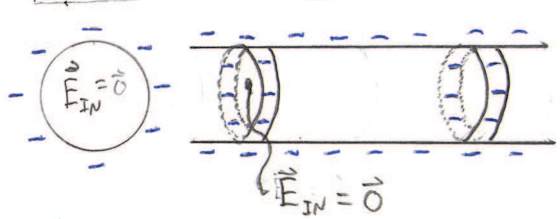
CLASSICAL MICROSCOPIC MODEL OF CURRENT

ELECTROSTATIC OVERVIEW

- ELECTROSTATIC EQUILIBRIUM
  - ANY NET CHARGE ON A CONDUCTOR RESIDES ON THE SURFACE.
  - THIS NET CHARGE DISTRIBUTES ITSELF OVER THE SURFACE OF THE CONDUCTOR SUCH THAT THE ELECTRIC FIELD INSIDE THE CONDUCTOR IS ZERO.
  - THE ACTUAL DISTRIBUTION OF NET CHARGE ON THE SURFACE IS COMPLICATED, BUT FOR HIGHLY SYMMETRIC CASES THE SURFACE CHARGE DISTRIBUTION IS UNIFORM
    - EXAMPLE: VERY LONG CYLINDER



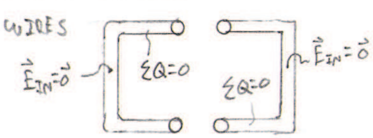
GETTING CHARGES TO ACCELERATE

- USE ELECTRIC FORCE TO PUSH FREE CHARGES AROUND INSIDE A CONDUCTOR.

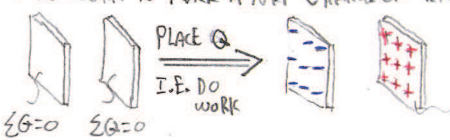
$\Sigma \vec{F}^{E_{IN}} \neq \vec{0}$ THEREFORE $\vec{E}_{IN} \neq \vec{0}$ ← NO LONGER ELECTROSTATICS

SETTING UP ELECTRIC FIELD INSIDE A CONDUCTOR

- START WITH 2 NEUTRAL WIRES

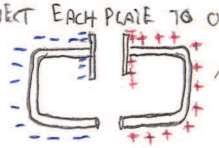


- GET 2 LARGE NEUTRAL CONDUCTORS (PLATES)
  - DO WORK TO PLACE A NET CHARGE ON EACH PLATE



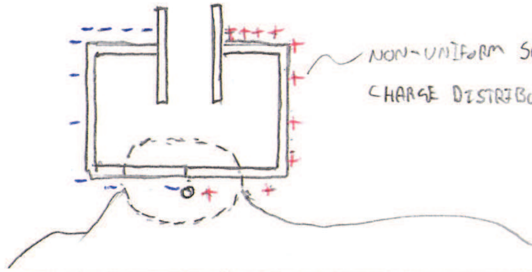
CHARGE RESIDES ON SURFACE

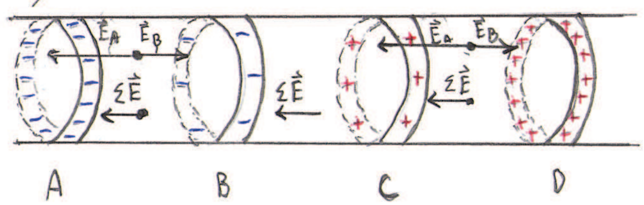
- CONNECT EACH PLATE TO ONE OF THE NEUTRAL WIRES



CHARGE UNIFORMLY DISTRIBUTES ITSELF ACROSS SURFACE OF WIRES

- CONNECT WIRES AT BOTTOM
  - A CHARGE GRADIENT IS NOW PRESENT WHICH LEADS TO A NON-UNIFORM SURFACE CHARGE DISTRIBUTION ON THE CONNECTED WIRE .... PROCESS TAKES ON THE ORDER OF 10^{-9} SECONDS .... BASICALLY INSTANTANEOUS





* $\Sigma \vec{E}_{IN}$ IS PARALLEL TO WIRE ∴ IT FOLLOWS DIRECTION OF WIRE
  CAUSES FREE ELECTRONS INSIDE CONDUCTOR TO ACCELERATE

MICROSCOPIC MODEL OF CURRENT

- CURRENT $[A] \equiv I = \dfrac{\Delta q}{\Delta t}$

  DIMENSIONS "AMPERE"

  - THE AMOUNT OF CHARGE THAT PASSES THROUGH A CROSSSECTIONAL AREA OF WIRE IN A GIVEN UNIT OF TIME.

- MICROSCOPIC MODEL PARAMETERS
  - CONSERVATION OF CHARGE – AMOUNT OF CHARGE THAT REACHES A CROSSSECTIONAL AREA IN A GIVEN AMOUNT OF TIME MUST LEAVE THAT CROSSSECTIONAL AREA IN THE SAME AMOUNT OF TIME, OTHERWISE CHARGE WOULD BUILD UP. IN OTHER WORDS... I = CONSTANT
  - CHARGE CARRIER DENSITY $\dfrac{\#}{[L]^3} \equiv n = \dfrac{N}{\text{VOLUME}}$ ← # OF CHARGE CARRIERS eg FREE ELECTRONS IN METALS

    * MATERIAL PROPERTY
  - DRIFT SPEED $\dfrac{[L]}{[T]} \equiv v_d = \dfrac{\Delta \bar{x}}{\Delta t}$ ← AVERAGE DISPLACEMENT

- MICROSCOPIC MODEL RESULT

CURRENT $\frac{\text{CHARGE}}{\text{TIME}}$ → $I = q\, n A v_d$ ✓

FUNDAMENTAL CHARGE OF CARRIER

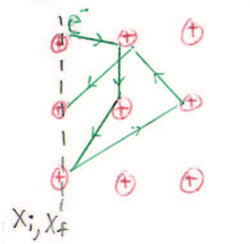
$\dfrac{\#\ \text{CHARGE CARRIERS}}{\text{TIME}} \rightarrow \dfrac{\#}{[L]^3} \cdot [L]^2 \cdot \dfrac{[L]}{[T]} = \dfrac{\#}{[T]}$

e.g. $q = e = 1.6\times10^{-16}\,C$ FOR ELECTRONS IF ELECTRONS ARE YOUR CHARGE CARRIERS

- CONVENTION: CURRENT FLOWS IN DIRECTION POSITIVE CHARGES WOULD FLOW EVEN IF CHARGE CARRIERS ARE NEGATIVE

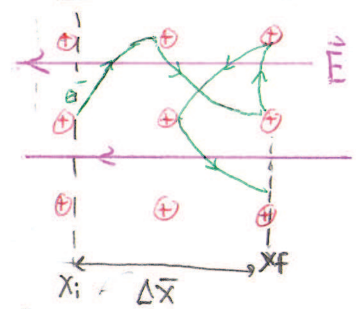
- CHARGE CARRIERS NAVIGATING THE CONDUCTOR'S LATTICE

$\vec{E} = \vec{0}$ TEMP $\neq 0$ K



e^- TRAVELS IN STRAIGHT LINES BECAUSE $\vec{E} = \vec{0}$ SO $\Sigma\vec{F} = \vec{0}$. SCATTERS OFF ION CORES WITH NO PREFERRED DIRECTION SO $\Delta\bar{x} = 0$ AND $\bar{v}_d = 0$

$\vec{E} \neq \vec{0}$ TEMP $\neq 0$ K



e^- TRAVELS IN PARABOLIC TRAJECTORIES BECAUSE $\vec{E} \neq \vec{0}$ SO $\Sigma\vec{F} \neq \vec{0}$. SCATTERS ION CORES AND IS BIASED IN ONE DIRECTION SO...

$\Delta\bar{x} \neq 0$ AND $\bar{v}_d \neq 0$