CH 24

GOAL: lecture on problems to illustrate EACH SECTION.

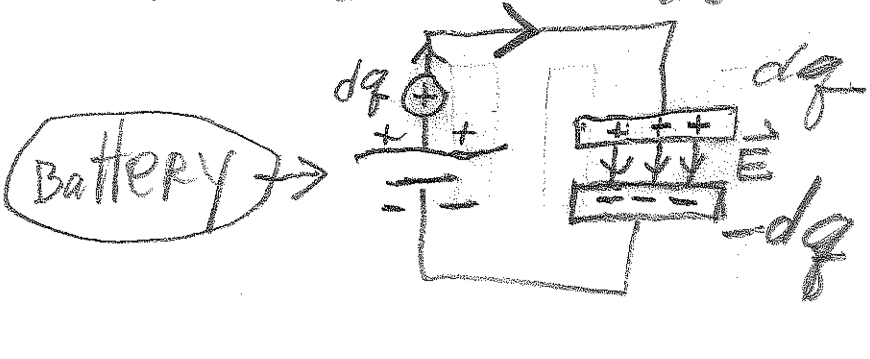
sections covered so far:

sec. 24.1, 24.2,

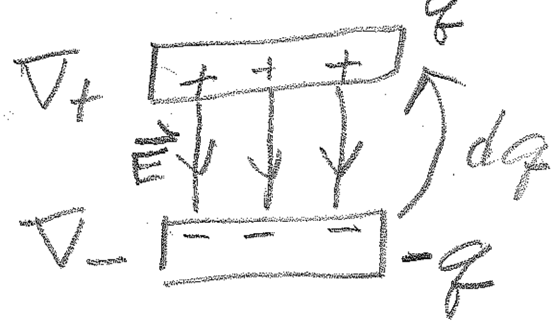
need 24.3, 24.4.

24.3 Energy calculations

IT TAKES WORK TO CHARGE UP a CAPACITOR, WORK that's stored as energy in the SPACE between the PLATES. $I = dq/dt$



Simulate charging process by removing dq from negative plate until $q = Q$.

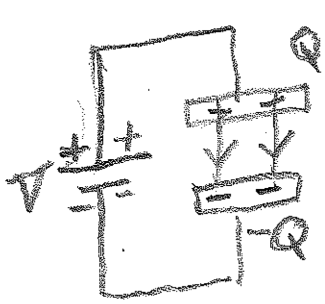


$$dU_E = dq \cdot (V_+ - V_-)$$

$$dU_E \equiv dq \cdot V, \quad V \equiv V_+ - V_-$$

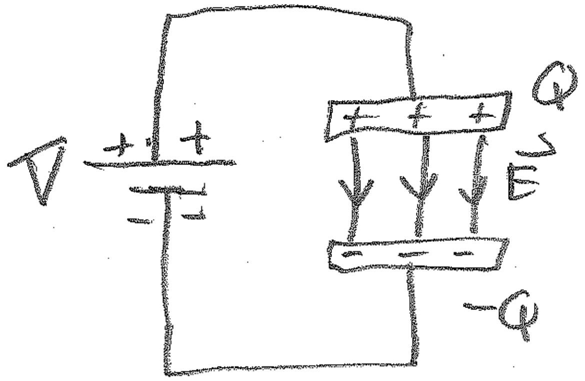
$$\int_0^{U} dU_E' = \int_0^{Q} dq \cdot V = \int_0^{Q} dq \cdot \left(\frac{q}{C}\right),$$

since $V = \frac{q}{C}$.



$$U_E = \int_0^{Q} \frac{q}{C} dq = \frac{Q^2}{2C} \Rightarrow \boxed{U_E = \frac{Q^2}{2C}}$$

↑ Assume plates initially uncharged.



NOTE:

$$\frac{Q^2}{2C} = \frac{(CV)^2}{2C} = \frac{1}{2}CV^2.$$

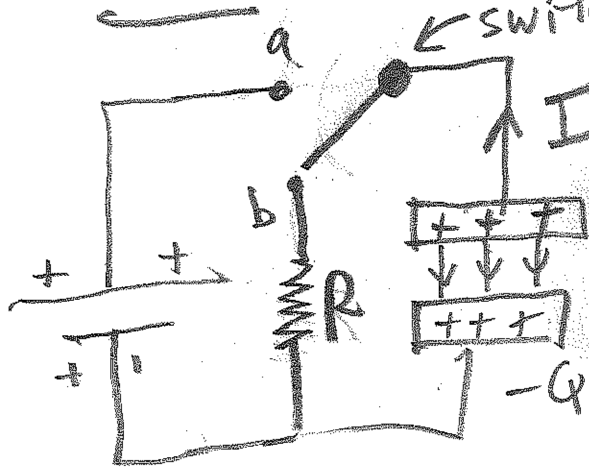
THUS, $U_E = \frac{1}{2}CV^2$

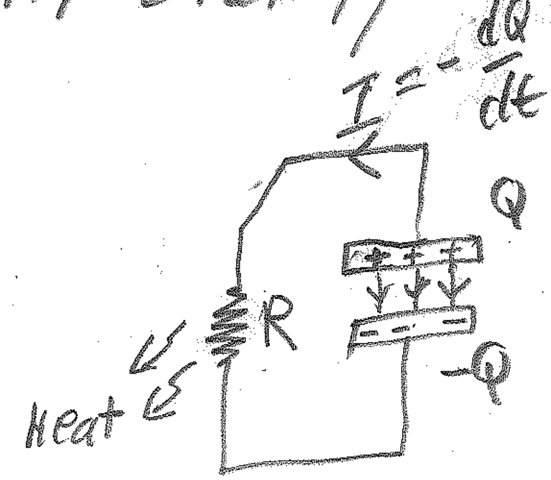
OR

$U_E = \frac{Q^2}{2C}$ (see test 2)

NOTE: U_E can be turned into

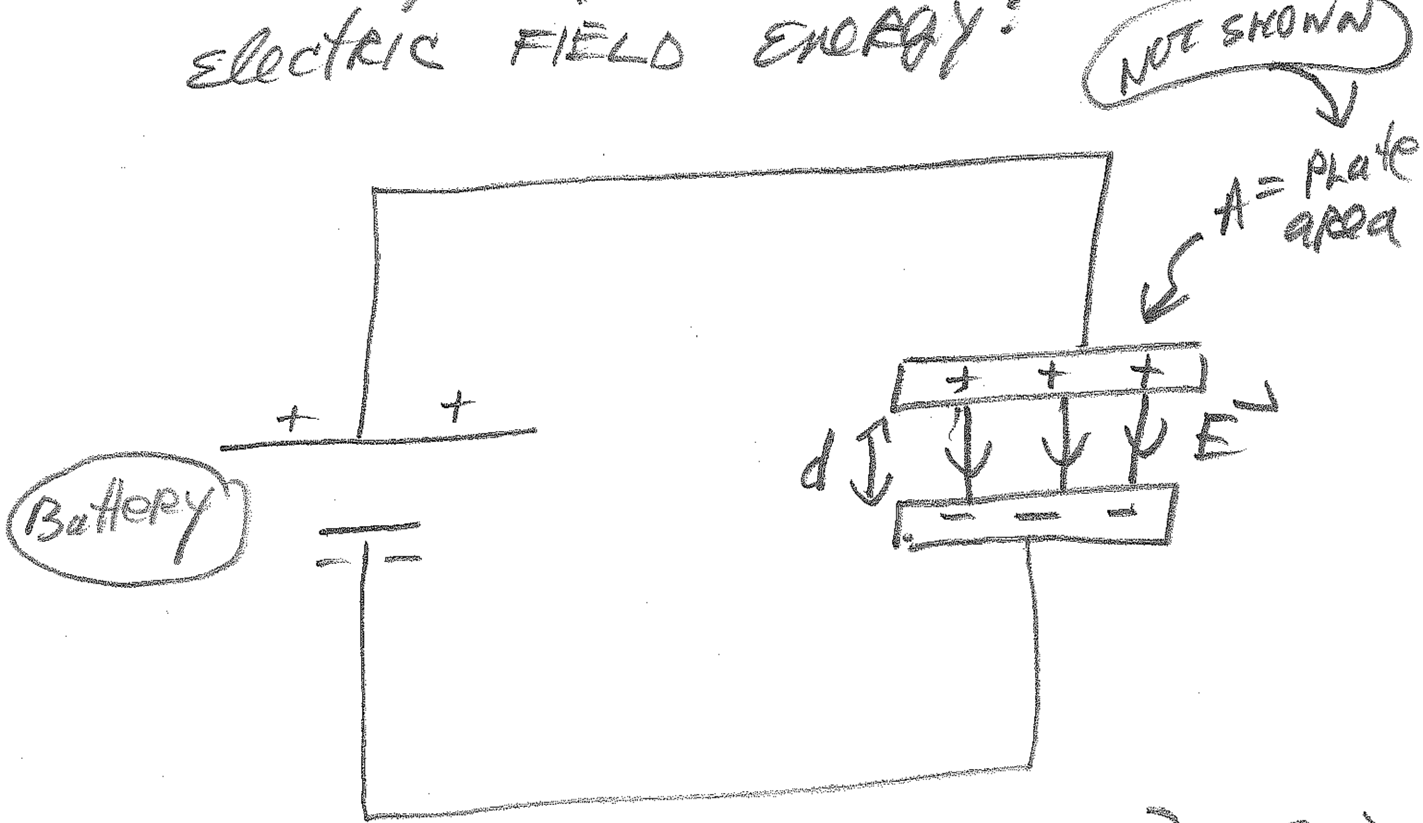
Heat OR light energy:





switch from a to b
to create Heat (OR Light)
THROUGH RESISTOR R.

Electric Field Energy:



$u_E \equiv$ Energy density $\equiv \dfrac{\frac{1}{2}CV^2}{A\cdot d}$ $\left(\dfrac{J}{m^3}\right)$

note: LOWER case.

$A\cdot d$ = volume between plates.

Energy density is for SPACE between plates.

UPPER case

Now, $\frac{1}{2}CV^2 = \frac{1}{2}\cdot\left(\dfrac{A\varepsilon_0}{d}\right)V^2 = U_E$

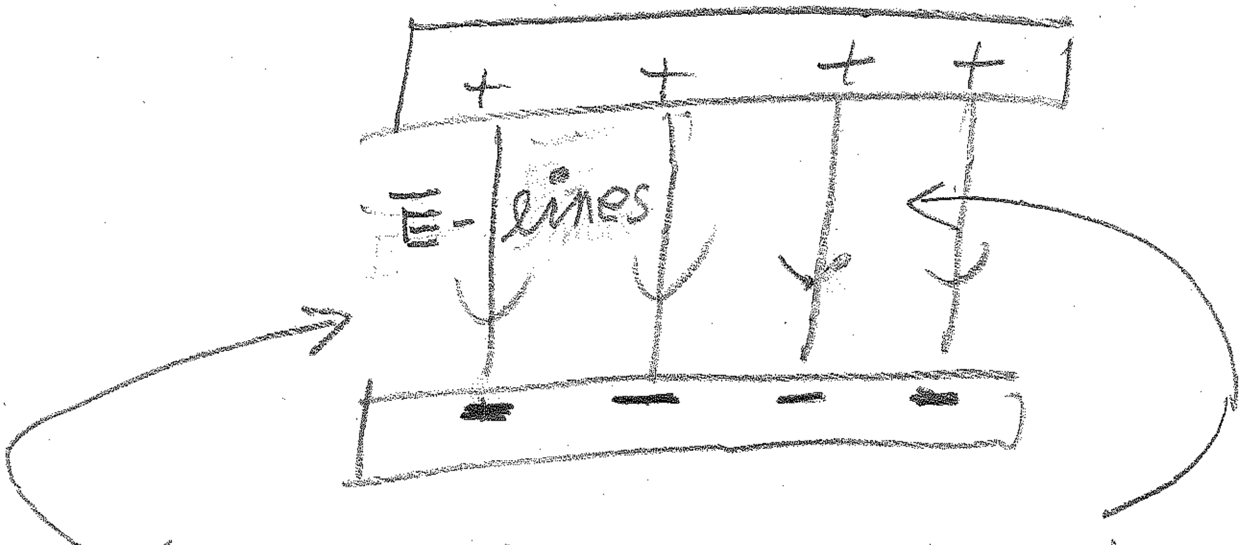
and $V = E\cdot d$

$\Rightarrow U_E = \frac{1}{2}\left(\dfrac{A\varepsilon_0}{d}\right)\cdot E^2 d^2 = \frac{1}{2}\varepsilon_0 E^2\cdot A\cdot d$

THUS:

$$u_E = \frac{U_E}{A \cdot d} = \frac{\frac{1}{2}\varepsilon_0 E^2 \cdot A \cdot d}{A \cdot d}$$

$$\boxed{u_E = \frac{1}{2}\varepsilon_0 E^2}$$

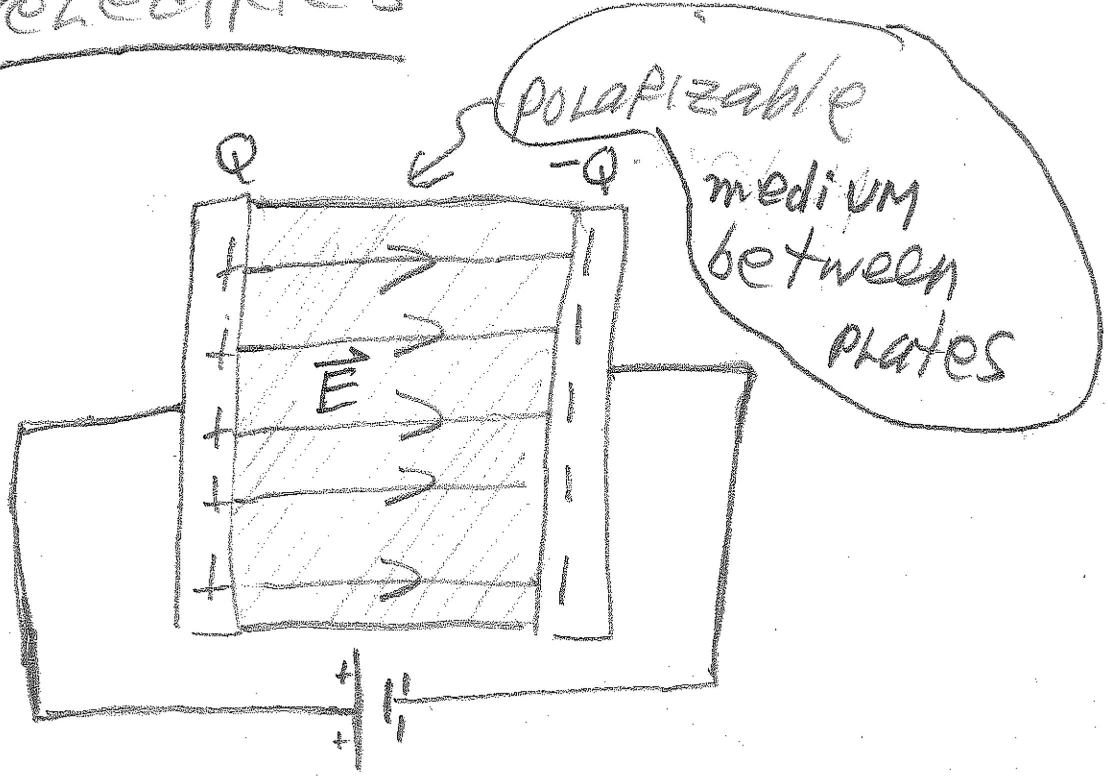


$u_E = \frac{1}{2}\varepsilon_0 E^2$

= ENERGY density IN SPACE of ELECTRIC FIELD.

THERE IS ENERGY IN THIS VACCUUM (EMPTY space).

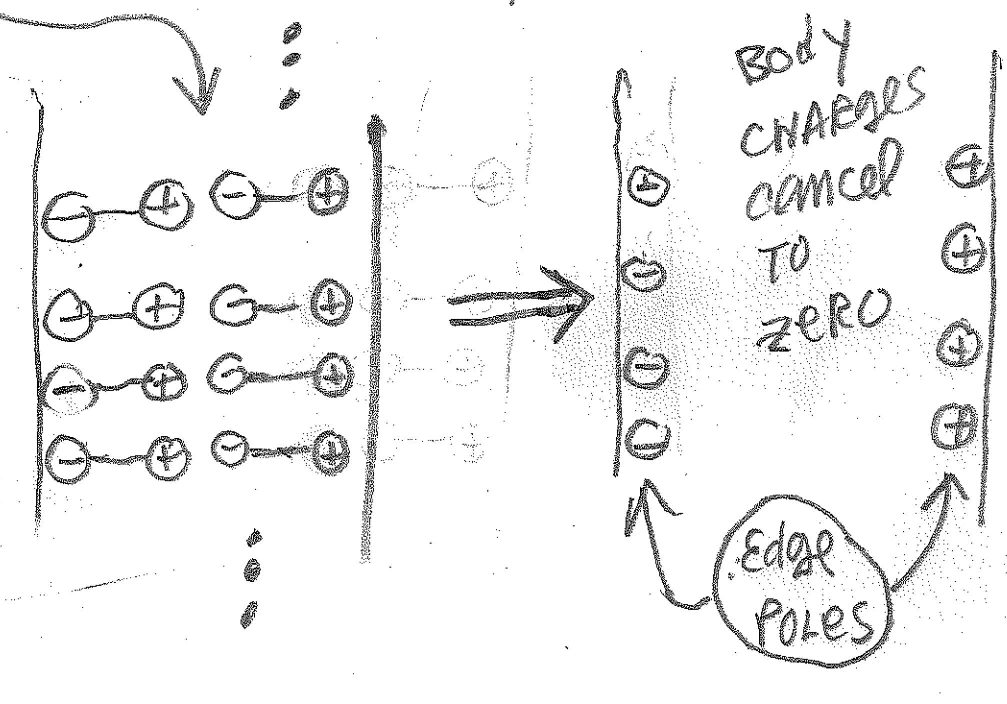
24.4 Dielectrics



see figure 24.5

SUB-microscopic view of medium:

The "body" poles cancel to zero, leaving only "edge" charges



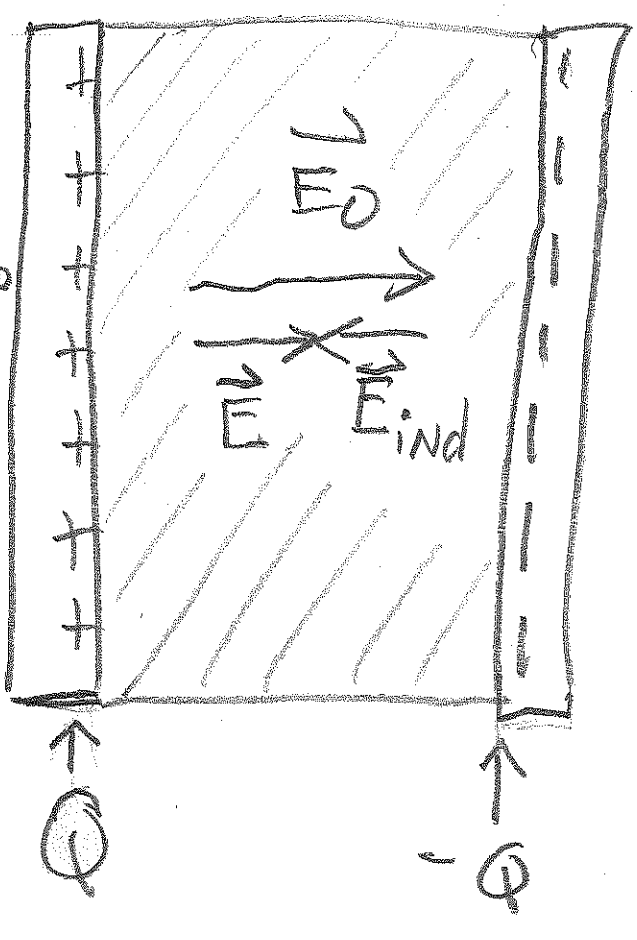
FIND NET ELECTRIC FIELD due TO EXTERNAL FIELD $\vec{E}_0$ (from PLATE CHARGES $\pm Q$) and the induced "edge" CHARGES:

$\vec{E} = \vec{E}_0 + \vec{E}_{IND}$

$|\vec{E}| < |\vec{E}_0|$

$E < E_0$

$$\boxed{E = \frac{E_0}{K}}$$



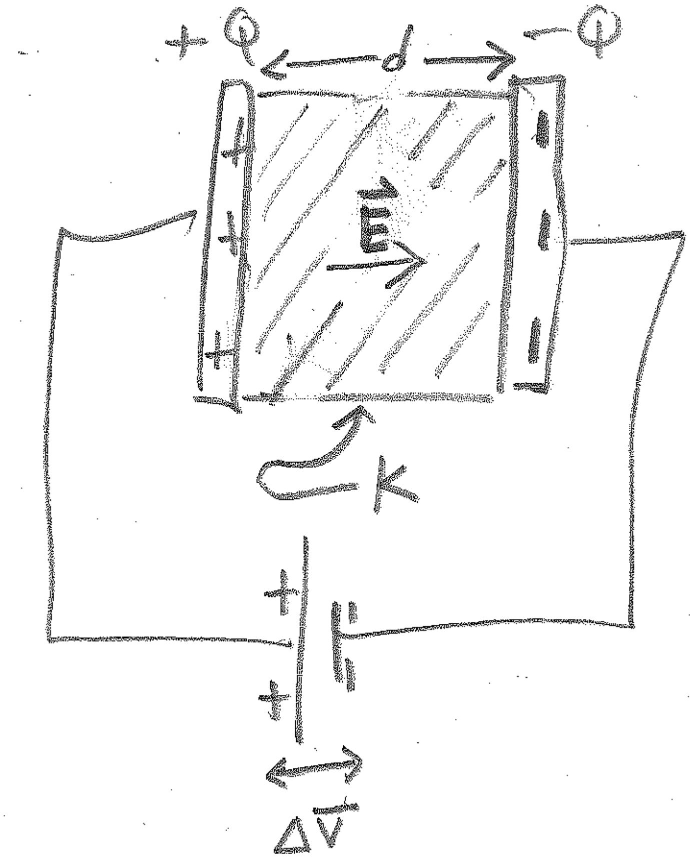
K = dielectric constant: see table

24.1

$K_{AIR} \approx 1$

$K_{MYLAR} = 3.1$

NOTE: with dielectric C increases:



$$C \equiv \frac{Q}{\Delta V} = \frac{Q}{E \cdot d}$$

$$= \frac{Q}{\frac{E_0}{K} \cdot d} = K \cdot \frac{Q}{E_0 \cdot d}$$

$$\boxed{C = K \cdot C_0}$$, C_0 = CAPACITANCE without dielectric (VACCUUM IN SPACE)