Electric physics
Tutorial 1

Examples

Three point charges lie along the x axis as shown in Figure 23.9. The positive charge $q_1 = 15.0\ \mu C$ is at $x = 2.00$ m, the positive charge $q_2 = 6.00\ \mu C$ is at the origin, and the resultant force acting on q_3 is zero. What is the x coordinate of q_3?

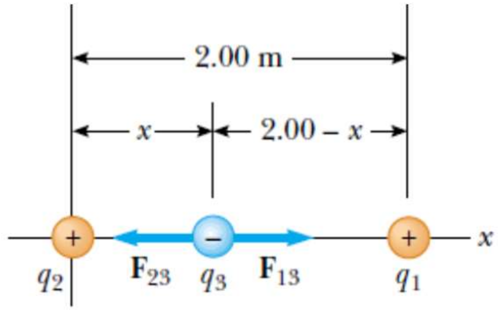


Figure 23.9 (Example 23.3) Three point charges are placed along the x axis. If the resultant force acting on q_3 is zero, then the force $\mathbf{F}_{13}$ exerted by q_1 on q_3 must be equal in magnitude and opposite in direction to the force $\mathbf{F}_{23}$ exerted by q_2 on q_3.

Solution Because q_3 is negative and q_1 and q_2 are positive, the forces $\mathbf{F}_{13}$ and $\mathbf{F}_{23}$ are both attractive, as indicated in Figure 23.9. From Coulomb's law, $\mathbf{F}_{13}$ and $\mathbf{F}_{23}$ have magnitudes

$$F_{13} = k_e \frac{|q_1||q_3|}{(2.00 - x)^2} \qquad F_{23} = k_e \frac{|q_2||q_3|}{x^2}$$

- For the resultant force on *q*3 to be zero, F23 must be equal in magnitude and opposite in direction to F13. Setting the magnitudes of the two forces equal, we have

$$k_e \frac{|q_2||q_3|}{x^2} = k_e \frac{|q_1||q_3|}{(2.00 - x)^2}$$

- Noting that *ke* and are common to both sides and so can be dropped, we solve for *x* and find that

$$(2.00 - x)^2|q_2| = x^2|q_1|$$

$$(4.00 - 4.00x + x^2)(6.00 \times 10^{-6}\text{ C}) = x^2(15.0 \times 10^{-6}\text{ C})$$

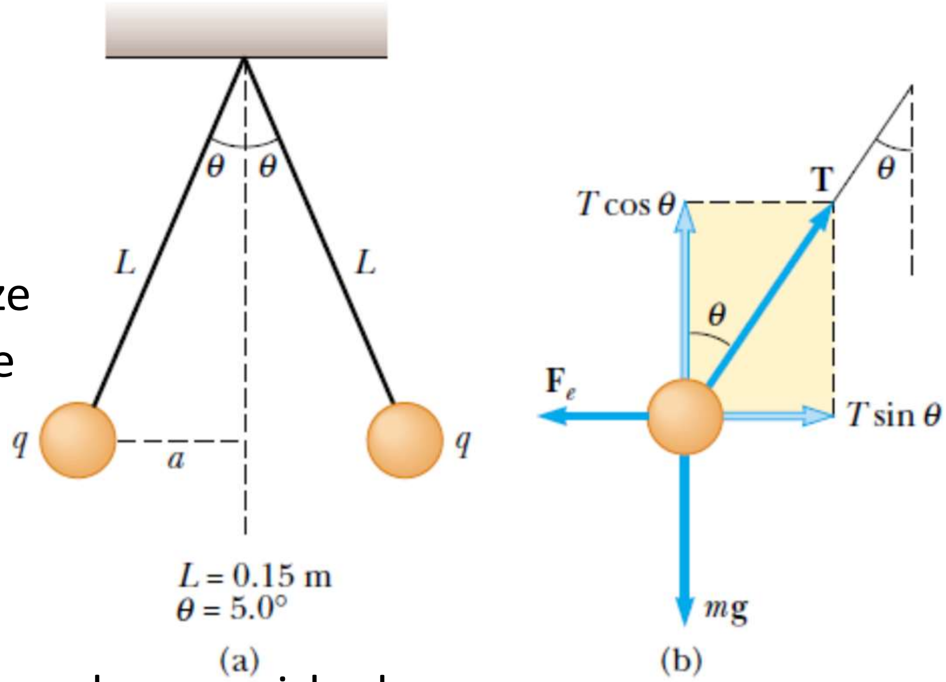
- This can be reduced to the following quadratic equation:

$$3.00x^2 + 8.00x - 8.00 = 0$$

- Solving this quadratic equation for *x*, we find that the positive root is *x= 0.775 m.* There is also a second root, *x* =-3.44 m. This is another location at which the magnitudes of the forces on *q*3 are equal, but both forces are in the same direction at this location.

Example: Find the Charge on the Spheres

- Two identical small charged spheres, each having a mass of 3.0 x 10-2 kg, hang in equilibrium as shown in Figure 23.10a. The length of each string is 0.15 m, and the angle ϴ is 5.0°. Find the magnitude of the charge on each sphere.
- **Figure 23.10** (Example 23.4) (a) Two identical spheres, each carrying the same charge *q*, suspended in equilibrium.(b) The free-body diagram for the sphere on the left.



- **Solution** Figure 23.10a helps us conceptualize this problem—the two spheres exert repulsive forces on each other. If they are held close to each other and released, they will move outward from the center and settle into the configuration in Figure 23.10a after the damped oscillations due to air resistance have vanished.

- The key phrase "in equilibrium'' helps us categorize this as an equilibrium problem with the added feature that one of the forces on a sphere is an electric force. We analyze this problem by drawing the free-body diagram for the left-hand sphere in Figure 23.10b. The sphere is in equilibrium under the application of the forces T from the string, the electric force F*e* from the other sphere, and the gravitational force *m*g. Because the sphere is in equilibrium, the forces in the horizontal and vertical directions must separately add up to zero:

$$(1) \qquad \sum F_x = T\sin\theta - F_e = 0$$

- From $(2) \qquad \sum F_y = T\cos\theta - mg = 0$; thus, *T* can be eliminated from Equation (1) if we make this sub $T = mg/\cos\theta$ his gives a value for the magnitude of the electric force F_e :

$$F_e = mg\tan\theta = (3.0\times10^{-2}\ \mathrm{kg})(9.80\ \mathrm{m/s^2})\ \tan(5.0^\circ)$$
$$= 2.6\times10^{-2}\ \mathrm{N}$$

- Considering the geometry of the right triangle in Figure 23.10a, we see that $\sin\theta = a/L$. Therefore,

$$a = L\sin\theta = (0.15\ \mathrm{m})\ \sin(5.0^\circ) = 0.013\ \mathrm{m}$$

- The separation of the spheres is $2a = 0.026$ m. From Coulomb's law (Eq. 23.1), the magnitude of the electric force is $F_e = k_e \frac{|q|^2}{r^2}$

where $r = 2a = 0.026$ m and $|q|$ is the magnitude of the charge on each sphere. (Note that the term $|q|^2$ arises here because the charge is the same on both spheres.) This equation can be solved for $|q|^2$ to give

$$|q|^2 = \frac{F_e r^2}{k_e} = \frac{(2.6 \times 10^{-2}\ \text{N})(0.026\ \text{m})^2}{8.99 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2} = 1.96 \times 10^{-15}\ \text{C}^2 \quad , \ |q| = 4.4 \times 10^{-8}\ \text{C}$$

- To finalize the problem, note that we found only the magnitude of the charge $|q|$ on the spheres. There is no way we could find the sign of the charge from the information given. In fact, the sign of the charge is not important. The situation will be exactly the same whether both spheres are positively charged or negatively charged.

Example:3

- An electron is moved by an external force at a constant velocity from a positively charged plate to a negatively charged plate the electron then released and moves back to the positive plate . The distance between the plates is 5.0 cm . The electric field strength between the plates is E =25000 v/m.
- A) how much work must the external force do to move the electron from positive plate to the negative plate ?
- B) calculate the acceleration of the electron as it falls back to the positive plate.
- C) determine the velocity of the electron when it returns back to the positive plate ?
- D) the time it takes for the electron to move from the positive plate back to the negative plate .

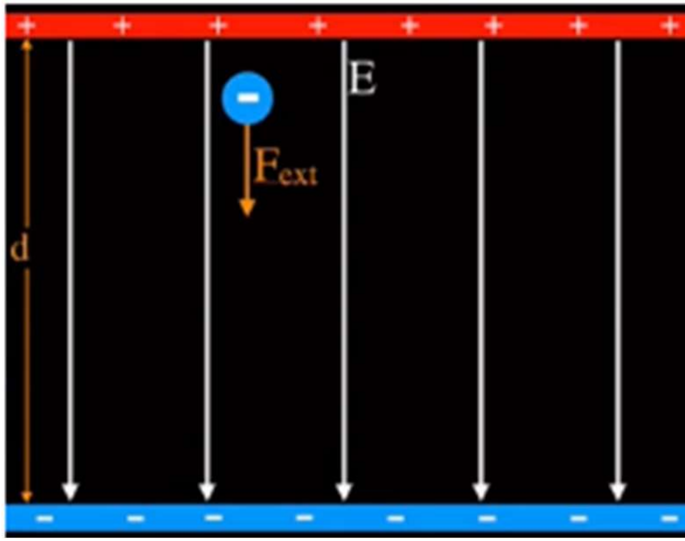
a) how much work must the external force do to move the electron from positive plate to the negative plate ?

W=F.d   E=F/q   F=q.E

W =q.E.d

w= $(1.602 \times 10^{-1}$)(25000v/m)(0.05)

w= 2.0×10^{-16}



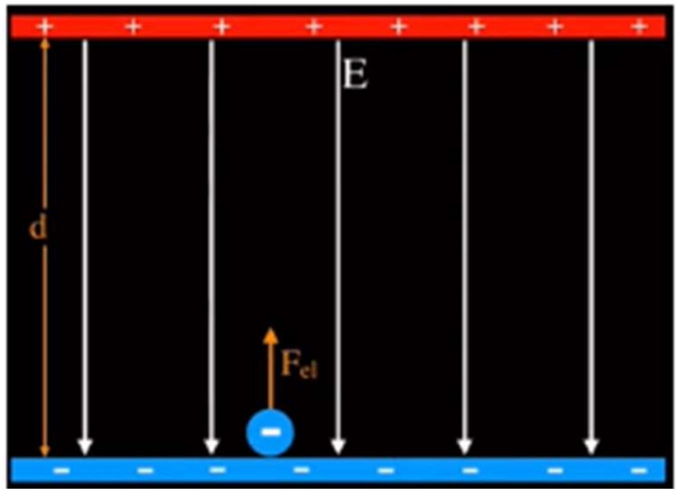
B) calculate the acceleration of the electron as it falls back to the positive plate.

F=m.a   ,   a=F/m ,   F=q.E

a=qE/m

a= $(1.602 \times 10^{-19}$)(25000v/m)/ 9.1×10^{-31} Kg

a= 4.4×10^{15} m/s^2



c) determine the velocity of the electron when it returns back to the positive plate ?

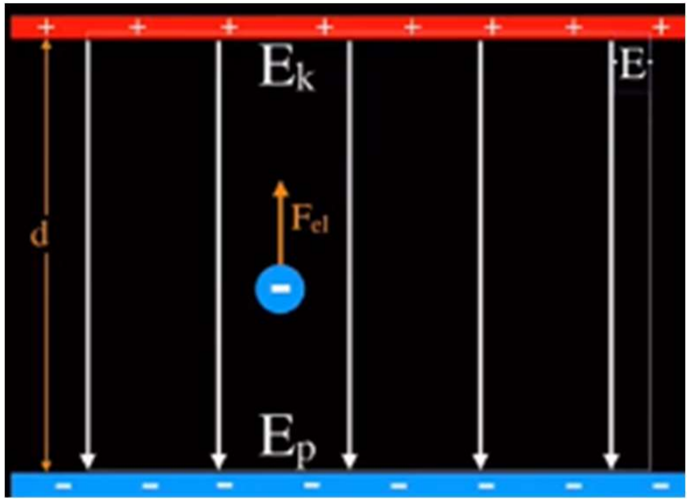
$E_K = E_p$,

$\frac{1}{2} mv^2$=q.E.d

v= $(2qEd/m)^{1/2}$

v= $(2(1.602 \times 10^{-19} * 25000 * 0.05m)/9.1 \times 10^{-31})^{1/2}$

v $= 440.1 \times 10^{12}$ m/s



d)) the time it takes for the electron to move from the positive plate back to the negative plate

$x = v_i t + \frac{1}{2} a \times t^2$

$x = \frac{1}{2} a \times t^2$

$t = (\frac{2x}{a})^{1/2}$, t=$(\frac{2*0.05}{4.4\times10^{15}})^{1/2}$= $0.046 \times 10^{-7} s$

Example 4

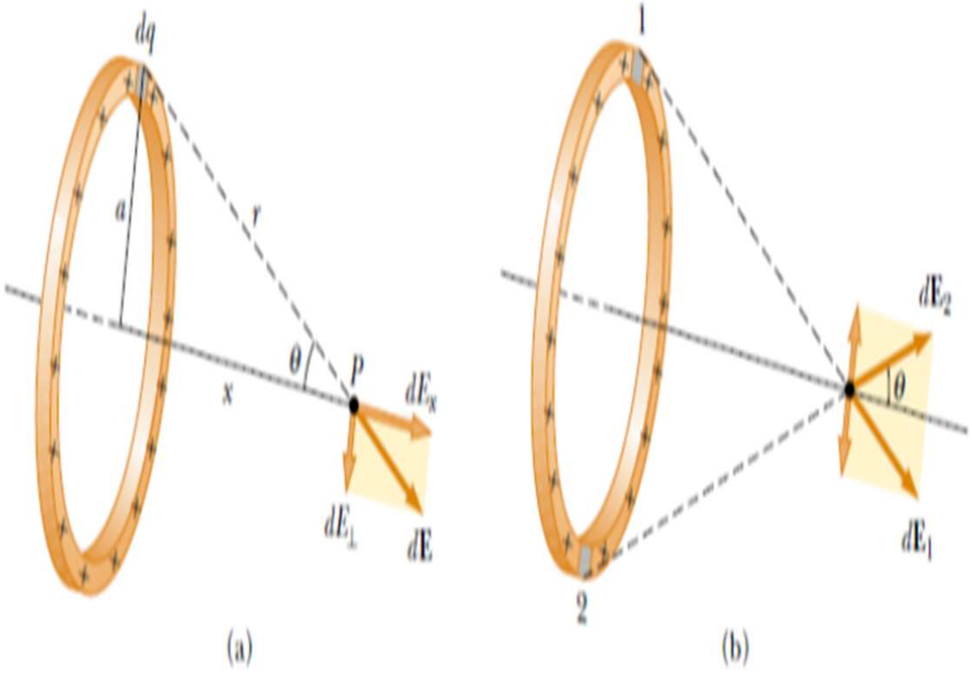
- A ring shaped conductor with radius 5cm has a total charge of +50 nc
- a) what is the electric field at a point 12 cm east from its center?
- b)what is the linear charge density of the ring?

Solution:-

a) The electric field due to the ring

dE= $\frac{K\,dQ}{r^2}$

- $E_{y1} = E_{y2}$ component in y-direction
- Ey=0 , Enet=Ex
- $dE_X = dE\cos\theta$
- $\cos\theta = \frac{x}{r}$
- $\int dE_X = \int dE\,\frac{x}{r}$
- $\int dE_X = \int \frac{K\,dQ}{r^2}\frac{x}{r}$



- $\int dE_X = \frac{K\,x}{r^3}\int dQ$
- $E_X = \frac{K\,.x.Q}{r^3}$

- $r^2 = a^2 + x^2$, r=$\sqrt{a^2 + x^2}$

  r=$\sqrt{0.05^2 + 0.12^2}$= 0.13m

- $E_X = \frac{K\,.x.Q}{r^3} = \frac{1.602\times10^{-19}\times(0.12)\times(50\times10^{-9})}{(0.13)^3}$

- $E_X = 24579\mathrm{N/C}$

- b) what is the linear charge density of the ring?

- $\lambda = \frac{Q}{L}$, where the length of the ring = circumference of the ring= $2\pi r$
- r=a , c = $2\pi a$
- $\lambda = \frac{50\times10^{-9}}{2\pi(0.05)} = 1.59 \times 10^{-7}$