

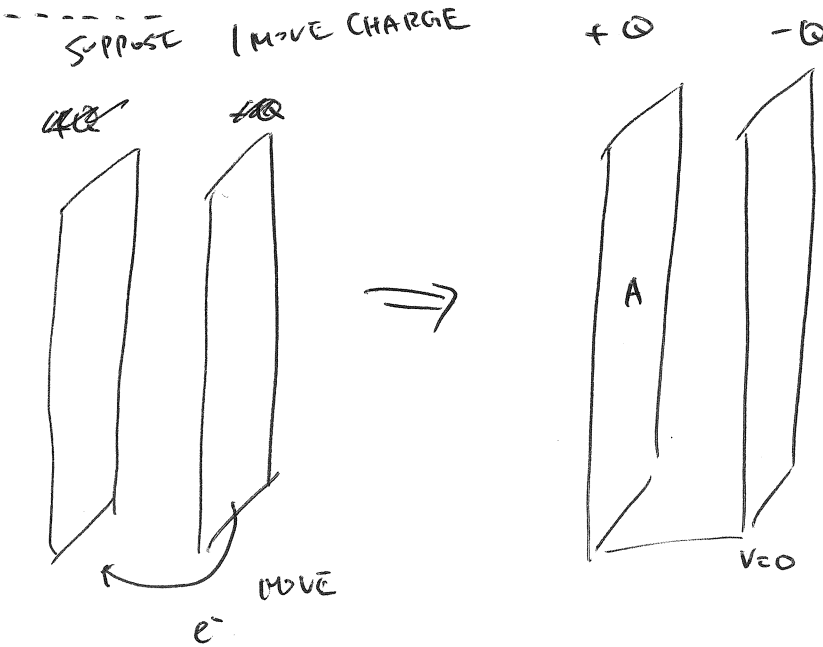
WEEK 4

~~WEEK 4~~

DEMO : MON EM 357 LARGE PARALLEL PLATES
 WED EM 352, 357 SCREW DRIVER DISCHARGE
 FRI EM 351 LEYDEN JAR

CAPACITANCE

$$C = \frac{Q}{|\Delta V|} \text{ (FARAD)} = 1 \text{ C/V}$$



$$\sigma = \frac{Q}{A}$$

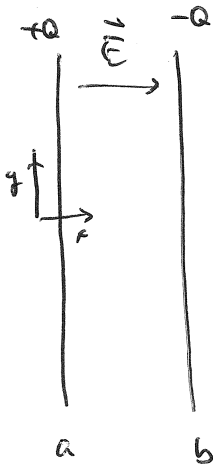


GAUSS'S LAW

$$|\vec{E}| = \frac{\sigma}{\epsilon_0}$$

$$|\vec{E}| = \frac{Q}{\epsilon_0 A}$$

$$V_f =$$



$$V(b) = 0$$

$$W_{ab} = \int_a^b \epsilon_r E dx = \epsilon_r E (b-a)$$

$$= U(a) - U(b) = \epsilon_r (V(a) - V(b))$$

$$\epsilon_r E (b-a) = \epsilon_r (V(a) - 0)$$

$$Ed = V(a)$$

$$V(b) = 0$$

~~$$C = \frac{Q}{V} \quad \left(\frac{\epsilon_r \epsilon_0 A}{d} \right) \quad \left(\frac{Q}{\epsilon_r \epsilon_0 A} \right) \quad \left(\frac{Q}{\epsilon_r \epsilon_0 A} \right) \quad \left(\frac{Q}{\epsilon_r \epsilon_0 A} \right)$$~~

~~$$C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{\epsilon_r \epsilon_0 A}} = \frac{\epsilon_r \epsilon_0 A}{d}$$~~

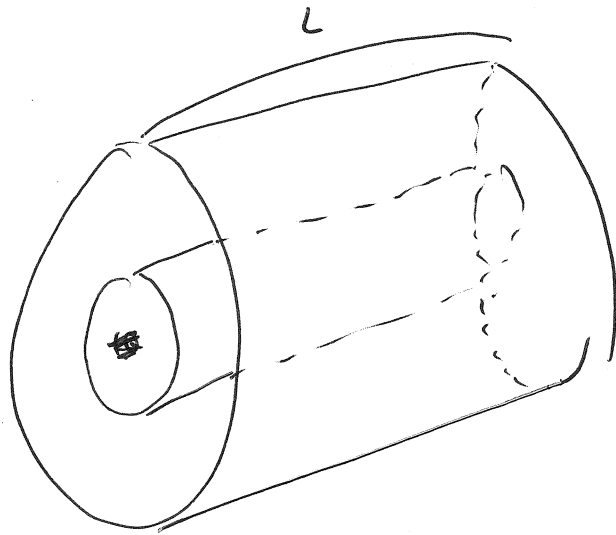
~~$$C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{\epsilon_r \epsilon_0 A}} = \frac{\epsilon_r \epsilon_0 A}{d}$$~~

$$V = \frac{Qd}{\epsilon_r \epsilon_0 A}$$

$$\therefore C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{\epsilon_r \epsilon_0 A}}$$

$$C = \frac{\epsilon_r \epsilon_0 A}{d}$$

HOW ABOUT FOR TWO METALLIC CYLINDERS?

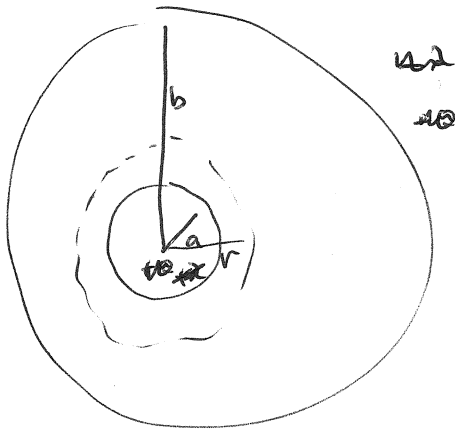


L IS LONG

CONTRIBUTION FROM

FILMGE FIELD IS LOW

HOW DO WE CALCULATE CAPACITANCE?



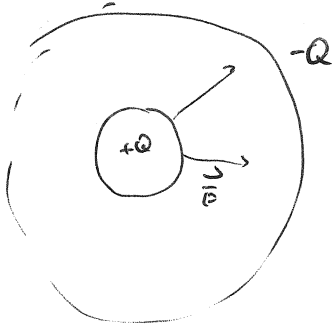
GAUSSIAN SURFACE IS A CYLINDER

$$\Phi = \frac{Q_{ENC}}{\epsilon_0}$$

$$\Phi = E(r) \cdot 2\pi r L = E(r) \cdot 2\pi r L$$

$$\frac{Q_{ENC}}{\epsilon_0} = \frac{1}{\epsilon_0} Q = \frac{Q}{\epsilon_0}$$

$$E(r) = \frac{Q}{2\pi r L \epsilon_0}$$



TAKE $V(a) = 0$

$$W_{ab} = \int_a^b \vec{E} \cdot d\vec{r} \quad r^{\hat{r}}$$

$$= \int_a^b \frac{Q}{2\pi r L \epsilon_0} \cdot dr$$

$$= \frac{Q}{2\pi L \epsilon_0} \ln r \Big|_a^b$$

$$= \frac{Q}{2\pi L \epsilon_0} \ln \frac{b}{a}$$

$$= \epsilon_0 (V(a) - V(b))$$

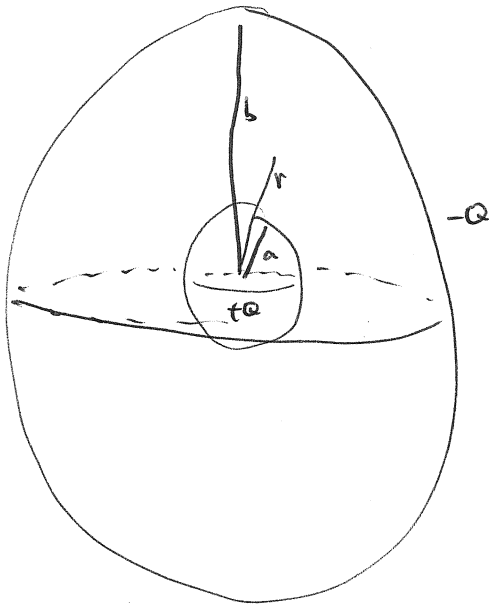
$$V(a) - V(b) = \frac{Q}{2\pi L \epsilon_0} \ln \frac{b}{a}$$

$$V(b) = -\frac{Q}{2\pi L \epsilon_0} \ln \frac{b}{a}$$

$$|\Delta V| = \frac{Q}{2\pi L \epsilon_0} \ln \frac{b}{a}$$

$$C = \frac{Q}{|\Delta V|} = \frac{Q}{\frac{Q}{2\pi L \epsilon_0} \ln \frac{b}{a}} = \frac{2\pi L \epsilon_0}{\ln(b/a)}$$

SPHERICAL CAPACITOR



$$\vec{E}(r) = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \hat{r}$$

$$V_a - V_b = \int_a^b \vec{E} \cdot d\vec{l} = \int_a^b \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} dr$$

$$= \frac{1}{4\pi\epsilon_0} \left[-\frac{Q}{r} \right]_a^b$$

$$= \frac{1}{4\pi\epsilon_0} \left[-\frac{Q}{b} + \frac{Q}{a} \right]$$

$$V(a) - V(b) = \frac{1}{4\pi\epsilon_0} \left[\frac{Q}{a} - \frac{Q}{b} \right]$$

$$\Delta V = \frac{1}{4\pi\epsilon_0} Q \left[\frac{1}{a} - \frac{1}{b} \right]$$

$$C = \frac{Q}{|\Delta V|} = \frac{\epsilon_0 \epsilon_r \frac{A}{ab}}{\frac{1}{a} - \frac{1}{b}}$$

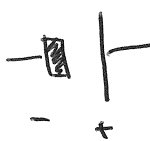
$$C = \frac{\epsilon_r \epsilon_0 \frac{A}{ab}}{\frac{b-a}{ab}}$$

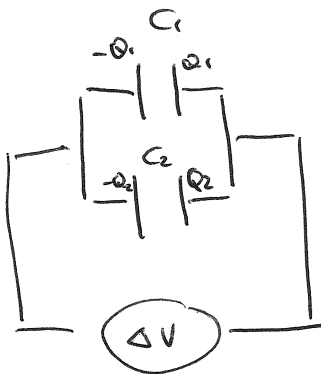
$$C = \epsilon_r \epsilon_0 \cdot \frac{ab}{b-a}$$

END FOR?

CAPACITORS IN PARALLEL AND SERIES

 CAPACITORS

 BATTERY



$$C = \frac{Q}{V} \Rightarrow CV = Q$$

$$Q_1 = C_1 \Delta V$$

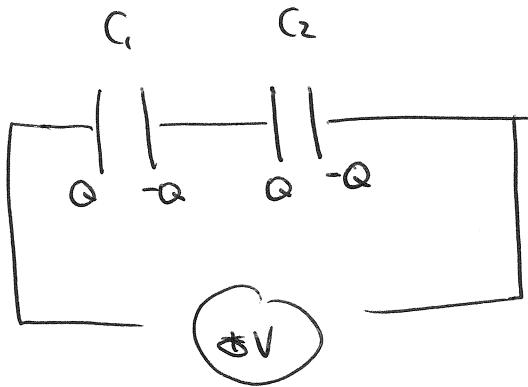
$$Q_2 = C_2 \Delta V$$

$$Q_1 + Q_2 = (C_1 + C_2) \Delta V$$

$$Q_T = C_T \Delta V$$

$$C_T = C_1 + C_2$$

C_T : TOTAL CAPACITANCE
 EQUIVALENT
 CAPACITANCE



$$Q = C_1 \Delta V_1$$

$$Q = C_2 \Delta V_2$$

$$\Delta V_1 + \Delta V_2 = \Delta V$$

$$\frac{Q}{C_1} + \frac{Q}{C_2} = \Delta V$$

$$Q \left(\frac{1}{C_1} + \frac{1}{C_2} \right) = \Delta V$$

$$Q \frac{1}{C_{eq}} = \Delta V$$

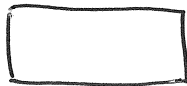
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

DRAW

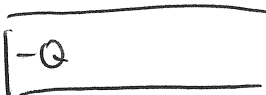
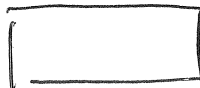
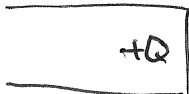
C_1

C_2

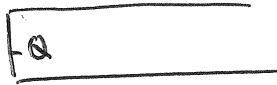
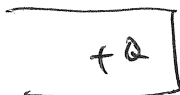
1.

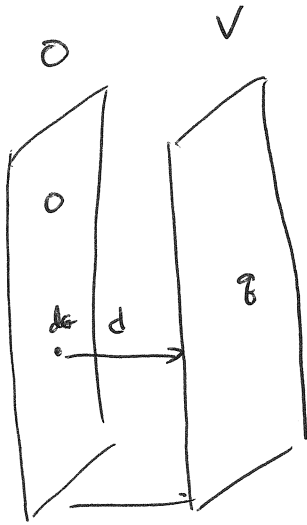


1.



2.





$$\text{WORK} = dq dE$$

$$E = \frac{\sigma}{\epsilon_0} = \frac{q d}{A \epsilon_0}$$

$$d\text{WORK} = dq = \frac{q d}{A \epsilon_0}$$

ENERGY STORED IN CAPACITOR

$$\begin{aligned} \text{ENERGY} &= \int_0^Q d\text{WORK} = \int_0^Q dq \frac{q d}{A \epsilon_0} = \left. \frac{q^2 d}{2 A \epsilon_0} \right|_0^Q \\ &= \frac{Q^2 d}{2 A \epsilon_0} = \frac{Q^2}{2C} \end{aligned}$$

$$C = \frac{\epsilon_0 A}{d}$$

$$Q = CV$$

$$\therefore \text{ENERGY} = \frac{Q^2}{2C} = \frac{C^2 V^2}{2C} = \frac{1}{2} CV^2$$

ELECTRIC FIELD STORES ENERGY

$$U = \frac{Q^2}{2C}$$

$$E = \frac{Q}{\epsilon_0 A}$$

$$U = \frac{\epsilon_0^2 A^2 E^2}{2C} = \frac{\epsilon_0^2 A^2 E^2}{2 \epsilon_0 \frac{A}{d}}$$

$$C = \frac{\epsilon_0 A}{d}$$

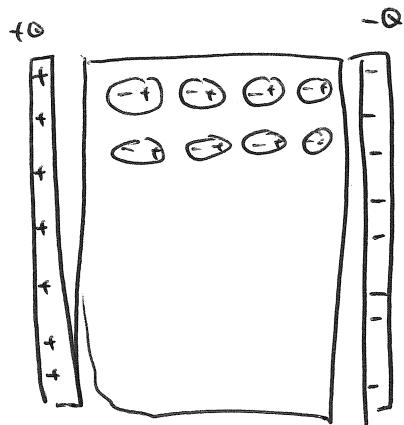
$$= \frac{\epsilon_0^2 A^2 E^2 d}{2 \epsilon_0 A}$$
$$= \frac{\epsilon_0 A d E^2}{2}$$

$Ad = \text{VOLUME}$

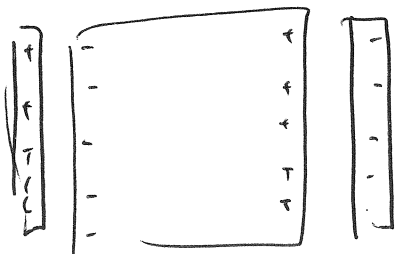
$$U = \frac{\epsilon_0 E^2}{2} V$$

$$\frac{U}{V} = \frac{\epsilon_0 E^2}{2}$$

DIELECTRICS



||



E INSIDE REDUCED

$$\bar{E}_{DIEL} = \frac{\bar{E}}{K}$$

$$V_{DIEL} = \frac{\bar{E}}{K} \cdot d = \frac{V}{K}$$

~~Q = CV~~

$$Q = CV$$

$$Q = C_{DIEL} V_{DIEL}$$

$$Q = C_{DIEL} \cdot \frac{V}{K}$$

$$Q = \frac{C_{DIEL}}{K} \cdot V$$

$$K C = DIEL$$

$$K = 1 \quad \text{VACUUM}$$

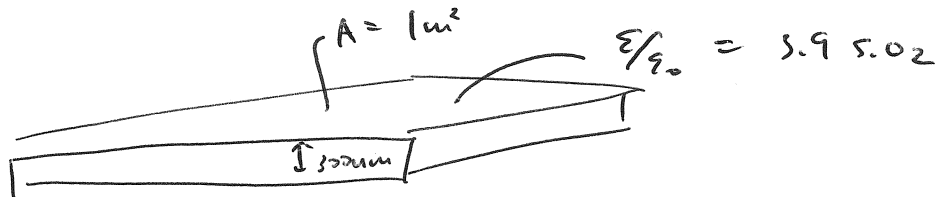
$$K = 80 \quad \text{WATER}$$

$$K = 310 \quad \text{SFT. OIL}$$

ϵ_0 : PERMITTIVITY OF FREESPACE (VACUUM)

$\epsilon = k\epsilon_0$ [PERMITTIVITY OF DIELECTRIC]

EXAMPLE CALCULATE CAPACITANCE OF S.D 2



$$C = 3.9 \cdot \frac{\epsilon_0 A}{d} \quad \text{FARADS}$$

$$= 3.9 \cdot \frac{8.85 \times 10^{-12}}{300 \times 10^{-9}}$$

$$C = 1.15 \times 10^{-4} \text{ F}$$

SO CAPACITANCE

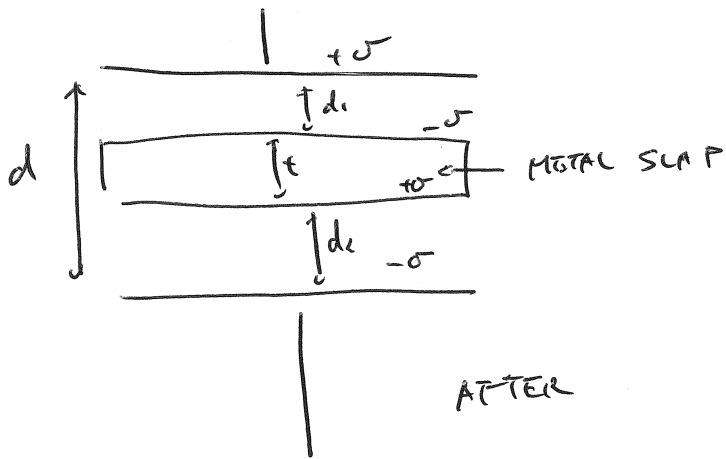
$$1.15 \times 10^{-4} \text{ F/m}^2$$

SO PER 1VOLT

$$1.15 \times 10^{-4} \text{ F/m}^2 \cdot 1 \text{ V} = 1.15 \times 10^{-4} \text{ C/m}^2$$

$$\frac{1.15 \times 10^{-4}}{1.6 \times 10^{-19}} = 7.2 \times 10^{14} \text{ e}^- / \text{m}^2 \text{ - VOLT}$$

EXAMPLE



ORIGINAL CAPACITANCE

$$\frac{\epsilon_0 A}{d}$$

CAPACITORS IN SERIES

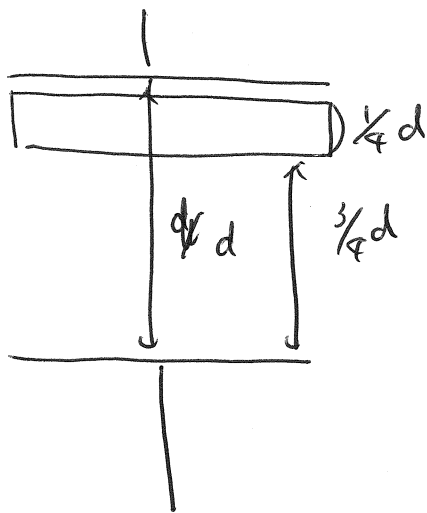
$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$d_1 = \frac{d-t}{2} = d_2$$

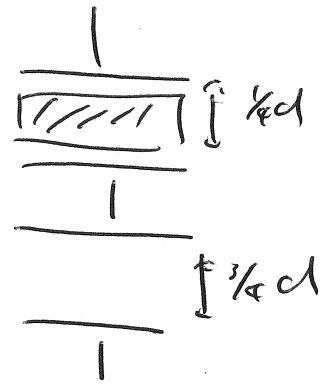
$$C_1 = C_2 = \frac{\epsilon_0 A}{\frac{d-t}{2}} = \frac{2\epsilon_0 A}{d-t}$$

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{2}{C_1} = \frac{2}{\frac{2\epsilon_0 A}{d-t}} = \frac{d-t}{\epsilon_0 A}$$

$$C_T = \frac{\epsilon_0 A}{d-t}$$



EQUIVALENT TO



$$\frac{1}{C_T} = \frac{1}{C_d} + \frac{1}{C_V}$$

$$C_d = \frac{k \epsilon_0 A}{\frac{1}{4} d}$$

$$C_V = \frac{\epsilon_0 A}{\frac{3}{4} d}$$

$$\frac{1}{C_T} = \frac{1}{\frac{k \epsilon_0 A}{\frac{1}{4} d}} + \frac{1}{\frac{\epsilon_0 A}{\frac{3}{4} d}}$$

$$= \frac{\frac{1}{4} d}{k \epsilon_0 A} + \frac{\frac{3}{4} d}{\epsilon_0 A}$$

$$\frac{1}{C_T} = \frac{\frac{1}{4} d + \frac{3}{4} k d}{k \epsilon_0 A} \quad \text{km}$$

$$C_T = \frac{k \epsilon_0 A}{\frac{1}{4} d + \frac{3}{4} k d}$$

END WED!

CURRENT AND RESISTANCE FRI

USE NOTES 2009

