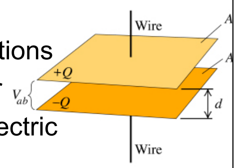
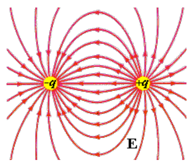
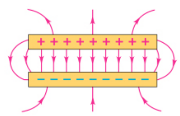
PHY132H1F Introduction to Physics II
Class 10 – **Outline:**

- The Electric Dipole
- Continuous Charge Distributions
- The Parallel Plate Capacitor
- Motion of a Particle in an Electric Field



(a)




(b)

Quick Ch. 27 reading quiz..

Which of these charge distributions did *not* have its electric field determined in Chapter 27?

A. A line of charge
B. A parallel-plate capacitor
C. A ring of charge
D. A plane of charge
E. They were *all* determined

- Electric Charge, q
- Electric Force, F
- Electric Field, E ← You are here, Ch.27
- Electric Potential, V
- Current and Ohm's Law: $\Delta V = IR$

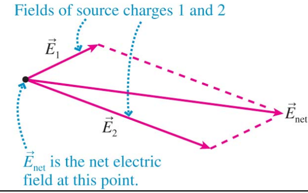
Electric Field Models

The net electric field due to a group of point charges is

$$\vec{E}_{net} = \frac{\vec{F}_{on\ q}}{q} = \frac{\vec{F}_{1\ on\ q}}{q} + \frac{\vec{F}_{2\ on\ q}}{q} + \cdots = \vec{E}_1 + \vec{E}_2 + \cdots = \sum_i \vec{E}_i$$

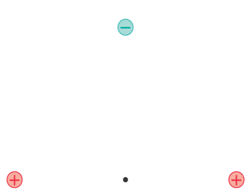
where E_i is the field from point charge i.

FIGURE 27.3 Electric fields obey the principle of superposition.



In Class Discussion Question.

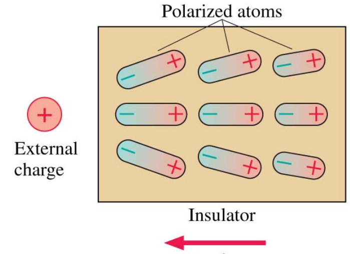
At the position of the dot, the electric field points



A. Up.
B. Down.
C. Left.
D. Right.
E. The electric field is zero.

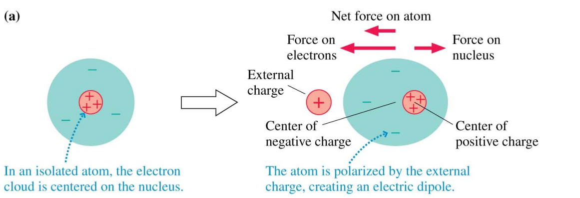
The Electric Dipole

FIGURE 26.15 The atoms in an insulator are polarized by an external charge.



The Electric Dipole

FIGURE 26.14 A neutral atom is polarized by an external charge, forming an *electric dipole*.

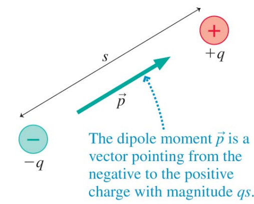


The Electric Field of a Dipole

We can represent an electric dipole by two opposite charges $\pm q$ separated by the small distance s.
The dipole moment is defined as the vector

$$\vec{p} = (qs, \text{ from the negative to the positive charge})$$

The dipole-moment magnitude $p = qs$ determines the electric field strength. The SI units of the dipole moment are C m.



In Class Discussion Question.
A particular dipole consists of a positive charge at x = 0 m, y = 0.1 m and a negative charge at x = 0 m, y = -0.1 m. What is the direction of the dipole moment?

A. $+\hat{x}$

B. $-\hat{x}$

C. $+\hat{y}$

D. $-\hat{y}$

In Class Discussion Question.
A particular dipole consists of a positive charge at x = 0 m, y = 0.1 m and a negative charge at x = 0 m, y = -0.1 m. If the charges have magnitudes of 1 nC each, what is the magnitude of the dipole moment?

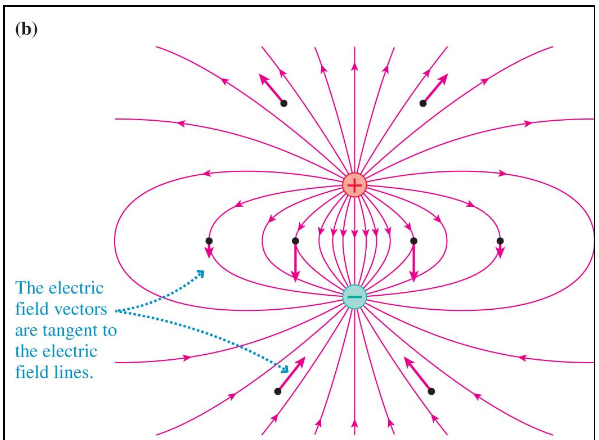
A. $1\times10^{-10}\,\text{Cm}$

B. $4\times10^{-10}\,\text{Cm}$

C. $2\times10^{-9}\,\text{Cm}$

D. $2\times10^{-10}\,\text{Cm}$

E. $4\times10^{-9}\,\text{Cm}$



The Electric Field of a Dipole

The electric field at a point on the axis of a dipole is

$$\vec{E}_{\text{dipole}} \approx \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{r^3} \qquad \text{(on the axis of an electric dipole)}$$

where r is the distance measured from the *center* of the dipole.
The electric field in the plane that bisects and is perpendicular to the dipole is

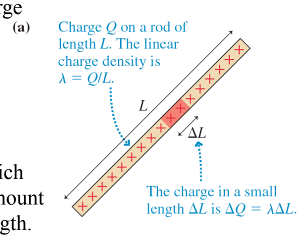
$$\vec{E}_{\text{dipole}} \approx -\frac{1}{4\pi\epsilon_0}\frac{\vec{p}}{r^3} \qquad \text{(perpendicular plane)}$$

This field is opposite to the dipole direction, and it is only half the strength of the on-axis field at the same distance.

The Electric Field of a Continuous Charge Distribution

The linear charge density of an object of length L and charge Q, is defined as

$$\lambda = \frac{Q}{L}$$



Linear charge density, which has units of C/m, is the amount of charge *per meter* of length.

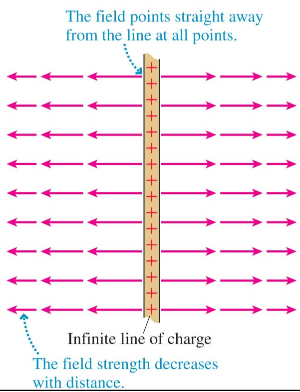
An Infinite Line of Charge

A very long, thin rod, with linear charge density λ, has an electric field

$$E_{\text{line}} = \lim_{L\to\infty} \frac{1}{4\pi\epsilon_0}\frac{|Q|}{r\sqrt{r^2+(L/2)^2}} = \frac{1}{4\pi\epsilon_0}\frac{|Q|}{rL/2} = \frac{1}{4\pi\epsilon_0}\frac{2|\lambda|}{r}$$

Where r is the radial distance away from the rod.

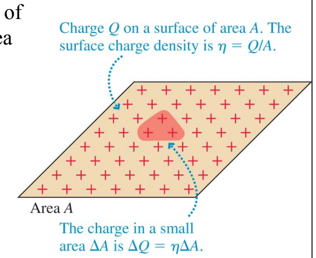
FIGURE 27.14 The electric field of an infinite line of charge.



The Electric Field of a Continuous Charge Distribution

The surface charge density of a two-dimensional distribution of charge across a surface of area A is defined as

$$\eta = \frac{Q}{A}$$



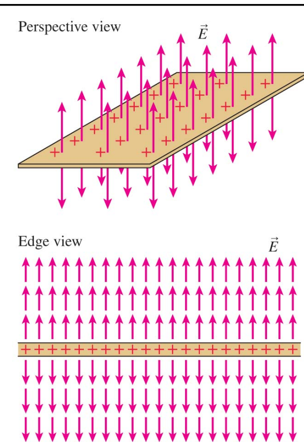
Surface charge density, with units C/m^2, is the amount of charge *per square meter*.

A Plane of Charge

The electric field of an infinite plane of charge with surface charge density η is:

$$E_{\text{plane}} = \frac{\eta}{2\epsilon_0} = \text{constant}$$

For a positively charged plane, with $\eta > 0$, the electric field points *away from* the plane on both sides of the plane.
For a negatively charged plane, with $\eta < 0$, the electric field points *towards* the plane on both sides of the plane.



A Sphere of Charge

A sphere of charge Q and radius R, be it a uniformly charged sphere or just a spherical shell, has an electric field *outside* the sphere that is exactly the same as that of a point charge Q located at the center of the sphere:

$$\vec{E}_{\text{sphere}} = \frac{Q}{4\pi\epsilon_0 r^2}\hat{r} \qquad \text{for } r \geq R$$

The Parallel-Plate Capacitor

- The figure shows two electrodes, one with charge $+Q$ and the other with $-Q$ placed face-to-face a distance d apart.
- This arrangement of two electrodes, charged equally but oppositely, is called a **parallel-plate capacitor.**
- Capacitors play important roles in many electric circuits.

FIGURE 27.20 A parallel-plate capacitor.

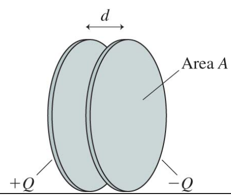
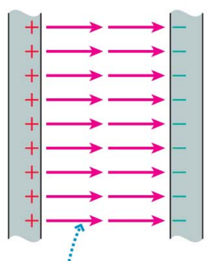


FIGURE 27.22 The electric field of a capacitor.

(a) Ideal capacitor



The Parallel-Plate Capacitor

The electric field inside a capacitor is

$$\vec{E}_{\text{capacitor}} = \vec{E}_+ + \vec{E}_- = \left(\frac{\eta}{\epsilon_0}, \text{ from positive to negative}\right)$$

$$= \left(\frac{Q}{\epsilon_0 A}, \text{ from positive to negative}\right)$$

where A is the surface area of each electrode. Outside the capacitor plates, where E_+ and E_- have equal magnitudes but *opposite* directions, the electric field is zero.

Before Next Class:

- Try the suggested end-of-chapter problems for Chapter 27, posted on the Materials part of the web-site.
- Please read the first half of Chapter 29 on Electric Potential before Wednesday's class. [We are skipping Chapter 28 in this course.]

See you Wednesday!