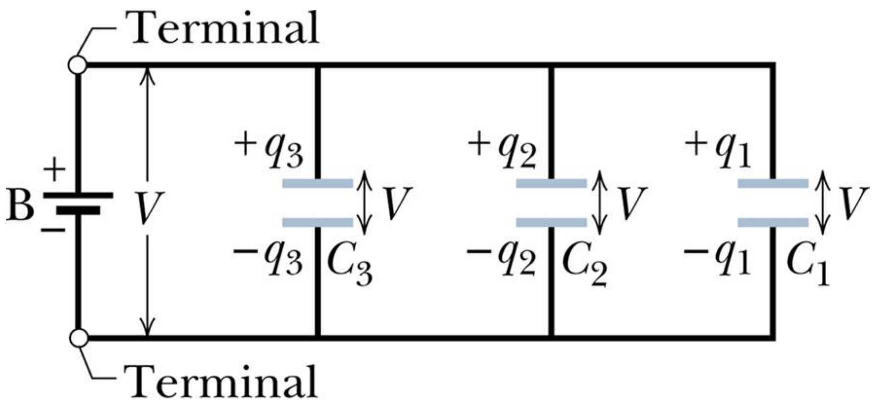
Copyright statement

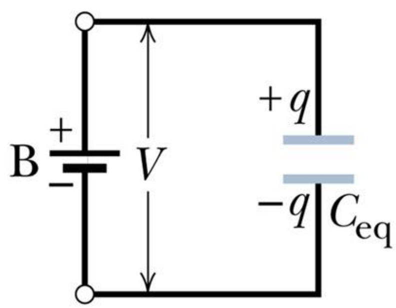
- The images and the pictures in this lecture are provided by the CDs accompanied by the books
  1. University Physics, Bauer and Westfall, McGraw-Hill, 2011.
  2. Principles of Physics, Halliday, Resnick, and Walker, Wiley, 8th and 9th Ed.
- The rest is made by me.

Capacitors in parallel



(a)

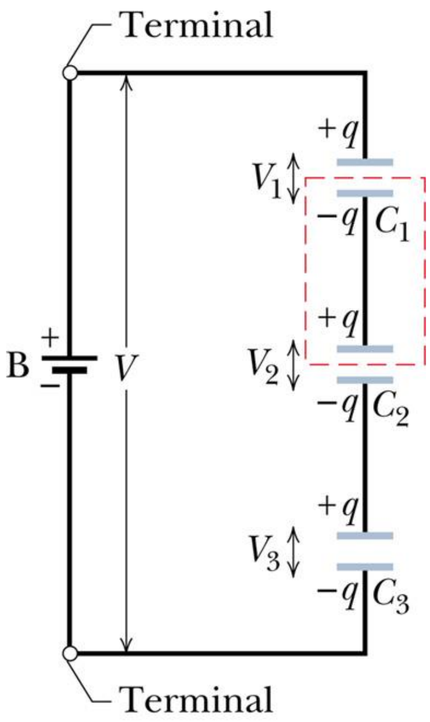
$$C_{\rm eq} = \frac{q}{V} = C_1 + C_2 + C_3$$



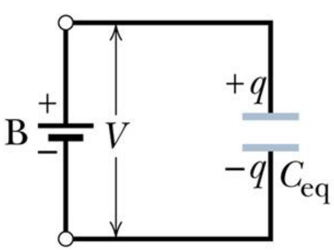
(b)

n 개가 연결된 경우 $$C_{\rm eq} = \sum_{i=1}^{n} C_i$$

Capacitors in series



(*a*)



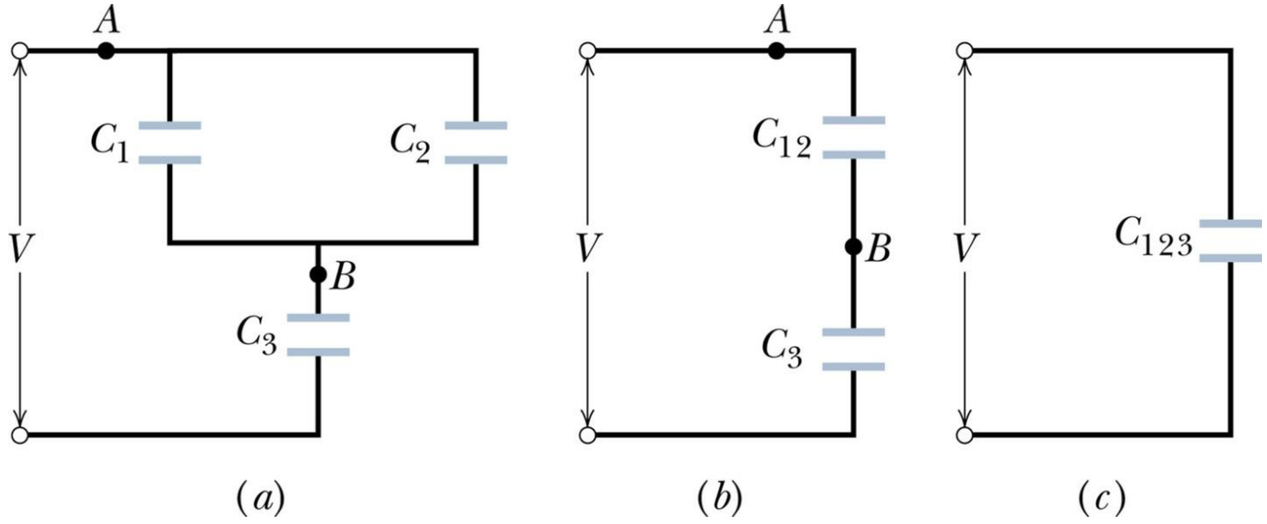
(*b*)

$$\frac{1}{C_{\mathrm{eq}}} = \frac{q}{V} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

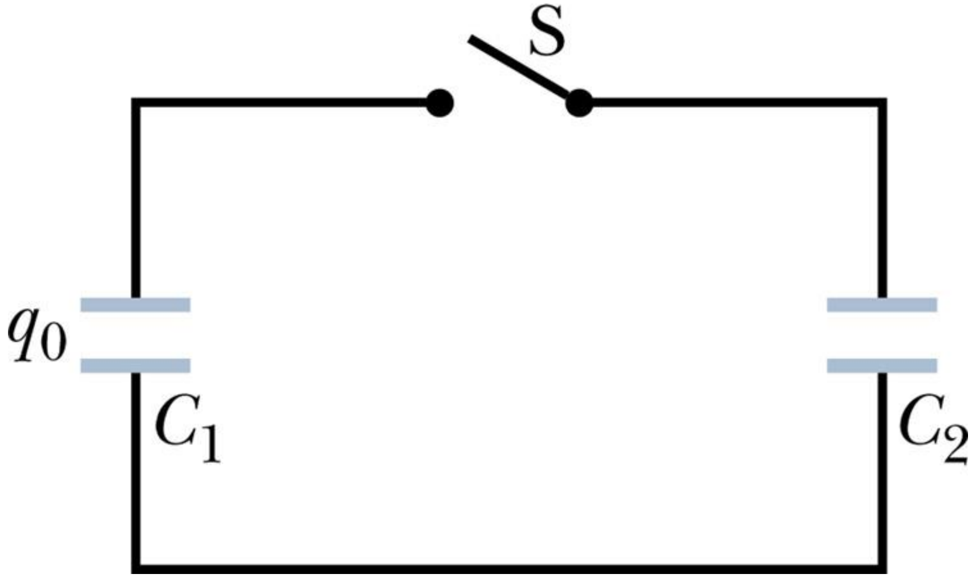
n 개가 연결된 경우

$$\frac{1}{C_{\mathrm{eq}}} = \sum_{i=1}^{n} \frac{1}{C_i}$$

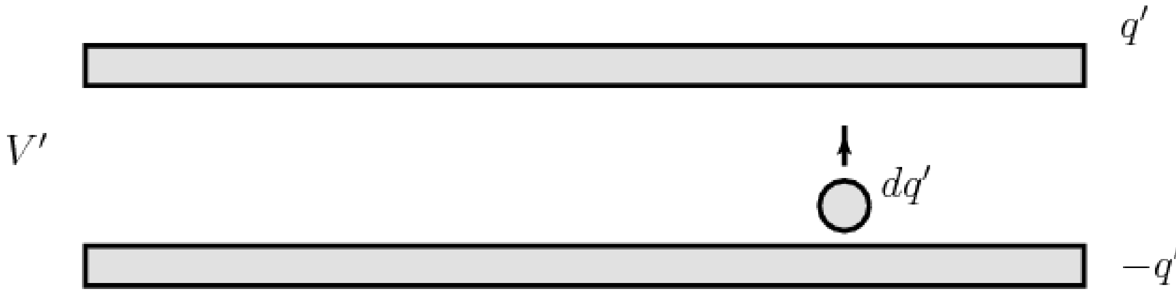
Example 1



Example 2



Energy stored in electric field



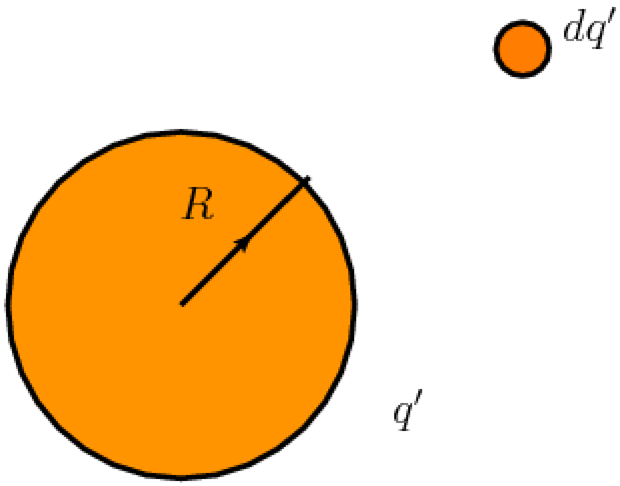
축전기의 전하를 0에서 q까지 만들 때 들어가는 일

축전기에 저장된 전기에너지와 전기에너지 밀도

$$U = \frac{q^2}{2C} = \frac{1}{2}CV^2$$

$$u = \frac{1}{2}\epsilon_0 E^2$$

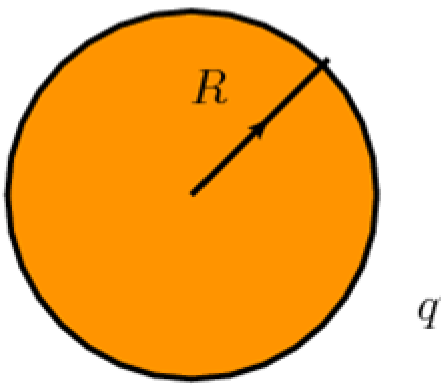
보기문제 25-5



$$U = \frac{q^2}{8\pi\epsilon_0 R}$$

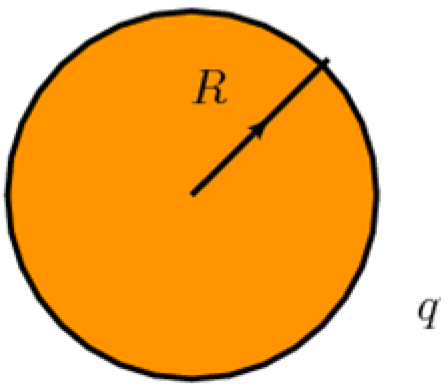
$$u = \frac{q^2}{32\pi^2\epsilon_0 R^4}$$

Electric energy of a charged sphere



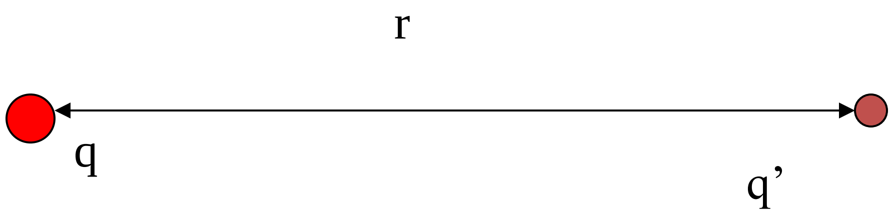
$$U = \frac{q^2}{8\pi\epsilon_0 R}$$

Charged sphere as a capacitor



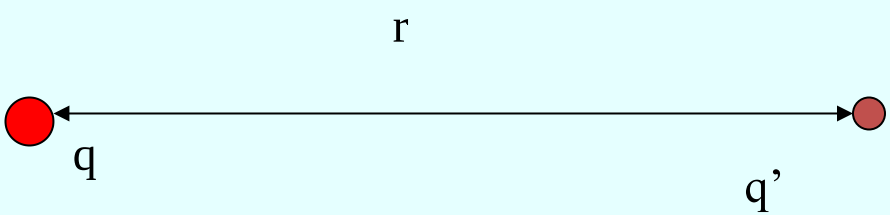
$$C = 4\pi\epsilon_0 R$$

$$U = \frac{q^2}{8\pi\epsilon_0 R}$$



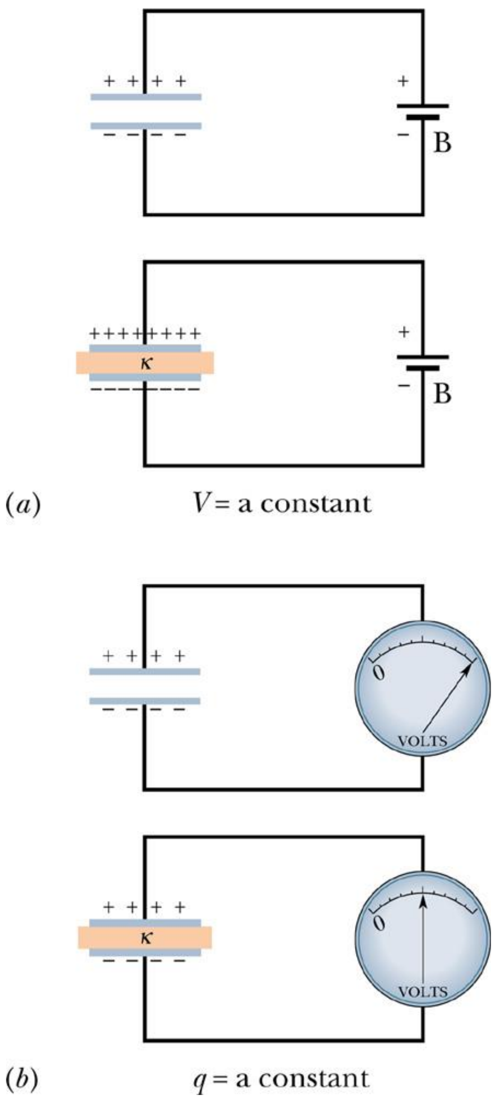
$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\,\hat{\mathbf{r}}$$

Dielectric material



$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\,\hat{\mathbf{r}}\ ?$$

Capacitor with dielectric material



$$C = \epsilon_0 \mathcal{L} \longrightarrow \kappa \epsilon_0 \mathcal{L} = \kappa C_{\text{air}}$$

Point charge in dielectric material

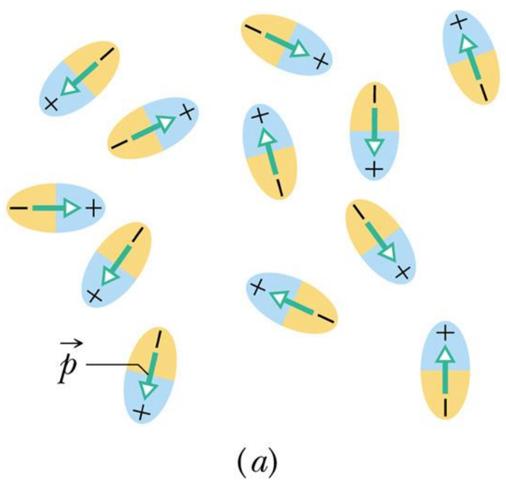
$$E = \frac{1}{4\pi\kappa\epsilon_0}\frac{q}{r^2}$$

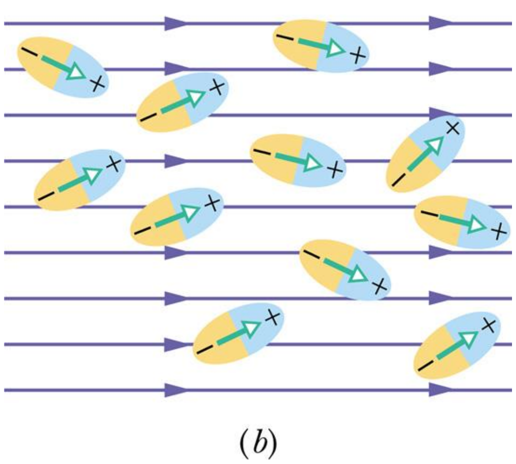
Electric field of an isolated charged surface inside dielectric material

$$E = \frac{\sigma}{\kappa\epsilon_0}$$

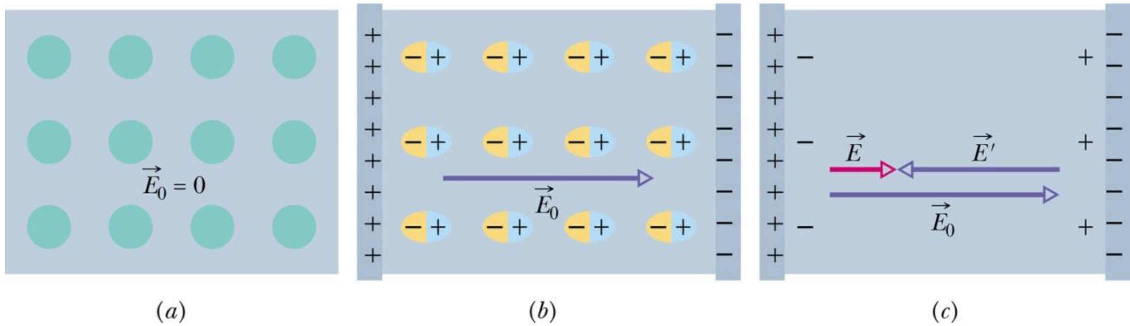
Dielectric material: atomic view

Polar dielectric material

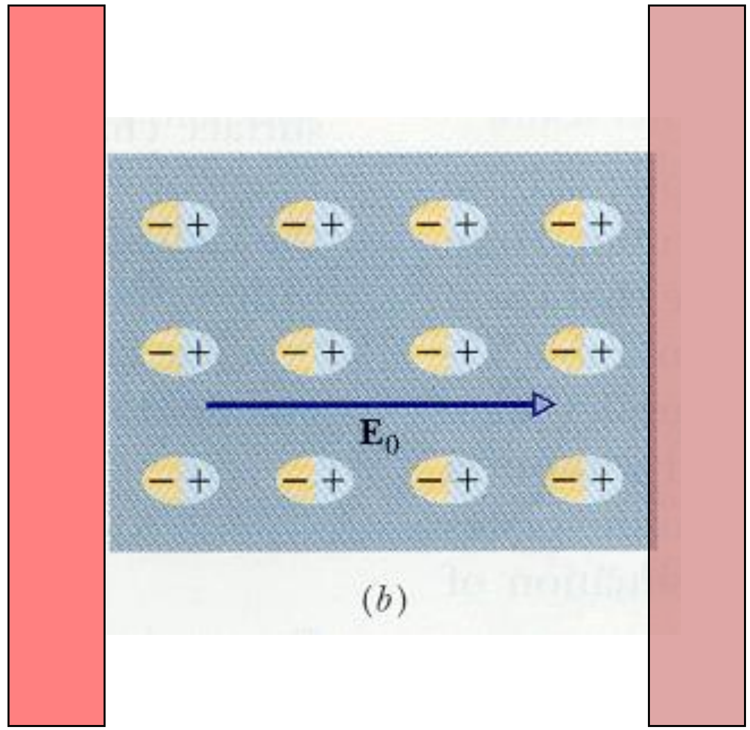




Nonpolar dielectric material



Effect of aligned dielectric on E

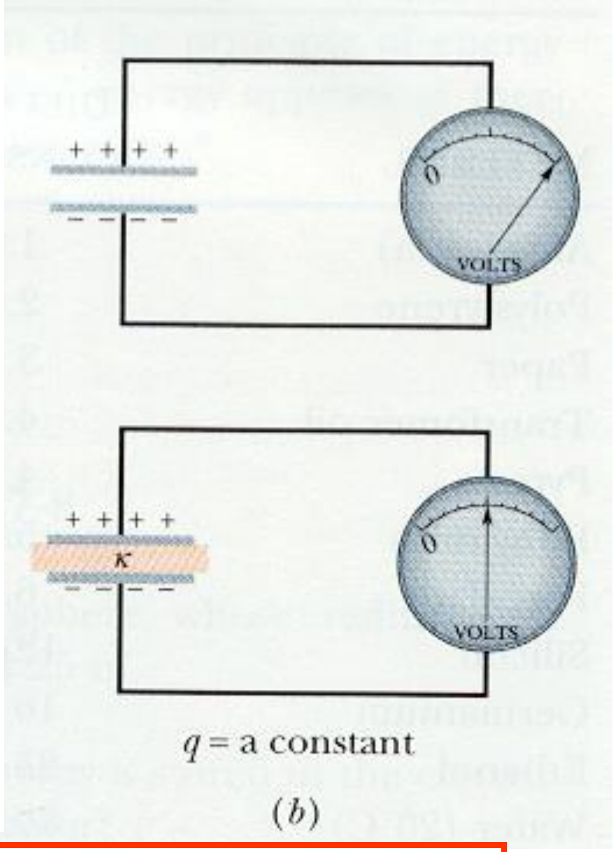


$$E < E_0$$

$$E_0 / E = \kappa \ \text{ with } \kappa > 1$$

여기서 κ를 유전상수 (dielectric constant)라고 한다.

Dielectric material and capacitors

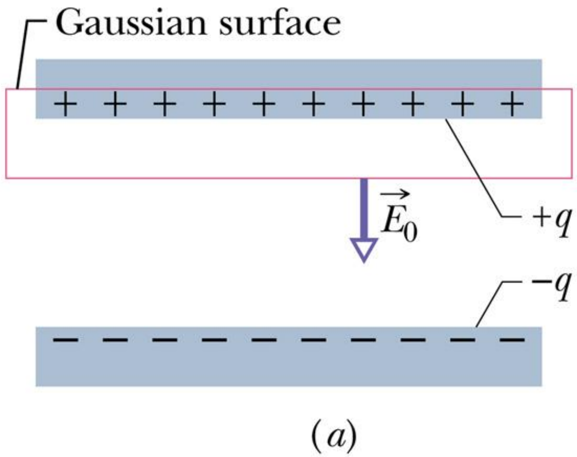


Q 일정

V 감소

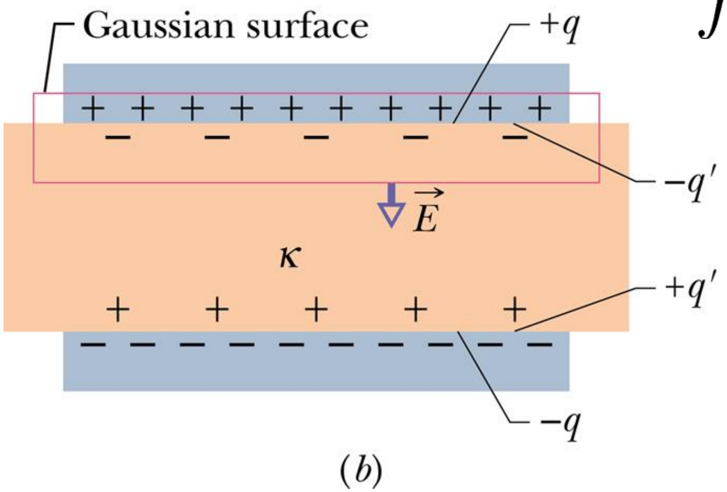
$$C\left(=\frac{q}{V}\right)=\kappa C_0 \quad (\kappa > 1)$$

Dielectric material and Gauss law



$$\epsilon_0 \oint \vec{E} \cdot d\vec{A} = \epsilon_0 E_0 A = q$$

$$E_0 = \frac{q}{\epsilon_0 A}$$



$$\epsilon_0 \oint \vec{E} \cdot d\vec{A} = \epsilon_0 E A = q - q' \qquad E = \frac{q - q'}{\epsilon_0 A}$$

$$E = \frac{E_0}{\kappa} = \frac{q}{\kappa \epsilon_0 A} \qquad q - q' = \frac{q}{\kappa}$$

$$\epsilon_0 \oint \kappa \vec{E} \cdot d\vec{A} = q$$

Free charge

진공과 유전체에서의 전기현상의 차이

Coulomb force

$$\mathbf{f}(2 \leftarrow 1) = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2 (\mathbf{r}_2 - \mathbf{r}_1)}{|\mathbf{r}_2 - \mathbf{r}_1|^3}$$

$$\mathbf{f}_C = \frac{1}{4\pi\kappa\varepsilon_0} \frac{q_1 q_2 (\mathbf{r}_2 - \mathbf{r}_1)}{|\mathbf{r}_2 - \mathbf{r}_1|^3}$$

Electric field

$$\mathbf{E}(\mathbf{r}) = \frac{1}{4\pi\varepsilon_0} \frac{q\,\mathbf{r}}{r^3}$$

$$\mathbf{E}(\mathbf{r}) = \frac{1}{4\pi\kappa\varepsilon_0} \frac{q\,\mathbf{r}}{r^3}$$

Gauss law

$$q/\varepsilon_0 = \oint \mathbf{E} \cdot d\mathbf{A}$$

$$q/\kappa\varepsilon_0 = \oint \mathbf{E} \cdot d\mathbf{A}$$

parallel plate capacitor

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

$$C = \kappa\varepsilon_0 \frac{A}{d}$$

electric field energy density

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

$$u = \frac{1}{2}\kappa\varepsilon_0 E^2$$

Capacitor connection 1