Announcements

1. No class on Monday – MLK holiday
2. Homework assignments HW1 & HW2 due at 5 PM on Wednesday, Jan. 22nd.
3. Tutorial sessions start Tuesday, Jan. 21st 7-9 PM (?). Section B tutorial Tuesdays at 5 or 6 PM??
4. Today's topics –

   Coulomb's force law

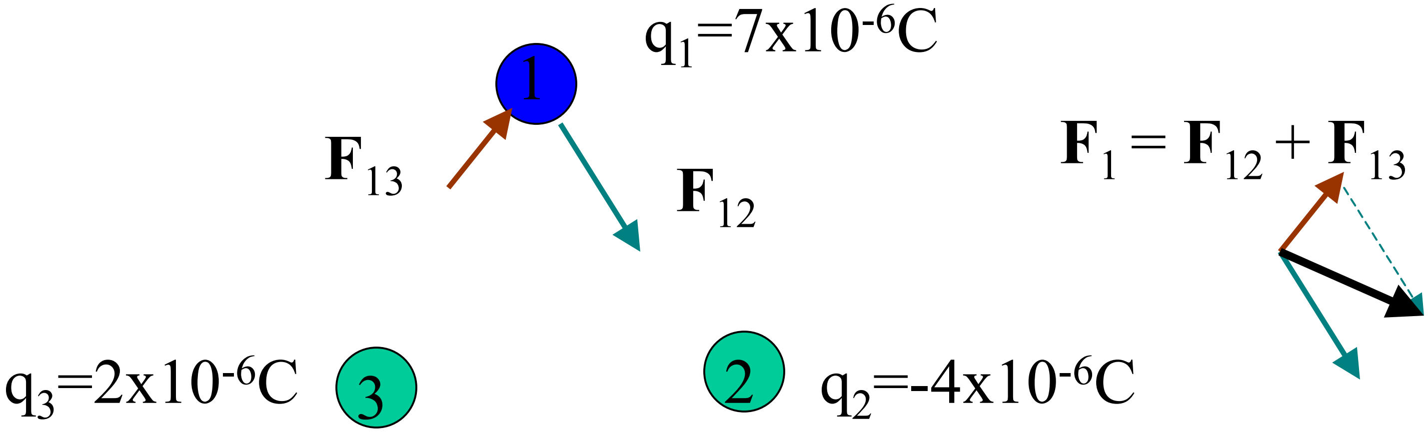
   Electric fields

   Gauss's law

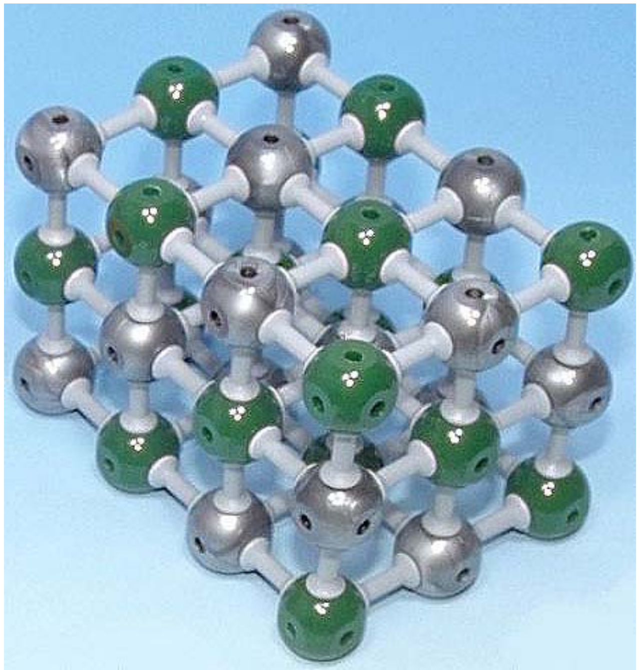
Coulomb's law:

$$\mathbf{F} = k_e \frac{q_1 q_2}{|\mathbf{r}_1 - \mathbf{r}_2|^2} \hat{\mathbf{r}}_{12}$$

k_e = 8.987551787 x 10^9 N · m^2/C^2



Peer instruction question

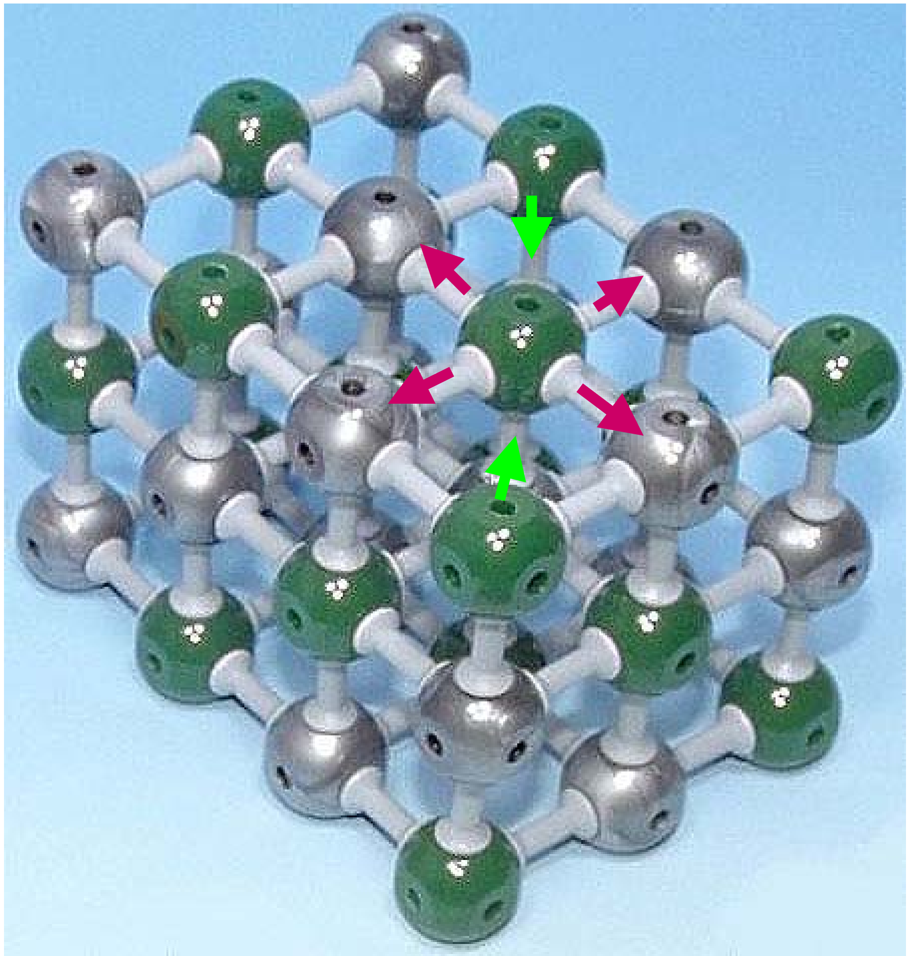


The picture on the right shows a model of a NaCl crystal (table salt). The Green balls represent Na^+ ions and the Grey balls represent Cl^- ions. Which of these statements is true?

(A) The net electrostatic forces in this crystal are attractive.

(B) The net electrostatic forces in this crystal are repulsive.

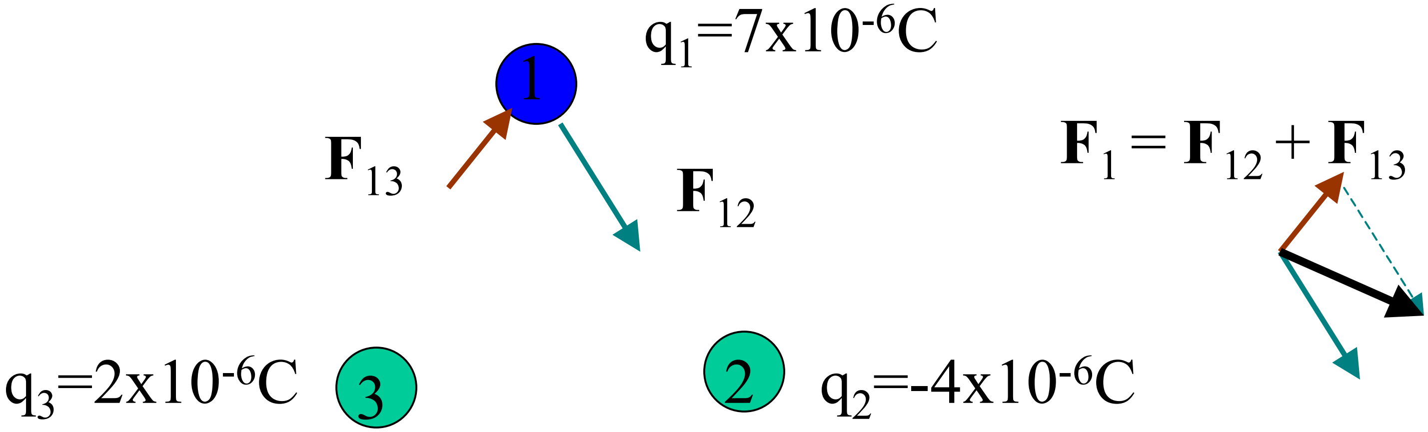
(C) The stability of this crystal can be explained completely in terms of electrostatic forces.



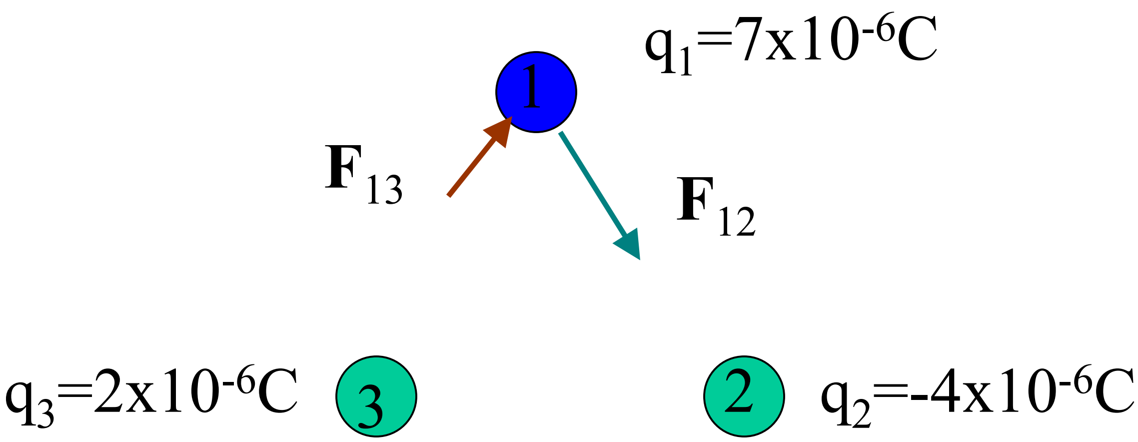
Coulomb’s law:

$$\mathbf{F} = k_e \frac{q_1 q_2}{|\mathbf{r}_1 - \mathbf{r}_2|^2} \hat{\mathbf{r}}_{12}$$

8.987551787×10^9 N · m^2/C^2



Another way to consider this system:



$$\mathbf{F}_1 = k_e \frac{q_1 q_2}{|\mathbf{r}_1 - \mathbf{r}_2|^2}\hat{\mathbf{r}}_{12} + k_e \frac{q_1 q_3}{|\mathbf{r}_1 - \mathbf{r}_3|^2}\hat{\mathbf{r}}_{13}$$

$$= q_1\left(k_e \frac{q_2}{|\mathbf{r}_1 - \mathbf{r}_2|^2}\hat{\mathbf{r}}_{12} + k_e \frac{q_3}{|\mathbf{r}_1 - \mathbf{r}_3|^2}\hat{\mathbf{r}}_{13}\right)$$

$$\mathbf{E}(\mathbf{r}_1) \equiv \mathbf{F}_1 / q_1 = k_e \frac{q_2}{|\mathbf{r}_1 - \mathbf{r}_2|^2}\hat{\mathbf{r}}_{12} + k_e \frac{q_3}{|\mathbf{r}_1 - \mathbf{r}_3|^2}\hat{\mathbf{r}}_{13}$$

Electric field == force on q_1 if it were 1 Coulomb

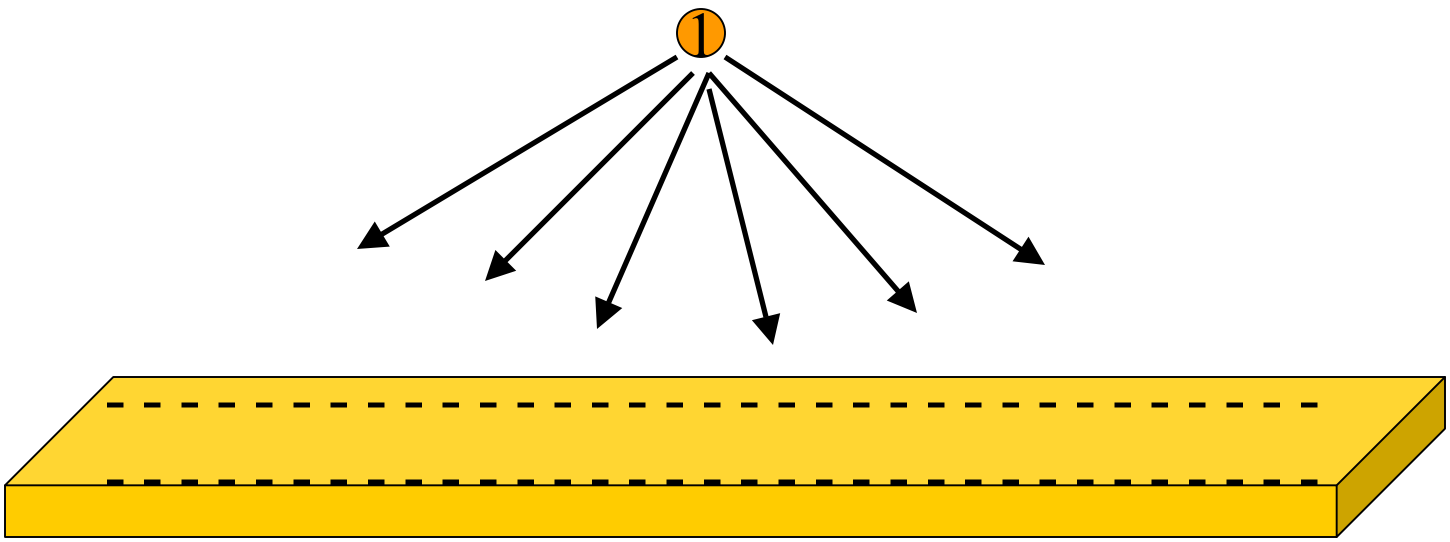
Why (when) the concept of an electric field is useful –

In general,

$$\mathbf{E}(\mathbf{r}_1) = \sum_i k_e \frac{q_i}{|\mathbf{r}_1 - \mathbf{r}_i|^2}\hat{\mathbf{r}}_{1i}$$

➔The force on a charge q_1 placed at $\mathbf{r}_1$ is then $\mathbf{F}_1 = q_1\mathbf{E}(\mathbf{r}_1)$.

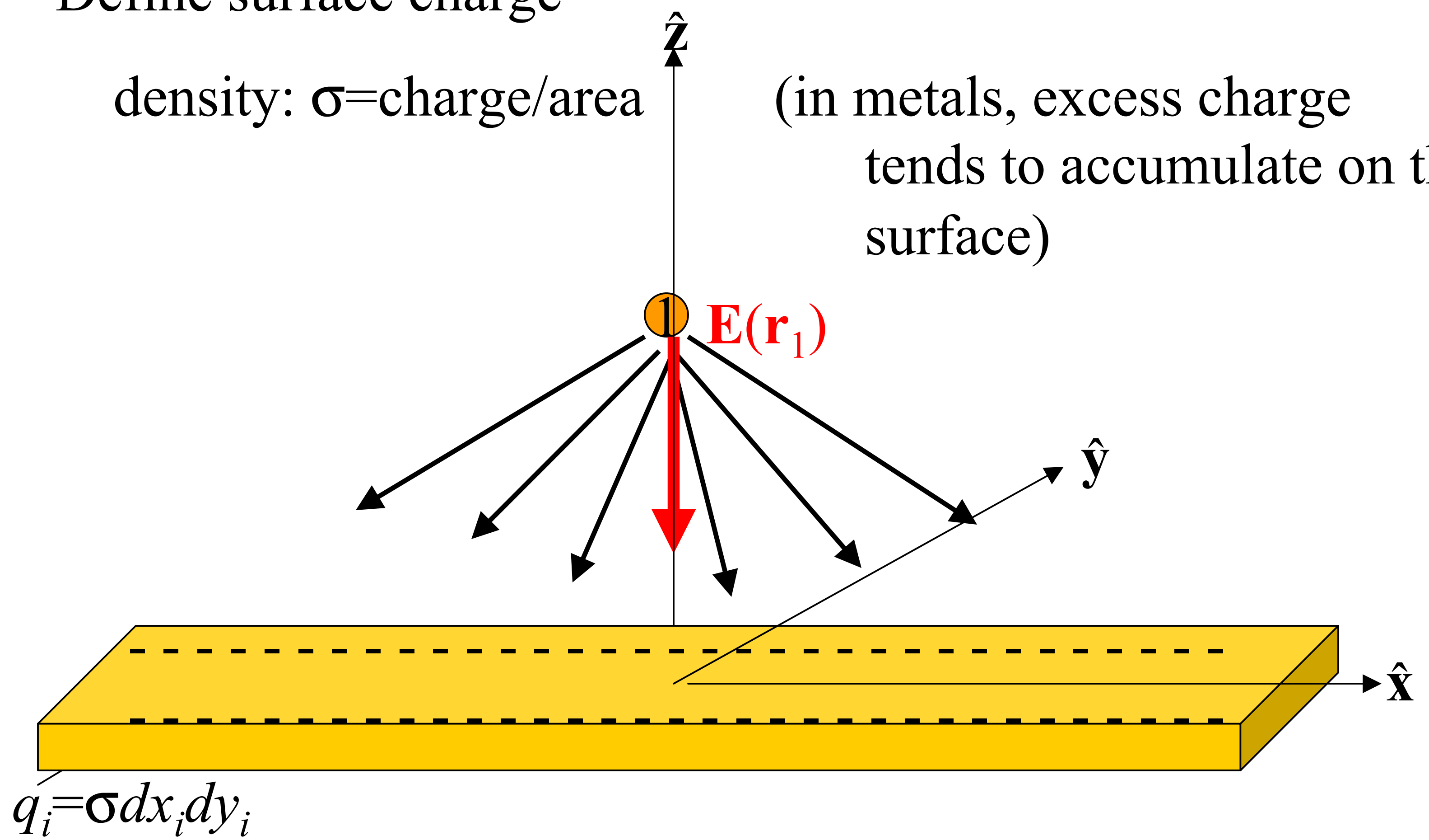
Example:



Calculation of the net electric field for a distribution of surface charge:

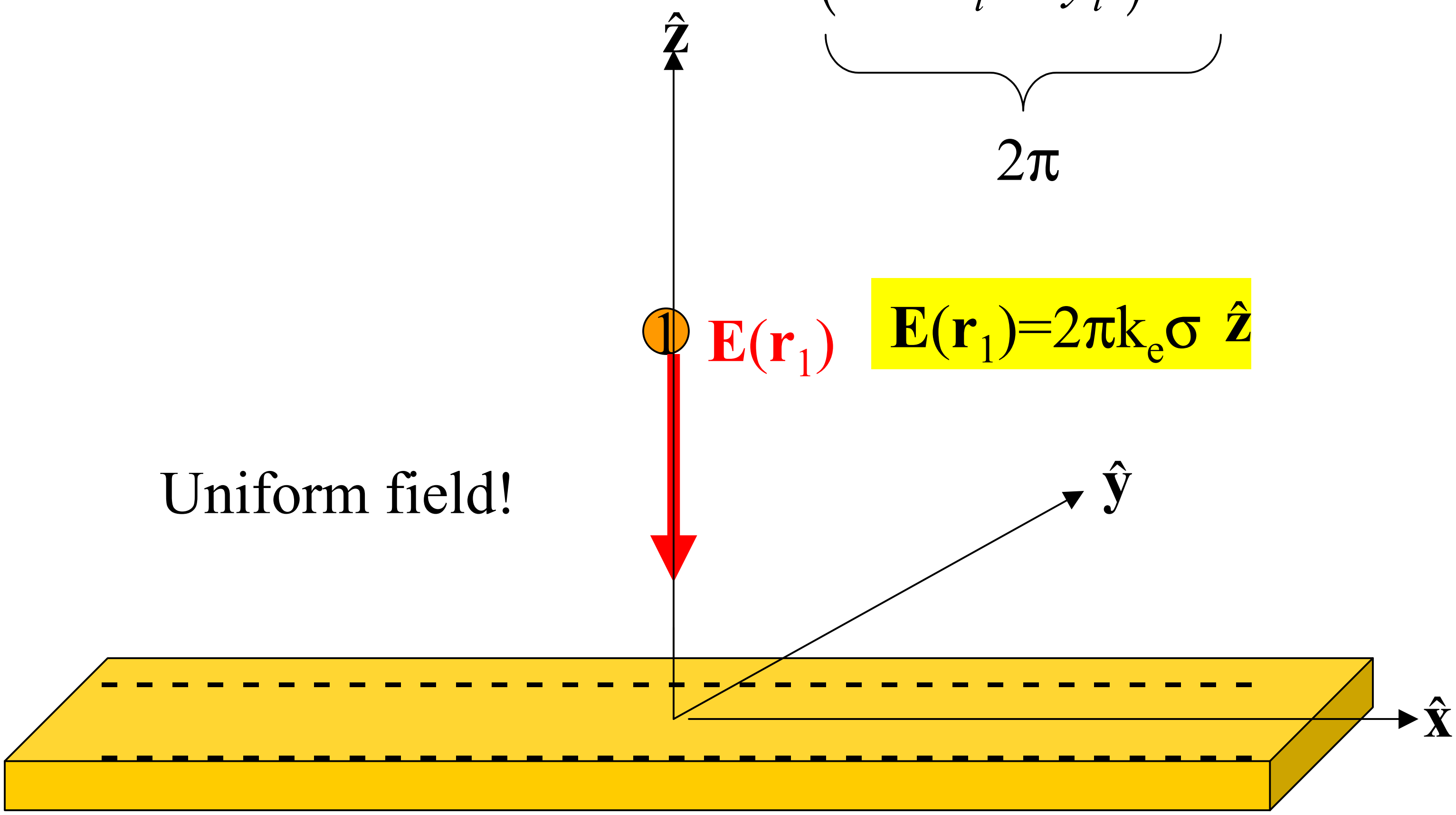
Define surface charge

density: σ=charge/area (in metals, excess charge tends to accumulate on the surface)



Some details:

$$\mathbf{E}(\mathbf{r}_1) = \sum_i k_e \frac{q_i}{|\mathbf{r}_1 - \mathbf{r}_i|^2}\hat{\mathbf{r}}_{1i} = k_e \sigma \hat{\mathbf{z}} \int_{-\infty}^{\infty} \underbrace{\frac{z\,dx_i\,dy_i}{\left(z^2 + x_i^2 + y_i^2\right)^{3/2}}}_{2\pi}$$

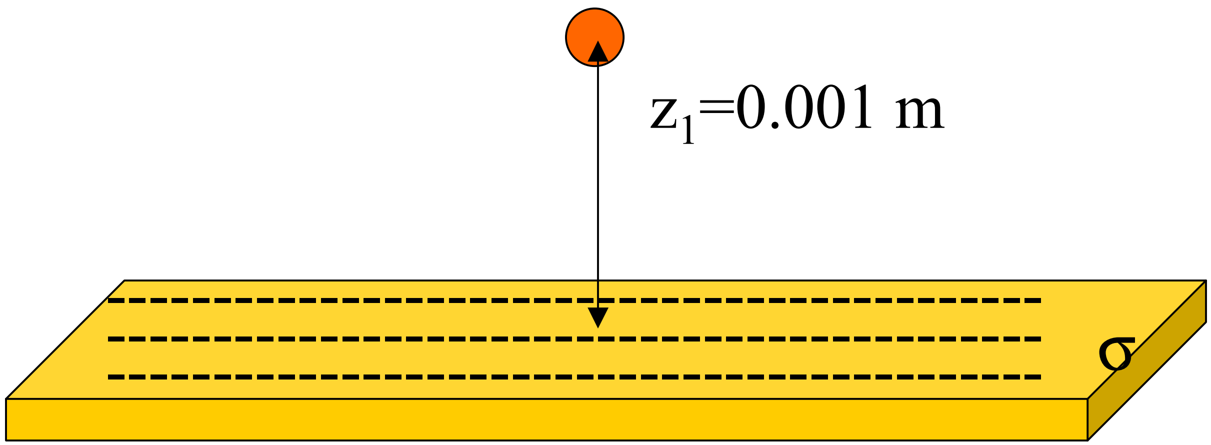


$\mathbf{E}(\mathbf{r}_1) = 2\pi k_e \sigma\ \hat{\mathbf{z}}$

Uniform field!

Example: Suppose $\sigma = -8.85 \times 10^{-9}$ C/m^2

$$\mathbf{E}(\mathbf{r}_1) = 2\pi k_e \sigma \,\hat{\mathbf{z}} \quad = -500 \text{ N/C } \hat{\mathbf{z}}$$



Question:

Suppose an ion of $q=1.6 \times 10^{-19}$C and $m=3 \times 10^{-27}$ kg is initial at rest at z_1=0.001 m. What will be its kinetic energy at z_1=0 m?

(A) 2.94×10^{-29} J (B) 8×10^{-20}J (C) 0.5 J (D) 500 J

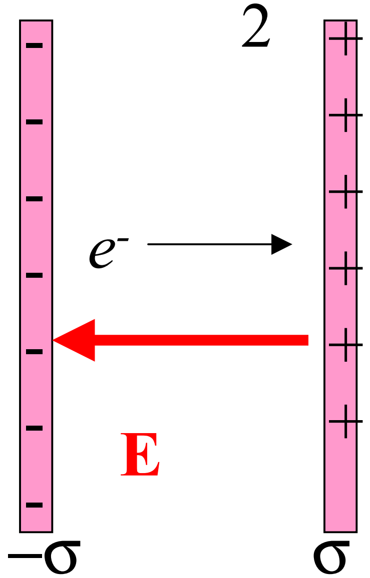
New unit of energy: "electron volt":

$$1\ \text{eV} = 1.60217733\text{x}10^{-19}\ \text{J}$$

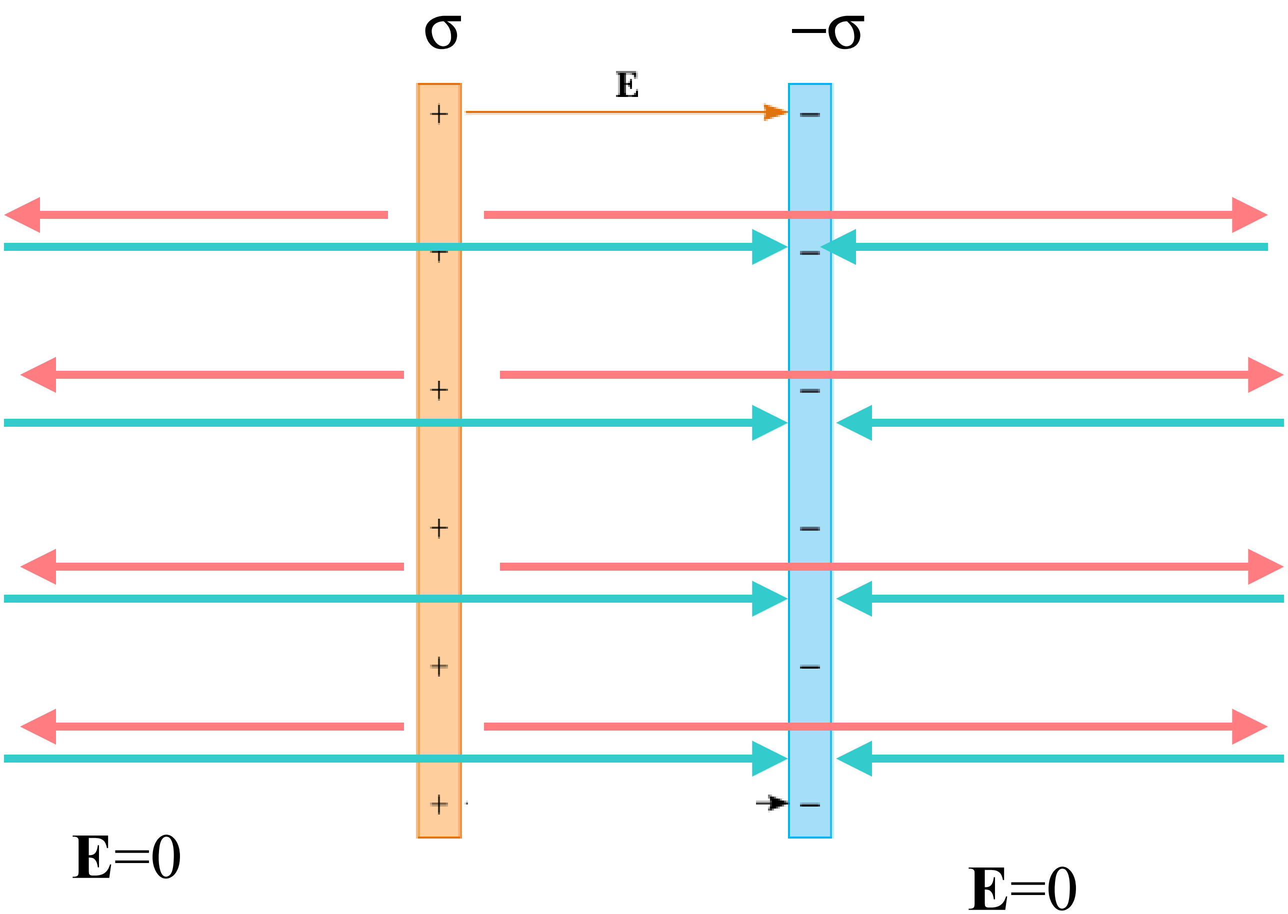
$$8\text{x}10^{-20}\ \text{J} = 0.5\ \text{eV}$$

Velocity of electron (mass m=$9.1\text{x}10^{-31}$kg) with K = $8\text{x}10^{-20}$ J :

$$K = \frac{1}{2}mv^2; \qquad v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2 \cdot 8\times10^{-20}}{9.1\times10^{-31}}} = 1.3\times10^5\ \text{m/s}$$

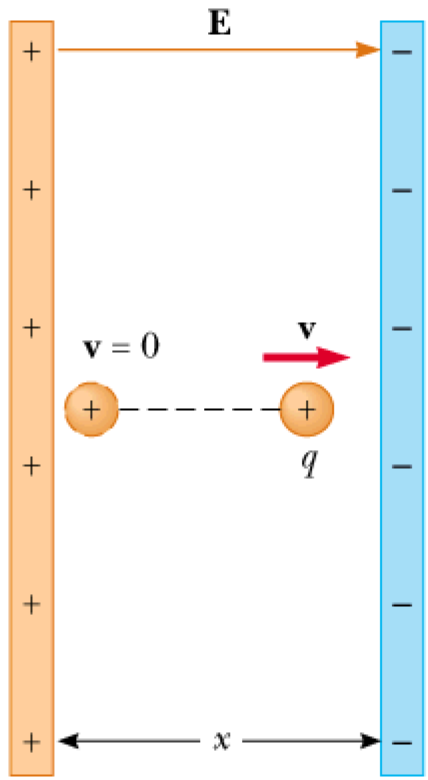


$$E = -4\pi k_e \sigma\ \hat{\mathbf{x}}$$



$$\mathbf{E} = -4\pi k_e \sigma\ \hat{\mathbf{x}}$$

Serway, Physics for Scientists and Engineers, 5/e
Figure 23.24



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

$$\mathbf{a} = q\mathbf{E}/m$$

Cathode ray tube (CRT)

Ref: http://www.howstuffworks.com/