FISICA 1 (PALEONTOLOGÍA)

2DO CUATRIMESTRE 2020

CLASE 16

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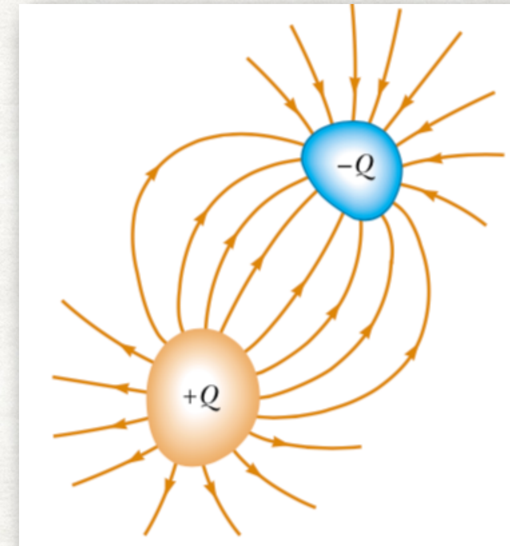
CLASE 16: Electrostática

Temas: Capacitores y dielectricos



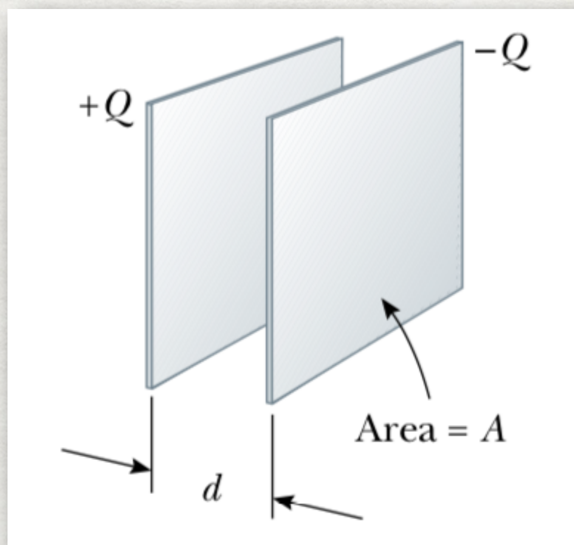
capacitores: dispositivos que almacenan carga eléctrica

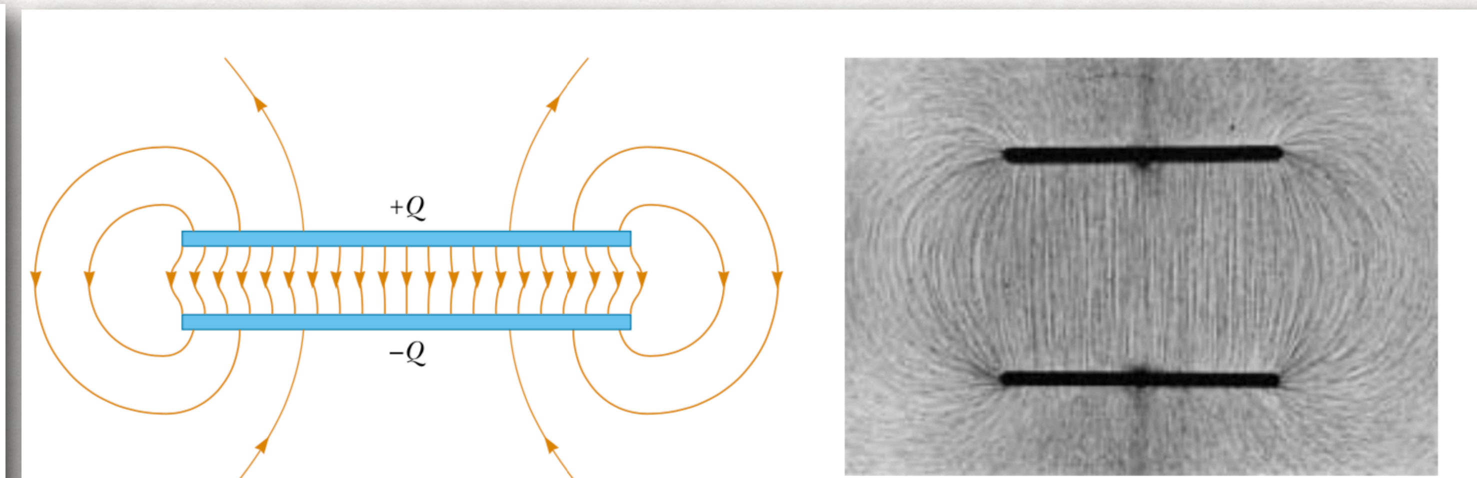
$$C \equiv \frac{Q}{\Delta V}$$ capacitancia

$$1\,F \equiv \frac{1\,C}{1\,V}$$ faradio

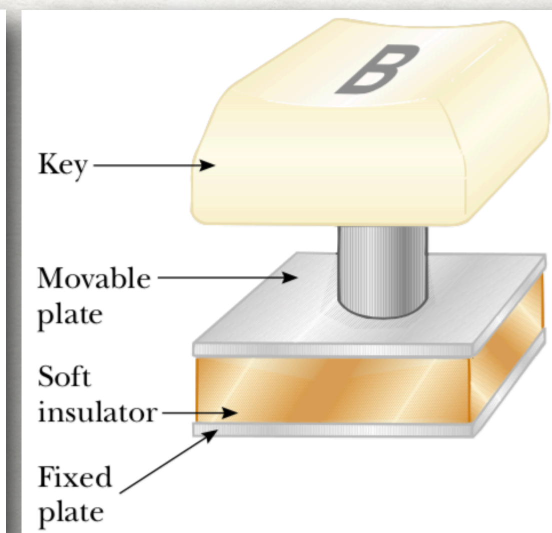
$$\mu F = 10^{-6} F$$

$$pF = 10^{-12} F$$





(a) (b)



$$F^e = E\,q_0 \qquad W_{ext} = -F^e\,d = \Delta U \qquad \Delta V = \frac{\Delta U}{q_0}$$

$$\sigma = \frac{Q}{A} \qquad E = \frac{\sigma}{\epsilon_0} = \frac{Q}{A\,\epsilon_0} \qquad \Delta V = E\,d = \frac{Q\,d}{A\,\epsilon_0}$$

$$C = \frac{Q}{\Delta\,V} = \frac{A\,\epsilon_0}{d} = \frac{2\,cm^2\,\epsilon_0}{1\,mm} = \frac{2 \times 10^{-4}\,m^2}{10^{-3}\,m}(8.85 \times 10^{-12}\,C^2/N \cdot m) = 1.77\,pF$$

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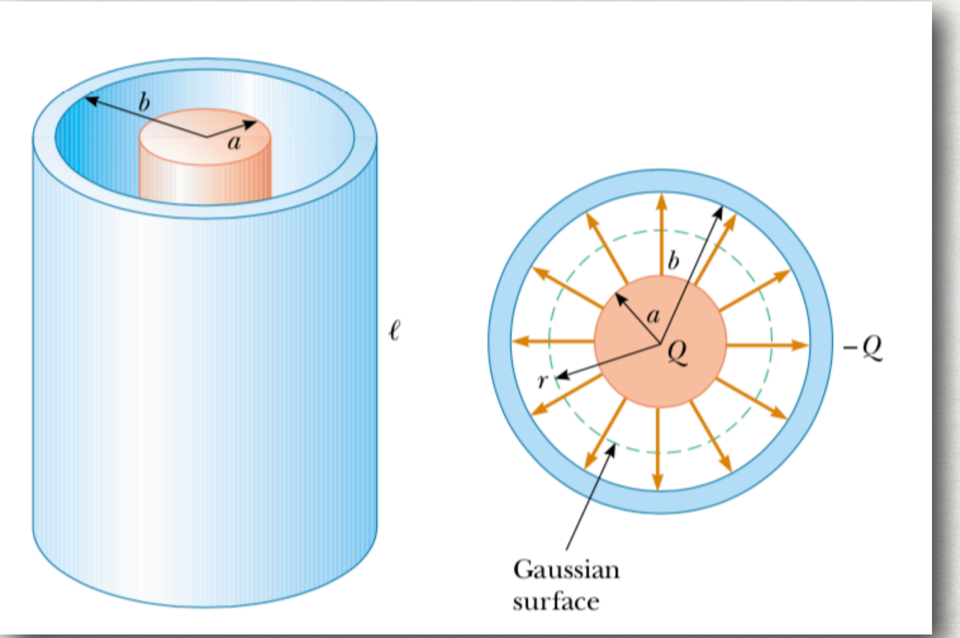
capacitores:

ejemplo: capacitor cilíndrico

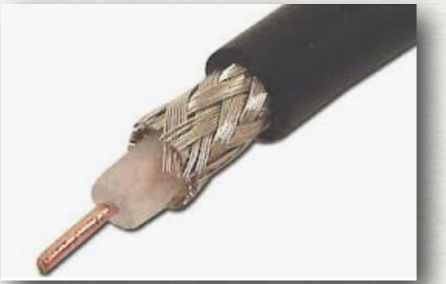


$$(l \gg a, b) \qquad \mathbf{E} = \frac{2\,k_e\,\lambda}{r}\hat{\mathbf{r}} \qquad \lambda = \frac{Q}{l}$$

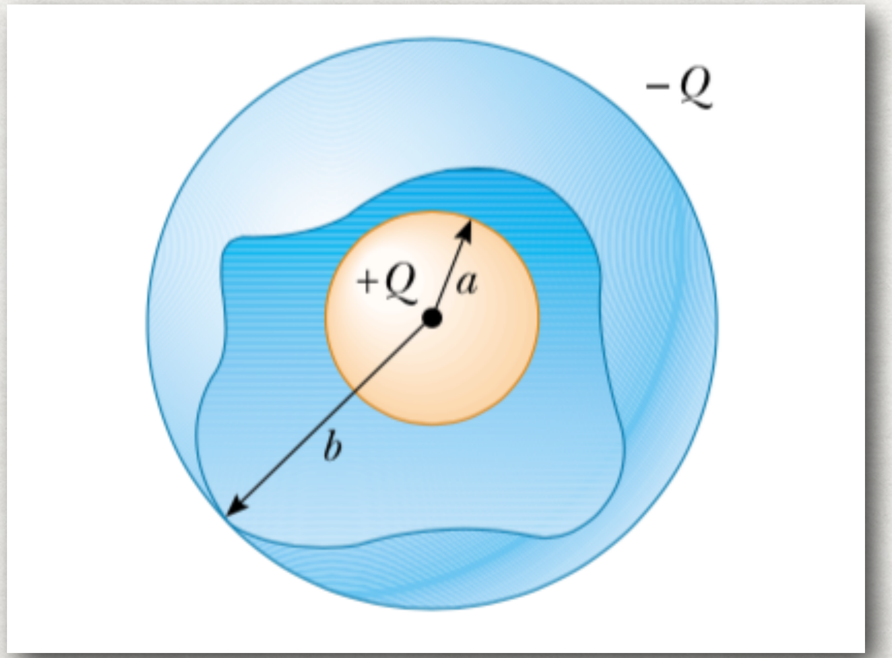
Gauss, Clase 15

$$V_a - V_b = -\int_b^a \mathbf{E}\cdot d\mathbf{s} = -\int_b^a E_r\,dr = -\,2\,k_e\,\lambda\int_b^a \frac{dr}{r} = 2k_e\,\lambda\,ln\frac{b}{a}$$

$$C = \frac{Q}{\Delta V} = \frac{Q\,l}{2k_e\,Q\,ln\frac{b}{a}} = \frac{l}{2k_e\,ln\frac{b}{a}}$$



ejemplo: capacitor esférico



$$\mathbf{E} = \frac{k_e\,Q}{r^2}\hat{\mathbf{r}}$$

$$V_a - V_b = -\int_b^a E_r\,dr = -\,k_e\,Q\int_b^a \frac{dr}{r^2} = k_e\,Q\left(\frac{1}{a} - \frac{1}{b}\right)$$

$$\Delta V = V_a - V_b = \frac{k_e\,Q\,(b-a)}{ab} \qquad C = \frac{ab}{k_e\,(b-a)}$$

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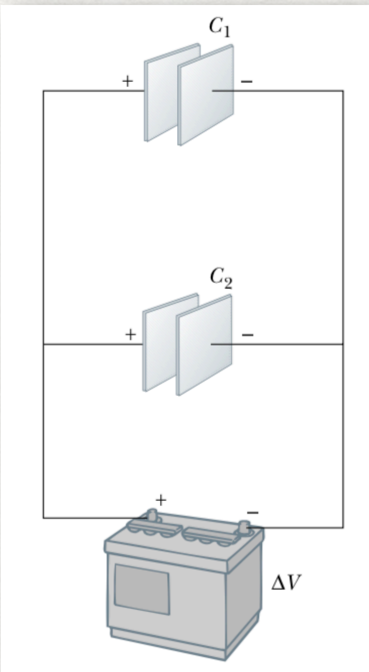
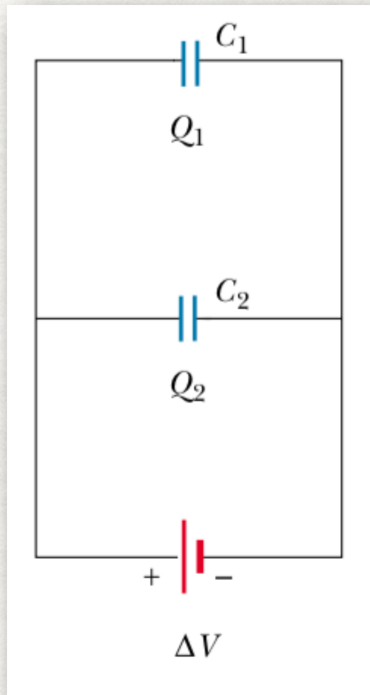
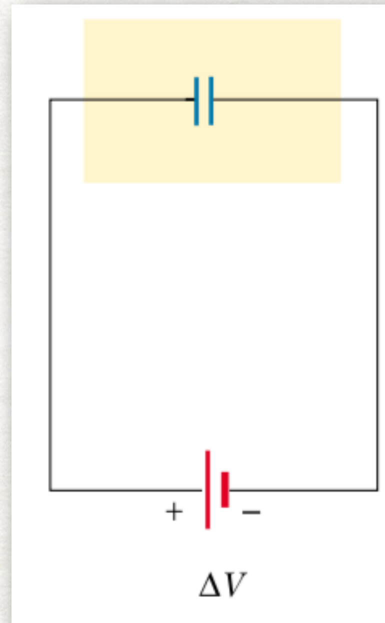
combinación de capacitores:





$$C_{eq} = C_1 + C_2$$

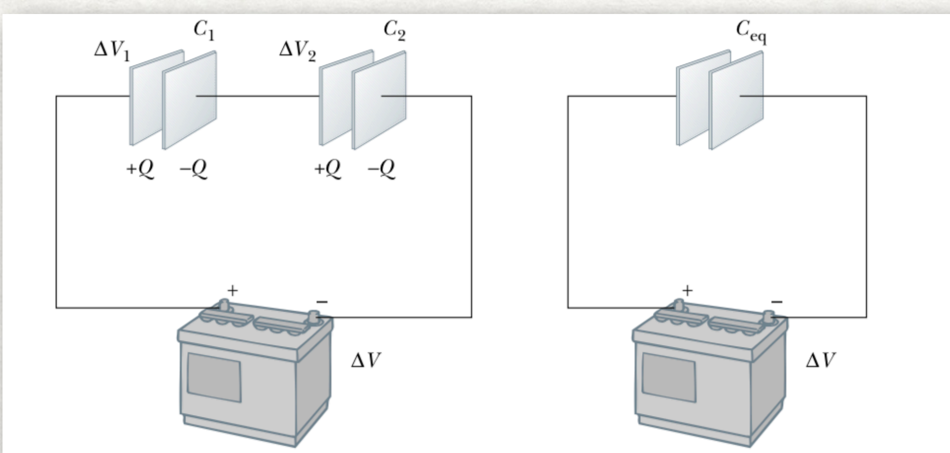


$$\Delta V = \Delta V_1 = \Delta V_2$$

$$Q = Q_1 + Q_2$$

$$C_{eq} = \frac{Q}{\Delta V} = \frac{Q_1 + Q_2}{\Delta V} = \frac{Q_1}{\Delta V} + \frac{Q_2}{\Delta V} = C_1 + C_2$$

$$C_{eq} = C_1 + C_2 + C_3 + \ldots$$ "paralelo"



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

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

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

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots$$ "serie"

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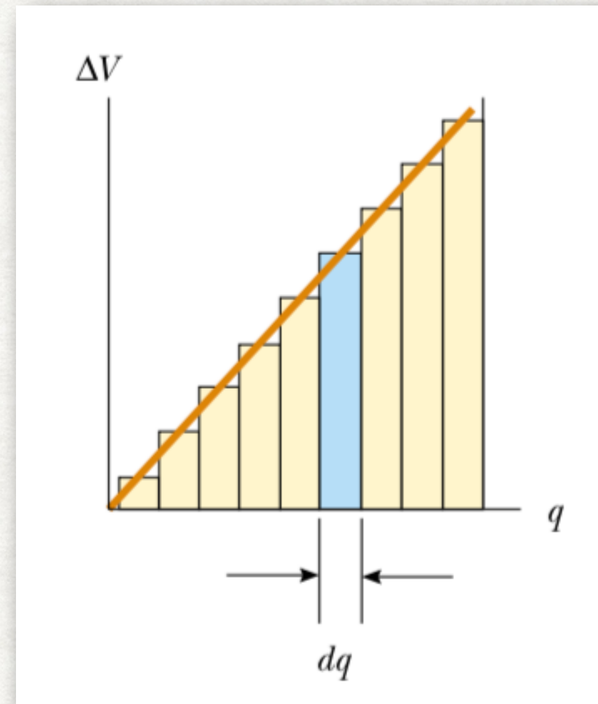
energía almacenada en un capacitor:

cargar un capacitor requiere trabajo…

$$dW = \Delta V\, dq = \frac{q}{C}\, dq$$

$$W = \int_0^Q \frac{q}{C}\, dq = \frac{Q^2}{2\,C} \qquad C = \frac{Q}{\Delta V}$$

$$U = \frac{Q^2}{2\,C} = \frac{1}{2} Q\,\Delta V = \frac{1}{2} C\,(\Delta V)^2$$



$$\Delta V = \frac{q}{C}$$

$$y = m\,x$$

m pendiente $\quad m = \frac{1}{C}$

$U = \frac{1}{2} Q\,\Delta V$ area

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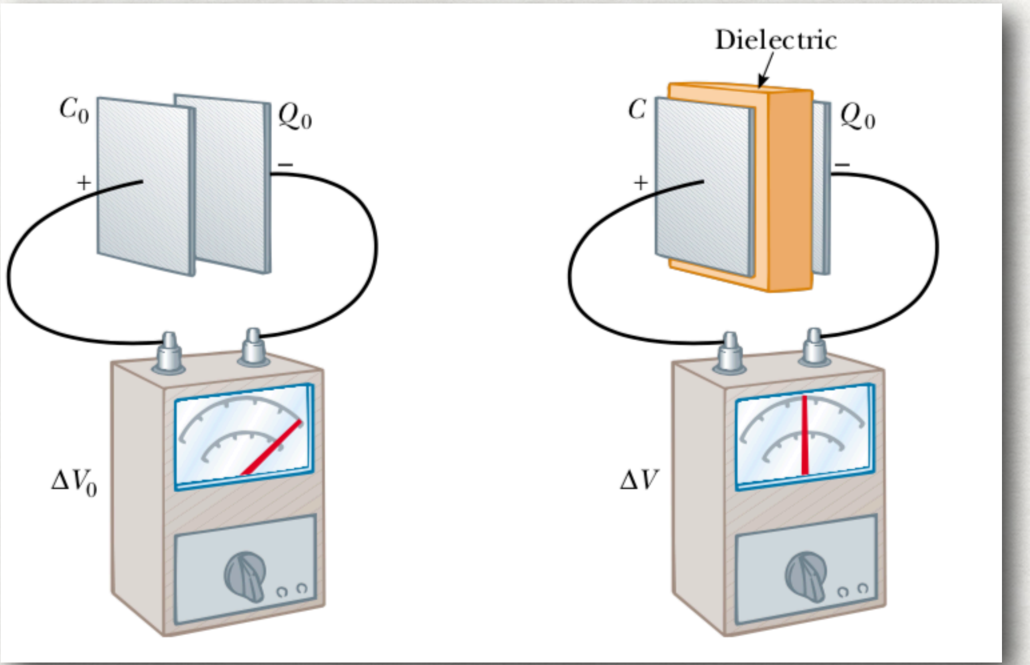
capacitores con dieléctrico: dieléctrico: material aislante que se inserta entre las placas

~modifica la capacitancia



$$\Delta V_0 = \frac{Q_0}{C_0} \qquad \Delta V = \frac{\Delta V_0}{\kappa} \qquad \Delta V < \Delta V_0 \quad \kappa > 1$$

$$C = \frac{Q_0}{\Delta V} = \frac{Q_0}{\Delta V_0/\kappa} = \kappa \frac{Q_0}{\Delta V_0} = \kappa C_0$$

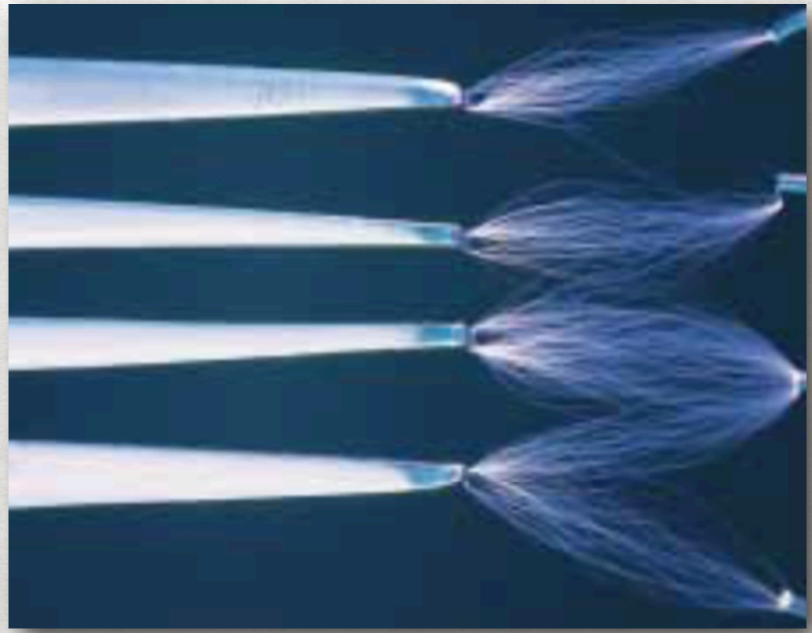
aumenta la capacitancia

permite mayor ΔV

sirve de soporte entre placas

Material	Dielectric Constant κ	Dielectric Strength[a] (V/m)
Air (dry)	1.000 59	3×10^6
Bakelite	4.9	24×10^6
Fused quartz	3.78	8×10^6
Neoprene rubber	6.7	12×10^6
Nylon	3.4	14×10^6
Paper	3.7	16×10^6
Polystyrene	2.56	24×10^6
Polyvinyl chloride	3.4	40×10^6
Porcelain	6	12×10^6
Pyrex glass	5.6	14×10^6
Silicone oil	2.5	15×10^6
Strontium titanate	233	8×10^6
Teflon	2.1	60×10^6
Vacuum	1.000 00	—
Water	80	—

[a] The dielectric strength equals the maximum electric field that can exist in a dielectric without electrical breakdown. Note that these values depend strongly on the presence of impurities and flaws in the materials.



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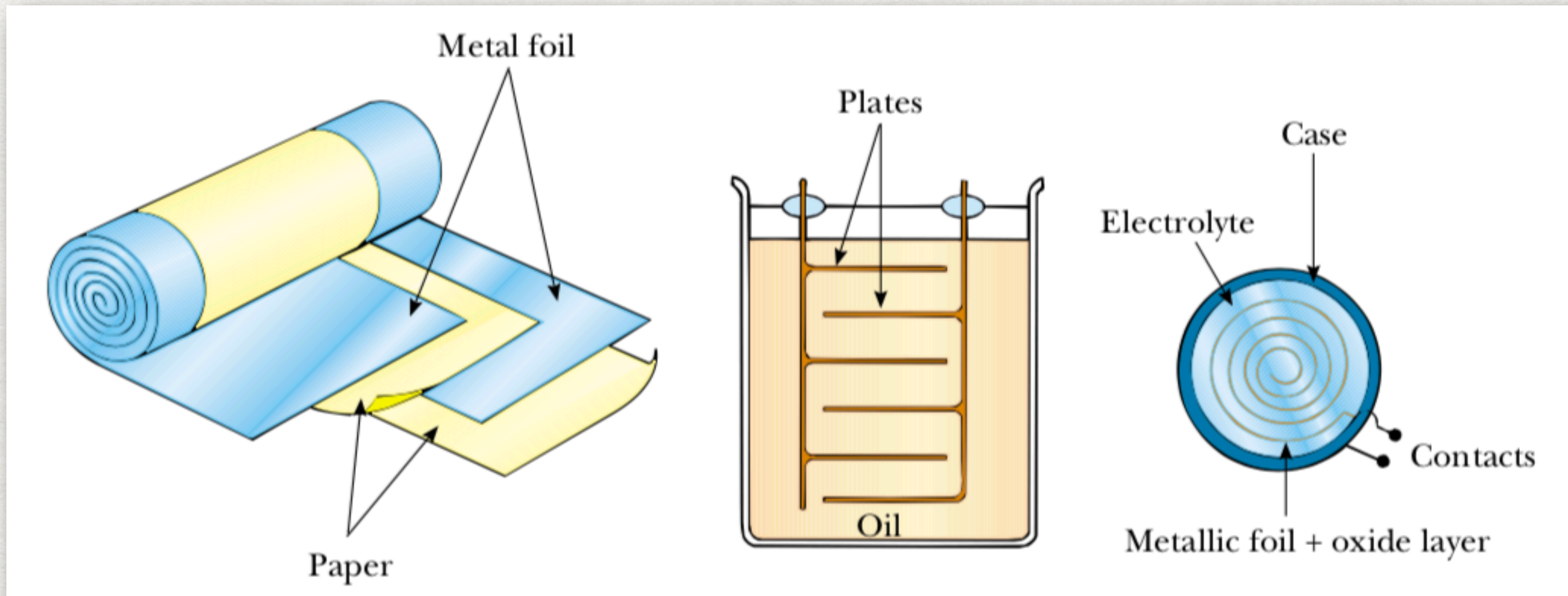
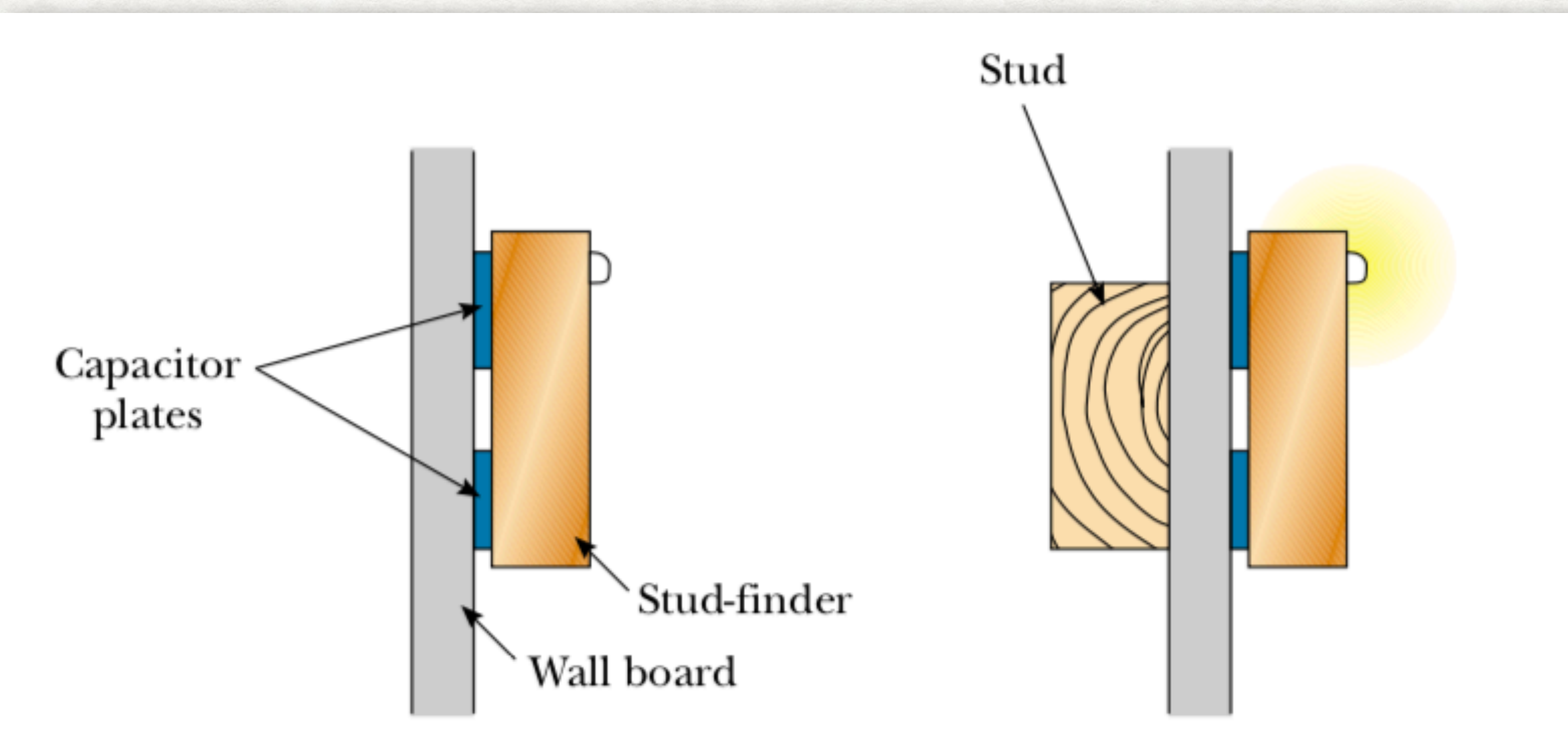
capacitores con dieléctrico:





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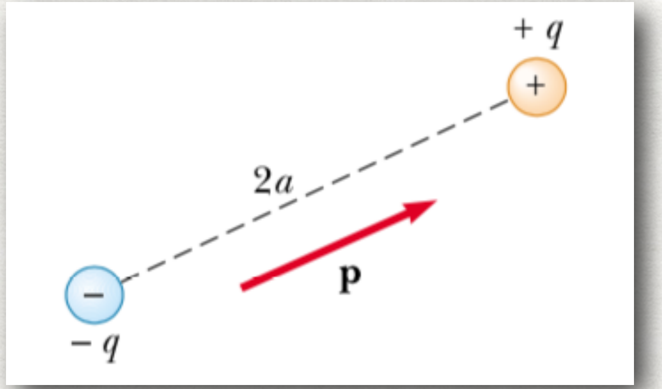
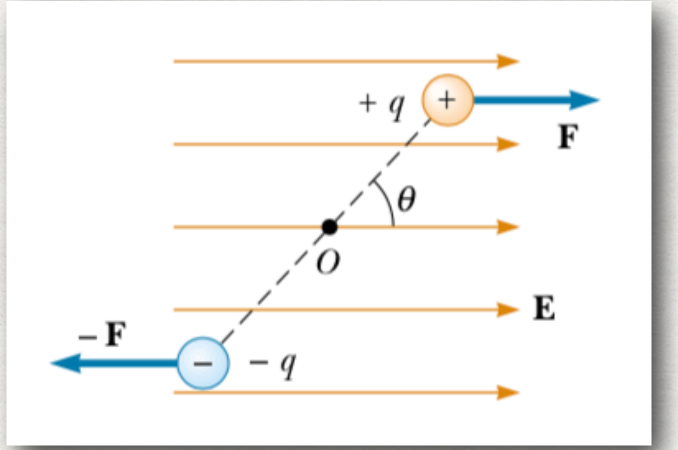
dipolo en un campo eléctrico:



$\mathbf{p} \equiv 2aq\,\hat{\mathbf{r}}_{-+}$ "momento dipolar eléctrico"



$$\mathbf{F} = q\,\mathbf{E}$$

$$\tau = 2Fa\,sen\theta \;= 2aqE\,sen\theta \;= pE\,sen\theta \qquad \tau = \mathbf{p} \times \mathbf{E}$$

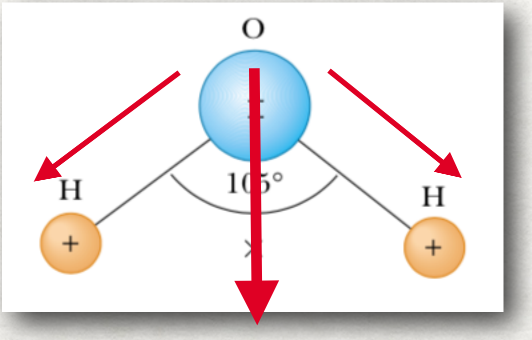
$$U_f - U_i = \int_{\theta_i}^{\theta_f} \tau\, d\theta \;= \int_{\theta_i}^{\theta_f} pE\,sen\theta\, d\theta \;= pE\,(-cos\theta)\Big|_{\theta_i}^{\theta_f}$$

$$(\theta_i = 90^o \;\; U_i = 0) \quad U_f = U = -\,pE\,cos\theta \;= -\,\mathbf{p}\cdot\mathbf{E}$$

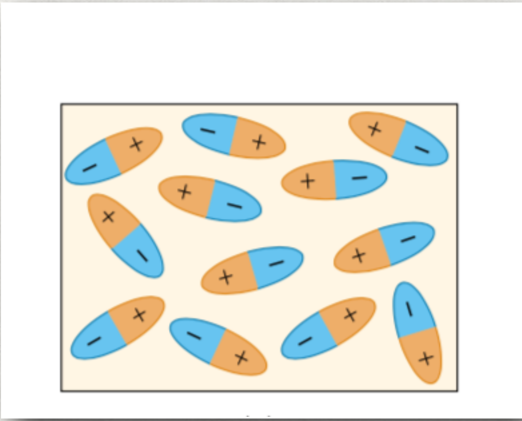
$\theta = 180^o \quad U = pE$

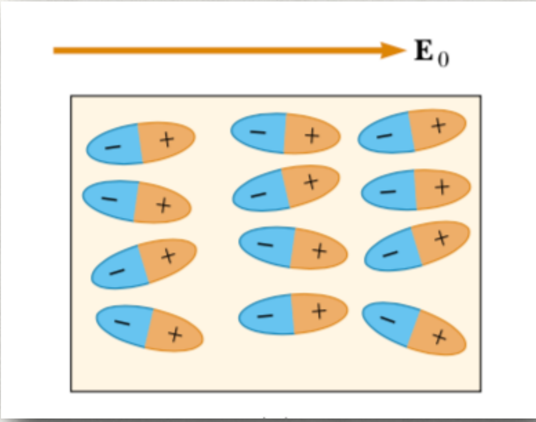
$\theta = 90^o \quad U = 0$

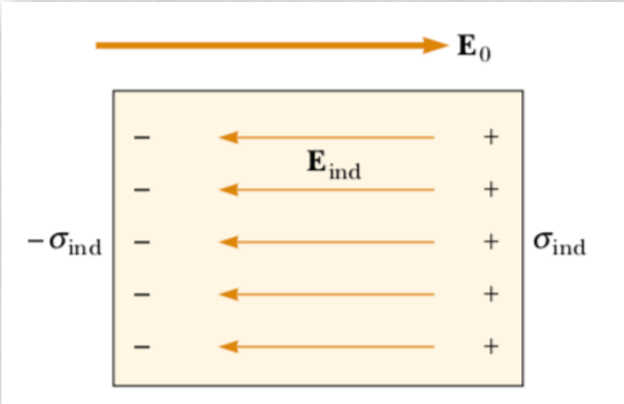
$\theta = 0^o \quad U = -\,pE$



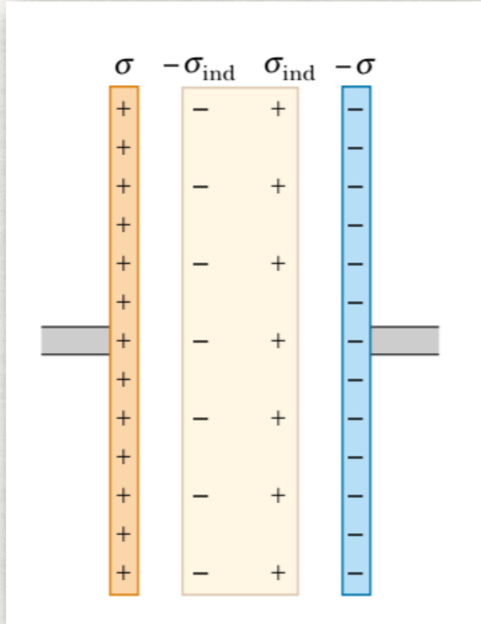
descripción microscópica de un dieléctrico:







$$\mathbf{E} = \frac{\mathbf{E_0}}{\kappa}$$



$$E = E_0 - E_{ind}$$

$$\frac{\sigma}{\kappa\,\epsilon_0} = \frac{\sigma}{\epsilon_0} - \frac{\sigma_{ind}}{\epsilon_0}$$

$$\sigma_{ind} = \left(\frac{\kappa}{\kappa - 1}\right)\sigma$$

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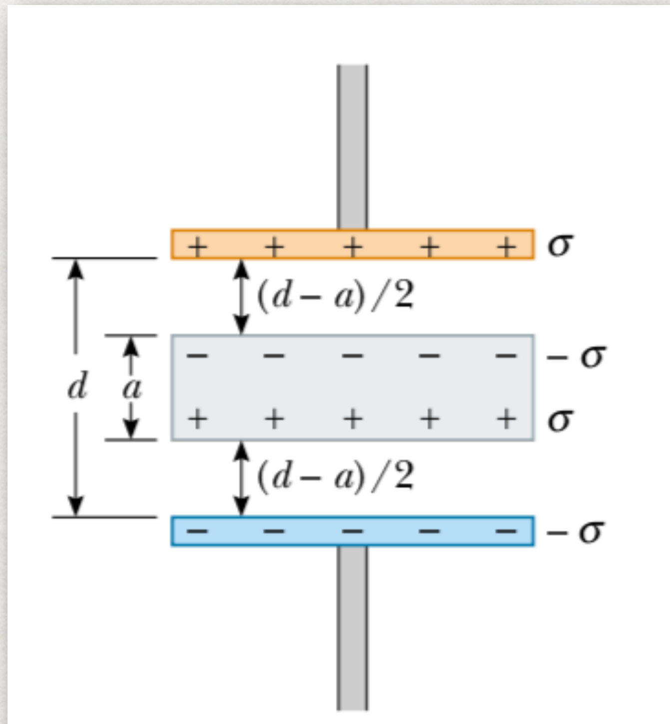
descripción microscópica de un dieléctrico:

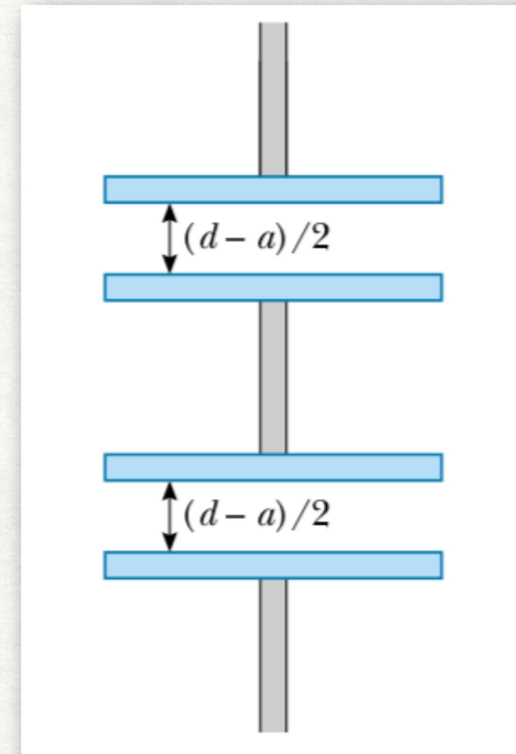
ejemplo: efecto de un conductor



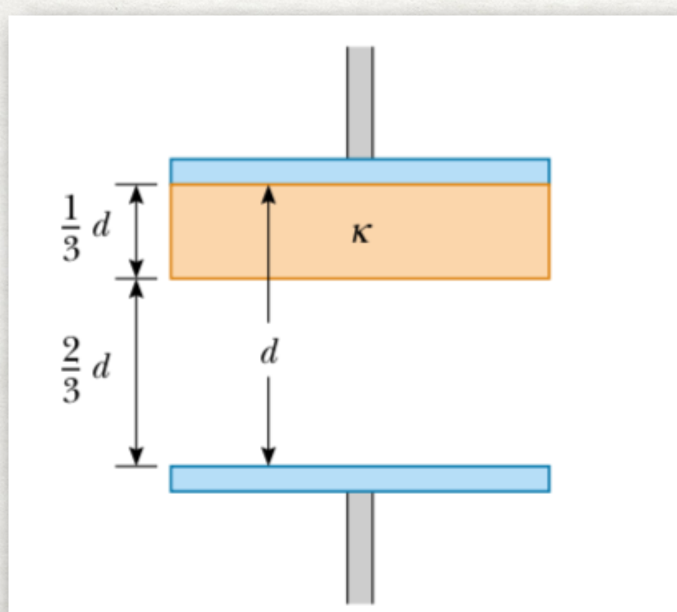
conductor anula el campo en su interior $\sigma_{ind} = \sigma$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \qquad C_{||} = \frac{A\,\epsilon_0}{d}$$

$$\frac{1}{C} = \frac{1}{\frac{A\epsilon_0}{(d-a)/2}} + \frac{1}{\frac{A\epsilon_0}{(d-a)/2}} \qquad C = \frac{A\epsilon_0}{(d-a)}$$



ejemplo: efecto de un dieléctrico



$$C_1 = \frac{A\epsilon_0\,\kappa}{d/3} \qquad C_2 = \frac{A\epsilon_0}{2d/3}$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{\frac{A\epsilon_0\kappa}{d/3}} + \frac{1}{\frac{A\epsilon_0}{2d/3}} = \frac{d/3}{A\epsilon_0\kappa} + \frac{2d/3}{A\epsilon_0}$$

$$C = \left(\frac{3\kappa}{2\kappa+1}\right)\frac{A\epsilon_0}{d}$$