Annoucements

1. Reminder about online quizes
2. Topics for today

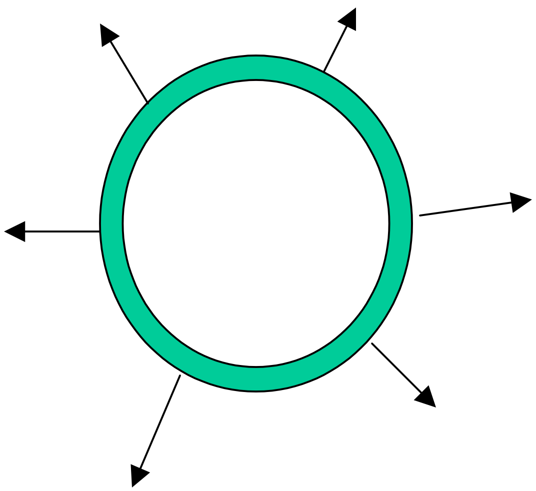
   Short discussion of materials response to electric fields

   Electrical potential and electrostatic potential energy

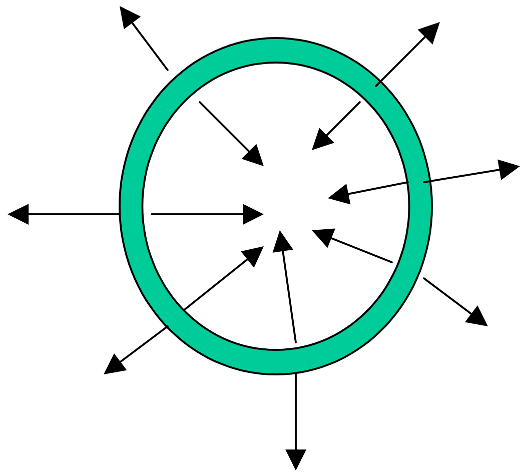
   Review of Gauss's law

Peer instruction question

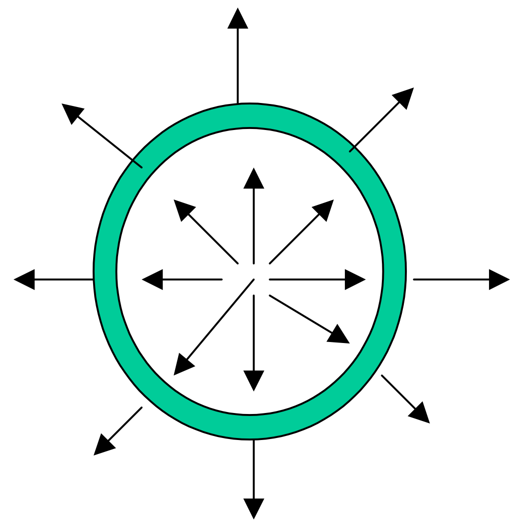
Suppose you have a uniformly charged spherical shell. Which of these diagrams correctly represent the field lines for this system? For this purpose, assume that the only charge in the system is a uniform positive charge represented by the green shell.



(A)



(B)



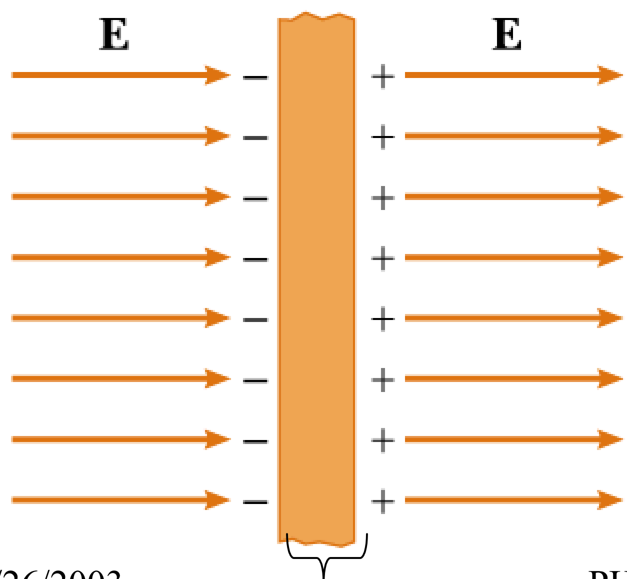
(C)

Response of materials to electrical fields

Solids: In metals, electrons are mobile and move within metal until there are no net forces acting on them. Excess charges migrate to the surfaces. In insulators, charges are constrained by atomic and molecular forces to move only a small amount.

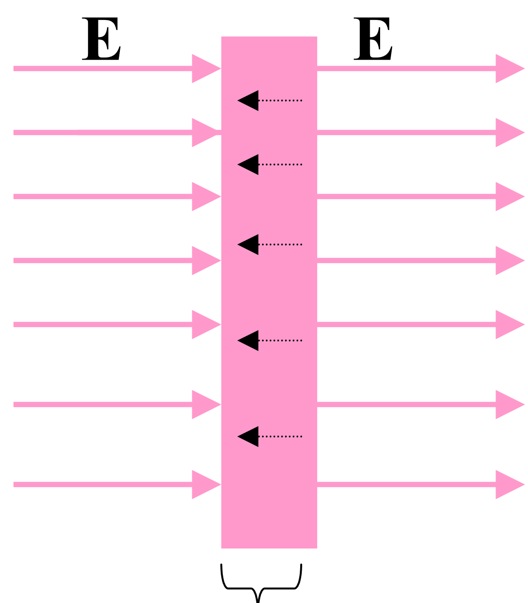
Examples:

Neutral non-grounded metal



E’=0

Neutral insulating sheet

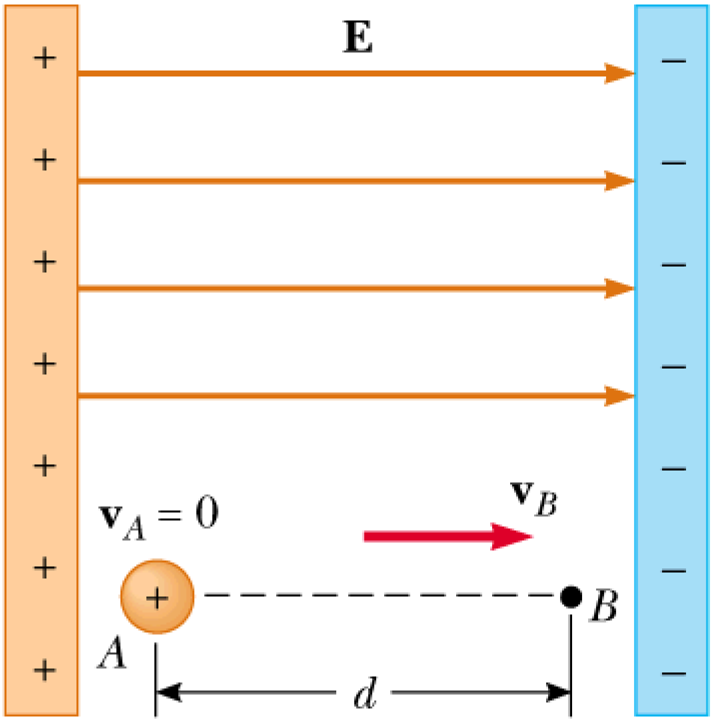


E’<E

Work and electrostatic potential energy

$$W = \int_A^B \mathbf{F} \cdot d\mathbf{r} = q \int_A^B \mathbf{E} \cdot d\mathbf{r} = U_A - U_B$$

Because electrostatic forces are conservative.



Example:

A proton (q=1.6x10^{-19}C) moves a distance d = 0.1m in the direction of a uniform electric field **E**=8000N/C.

What is its change in kinetic energy?

$K_B - K_A = U_A - U_B = 1.28\times10^{-16}$ J

Electrostatic potential

$$V = U/q$$

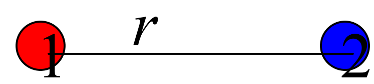
Note:

$$U(\mathbf{r}) = -\int_{\mathbf{r}_{ref}}^{\mathbf{r}} \mathbf{F}\cdot d\mathbf{r}$$

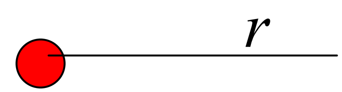
$$V(\mathbf{r}) = -\int_{\mathbf{r}_{ref}}^{\mathbf{r}} E\cdot d\mathbf{r}$$

Volt=J/C

N/C



$$U(r) = k_e\,\frac{q_1 q_2}{r}$$



$$V(r) = k_e\,\frac{q}{r}$$

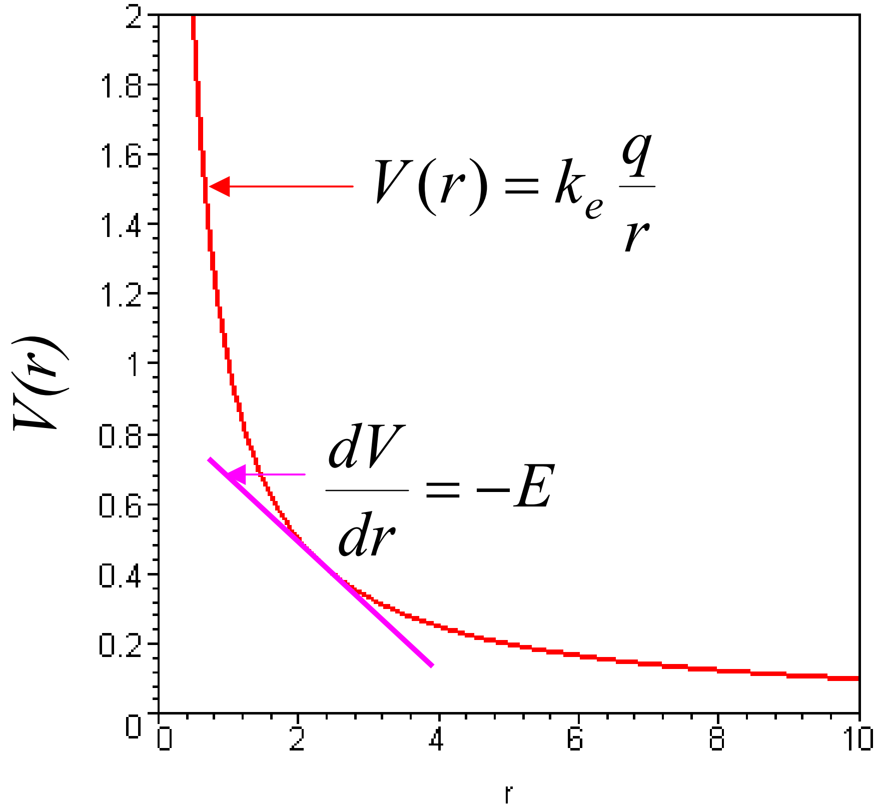
For a point charge, a convenient choice is $r_{ref}=\infty$.

Some details:

$$U(r) = -\int_{\infty}^{r} \frac{k_e q_1 q_2}{r'^2} dr' = \left. \frac{k_e q_1 q_2}{r} \right|_{\infty}^{r}$$

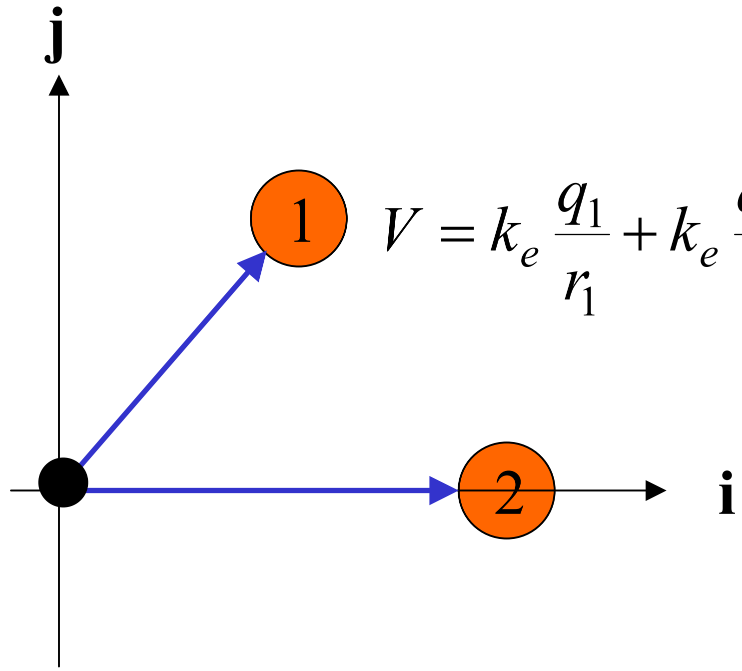
$$V(r) = -\int_{\infty}^{r} \frac{k_e q}{r'^2} dr' = \left. \frac{k_e q}{r} \right|_{\infty}^{r}$$

Electrostatic potential of a point charge continued --



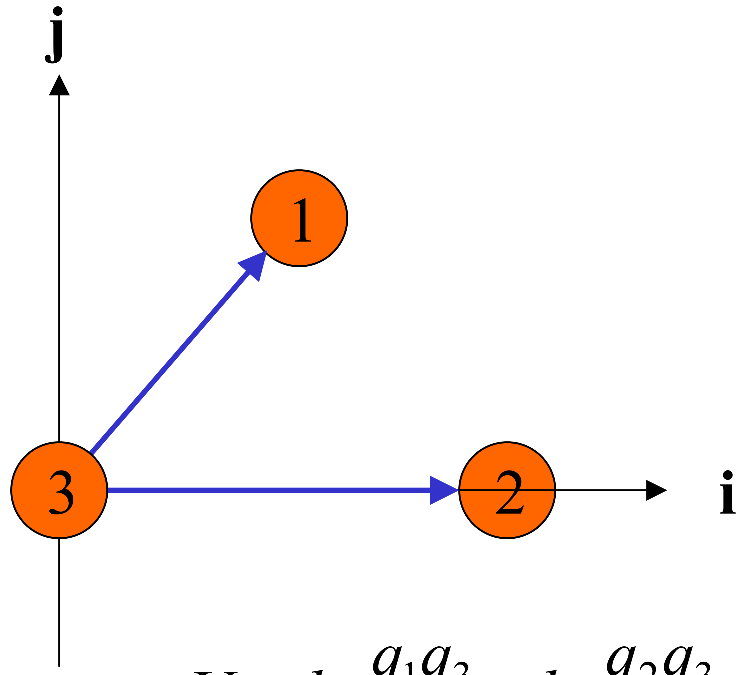
$$\mathbf{E}(r) = -\nabla V(r) = k_e \frac{q}{r^2}\,\hat{\mathbf{r}}$$

Electrostatic potential due to 2 point charges



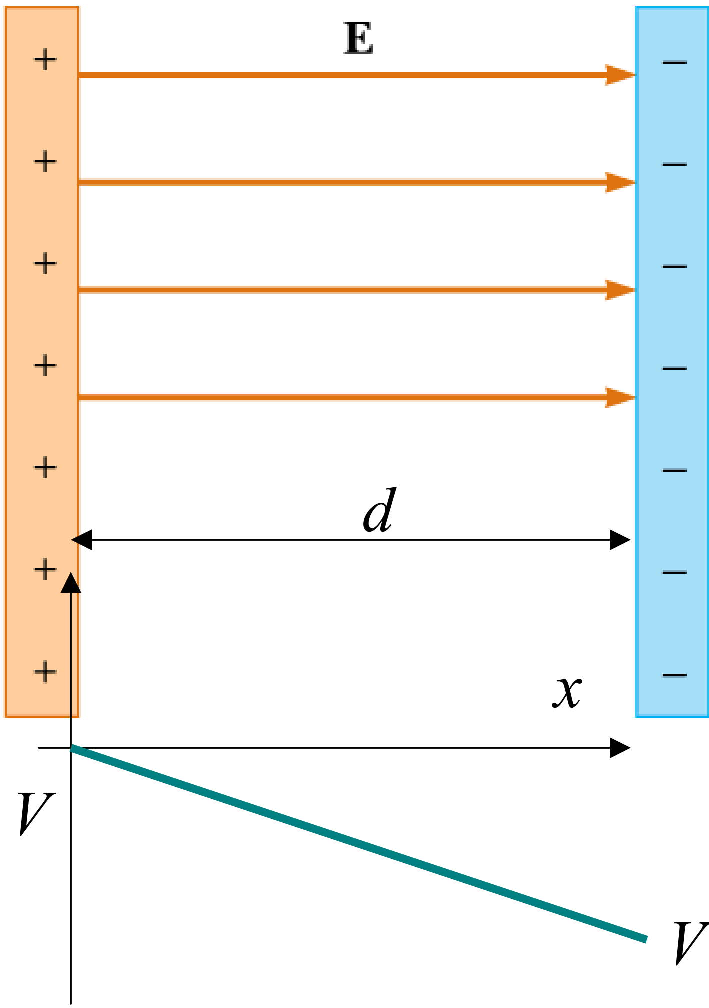
$$V = k_e \frac{q_1}{r_1} + k_e \frac{q_2}{r_2}$$

Electrostatic energy to assemble 3 point charges



$$U = k_e \frac{q_1 q_3}{r_1} + k_e \frac{q_2 q_3}{r_2} + k_e \frac{q_1 q_2}{|\mathbf{r}_1 - \mathbf{r}_2|}$$

Electrostatic potential between two parallel plates



$V(d) = -Ed = -\sigma\, d/\varepsilon_0$

Example:

If $V = 1$ Volt
and $d = 0.01$ m

$\sigma = 8.854\text{x}10^{-10}\text{C/m}^2$

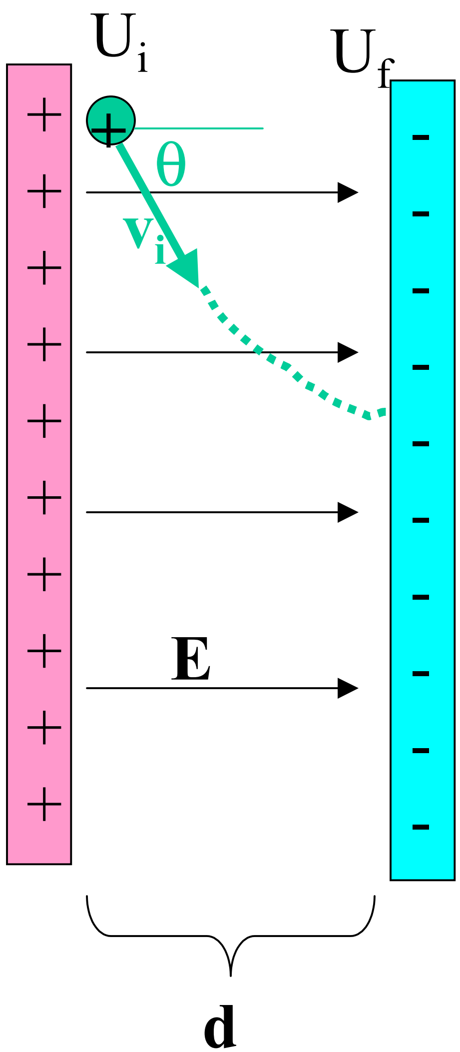
Energy units

$1\ eV = 1.602177x10^{-19}\ J$

= magnitude of the potential energy of an electron or proton in a 1V electrostatic potential

speed of 1eV proton: $1.4x10^{4}$ m/s

electron: $5.9x10^{5}$ m/s



$$K_f + U_f = K_i + U_i$$

$$K_f - K_i = U_i - U_f = -q\Delta V = qEd$$

3. [SB5 24.P.41.] A square plate of copper with 48.0 cm sides has no net charge and is placed in a region of uniform electric field of 79.0 kN/C directed perpendicularly to the plate.

(a) Find the charge density of each face of the plate.

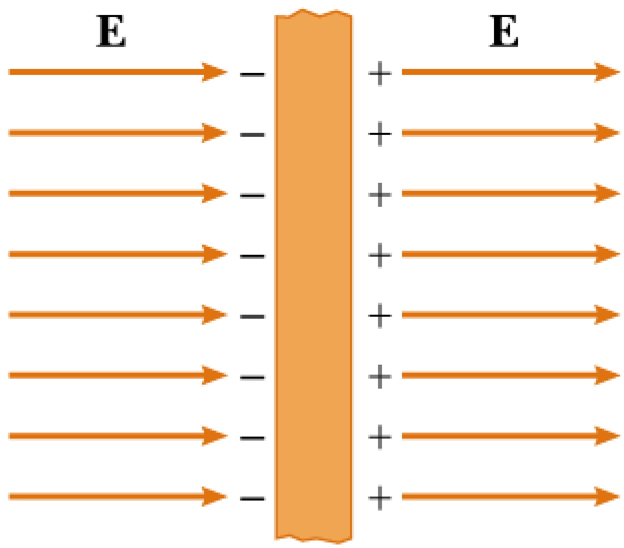
[0.0666666666667] ✗ nC/m^2

[0.0666666666667] ✗ nC/m^2

(b) Find the total charge on each face.

[0.0666666666667] ✗ nC

[0.0666666666667] ✗ nC



E=79000 N/C σ ?

1. [SB5 24.P.05.] Consider a closed triangular box resting within a horizontal electric field of magnitude $E = 7.40 \times 10^4$ N/C, as shown in Figure P24.5.

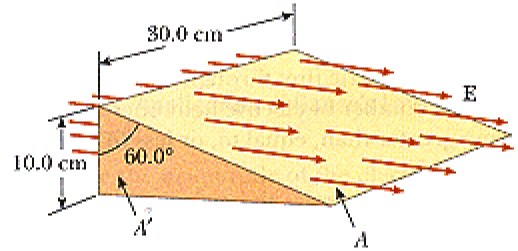


Figure P24.5.

(a) Calculate the electric flux through the vertical surface of the box.

[0.066666666667] ✗ $\mathrm{kN \cdot m^2/C}$

(b) Calculate the electric flux through the slanted surface of the box.

[0.066666666667] ✗ $\mathrm{kN \cdot m^2/C}$

(c) Calculate the electric flux through the entire surface of the box.

[0.066666666667] ✗ $\mathrm{kN \cdot m^2/C}$