

March 3, 2013

Physics 132

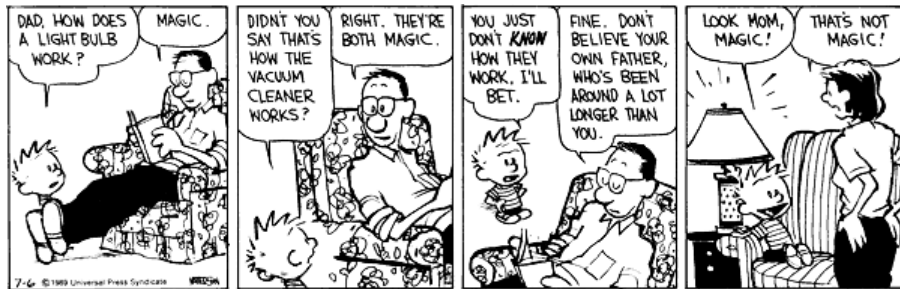
Prof. E. F. Redish

■ **Theme Music:** Bob Gramann

*You're nothin' but a pack of neurons*

■ **Cartoon:** Bill Watterson

*Calvin & Hobbes*

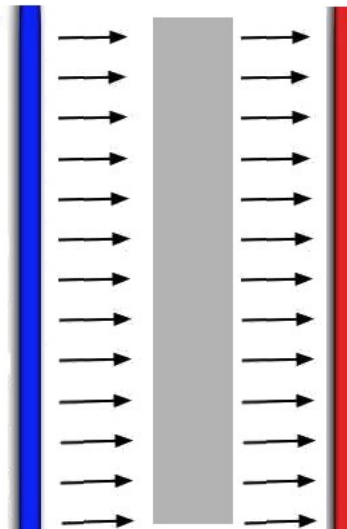


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What happens if I put a conductor into an electric field?



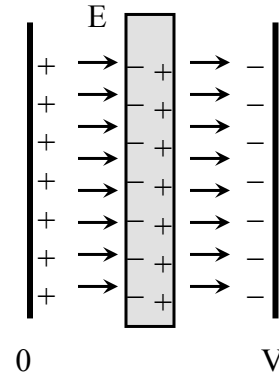
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## Consider what happens with a conductor

- The potential difference is produced by adding up  $E \Delta s$ .
- If we can reduce  $E$  along the path, we can reduce  $\Delta V$ .
- Inside a static conductor, there can be no  $E$  field. (Why not?)
- What happens if we put a conducting sheet between the plates?



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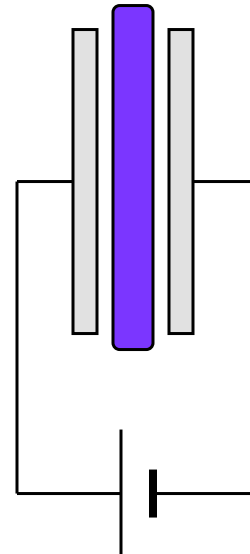
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## Conductors

- Putting a conductor inside a capacitor eliminates the electric field inside the conductor.
- The distance,  $d'$ , used to calculate the  $\Delta V$  is only the place where there is an  $E$  field, so putting the conductor in reduces the  $\Delta V$  for a given charge.

$$C = \frac{1}{4\pi k_C} \frac{A}{d'}$$



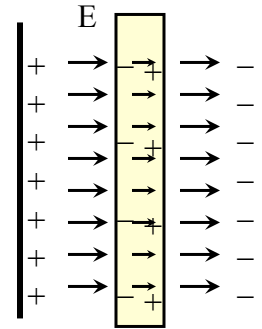
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## Consider what happens with an insulator

- We know that charges separate even with an insulator.
- This reduces the field inside the material, just not to 0.
- The field reduction factor is defined to be  $\kappa$ .



$$E_{\text{inside material}} = \frac{1}{\kappa} E_{\text{if no material were there}}$$

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## Foothold ideas: Electric charges in materials



- **Electroneutrality** – opposite charges in materials attract each other strongly. Pulling them apart to create a charge unbalance costs energy.
- If a charge is placed in an ionic solution, it tends to draw up ions of the opposite type and push away ones of the same type.
  - Result: the charge is **shielded**. As you get farther away from it the “apparent charge” gets less.
  - The scale over which this happens is called the **Debye length,  $\lambda_D$** .

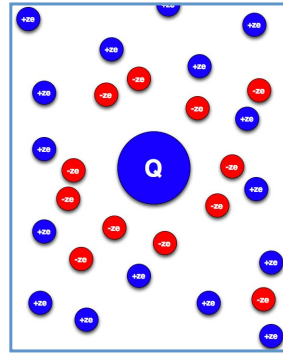
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## Debye length equations

- Charge imbedded in an ionic solution.
  - Ion charge =  $ze$
  - Concentration =  $c_0$
  - Temperature =  $T$
  - Dielectric constant =  $\kappa$
- The ion cloud cuts off the potential



$$\lambda_D = \sqrt{\frac{k_B T}{8\pi \left(\frac{k_C z^2 e^2}{\kappa}\right) c_0}} = \sqrt{\frac{k_B T}{2 \left(\frac{z^2 e^2}{\kappa \epsilon_0}\right) c_0}}$$

$$V(r) = \frac{k_C Q}{\kappa r} e^{-r/\lambda_D}$$

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## Foothold Ideas: Electric Current

- Current is a measure of the motion of charge.
- The current is defined as the rate at which charge crosses a given surface.  $I = \frac{\Delta q}{\Delta t}$
- You can have current even in neutral matter if one kind of the charge is moving differently from the other.
- Unit of current: Ampere = Coulomb/second.
- Sign of current: We choose a direction as +. Current is + when + charges cross in the + direction.



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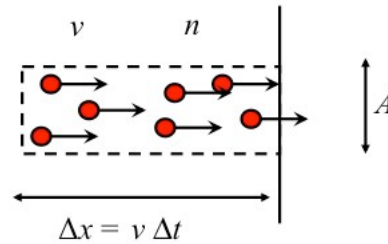
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## Foothold Ideas: Current Density



- How much charge crosses an area  $A$  in a time  $\Delta t$ ?

- each moving charge has a charge,  $q$
- the density of moving charge per unit volume is  $n$
- the speed of the moving charges are  $v$



- $J =$  current density (current/unit area)

$$I = JA$$

$$J = qnv$$

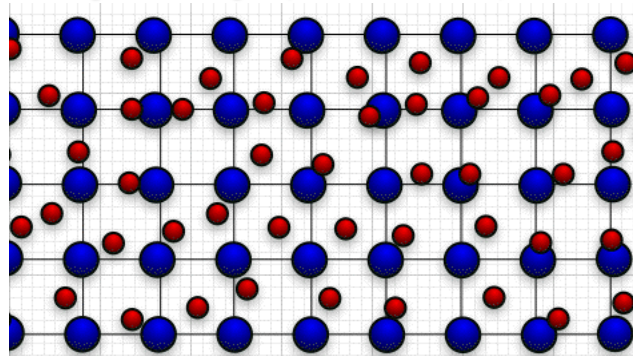
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## Moving Charges in a Neutral Conductor

- What happens if we arrange charges to put an electric force on a neutral conductor?
  - Positive ions are fixed in a lattice
  - Some negative charges (shared electrons) are free to move



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