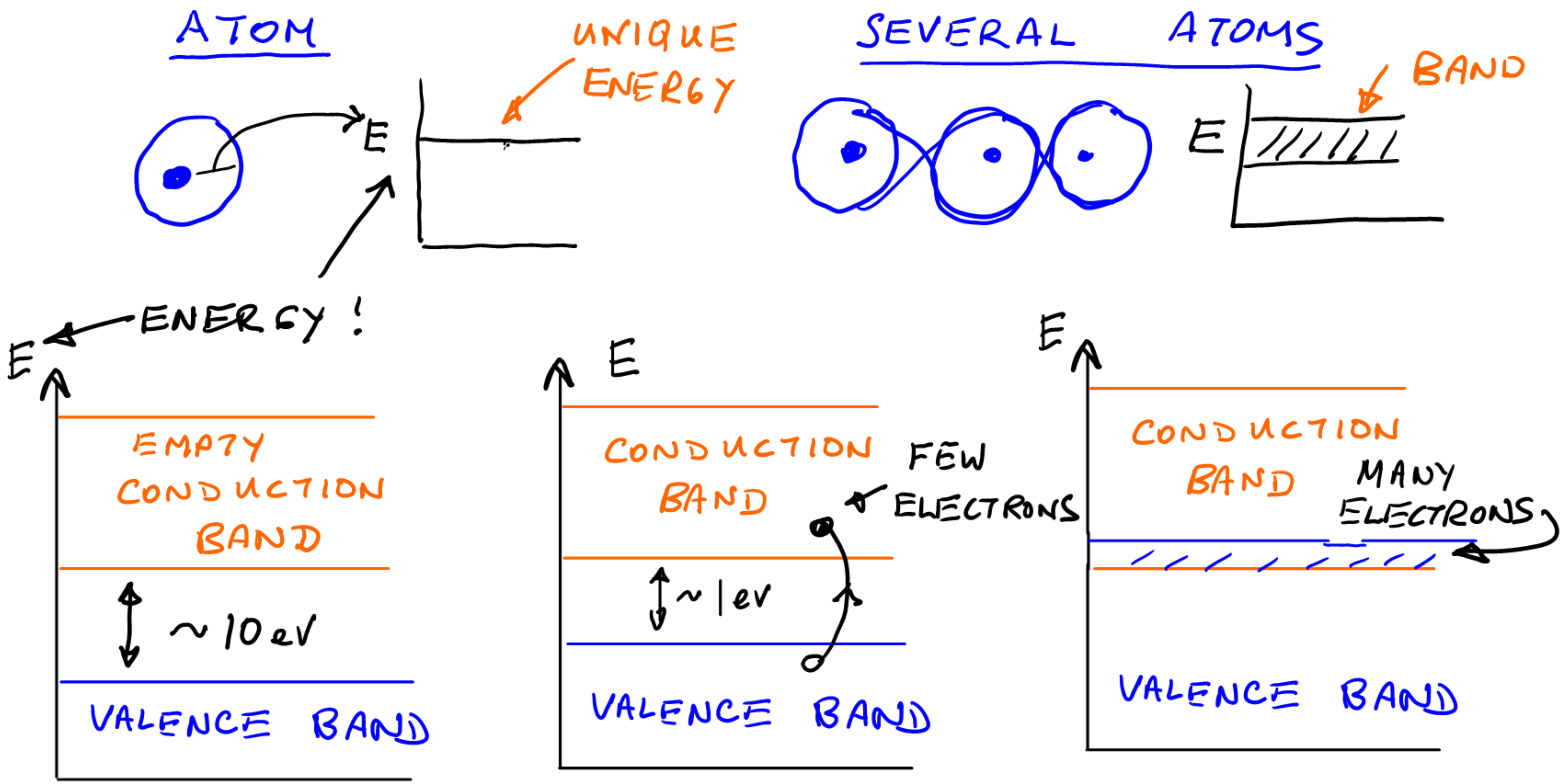
CONDUCTORS

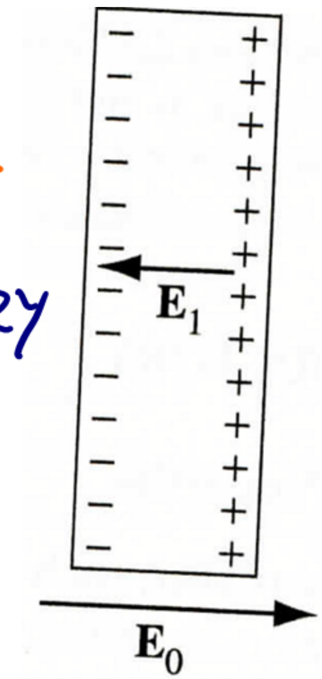


INSULATOR (CERAMIC)

SEMI-CONDUCTOR (SILICON)

METAL (COPPER)

i) FIELD INSIDE A CONDUCTOR $= 0$



EXTERNAL +VE $\bar{E}_0$ DRIVES +VE CHARGES RIGHT

DRIVES −VE CHARGES LEFT

CHARGES PILE UP AT CONDUCTOR BOUNDARY

THESE INDUCED CHARGES PRODUCE THEIR OWN FIELD $\bar{E}_1$ IN DIRECTION OPPOSITE $\bar{E}_0$

CHARGES FLOW UNTIL $|\bar{E}_1| = |\bar{E}_2|$

FIELD INSIDE CONDUCTOR $= 0$

ii) $\rho = 0$ INSIDE CONDUCTOR

FOLLOWS FROM GAUSS $\quad \bar{\nabla}\cdot E = \rho/\varepsilon_0$

0

iii) ANY NET CHARGE RESIDES ON SURFACE

CHARGES MIGRATE UNDER EXTERNAL FIELD UNTIL THIS IS TRUE.

iv) CONDUCTOR IS AN EQUIPOTENTIAL

THE WHOLE CONDUCTOR IS AT THE SAME POTENTIAL

FOR 2 POINTS ON SURFACE, OR INSIDE $\bar{a}$, $\bar{b}$

$$\underbrace{V(\bar{a}) - V(\bar{b})}_{V(\bar{a}) = V(\bar{b})} = -\int_a^b \underbrace{\bar{E}}_{=0} \cdot d\bar{l} = 0$$

v) $\bar{E}$ IS PERPENDICULAR TO SURFACE

IF FIELD HAD TANGENTIAL COMPONENT CHARGE WOULD FLOW UNTIL IT WAS CANCELED

CHARGE UNIFORMLY DISTRIBUTED ON SURFACE IS MINIMUM ENERGY $W = \frac{1}{8\pi\varepsilon_0} q^2/R$

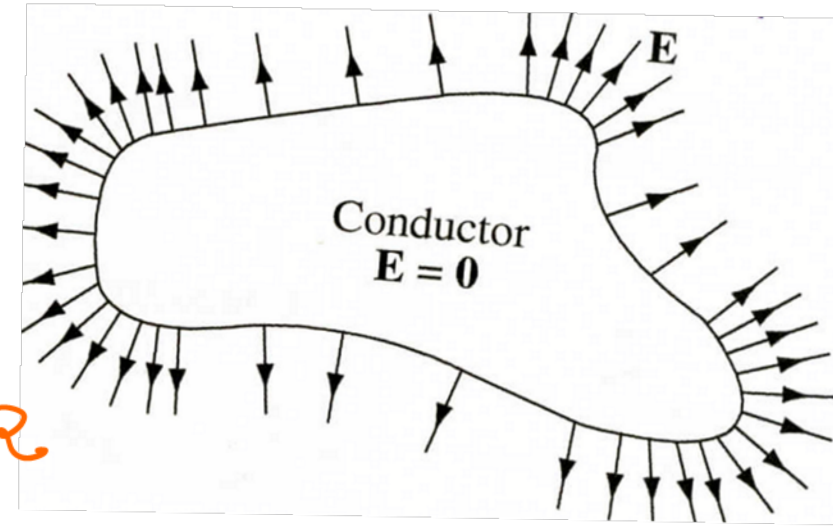
DISTRIBUTED UNIFORMLY THRU VOLUME

$$W = \frac{3}{20\pi\varepsilon_0} q^2/$$

ELECTRIC FIELD $\bar{E}$ AROUND CONDUCTOR

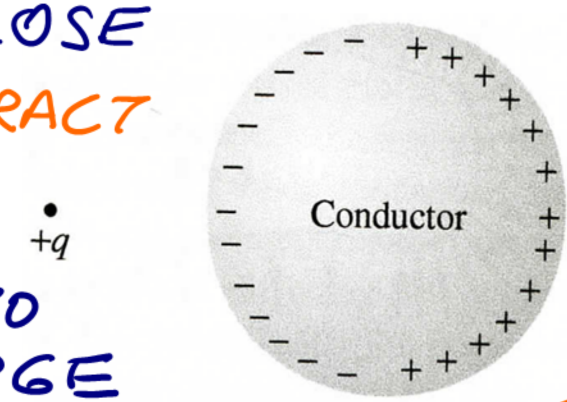
- PERP $\rightarrow$ CHARGE UNIFORM

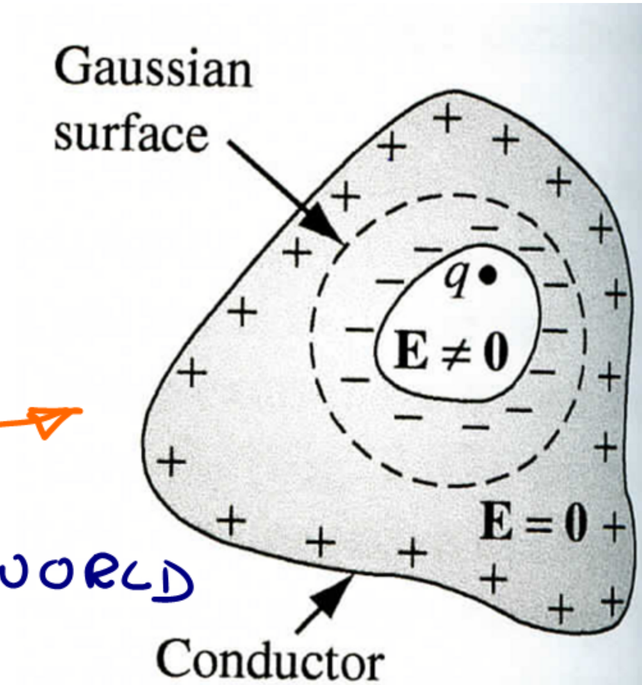
- ZERO INSIDE CONDUCTOR



INDUCED CHARGES

- HOLD CHARGE CLOSE TO CONDUCTOR ATTRACT
- UNLIKE CHARGES MOVE CLOSER TO EXTERNAL CHARGE





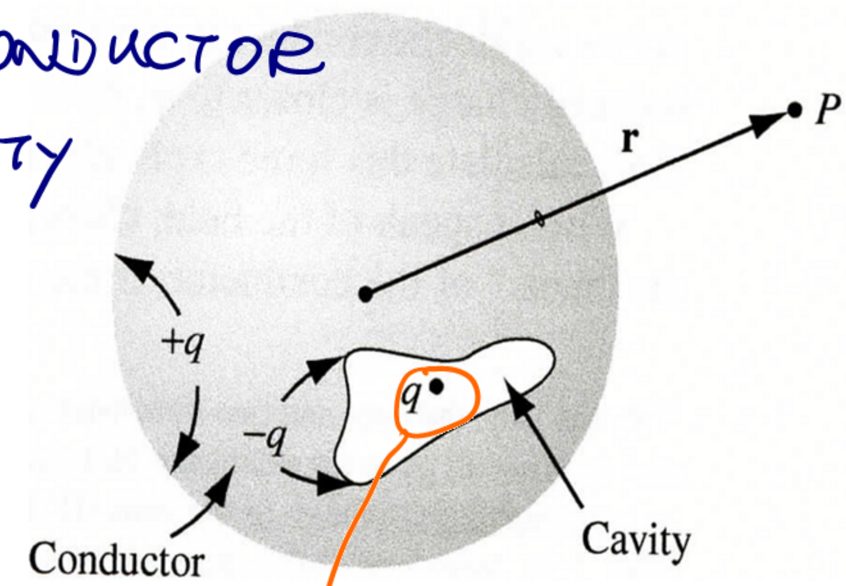
- CAVITY ISOLATED FROM EXTERAL WORLD
  FIELD IN CAVITY NOT ZERO
- NO EXTERAL FIELD PENETRATES CAVITY
  CANCELED BY SURFACE CHARGES
- NO FIELD FROM CAVITY GETS OUT
  CANCELED BY CHARGES ON WALL OF CAVITY
- GAUSSIAN SURFACE INSIDE CONDUCTOR

$$\int \bar{E} \cdot d\bar{a} = 0 \rightarrow Q_{ENC} = q + q_{INDUCED} = 0$$

$$q_{INDUCED} = -q \rightarrow$$ CONDUCTOR NEUTRAL OVERALL

↳ $+q$ ON SURFACE

AN UNCHARGED SPHERICAL CONDUCTOR HAS AN ODDLY SHAPED CAVITY INSIDE IT → WHAT IS THE FIELD OUTSIDE SPHERE?



CHARGE INSIDE CAVITY

CHARGE +q IN CAVITY INDUCES −q ON WALL

DISTRIBUTES ITSELF ON WALL OF CAVITY → CANCELS q FOR ALL POINTS OUTSIDE CAVITY

CONDUCTOR — NO NET CHARE ∴ +q UNIFORMLY OVER SURFACE

$$\bar{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

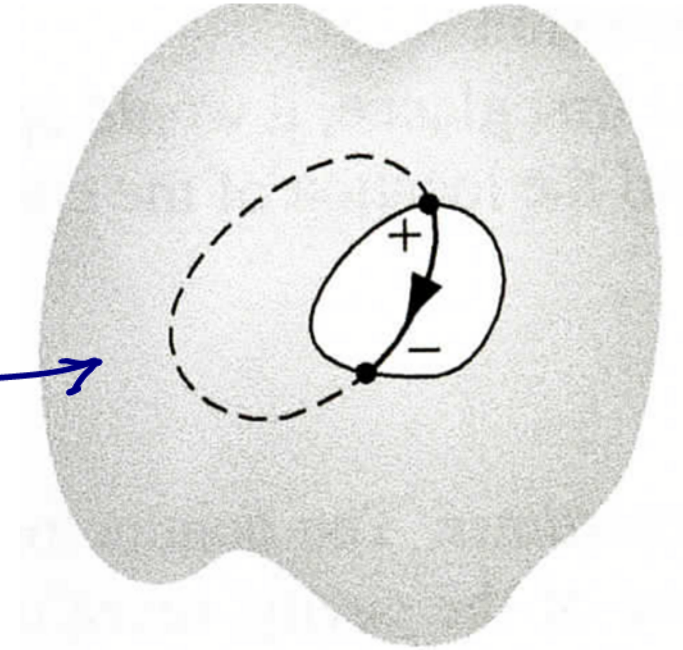
READ DISCUSSION IN TEXT BOOK

CAVITY CONTAINING ZERO CHARGE

→ FIELD IN CAVITY = 0

ANY FIELD LINE WOULD GO + → −

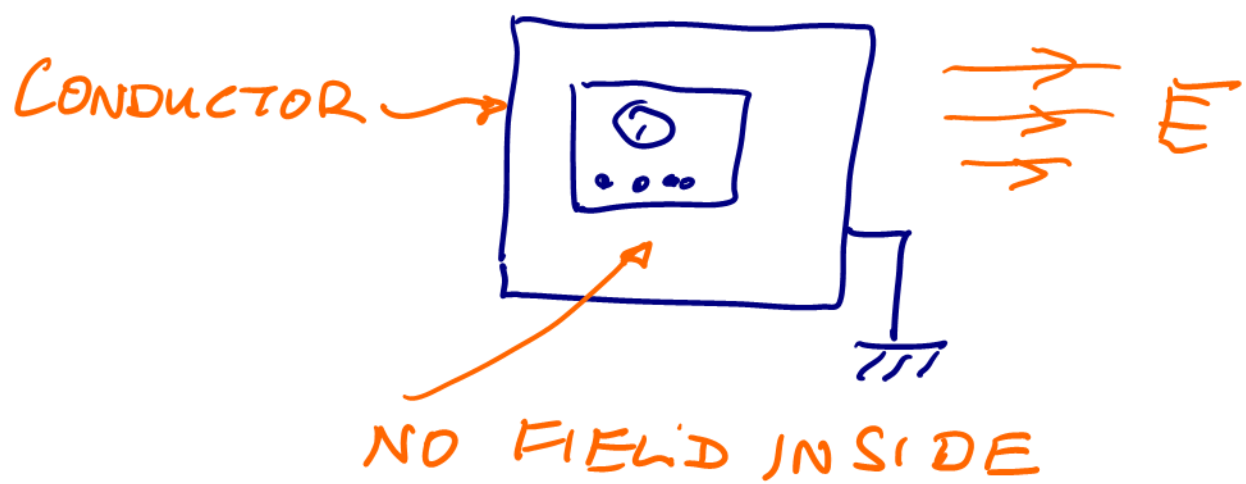
$\int$ING AROUND A LOOP



IF $\bar{E} \neq 0$ $\oint \bar{E} \cdot d\bar{l}$ +VE

BUT $\oint \bar{E} \cdot d\bar{l} = 0$ → NO CHARGE ON SURFACE OF CAVITY

→ FARADAY CAGE

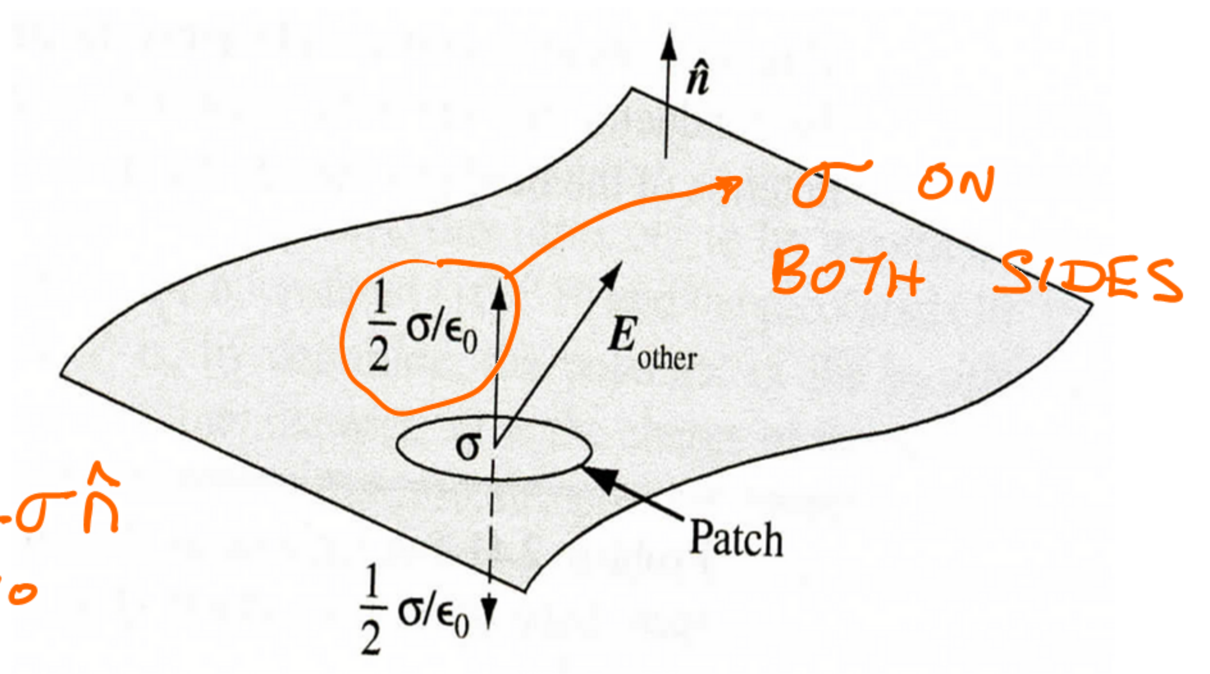


SURFACE CHARGE & FORCE ON A CONDUCTOR

FIELD INSIDE $= 0$

BOUNDARY CONDITION

$$E = \frac{\sigma}{\varepsilon_0} \hat{n}$$



HAD $\frac{\partial V_{ABOVE}}{\partial n} - \frac{\partial V_{BELOW}}{\partial n} = \frac{1}{\varepsilon_0}\sigma \hat{n}$

$$\sigma = -\varepsilon_0 \, \partial V / \partial n$$

IN ELECTRIC FIELD $\longrightarrow$ FORCE ON CONDUCTOR

$\bar{E}$ IS DISCONTINUOUS AT SURFACE

USE AVERAGE

$$\bar{f} = \sigma \bar{E}_{AV} = \frac{1}{2}\sigma\left(\bar{E}_{ABOVE} + \bar{E}_{BELOW}\right)$$

LOOK AT LITTLE PATCH IN DIAGRAM

↳ SMALL ENOUGH TO BE FLAT

$$\bar{E}_{TOTAL} = \bar{E}_{PATCH} + \bar{E}_{OTHER}$$

THIS CANNOT EXERT FORCE ON PATCH

REST OF SURFACE OF CONDUCTOR

E_{OTHER} HAS NO DISCONTINUITY

↳ DISCONTINUITY IS FROM $\bar{E}_{PATCH}$

$$\bar{E}_{ABOVE} = \bar{E}_{OTHER} + \frac{\sigma}{2\varepsilon_0}\hat{n} \; ; \; \bar{E}_{BELOW} = \bar{E}_{OTHER} - \frac{\sigma}{2\varepsilon_0}\hat{n}$$

$$\bar{E}_{OTHER} = \frac{1}{2}\left(\bar{E}_{ABOVE} + \bar{E}_{BELOW}\right) = \bar{E}_{AVERAGE}$$

$$\bar{f} = \frac{1}{2\varepsilon_0}\sigma^2\hat{n}$$

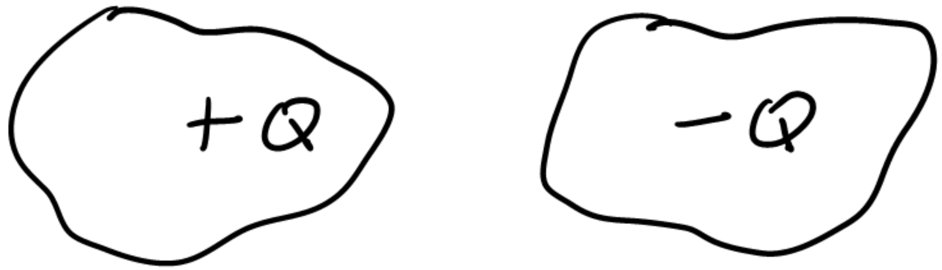
PULLS CONDUCTOR INTO FIELD

↳ FORCE / UNIT AREA

$$P = \frac{1}{2\varepsilon_0} E^2$$

ELECTROSTATIC PRESSURE

CAPACITORS



TWO CONDUCTORS

V IS CONSTANT OVER CONDUCTOR

WELL DEFINED → $V = V_+ - V_- = \int_-^+ \bar{E} \cdot d\bar{l}$

DO NOT KNOW CHARGE DISTRIBUTION

↳ CANNOT CALCULATE $\bar{E}$

$\bar{E} \propto Q \rightarrow \bar{E} = \frac{1}{4\pi\varepsilon_0} \int \frac{\rho}{\mathscr{r}^2} \hat{\mathscr{r}} \, d\tau$

DOUBLE CHARGE
DOUBLE $\bar{E}$

$\bar{E} \propto Q \rightarrow V \propto Q$

$C = \frac{Q}{V}$ → CAPACITANCE

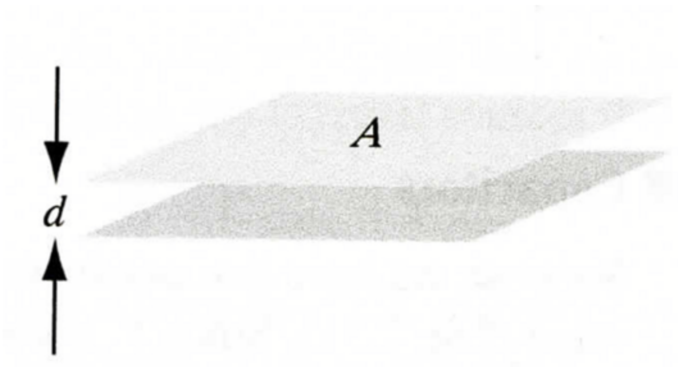
$C = \frac{(+)}{(+)} = (+)$

UNITS COULOMB/VOLT

= FARAD

μF, pF

PARALLEL PLATE CAPACITOR



TWO METAL PLATES

AREA → A

DISTANCE APART → d

→ CHARGE SPREADS OUT UNIFORMLY

SURFACE CHARGE DENSITY TOP PLATE $\sigma = \frac{Q}{A}$

$$E = \frac{1}{\varepsilon_0}\frac{Q}{A} \longrightarrow V = \frac{Q}{A\varepsilon_0}\cdot d$$

$$C = \frac{Q}{V} = \frac{A\varepsilon_0}{d}$$

$A = 1\,cm \times 1\,cm$

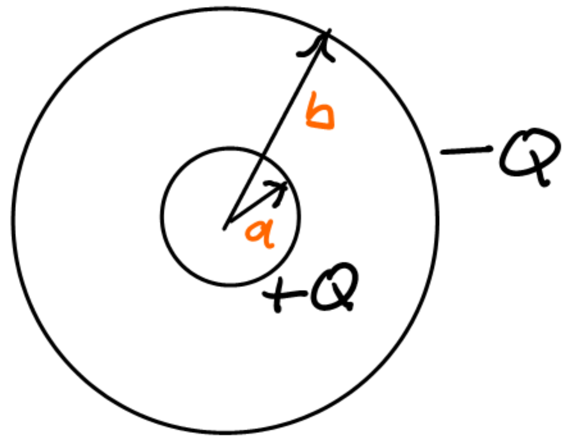
$d = 1\,mm$

$C = 9 \times 10^{-13}\,F$

$$C = \frac{1\times10^{-2} \times 1\times10^{-2}}{1\times10^{-3}} \cdot 8.85\times10^{-12} \approx 9\times10^{-13}$$

$\approx 1\,pF$ (ONE PUFF)

CAPACITANCE OF 2 CONCENTRIC SPHERICAL SHELLS



$$\bar{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\,\hat{r}$$

$$V = -\int_b^a \bar{E}\cdot d\bar{l} = -\frac{Q}{4\pi\varepsilon_0}\int_b^a \frac{1}{r^2}\,dr = Q\left(\frac{1}{a} - \frac{1}{b}\right)$$

$$C = \frac{Q}{V} = 4\pi\varepsilon_0\,\frac{ab}{(b-a)}$$

WORK DONE TO CHARGE CAPACITOR

MOVE ELECTRONS FROM +VE → −VE PLATE

DO WORK AGAINST $\bar{E}$

SOME INTERMEDIATE STAGE

↳ CHARGE ON +VE PLATE q

↳ POT DIFFERENCE q/C

$$V(\bar{b}) - V(\bar{a}) = \frac{W}{Q} \rightarrow \quad dW = V\,dq \rightarrow dW = \frac{q}{C}\cdot dq$$

WORK TO GO FROM $q = 0 \rightarrow q = Q$

$$W = \int_0^Q \frac{q}{C}\cdot dq = \frac{1}{2}\frac{Q^2}{C}$$

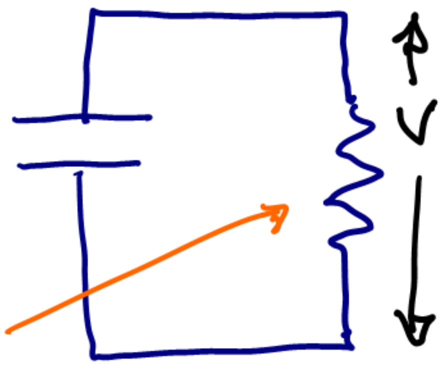
$$Q = CV \rightarrow \quad W = \frac{1}{2}CV^2$$

ENERGY STORED ON CAPACITOR

APPLICATIONS of CAPACITORS

TIMING CIRCUIT

CAPACITOR C



RESISTOR R

CHARGE CAPACITOR TO Q_0 AT TIME $t=0$

$$Q(t) = Q(0)\, e^{-t/RC}$$

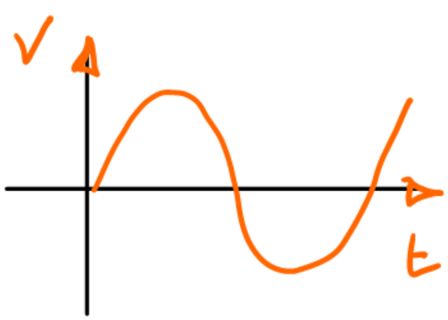
$$V(t) = V(0)\, e^{-t/RC}$$

FREQUENCY FILTER

CONSTANT V

$V=0$

IN EQUILIBRIUM



$V = V_0 \cos\omega t$

$V = V_0 \cos\omega t$

FREQUEN

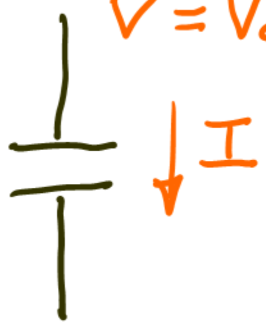
PHASE SHIFT

RESISTOR

$V = IR$ OHM'S LAW FOR D.C.

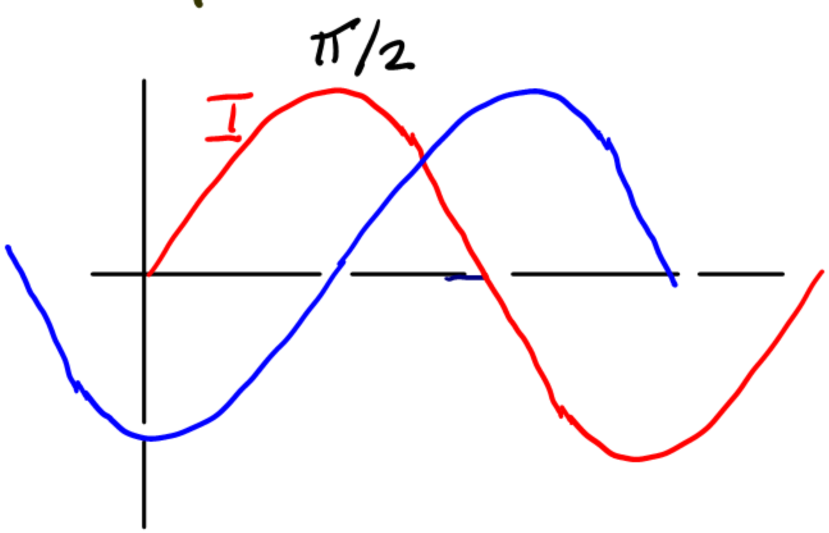
$V = V_0 \cos \omega t$

FREQUENCY



$$V = \frac{I}{j\omega C}$$

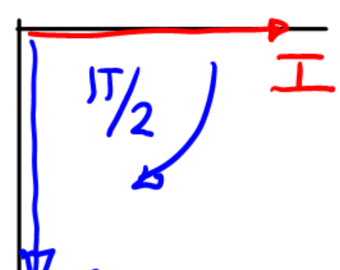
$\sqrt{-1}$



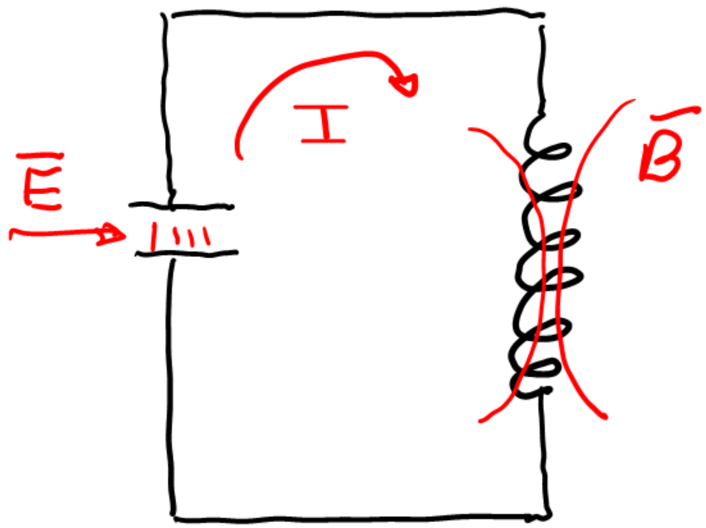
ϕ in $\cos(\omega \phi)$

$= \cos(\omega t) \Rightarrow V = V_0 e^{j\omega t}$

$V_0(\cos \omega t + j \sin \omega t)$



GENERATE ELECTROMAGNTIC WAVES



CAPACITOR DISCHARGES THRU INDUCTOR

CURRENT PRODUCES B FIELD

B FIELD COLLAPSES

PRODUCES CURRENT → CHARGES CAPACITOR