

Lecture # 2

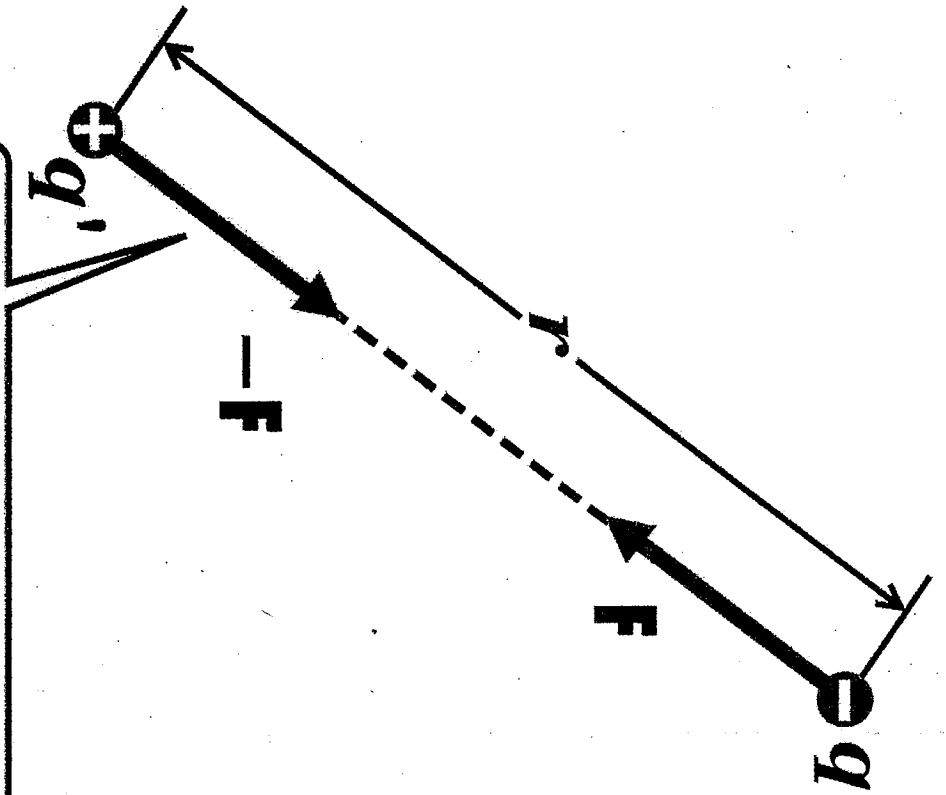
Electric Forces



## Checkup 22.4

Is it possible for a body to have an electric charge of  $2.0 \times 10^{-19}$  C?  $3.2 \times 10^{-19}$  C?

- a. Yes; yes
- b. Yes; no
- c. No; yes
- d. No; no



**For unlike charges, the attractive force of each lies along the line joining the charges...**

Figure 22-4a Physics for Engineers and Scientists 3/e  
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Total Forces is Vector Sum of Individual Forces

Net force on  $q$  is obtained by parallelogram method.

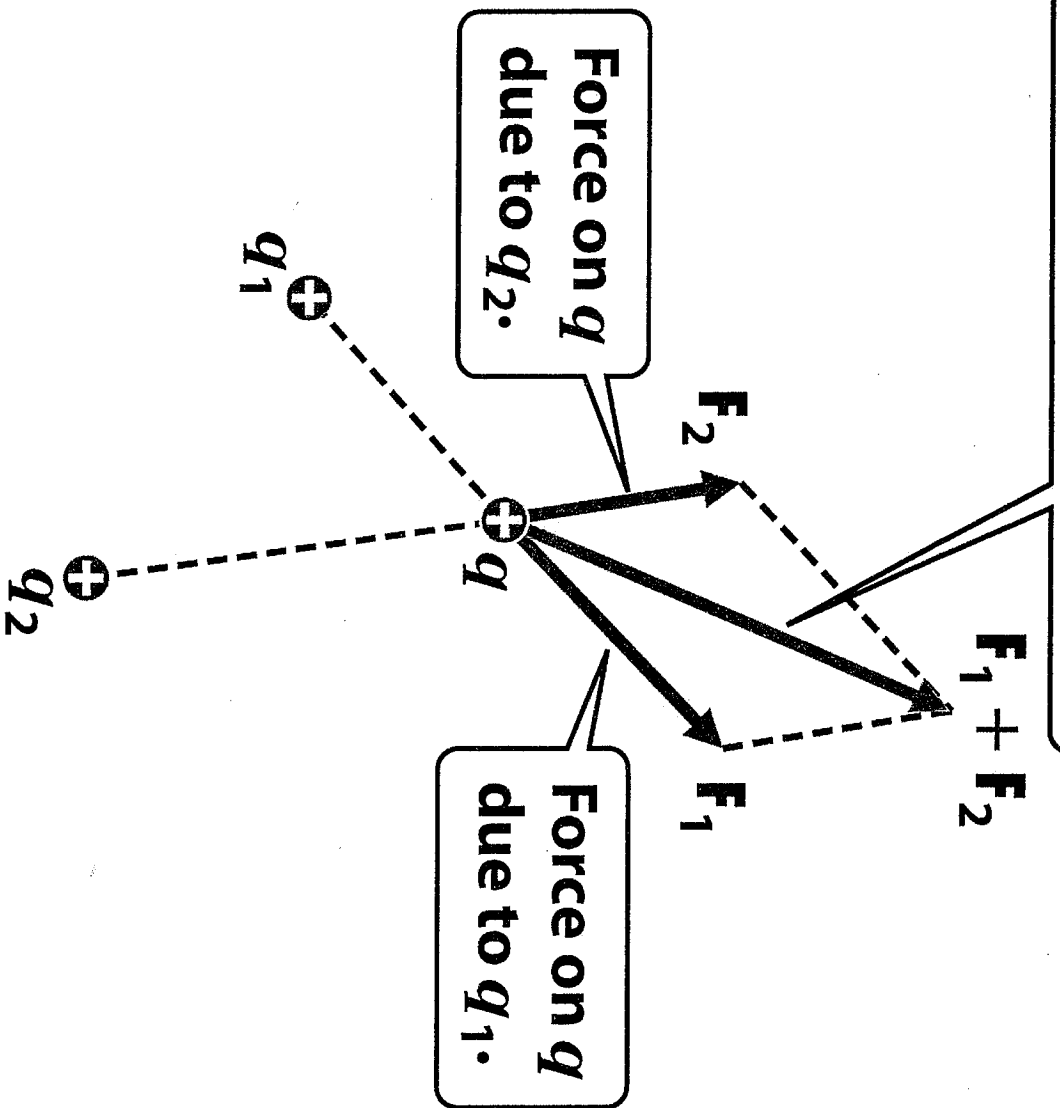
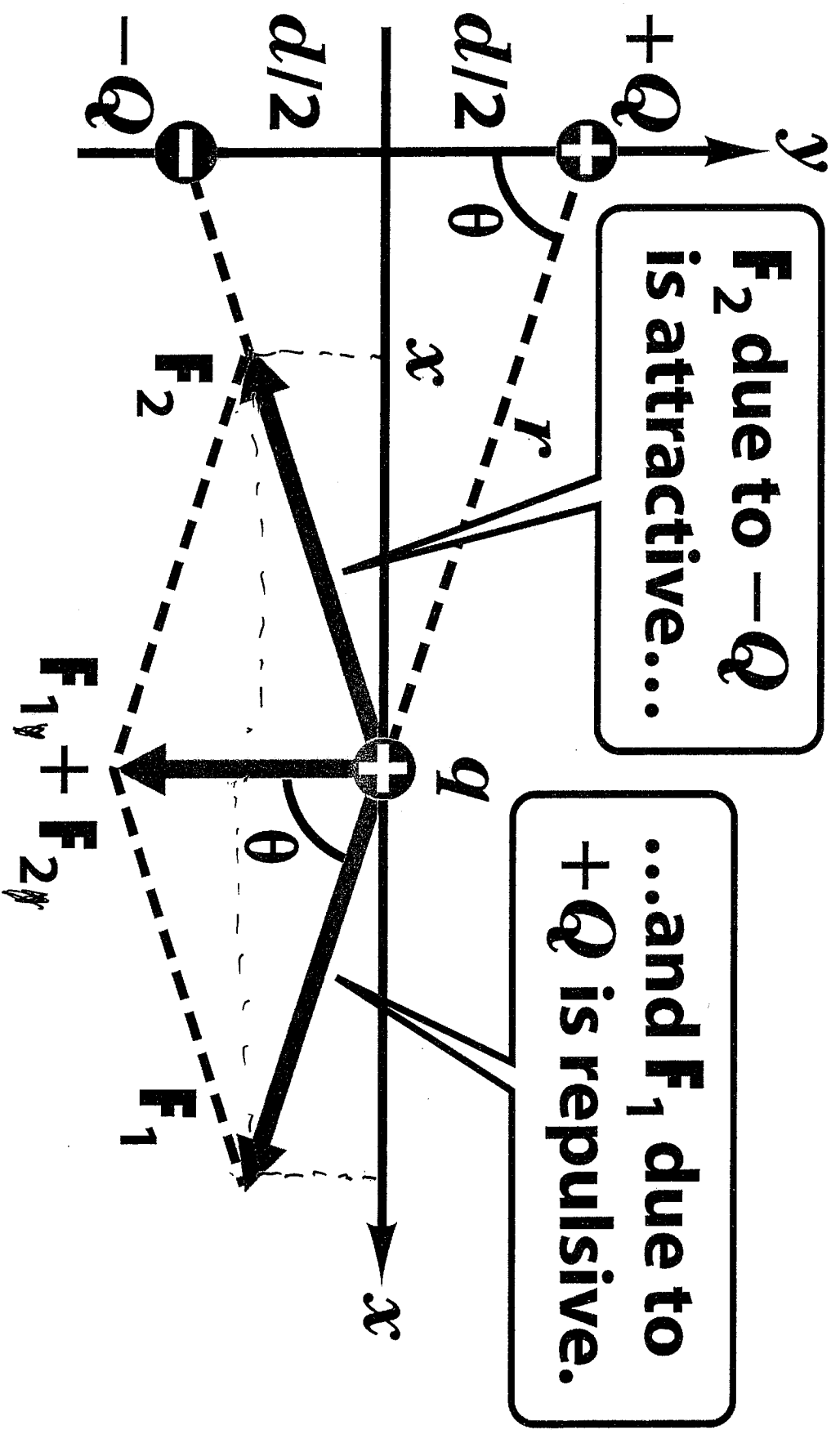


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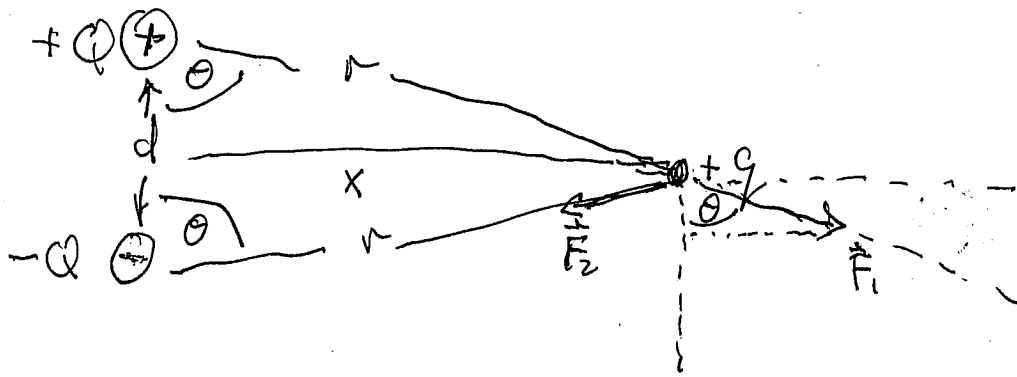
**$F_2$  due to  $-Q$  is attractive...**

**...and  $F_1$  due to  $+Q$  is repulsive.**

What is magnitude of force.

What is direction of force on  $q$  if charges of left are both positive?

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$$|\vec{F}_1| = \frac{kQq}{r^2} = |\vec{F}_2|$$

Component in  $-y$  - direction is

$$|\vec{F}_1| \sin \theta = \frac{kQq}{r^2} \sin \theta$$

Total Force, add component from  $|\vec{F}_2|$  that is of equal magnitude  
 $(\cos \theta = \frac{d/2}{r})$

$$|\vec{F}_{\text{total}}| = \frac{2kQq \sin \theta}{r^2} = \frac{2kQq \frac{d}{2r}}{r^2}$$

$$r^2 = x^2 + (d/2)^2$$

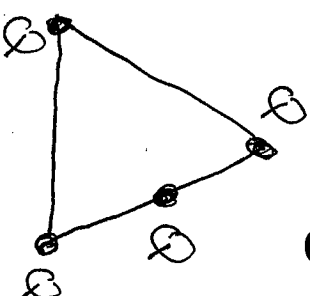
$$|\vec{F}_{\text{total}}| = \frac{2kQq d}{2(x^2 + d^2/4)^{3/2}}$$



## Checkup 22.3

Three identical point charges are at the vertices of an equilateral triangle. A fourth, identical point charge is placed at the midpoint of one side of the triangle. As a result of the three electric force contributions from the vertex charges, the fourth charge

- is in equilibrium and remains at rest
- is pushed toward the center of the triangle
- is pushed outside the triangle



Rod has a total charge  $Q$   
uniformly distributed

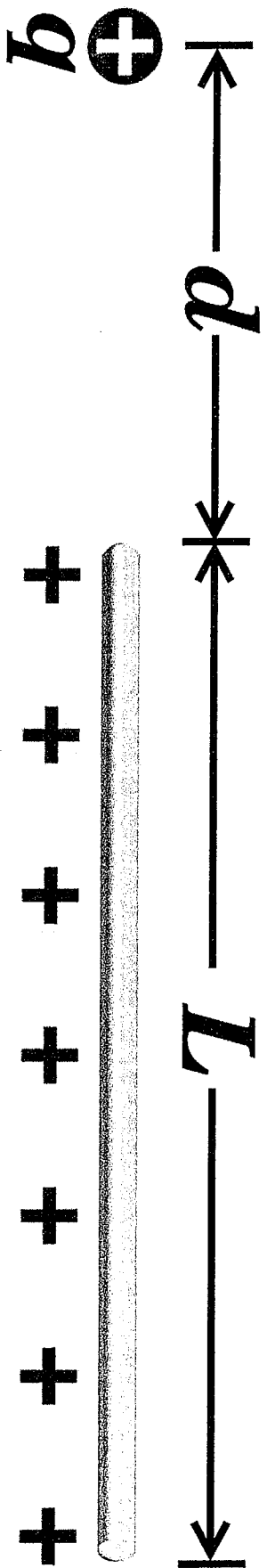
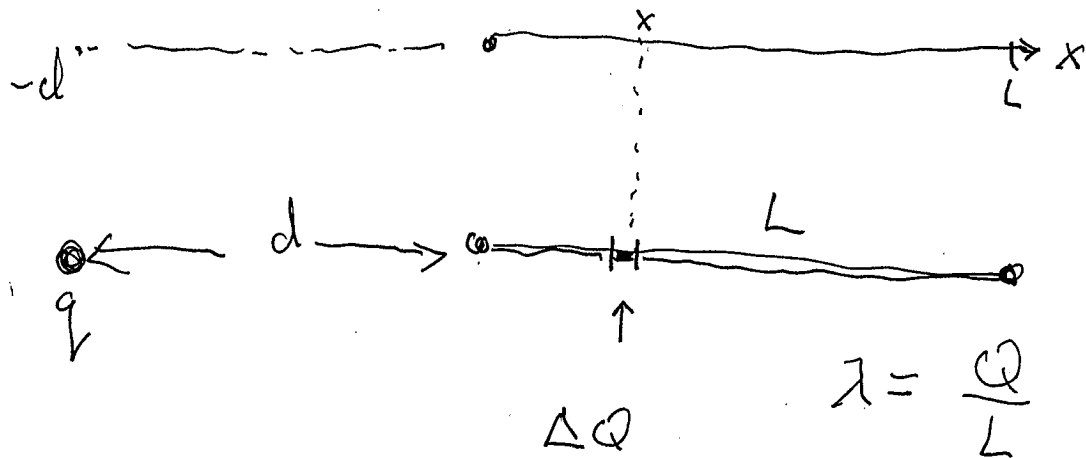


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Find force on  $q$





$$\Delta Q = \frac{Q}{L} \Delta x \quad \left( \frac{Q}{L} \equiv \lambda \equiv \text{linear charge density} \right)$$

Force on  $q$  from  $\Delta Q$

$$\Delta \vec{F}_q = - \frac{k q \Delta Q}{(x+d)^2} \hat{x} = - \frac{k q Q \Delta x}{L (x+d)^2} \hat{x}$$

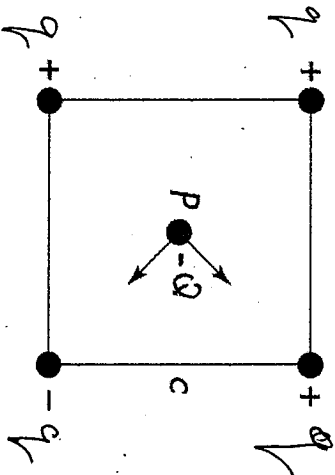
Go to infinitesimal limit

$$d\vec{F}_q = - \hat{x} \frac{k q Q}{L} \frac{dx}{(x+d)^2}$$

$$\vec{F}_q = - \hat{x} \frac{k q Q}{L} \int_0^L \frac{dx}{(x+d)^2} = \hat{x} \frac{k q Q}{L} \left. \frac{1}{x+d} \right|_0^L$$

$$\vec{F}_q = - \hat{x} \frac{k q Q}{L} \left( \frac{1}{d} - \frac{1}{d+L} \right)$$

# PhysiQuiz 22-4



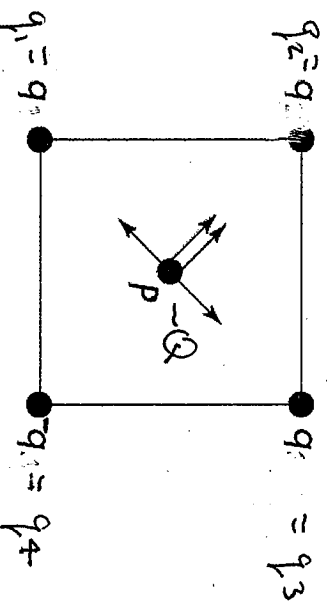
What is the direction of the electric force at  $P$  on a negative charge  $-Q$ ?  
Assume the magnitudes of the charges at the corners have the same value  $q$ .

- A      B      C      D
- ↘      ↖      ↗      ↙

**Extra:** Show that the magnitude of the electric force at  $P$  is  $F = 4kqQ/c^2$ ,  
where  $c$  is the side of the square.

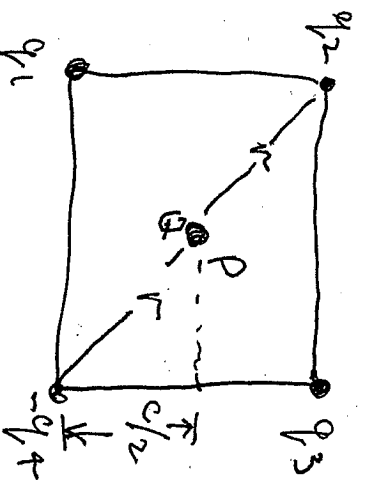
# PhysiQuiz 22-4 answer

**Explanation:**



**Explanation—extra:** From the sketch in the explanation, the force contributions at  $P$  from  $q_3$  and  $q_1$  cancel each other. Thus the magnitude of the resultant force at  $P$  is  $F = 2(kqQ/r^2)$ . Because the distance from corner to the center is  $r = \frac{\sqrt{2}}{2}c$ , the magnitude of the force can be written as

$$F = 4kqQ/c^2.$$

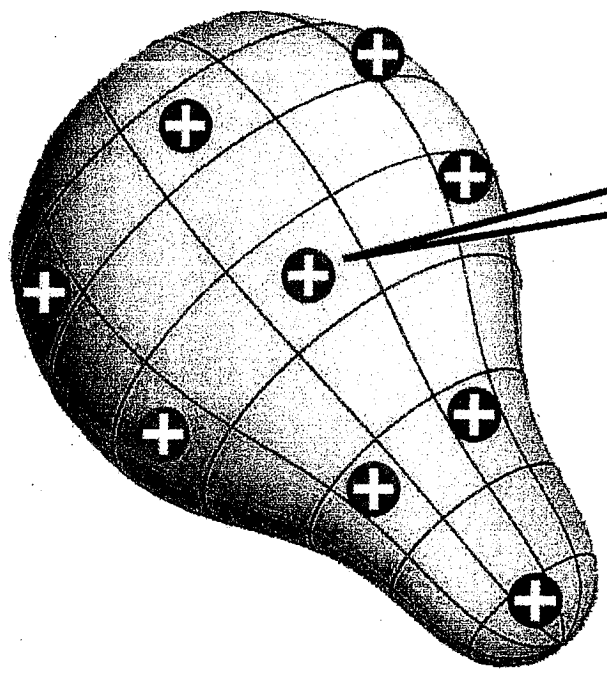


$$r = \frac{c}{\sqrt{2}}$$

*Difference of Conductor and Insulator*

(a)

**For a conductor, charge can move freely and find an equilibrium distribution.**



(b)

**For an insulator, charge cannot move easily.**

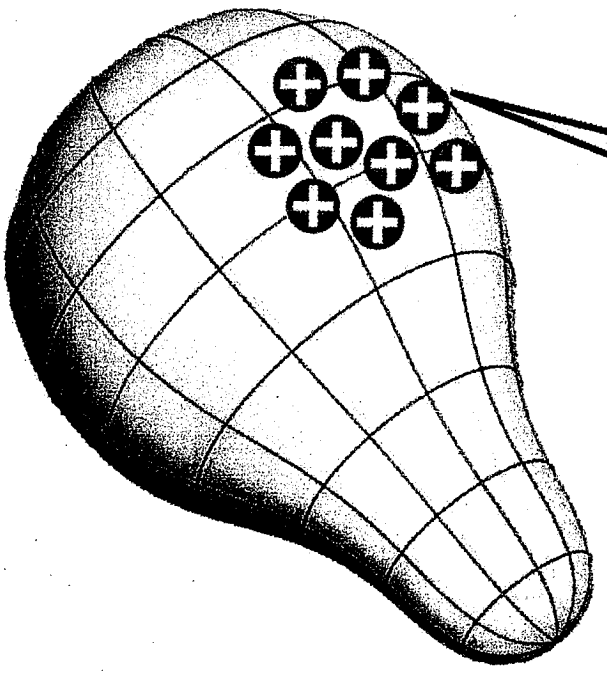
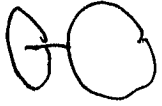


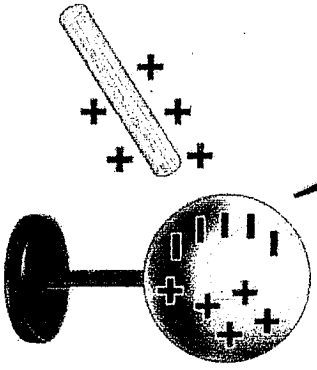
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# Charging Metallic Sphere

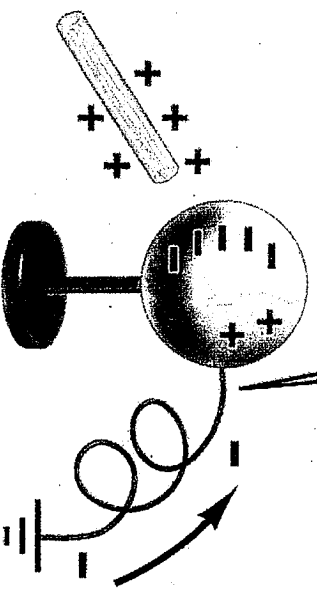
Zeroth  
We have an isolated sphere with no charge



(a) First the charge on a neutral sphere redistributes when rod of positive charge is near...

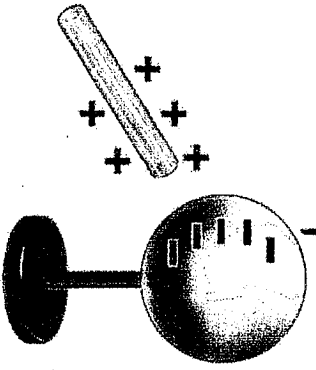


(b) ...and then a wire provides a path for electrons from ground.



then sphere has excess of electrons

(c) When wire is disconnected, a net charge remains on sphere...



(d) ...and that charge distributes evenly when the rod is gone.

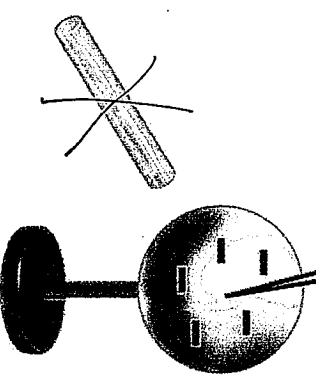
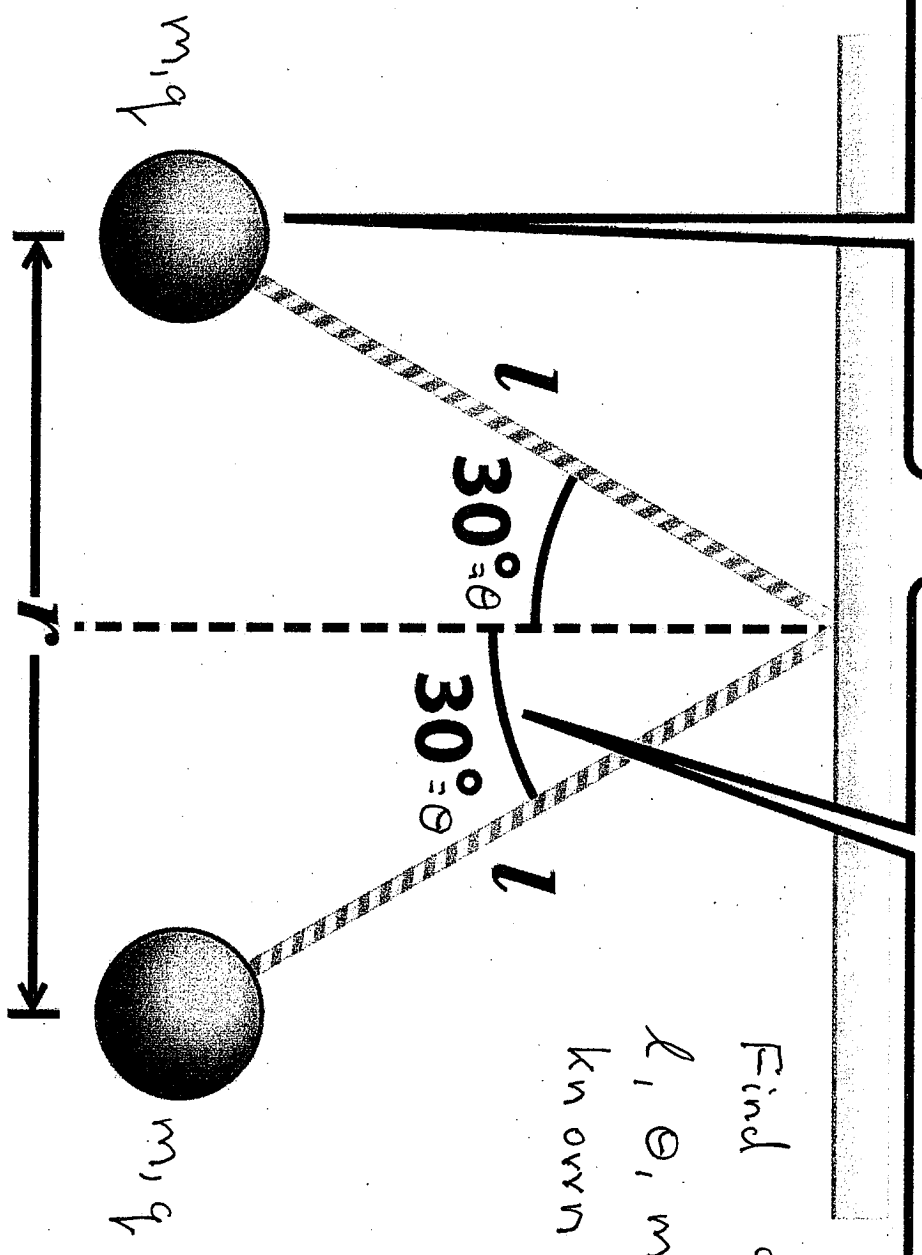


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Electric force pushes balls apart...

...causing threads to make this equilibrium angle.



Find  $q$  if  $l, \theta, m$  are known

$$\frac{r}{2} = l \sin \theta$$

Figure 22-5a Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.

$$T \cos \theta = mg$$

$$T \sin \theta = \frac{kq^2}{r^2} = \frac{kq^2}{(2\ell \sin \theta)^2}$$

eliminate  $T$  by dividing both terms

$$\frac{\sin \theta}{\cos \theta} = \frac{kq^2}{4\ell^2 \sin^2 \theta} / mg$$

$$q^2 = 4\ell^2 \sin^3 \theta mg / k \cos \theta$$

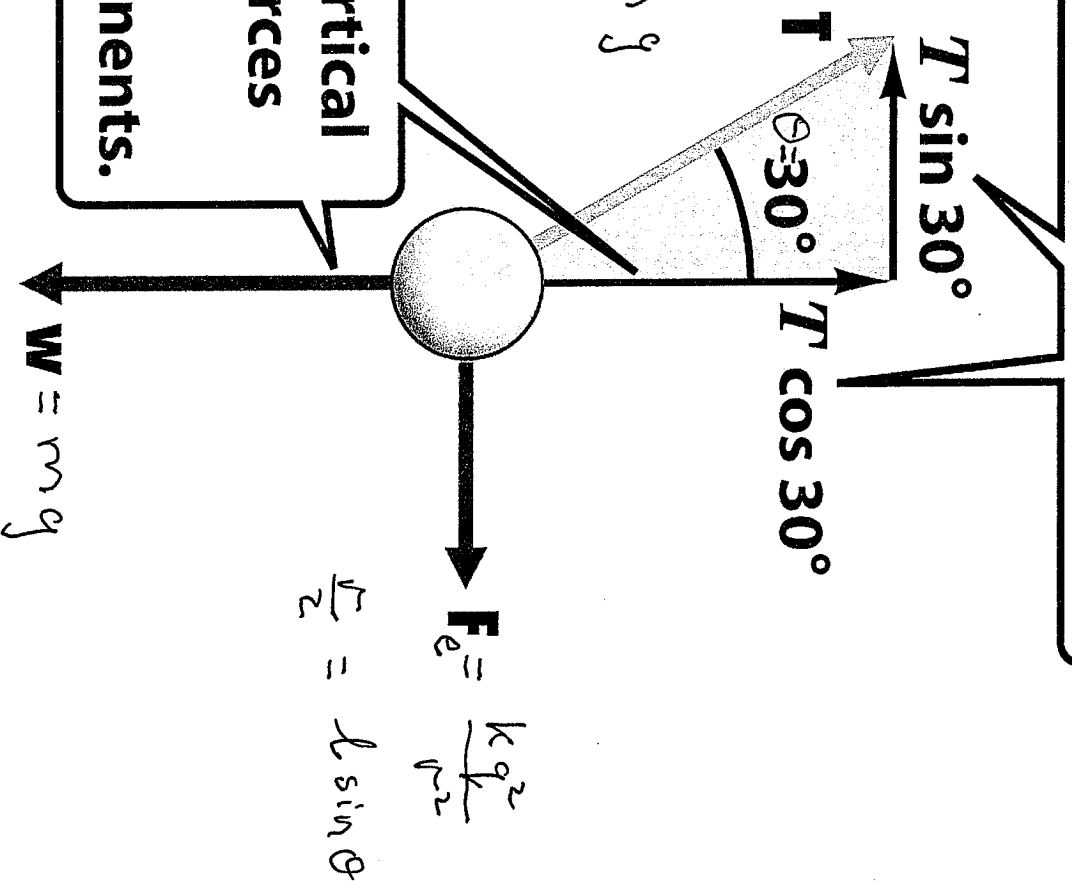
for  $\theta = 30^\circ$

$$\cos \theta = \sqrt{3}/2$$

$$\sin \theta = 1/2$$

$$q^2 = \frac{2\ell^2 mg}{\sqrt{3}k}$$

We resolve the tension into components.



In equilibrium, vertical components of forces sum to zero, as do horizontal components.

Figure 22-5b Physics for Engineers and Scientists 3/e  
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## COULOMB CONSTANT

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$$

$\equiv$  permittivity of free space