Announcements

1. Tutorial schedule
2. HW1 & HW2 due at 11:59 PM this evening.
3. Topics for today:

   Review of the notion of an electric field

   Coulomb's law ←→ Gauss's law

PHY 114 General Physics II -- Section B

MWF 11-11:50 AM	OPL 101	http://www.wfu.edu/~natalie/s05phy114/

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PHY 114 Tutorial Schedule

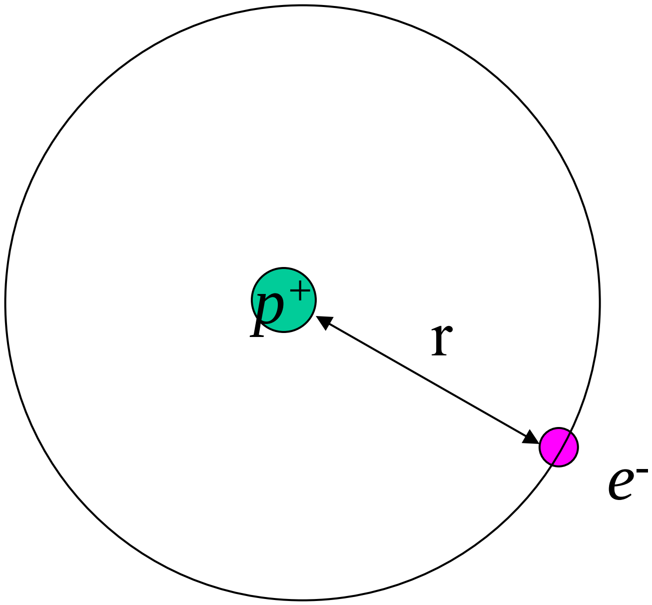
Olin - Room 103

	Monday	Tuesday	Wednesday	Thursday
5 -6 PM	Todd Falleson (A)			
6 -7 PM			Todd Falleson (B)	Doug Bonessi (A)
7 - 8 PM	Todd Falleson (C)	Todd Falleson (B)	Todd Falleson (C)	
8 -9 PM				Doug Bonessi (B)
9 - 10 PM				

Students from all PHY 114 sections are welcome to attend the tutorials; priority will be given to students in the designated sections.

Problem solving session for Section B 6-7 PM

Review – Coulomb's law



$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_e q_p}{r^2}\hat{\mathbf{r}}$$

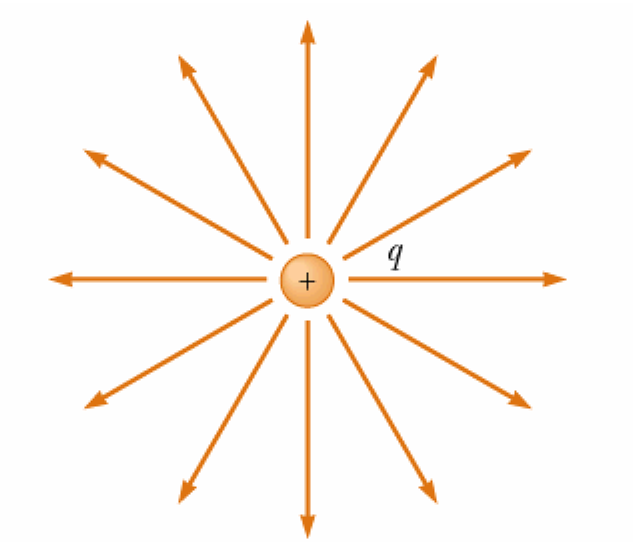
Consider an electron and a proton attracted to each other according to Coulomb's law. Show that the electron can have a stable circular orbit around the proton. Suppose that the radius is r = 0.529×10^{-10} m; calculate the period and energy of the orbit.

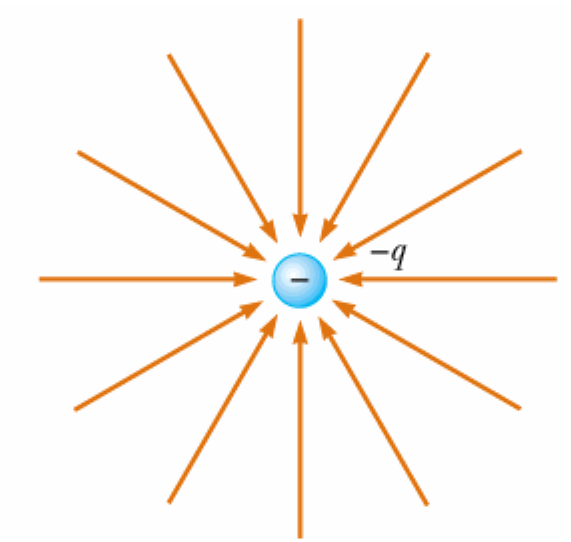
Electric field:

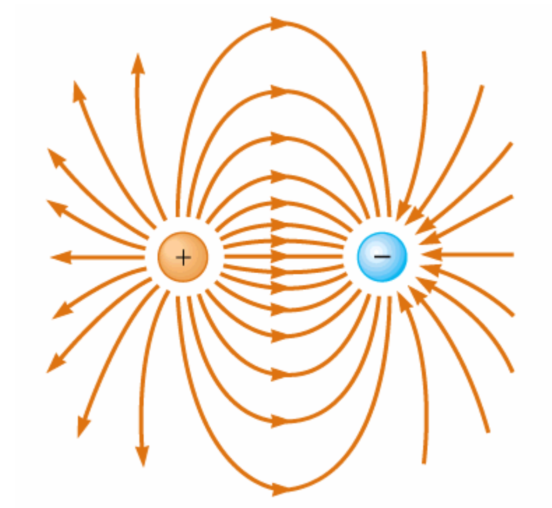
$$\mathbf{E}(\mathbf{r}_1) = \sum_i \frac{1}{4\pi\varepsilon_0} \frac{q_i}{|\mathbf{r}_1 - \mathbf{r}_i|^2} \hat{\mathbf{r}}_{1i}$$

The force on a 1 C charge placed at r_1.

Field lines help to visualize electric field:

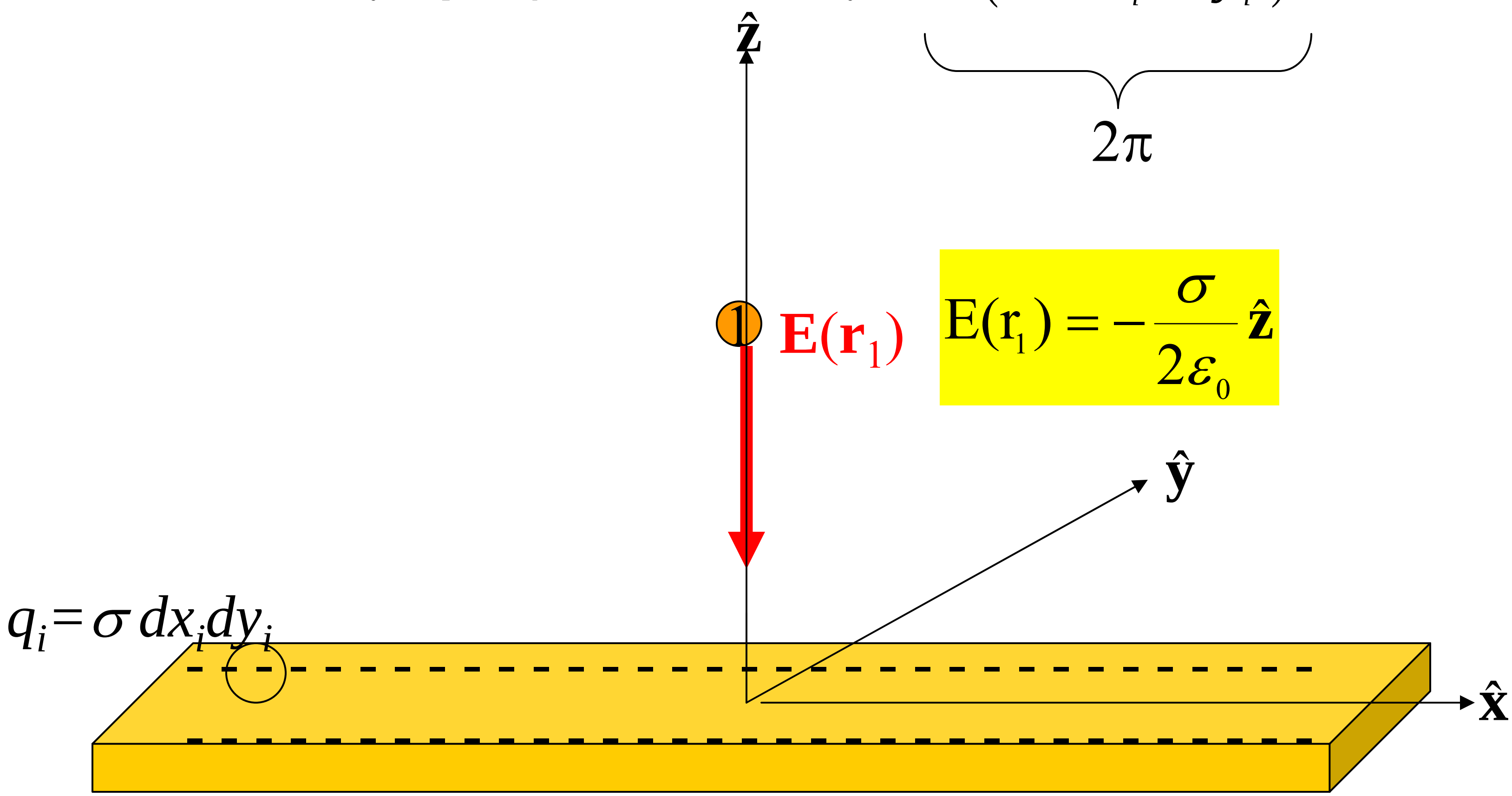






Electric field due to large uniformly charge plate:

$$\mathbf{E}(\mathbf{r}_1) = \sum_i \frac{1}{4\pi\varepsilon_0} \frac{q_i}{|\mathbf{r}_1 - \mathbf{r}_i|^2} \hat{\mathbf{r}}_{1i} = -\frac{1}{4\pi\varepsilon_0} \sigma \hat{\mathbf{z}} \underbrace{\int_{-\infty}^{\infty} \frac{z\,dx_i\,dy_i}{\left(z^2 + x_i^2 + y_i^2\right)^{3/2}}}_{2\pi}$$



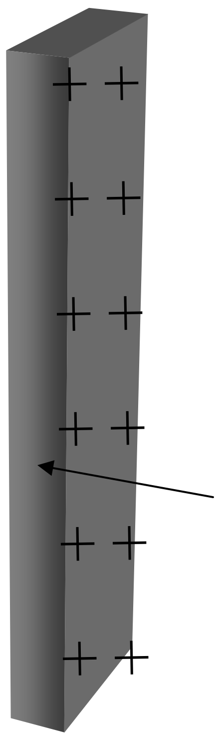
$$\mathrm{E}(\mathrm{r}_1) = -\frac{\sigma}{2\varepsilon_0} \hat{\mathbf{z}}$$

Peer instruction question

We have discussed the notion that if we know that field at the point $\mathbf{r}_1$ is $\mathbf{E}(\mathbf{r}_1)$, we can determine the force on a charge q at that point according to $\mathbf{F} = q\,\mathbf{E}(\mathbf{r}_1)$. This assumes that the charges that determine $\mathbf{E}(\mathbf{r}_1)$ are not effected by q. When is this a good approximation?

(A) Always (B) Never (C) Most often for metals.
(D) Most often for insulators.

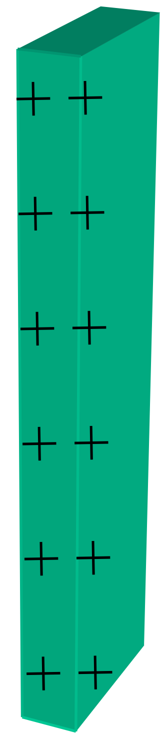
Metals



Electric field within metal is 0.

Net charge moves to surface of metal.

Insulators

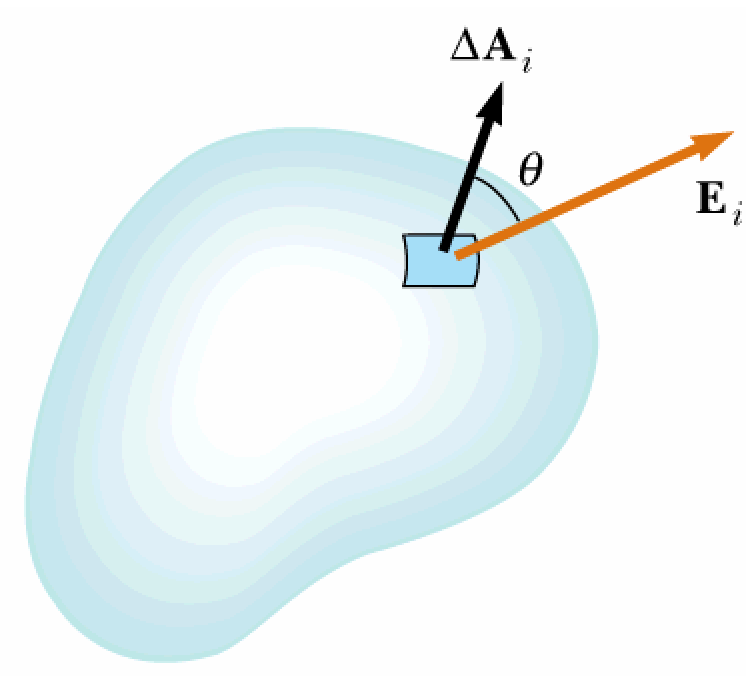


Net charge may remain within insulator.

An alternative method for calculating electric fields –

Gauss's Law

Define electric "flux":



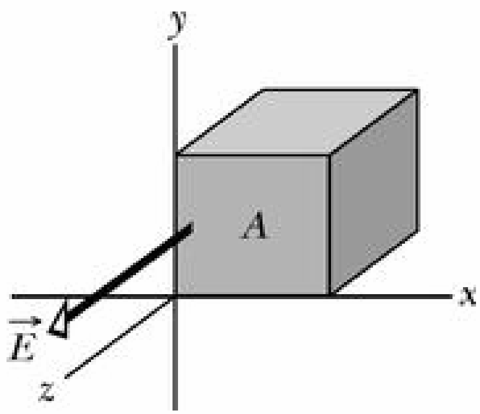
$$\Phi_E \equiv \int \mathbf{E} \cdot d\mathbf{A}$$
$$= \int E dA \cos\theta$$

Gauss's law says:

$$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{1}{\varepsilon_0}(\text{charge inside})$$

Integral of surrounding surface

Online Quiz for Lecture 3
Electric field due to charged particles -- Jan. 14, 2005



For each of these questions choose one of the following answers:

(a) (EA) (b) -(EA) (c) 2(EA) (d) 0

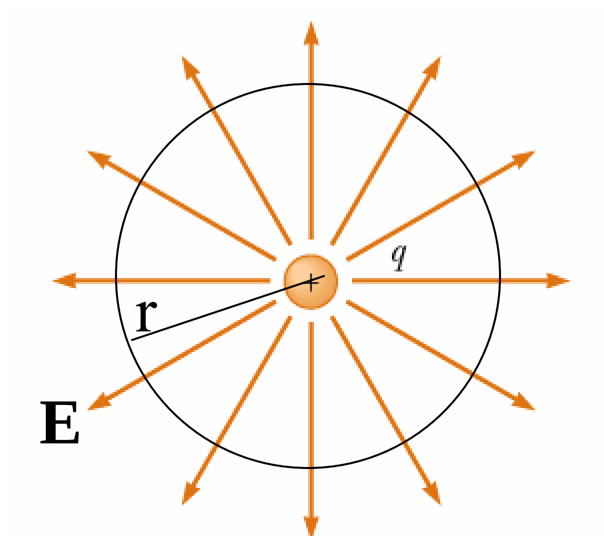
The figure here shows a cube for which face has an area A. Also in the figure is a uniform electric field **E** that is directed along the positive **z** axis.

1. What is the flux through the front face (x-y) plane? (EA)
2. What is the flux through the back face? (-EA)
3. What is the flux through the top face? (0)
4. What is the total flux through the cube? (0)
5. What is the total charge inside the cube? (0)

$$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{1}{\varepsilon_0}(\text{charge inside})$$

How can it be true?:

Consider simple case:



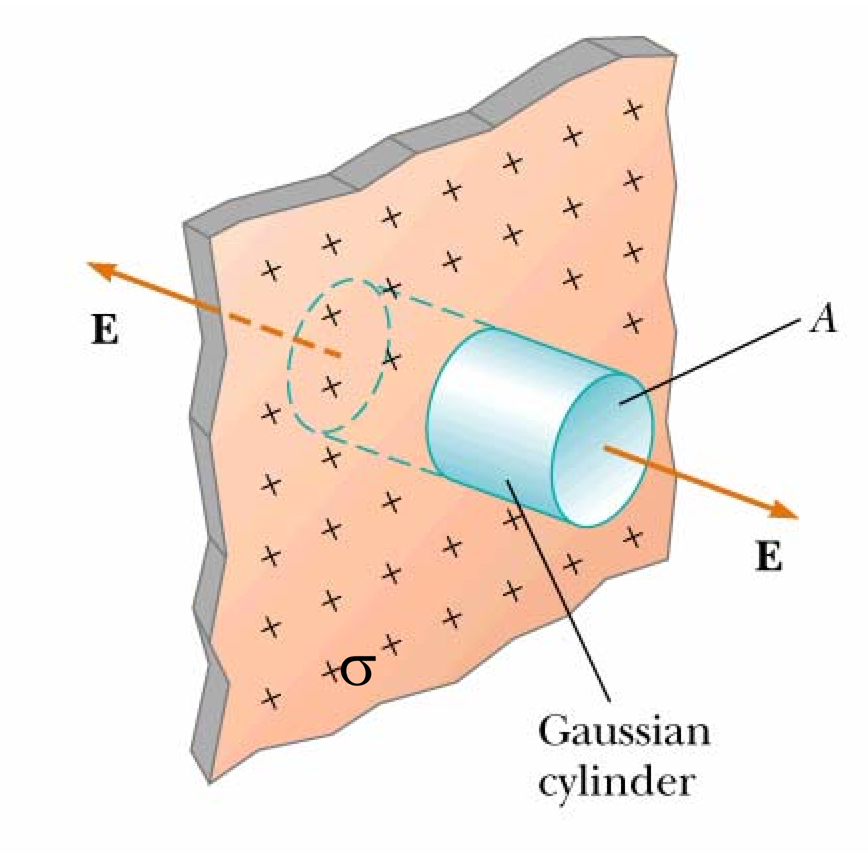
Assume **E** is purely radial and has a constant value on the surface of a sphere of radius r.

$$\oint \mathbf{E} \cdot d\mathbf{A} = |\mathbf{E}|(\text{area of sphere}) = |\mathbf{E}|\ (4\pi r^2)$$

$$|\mathbf{E}|\ (4\pi r^2) = \frac{1}{\varepsilon_0} q$$

$$|\mathbf{E}| = \frac{q}{4\pi\varepsilon_0 r^2}$$

Electrostatic field from charged sheet



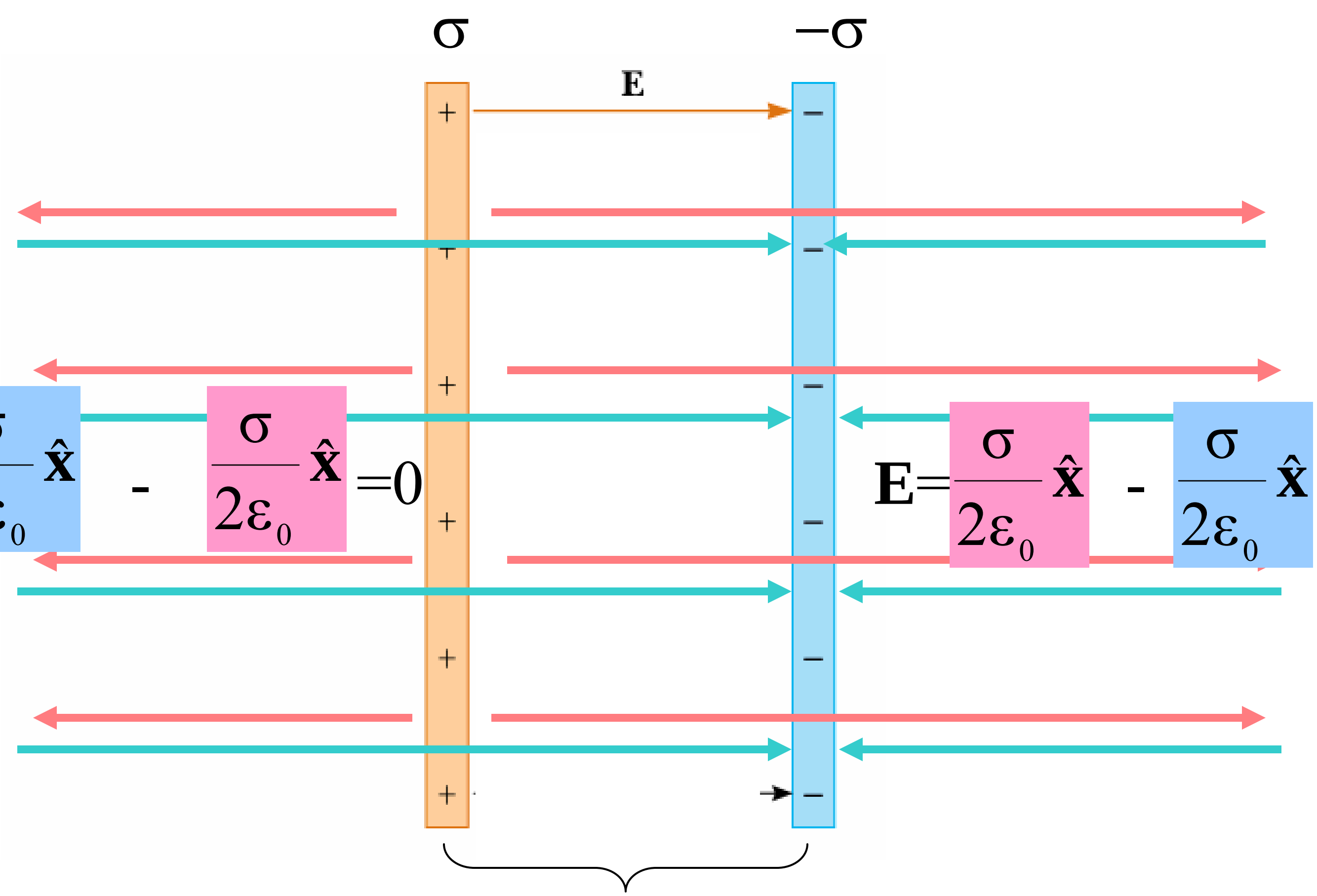
2 ends of cylinder

$$2EA = \frac{1}{\varepsilon_0}(\text{charge inside})$$

$$\Rightarrow E = \frac{\sigma A}{2A\varepsilon_0} = \frac{\sigma}{2\varepsilon_0}$$

$$\Rightarrow E = \frac{\sigma}{2\varepsilon_0}$$

permittivity constant =$8.854 \times 10^{-12}\ C^2/(Nm^2)$



$$\mathbf{E} = \frac{\sigma}{2\varepsilon_0}\hat{\mathbf{x}} - \frac{\sigma}{2\varepsilon_0}\hat{\mathbf{x}} = 0$$

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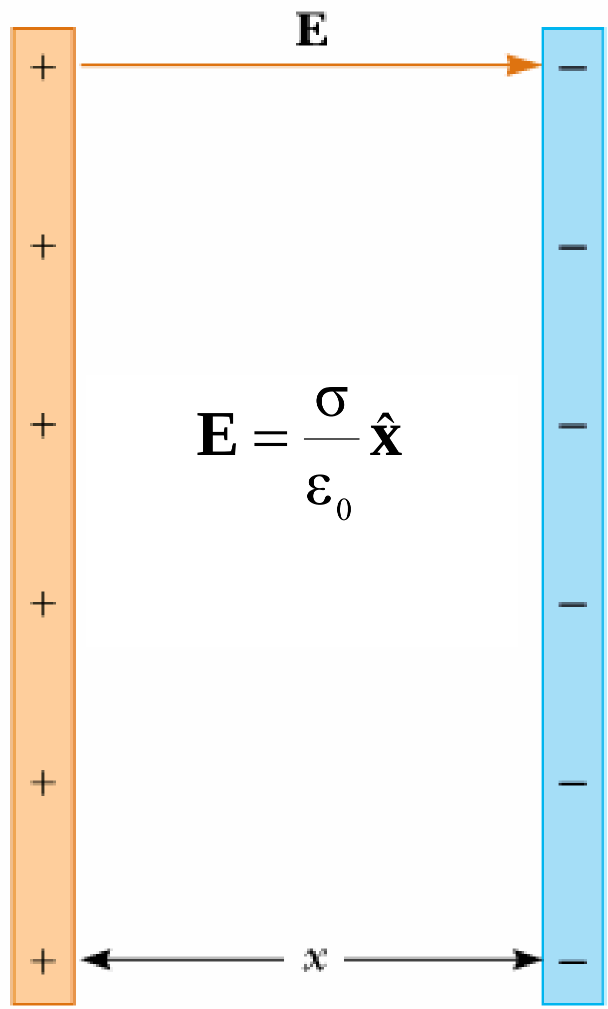
$$\mathbf{E} = \frac{\sigma}{2\varepsilon_0}\hat{\mathbf{x}} + \frac{\sigma}{2\varepsilon_0}\hat{\mathbf{x}} = \frac{\sigma}{\varepsilon_0}\hat{\mathbf{x}}$$

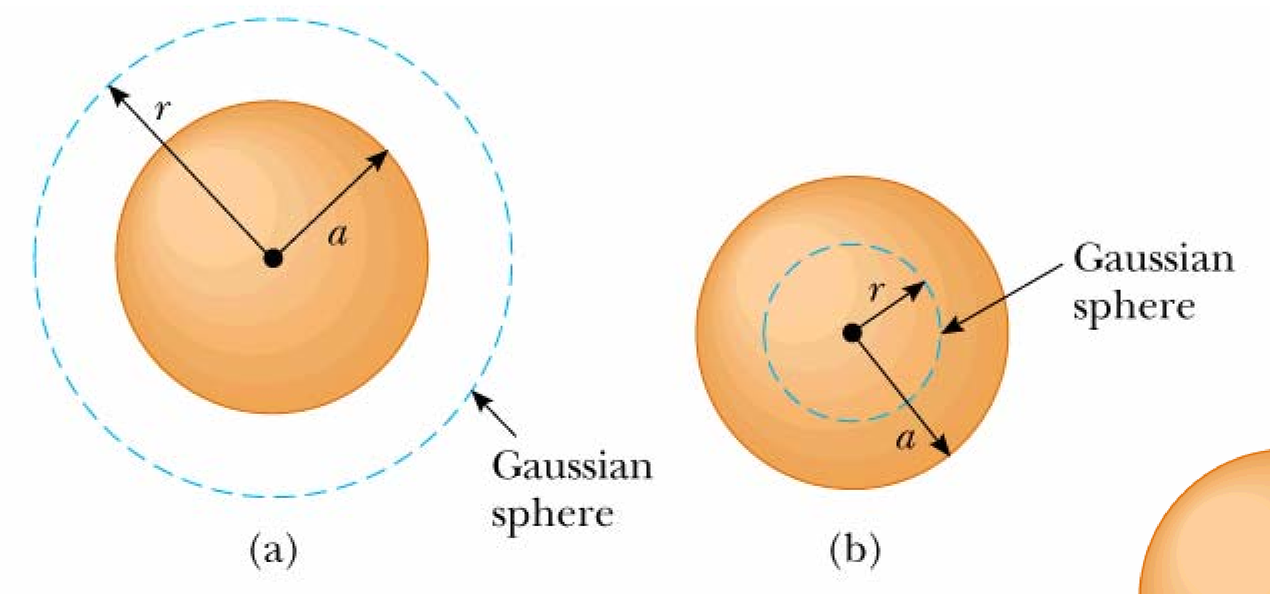
$$\mathbf{E} = 0$$

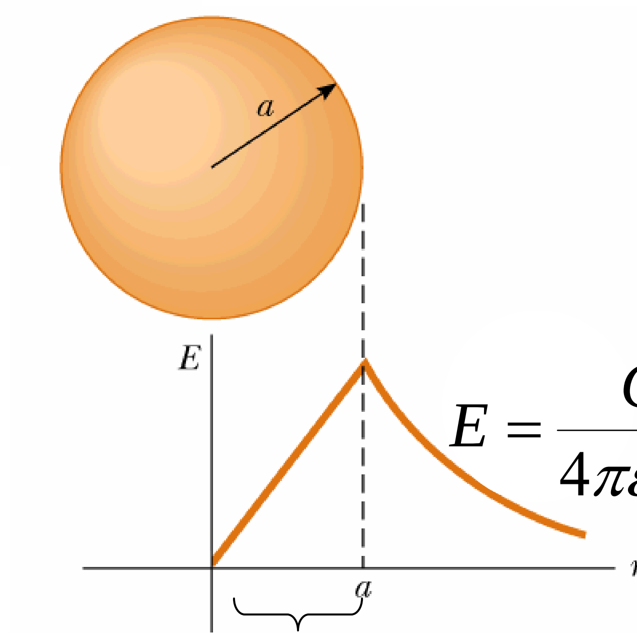


$$\mathbf{E} = \frac{\sigma}{\varepsilon_0}\hat{\mathbf{x}}$$

$$\mathbf{E} = 0$$

Electric field inside and outside uniformly charged sphere:





$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

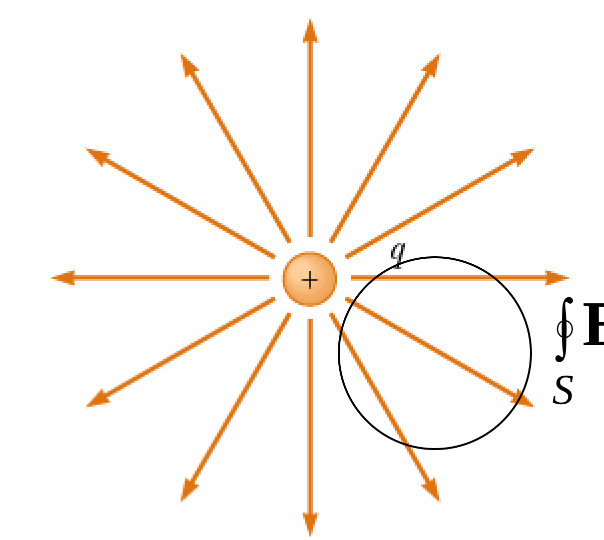
$$E = \frac{Qr}{4\pi\varepsilon_0 a^3}$$

Summary – Gauss's law

$$\oint_S \mathbf{E}\cdot d\mathbf{A} = \frac{1}{\varepsilon_0}\int_V dV\rho$$

closed surface

volume inside surface

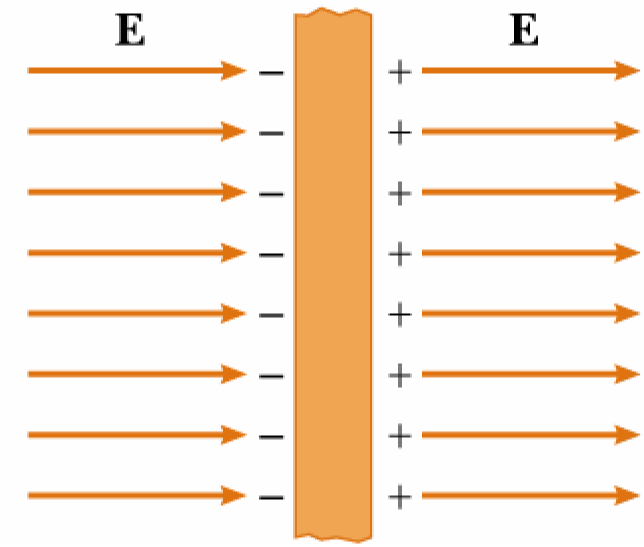


$$\oint_S \mathbf{E}\cdot d\mathbf{A} = 0$$

Behavior of materials in an electric field

➔ Charges move in response to the forces applied to them until they come to equilibrium.

- Insulators – charges are (more or less) held in place by atomic and molecular forces
- Conductors – charges are mobile and move such that the electric field within the conductor is approximately 0.



2. [HRW6 24.P.009] It is found experimentally that the electric field in a certain region of Earth's atmosphere is directed vertically down. At an altitude of 240 m the field has magnitude 60.0 N/C; at an altitude of 110 m, 100 N/C. Find the net amount of charge contained in a cube 130 m on edge, with horizontal faces at altitudes of 110 and 240 m. Neglect the curvature of Earth.

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