# Announcements

- Homework
  - Online HW10 due tonight
  - Video HW over the weekend
- Grade reports either out now or are going to go out this weekend
  - Lab scores won't be factored in probably
  - Mistakes or something missing? Let me know!
- Physics Fridays!
  - Physics Tea at 3pm today!
  - I don't think there is a speaker today
- Polling: `rembold-class.ddns.net`

# Review Question!

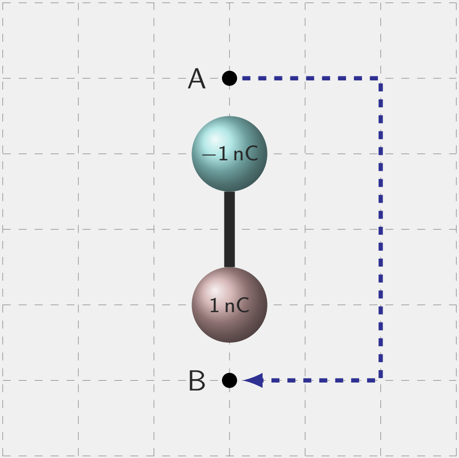
You start a short distance above the dipole to the right at point A. If you follow the path to point B, what is your change in potential? Each grid line corresponds to 1 m.

A. $-6\,\mathrm{V}$

B. $6\,\mathrm{V}$

C. $9\,\mathrm{V}$

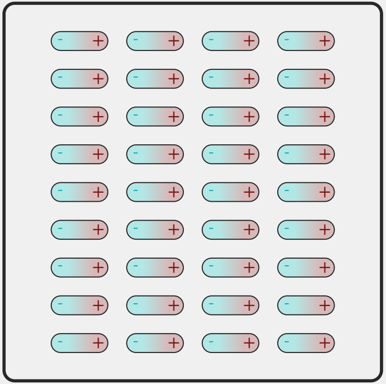
D. $12\,\mathrm{V}$




**Solution:** $12\,\mathrm{V}$

# Potential and Insulators

- Can be difficult to determine a net induced electric field inside an insulator
  - Efield points left then right as you pass by the induced dipoles
- Potential difference and loop rules can tell us that it must be pointing to the left! (in this image)
- Strength of this induced electric field determined by the dielectric constant



# It's Dielectrical!

- Related to the polarizability:
$$\vec{\mathbf{p}} = \alpha \vec{\mathbf{E}}$$
- Gives the net electric field inside the conductor
  - Slightly less than the applied electric field
$$\vec{\mathbf{E}}_{net,insulator} = \frac{\vec{\mathbf{E}}_{applied}}{K}$$
    where $K$ is the dielectric constant
  - $K$ must be 1 or larger
- For a capacitor, a change in $\vec{\mathbf{E}}$ implies the same change in $\Delta V$:
$$\Delta V_{insulator} = \frac{\Delta V_{vacuum}}{K}$$

# Partial Capacitor

Suppose we have a capacitor in which the two plates are separated by a distance of 1 cm and have a potential difference of 10 V. We then slide a 2.5 mm thick piece of glass between the plates, which has a dielectric constant of 2.8. What is the new potential difference between the two plates?

**Solution:** 8.39 V

# Electric Fields store Energy!

- Have related energy to interacting charged particles
- Alternatively, could consider energy to be thing stored in electric fields!
  - Sometimes, especially going forward, this is an easier way to consider things
- Consider a capacitor with plates barely separated such that

$$E_{\text{one plate}} = \frac{(Q/A)}{2\epsilon_0}$$

- Exerts a force on the other plate, and could move it a small distance, doing work:

$$F = QE_{\text{one plate}} \quad \Rightarrow \quad W = \Delta U = F\Delta s = Q\left(\frac{(Q/A)}{2\epsilon_0}\right)\Delta s$$

# The Energy Density

- Can rearrange:

$$\Delta U = Q\left(\frac{(Q)}{2A\epsilon_0}\right)\Delta s = \frac{1}{2}\underbrace{\left(2\cdot\frac{Q}{2A\epsilon_0}\right)}_{\text{E inside capacitor}}^{2}\epsilon_0 A\Delta s$$

- Since $A\Delta s = \Delta(\text{volume})$, we have

$$\frac{\Delta U}{\Delta(\text{volume})} = \frac{1}{2}\epsilon_0 E^2$$

- Called the energy density
- Describes more fundamental way of associating energy with fields

# Capacitor Breakdown

A circular capacitor has a radius of 10 cm and the plates are spaced 1 cm apart. Both plates are initially neutral. How much work will it take to charge the plates to the point where a spark will jump across the plates? The electrical field breakdown point for air is about $3 \times 10^6$ V/m.

**Solution:** 12.5 mJ

Upcoming:

# Magnetic Fields

# Origin Story

- Charged particles have two fields associated with them
  - Stationary charges: electric fields
  - Moving charges: electric fields <u>and magnetic fields</u>
- Can quantify with the <u>electron current</u>, the number of electrons per second that enter a conductor
- Magnetic fields create a torque on a compass needle exactly like electric fields create a torque on dipoles.
- Can let us "see" the directions of the fields
- Evidence that moving charges create or interact with magnetic fields:
  - Demos!