Announcement

EXAM I is TONIGHT

8:00-9:30 PM –MONDAY SEPT. 24 in STEW 183

Material: Through Chapter 16 in the book.

No HW due Tuesday this week. You need a break!

8:00-10:00 PM -THURS SEP 16, Elliott Hall

Exam 1 - Monday, September 24, 8:00-9:30 PM in STEW 183

1. Absences must be excused in advance by filing an Absentee Report form in Rm 144 PHYS. See the syllabus on Blackboard Learn (BBL) at mycourses.purdue.edu . For emergencies, contact Prof. Carlson by email as soon as possible, ewcarlson@purdue.edu .

2. Students approved for separate test environments must contact Prof. Carlson as soon as possible for further instructions. ewcarlson@purdue.edu

3. You may NOT bring equations sheets, books, etc. It is a closed book exam. Necessary equations and constants will be provided. DO bring pencils and a calculator which cannot access the internet. Graphing Calculator is okay.

4. You must show your **Purdue Student ID card** when turning in your completed exam to your recitation TA.

5. The exam covers all assigned material in this course through Chapter 16 in the book, including lectures, labs, recitations, and homework.

8:00-10:00 PM -THURS SEP 16, Elliott Hall

Exam 1 - Thursday September 15, 8:00-10:00 PM PHYS Room 112

6. Mostly multiple choice questions + 1 hand graded question

7. Practice Exam + Solution are now on BBL.

8. Exam scores will be uploaded to BBL

9. STUDY HARD AND GOOD LUCK!

Last Time

- Electric Potential (Voltage relative to infinite separation)
- Potential Difference and Electric Field
- Path Independence of Potential Difference

Topics for today

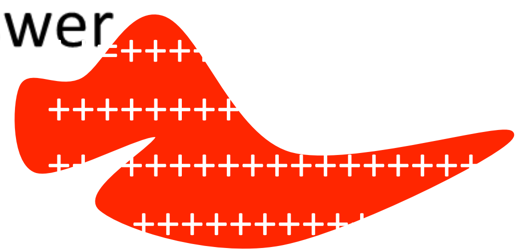
- Review definitions of electric potential
- Potential at one point
- Potential inside a conductor
- Potential inside an insulator
- Energy stored in a field

Calculating potential

- Remember: $\Delta V = -\int_a^b \vec{E} \cdot d\vec{x} = V_a - V_b$
- If E is constant, it can be pulled out of the integral, and it just becomes $-\vec{E} \cdot \Delta\vec{x}$
- The potential at a single point is the potential relative to infinite separation

Two ways to get the potential

- We could either:
  - Find the electric field of an object
  - Integrate $-\int_a^b E \cdot dl$
- Or:
  - Remember that the potential of a point charge is $\frac{q}{4\pi\epsilon_0 r}$
  - Break the object into point charges and add up the potential from each one
- Either way works for any arbitrary shape and provides the same answer



This odd shape can be broken into point charges. They can be used directly to find the electric field or potential.

iClicker question

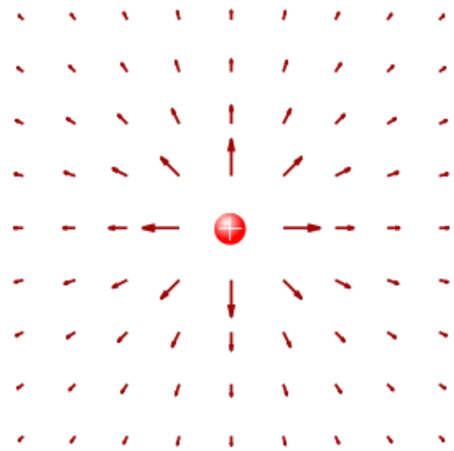
iClicker question

Potential of a point charge

$$\Delta V = -\int_a^b \vec{E} \cdot d\vec{x}$$

- Field of a point charge goes as $1/r^2$, so potential goes as:

$$\Delta V = \frac{1}{4\pi\epsilon_o} \frac{q}{r}\Big|_a^b$$



Electric potential at r=∞: $V_\infty = \lim_{r\to\infty} \frac{1}{4\pi\epsilon_0} \frac{q}{r} = 0$

So, $V_a = V_a - V_\infty$

In other words, the potential at location a is the potential relative to infinity.

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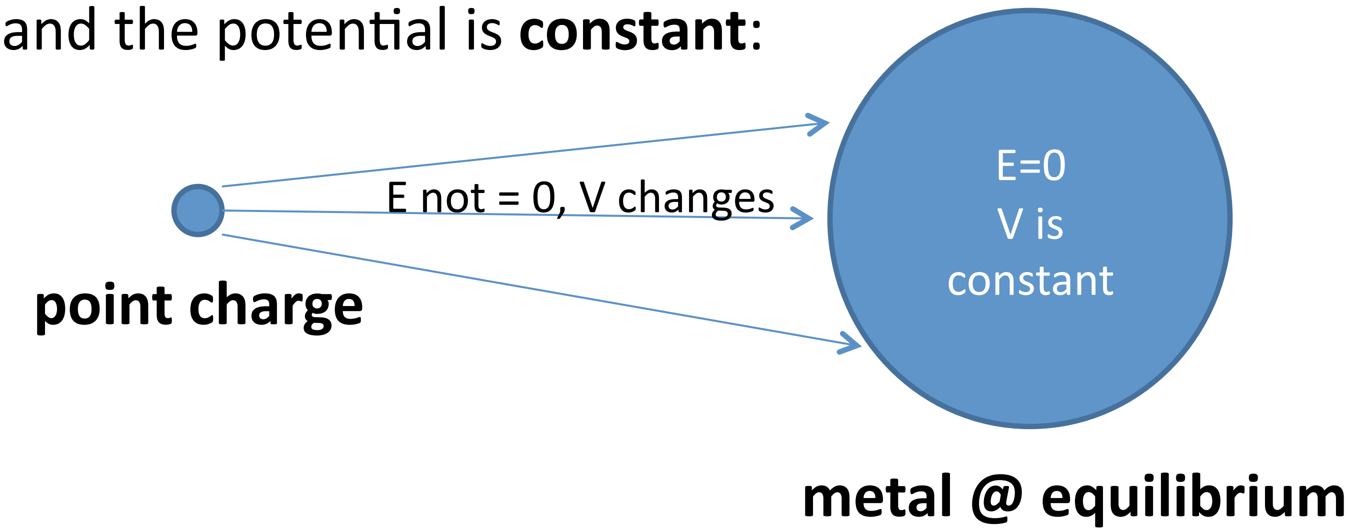
Inside a Metal

$$\Delta V = -\int_a^b \vec{E} \cdot d\vec{x}$$

For a metal in EQUILIBRIUM, E = 0 inside,
and the potential is **constant**:

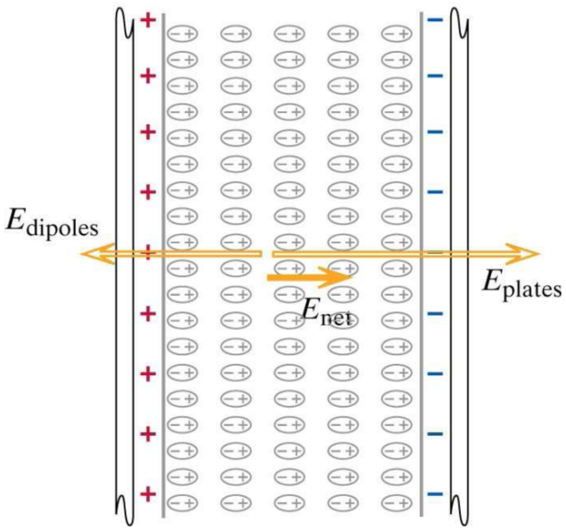


What is EQUILIBRIUM for a metal? *Electron Sea has* $v_{net} = 0$.
When is a metal OUT OF EQUILIBRIUM?

- Applied voltage (*i.e.* hooked up in a circuit.)
- Immediately after applying a field (electrons move to screen it).

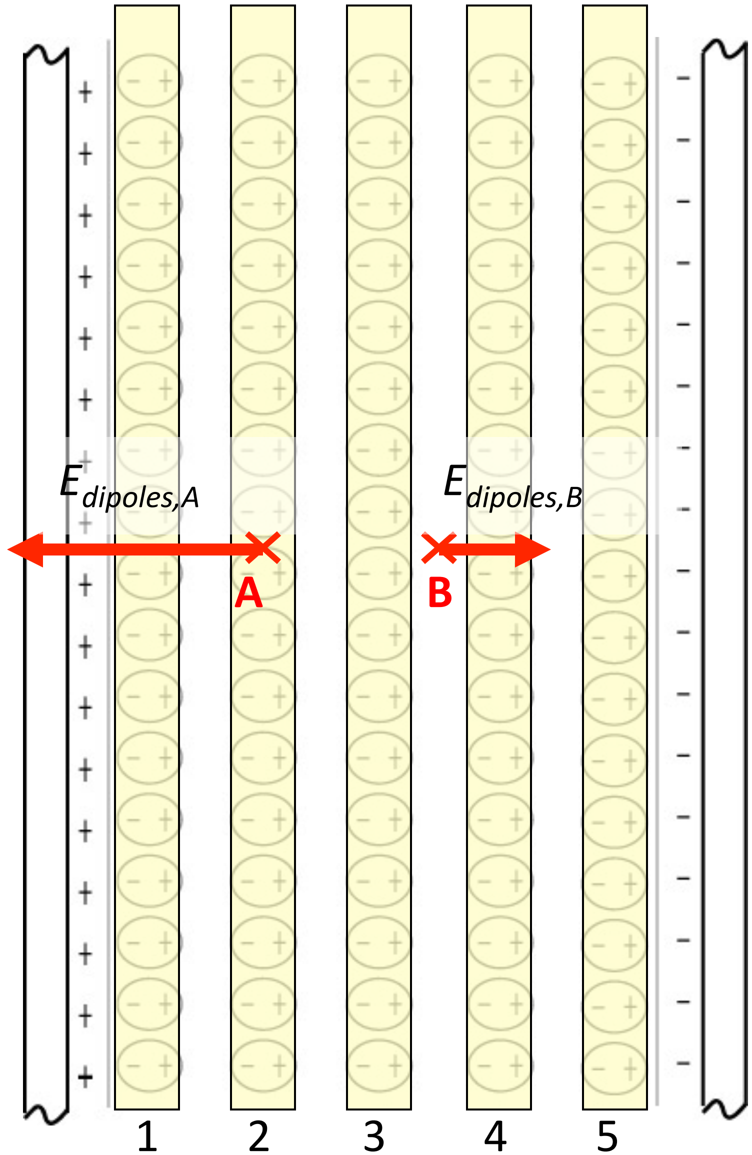
Electric potential in an insulator

Place an insulator between 2 charged plates...



- Two components to the field in an insulator
  - Field from the charges on plates
  - Field from the induced dipoles
- Field from induced dipoles counteracts the field from the plates
- In fact, a "dielectric medium" (linear medium) will shield the field from any charges inside, reducing the strength of their fields

Potential Difference in an Insulator



Electric field in capacitor filled with insulator:

$E_{net}=E_{plates}+E_{dipoles}$

E_{plates}=const (in capacitor)

$E_{dipoles}=f(x,y,z)$

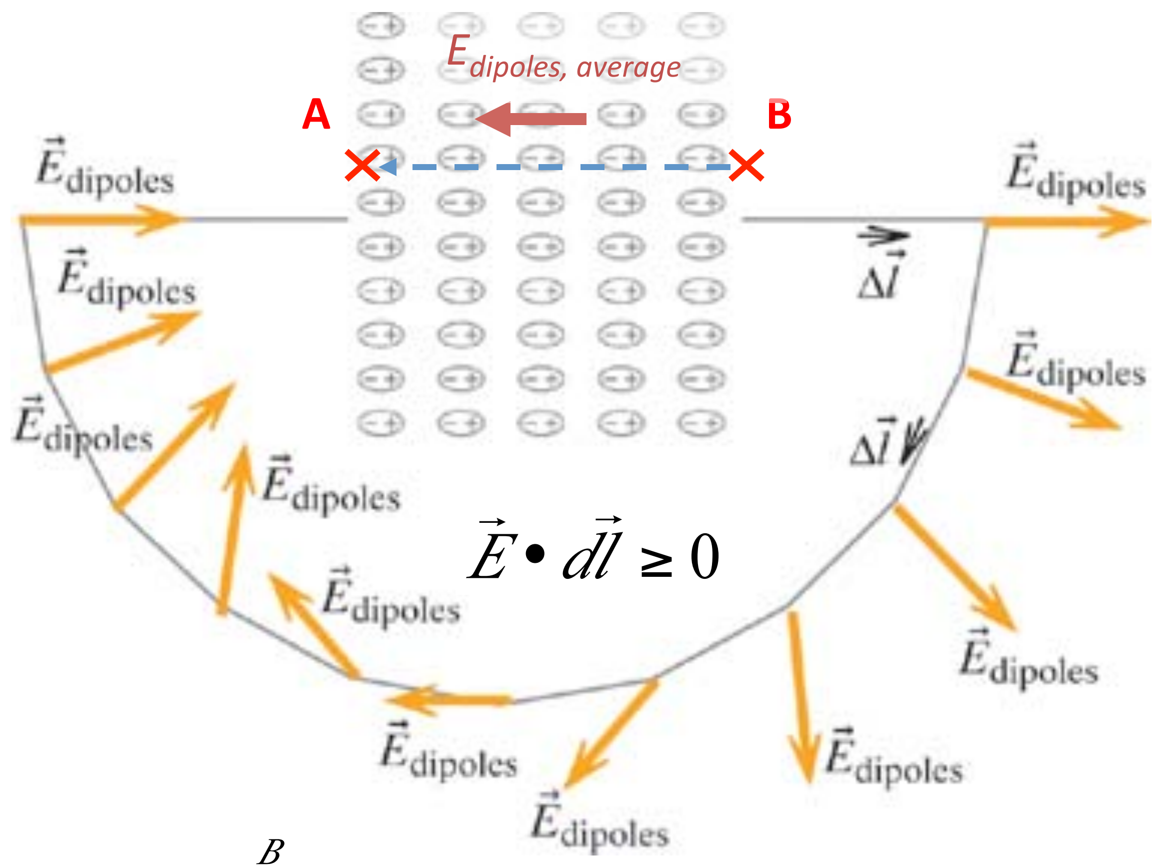
$$\Delta V = -\int_a^b \vec{E} \cdot d\vec{x}$$

Travel from B to A:

$E_{dipoles}$ is sometimes parallel to *dl*, and sometimes antiparallel to *dl*

Potential Difference in an Insulator

Instead of traveling through inside – travel outside from B to A:

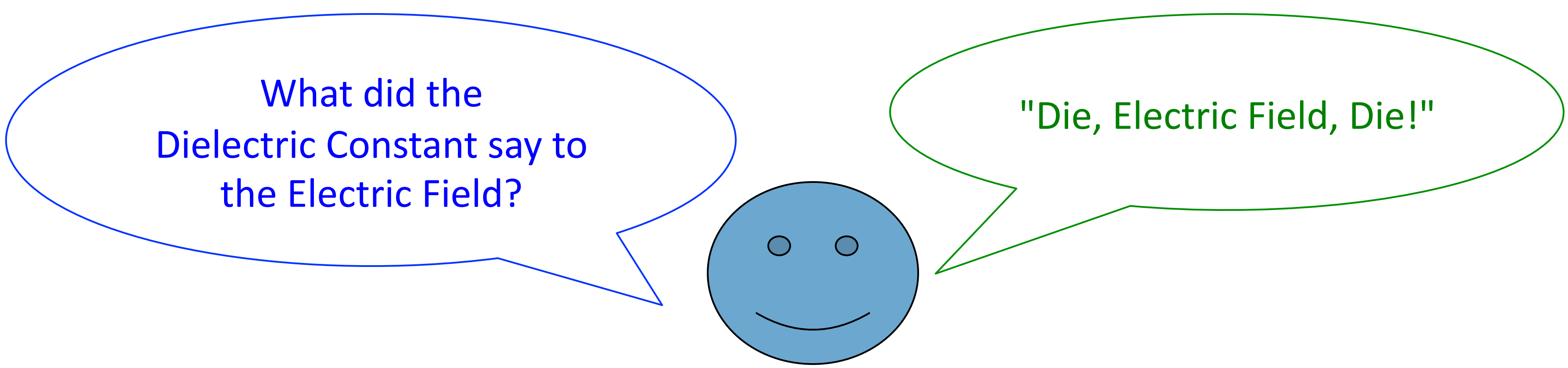


$$\Delta V_{BA} = V_B - V_A = -\int_A^B \vec{E}\bullet d\vec{l} < 0$$

Effect of dielectric is to reduce the potential difference.

Dielectric constant

- Dielectric medium has a constant K
- Inside the medium $\vec{E}_{net} = \dfrac{\vec{E}_{applied}}{K}$
- The bigger K is, the more it dampens the electric field.
  - A bigger K means greater polarization
- For plastic, K=5, for water at 20 degrees C, K = 80
- What are the units on K?



Dielectric Constant

Inside an insulator: $$E_{net} = \frac{E_{applied}}{K}$$

Dielectric constant for various insulators:

vacuum	1 (by definition)
air	1.0006
typical plastic	5
NaCl	6.1
water	80
strontium titanate	310

Energy stored in a field

- Rather than potential energy, we can talk about the energy of the EM field
- This is useful because radiation (e.g. light) carries energy, and we may want to know how much
- Instead of a change in potential energy, we can say that rearranging charges changes the field energy
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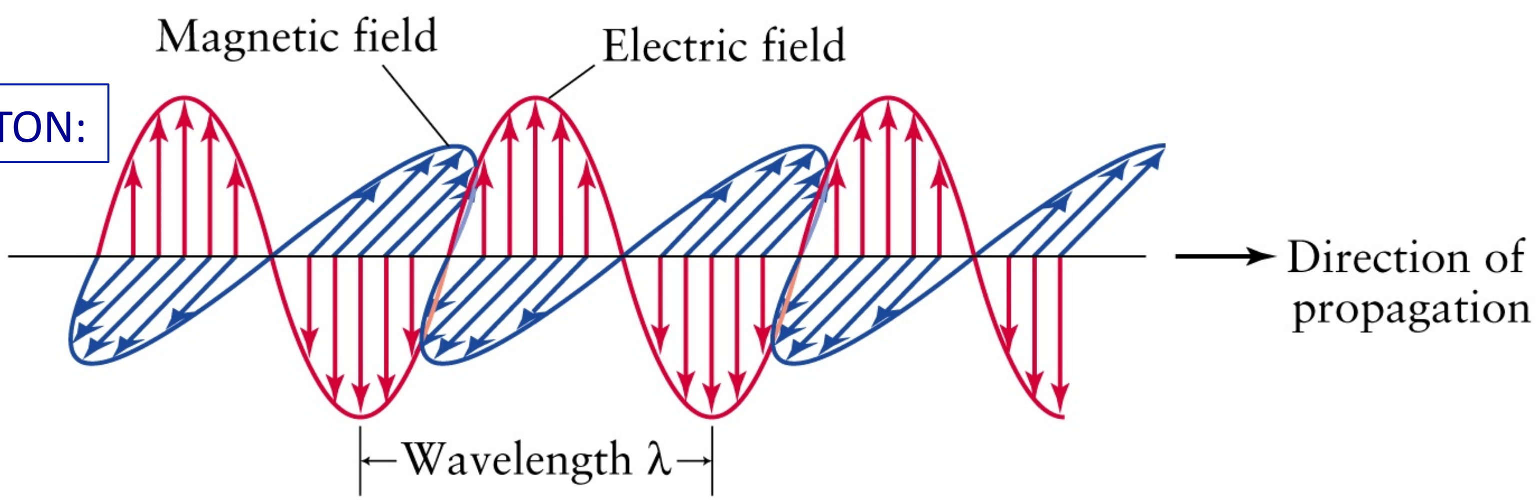
PHOTON:



http://www.physast.uga.edu/~jss/1010/ch5/ovhd05.html

iClicker question

Field energy density

$$E \approx \frac{Q/A}{\epsilon_o}$$

$W = Q^2/2A\varepsilon_o \, \Delta s$

- We could write
- $\Delta K + \Delta U = W$, since $\Delta K = 0$, $\Delta U = W$
- Or, instead of potential energy, we can think of it as field energy
- $\Delta K + \Delta U_{field} = W$, $\Delta K = 0$, $\Delta U_{field} = W$
- This means $\Delta U_{field} = Q^2/2A\varepsilon_o \Delta s = ½\varepsilon_0 E^2 A \Delta s = ½\varepsilon_0 E^2 \Delta V$

Energy density

Volume, not potential

- So, $\frac{\Delta U}{\Delta V} = \frac{1}{2} \epsilon_0 \, E^2$

What we did today

- Review definitions of electric potential
- Potential at one point
- Potential inside a conductor
- Potential inside an insulator
- Energy stored in a field