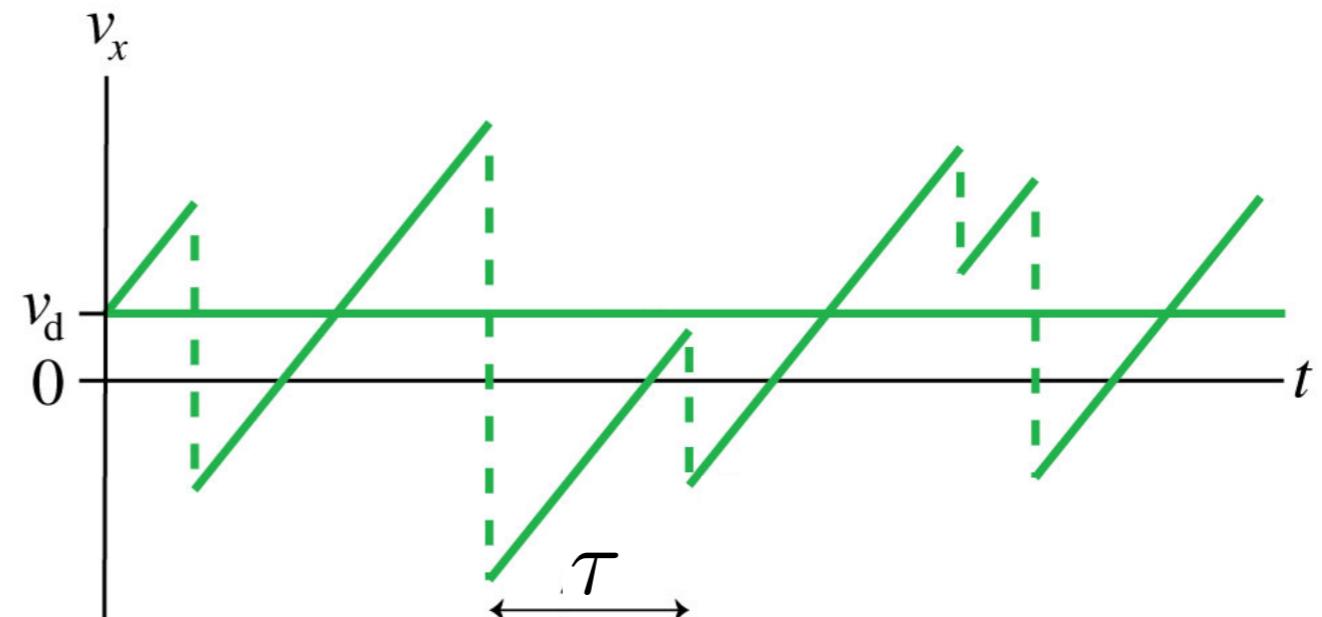
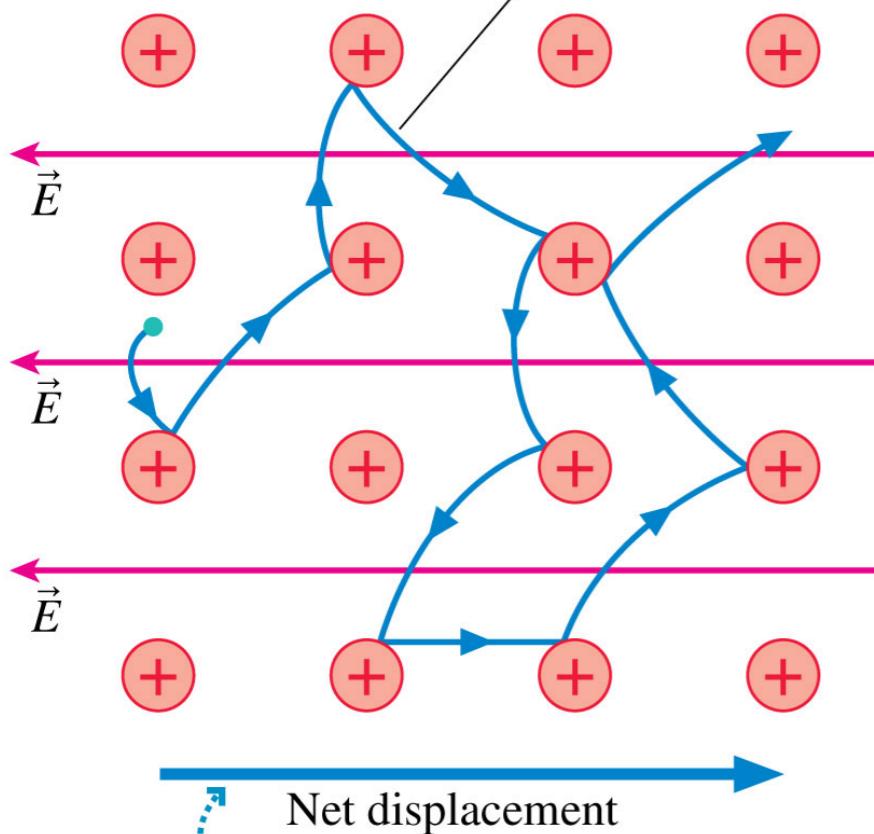
With an electric field Parabolic trajectories in the electric field



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

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

With an electric field Parabolic trajectories in the electric field



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

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