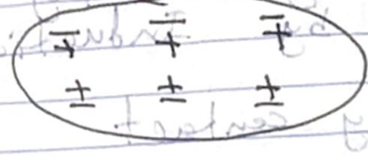
chapter (23)
Electric Field

Electric charge

Electricaly neutral objects

- neutral objects

In any object there is alarge number of positive and negative charges

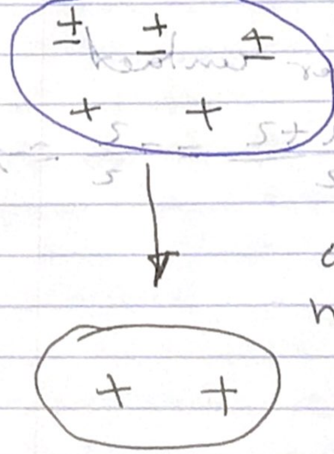


$q=0$

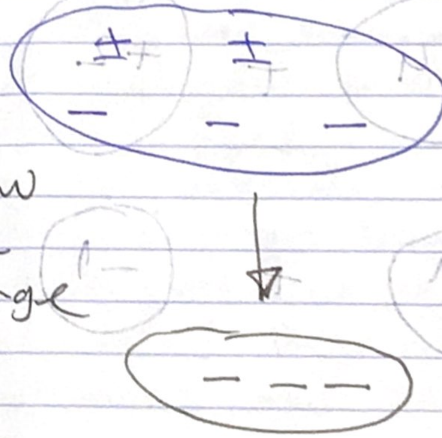
If the number of positive and negative charges are equal we say that the object is electrically neutral. or the object contains no net charge. positive and negative charges are balanced.

(Electrically charged objects)

If the number of positive and negative charges are not equal we say that the object is charged or the object has a net charge or positive and negative charges are imbalanced.



we show only the net charge

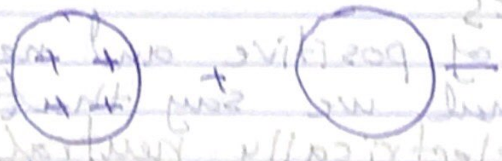


$q=+2$ $q=-3$

Methods of chargeng objeets

1- by contact بالتوصيل
2- by rubbing بالدلك
3- by Induction بالحث

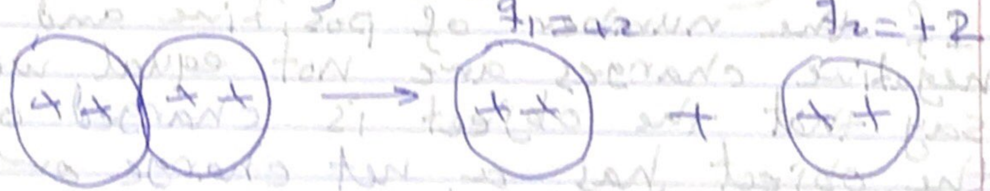
1- by contact



(befor contact)

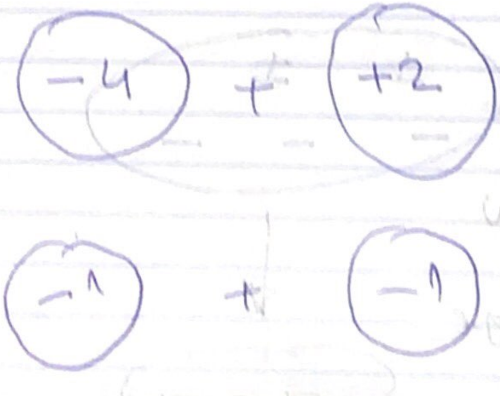
Object1 Object2

when contact they will have the same kind of charge and the same magnitude if they are identical



when contact

after contact

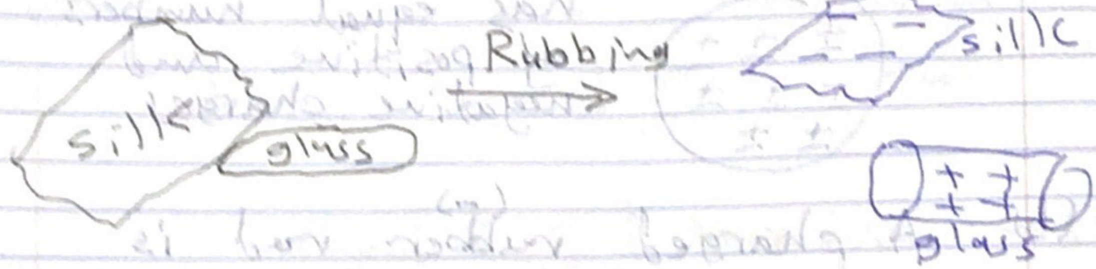


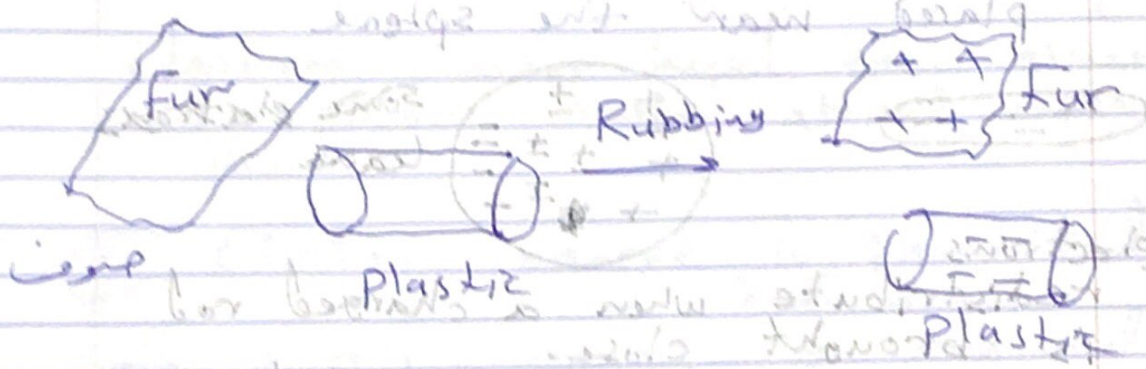
befor contact

$\frac{-4+2}{2} = \frac{-2}{2} = -1$

charging by rubbing الشحن بالدلك

silk + glass : حرير + زجاج (a)





Electrostatic charges are stationary or move very slowly

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charging by Induction : الشحن بالحث

~~Electrical conductors are materials~~ classifying materials in terms of the ability of electrons to move through the material

A- Conductors : الموصلات : materials in which some of the electrons are free. → gold, iron, Aluminium

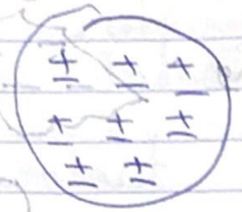
B- Insulators : المواد العازلة : materials in which all electrons cannot move freely through material (glass, wood, rubber, ...)

C- Semiconductors : أشباه الموصلات : their electrical properties between conductors and insulators

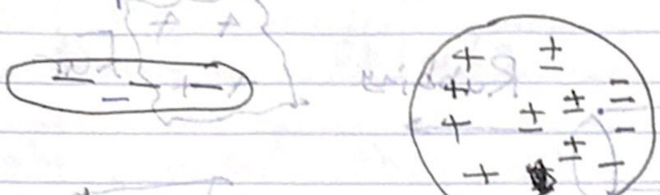
silicon, germanium

charging objects by Induction

(a) A neutral metalic sphere has equal numbers of positive and negative charges



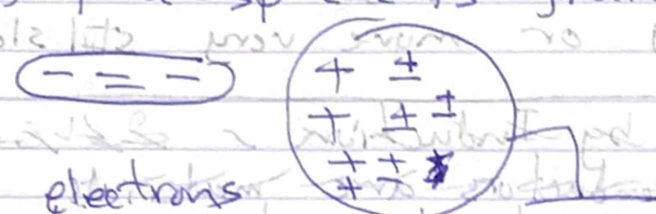
(b) A $(-)$ charged rubber rod is placed near the sphene



Some electrons leave

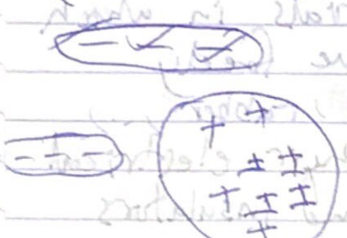
electrons redistribute when a charged rod is brought close.

(c) The sphene is grounded



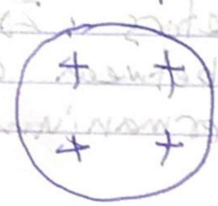
some electrons (free) leave the grounded sphene through the ground wire. and the positive charge non uniformly distributed.

(d) The ground connection is removed

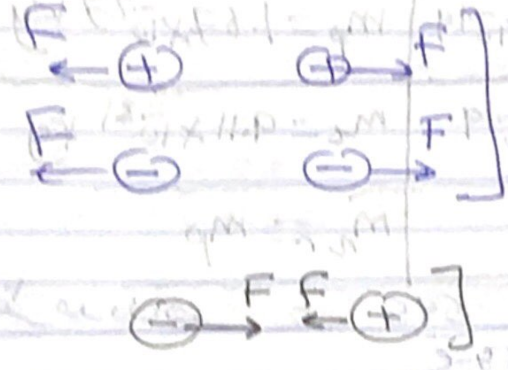


non uniforly (+) charge

(e) The rod is removed
The sphene has uniform positive charge



Some properties of charges

① 

Repulsion تنافر

Attraction تجاذب

identical charges Repel each other and opposit charges attract each other

② Electric charge is quantized مكمّاة

→ Electric charge is measured in Coulomb.

→ The smallest charge you can find is the electron

$$q_e = 1.6 \times 10^{-19} \, C$$

→ All other charges are a multiple of this charge

$$q = N * q_e$$

$N = \pm 1, \pm 2, \pm 3, \ldots$

$q = (+12) q_e$ or $(-60) q_e$ possible

$(q = +3.5 q_e)$ or $(q = -5.1 q_e)$ impossible

Ex How many electrons in an 6.4 MC charged object.

$$N = \frac{q}{q_e} = \frac{6.4 \times 10^{-6}}{1.6 \times 10^{-19}} = 4 \times 10^{13} \text{ electrons.}$$

charges of

protons, electrons and neutrons

	charge (C)	
proton	$q_p = +1.6 \times 10^{-19}$	$m_p = 1.67 \times 10^{-27}$ kg
electron	$q_e = -1.6 \times 10^{-19}$	$m_e = 9.11 \times 10^{-31}$ kg
neutron	$q_n = 0$	$m_n \simeq m_p$

اتقر مدلص : 695

negative charge

→ when object accepts electrons

positive charge

→ when object losses electrons

EX An object of $q = +4.8 \times 10^{-19}$ C

$$N = \frac{4.8 \times 10^{-19}}{1.6 \times 10^{-19}} = 3$$

so losses 3 electrons

EX No object have a charge of 5.1×10^{-19} C

because $N = \dfrac{5.1 \times 10^{-19}}{1.6 \times 10^{-19}} = 3.19$ → غير صحيح

EX $q = 1$ C

$$N = \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18}\ e$$

Coulomb's Law

q_1 : point charge
q_2 : point charge

F : electrical force of q_1 on q_2 or q_2 on q_1

$F \propto q_1 q_2$

$F \propto \frac{1}{r^2}$

$$F_e = \frac{K q_1 q_2}{r^2}$$

$K = 9 \times 10^{9}\ N.m^2/C^2$

electrical force.

K : coulomb's constant

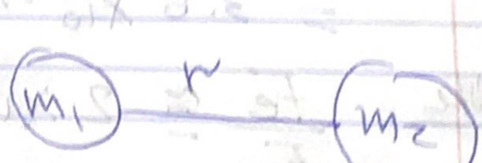
$$K = \frac{1}{4\pi\epsilon_0}$$

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

ϵ_0 : electric permitivity constant of free space.

Gravitational force

$$F_g = \frac{G m_1 m_2}{r^2}$$



m_1 : mass object 1
m_2 : " " 2
r : distance

G : universal gravitational constant

$G = 6.67 \times 10^{-11}\ N.m^2/Kg^2$

Ex (23.1) / 695 | The Hydrogen Atom

(p⊕ ⊖e)

The electron and proton of a hydrogen atom are seperated by a distance of $r = 5.3 \times 10^{-11}$ m.
Find the magnitudes of the
(1) electrostatic Force
(2) gravitational force

(1) $$F_e = \frac{K\, q_p \cdot q_e}{r^2}$$

$$= \frac{9\times10^{9} \times (1.6\times10^{-19})^2}{(5.3\times10^{-11})^2}$$

$$= 8.2 \times 10^{-8}\ N$$

(2) $$F_g = \frac{G\, m_p m_e}{r^2}$$

$$= \frac{6.67\times10^{-11} \times 1.67\times10^{-27} \times 9.11\times10^{-31}}{(5.3\times10^{-11})^2}$$

$$= 3.6 \times 10^{-47}\ N$$

Note $$\frac{F_e}{F_g} \simeq 2\times10^{39}$$

Notation

$\vec{F}_{54}$ → on particle 5 ; due to particle 4

$\vec{F}_{12} \leftarrow (q_1) \qquad (q_2) \rightarrow \vec{F}_{21}$

Force on q_1 due to q_2 — Force on q_2 due to q_1

According to Newton's 3rd Law

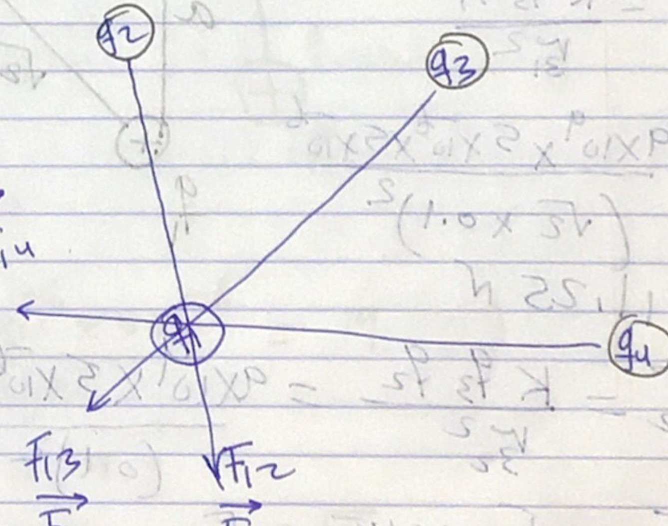
$$|F_{12}| = |F_{21}|$$

$$\vec{F}_{12} = -\vec{F}_{21}$$

Superposition principle — مبدأ التراكب

$\vec{F}_1 = ??$

Vector sum



$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14}$$

The net force acting on any object is the vector sum of the forces acting on the object due to each object.

EX 23.2
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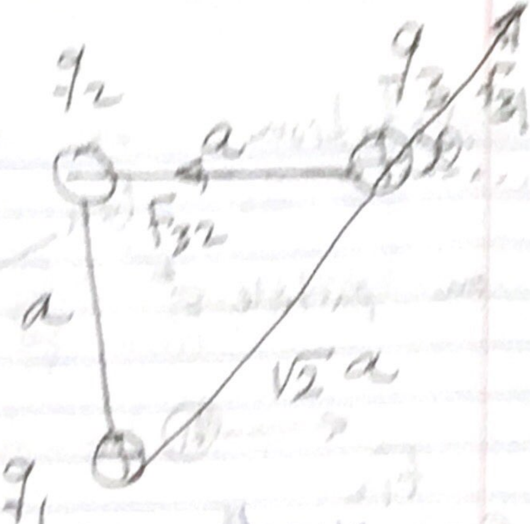
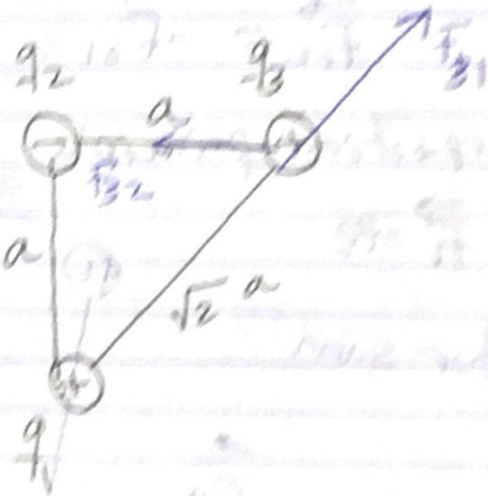


Consider three point charges located at the corners of a right triangle as shown in Fig where $q_1 = q_3 = 5\ \mu C$, $q_2 = -2\ \mu C$ and $a = 0.1\ m$. Find the resultant force exerted on charge ① q_3 ② q_2 ③ q_1

① on q_3



$$F_{31} = \frac{k\, q_3\, q_1}{r_{31}^2}$$

$$= \frac{9\times10^{9} \times 5\times10^{-6} \times 5\times10^{-6}}{(\sqrt{2}\times 0.1)^2}$$

$$= 11.25\ N$$

$$F_{32} = \frac{k\, q_3\, q_2}{r_{32}^2} = \frac{9\times10^{9}\times 5\times10^{-6}\times 2\times10^{-6}}{(0.1)^2} = 9\ N$$

$$F_x = F_{31}\cos 45 - F_{32}$$
$$= (11.25)(0.7) - 9 = -1.05$$
$$F_y = F_{31}\sin 45 = 11.25(0.7) = 7.95$$

$\vec{F_3} = (-1.05\,\hat{i} + 7.95\,\hat{j})\,N$

magnitude of $|F_3|$

$|F_3| = \sqrt{F_x^2 + (F_y)^2}$

$= \sqrt{(1.05)^2 + (7.95)^2}$

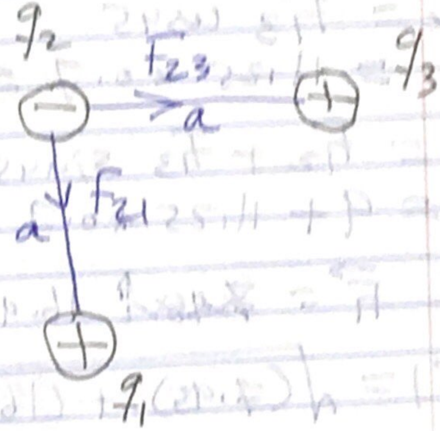
$= 8$

direction $\phi = \tan^{-1}\left(\frac{F_y}{F_x}\right)$

$= \tan^{-1}\left(\frac{7.95}{-1.05}\right)$

$= -82^\circ$

② $F_2 = ??$ Force exerted on q_2



$F_{23} = \frac{K q_2 q_3}{r_{23}^2}$

$= \frac{9\times10^{9} \times 2\times10^{-6} \times 5\times10^{-6}}{(0.1)^2}$

$F_{23} = 9\,N\,\hat{i}$

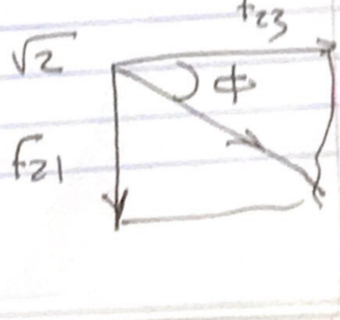
$F_{21} = \frac{K q_2 q_1}{r_{21}^2}$

$= \frac{9\times10^{9} \times 2\times10^{-6} \times 5\times10^{-6}}{(0.1)^2} = 9\,(-\hat{j})$

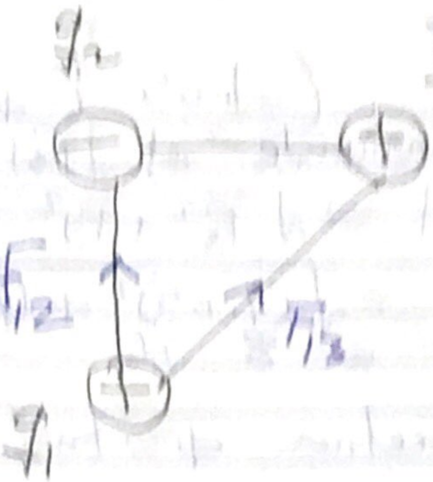
$\vec{F_2} = 9\,\hat{i} - 9\,\hat{j}$

$|F_2| = \sqrt{(9)^2 + (9)^2} = 9\sqrt{2}$

$\phi = \tan^{-1}\left(\frac{-9}{9}\right) = -45^\circ$



$\vec{F_1} = ?$



$F_{12} = \frac{k q_1 q_2}{r_{12}^2}$

$= \frac{9\times10^9 \times 5\times10^{-6} \times 2\times10^{-6}}{(0.1)^2}$

$= 9 \hat{j}$

$F_{13} = 11.25$

$F_x = F_{13} \cos 45$

$= 11.25 \times 0.7 = 7.95$

$F_y = F_{12} + F_{13} \sin 45$

$= 9 + 11.25 \times 0.7 = 16.9$

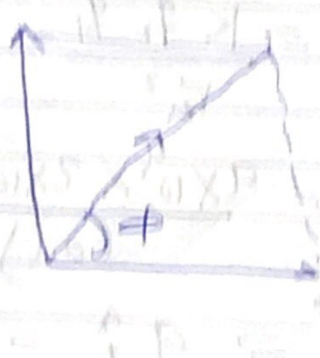
$\therefore \vec{F_1} = 16.9 \hat{i} + 7.95 \hat{j}$

$|F_1| = \sqrt{(7.95)^2 + (16.9)^2}$

$|F_1| = 18.7\ N$

$\phi = \tan^{-1}\left(\frac{7.95}{16.9}\right)$

$= 25.2°$



Ex (23.3)

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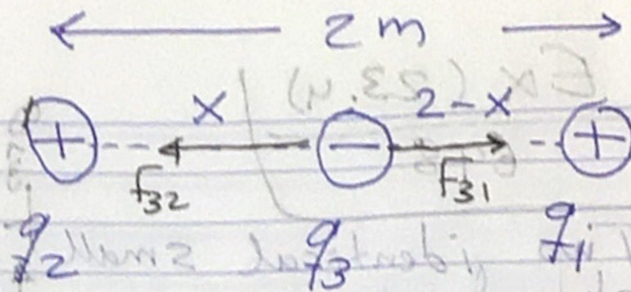

Three point charges lie along the x-axis as shown in Fig. The positive charge $q_1 = 15\ \mu C$ is at $x = 2$ m the positive charge $q_2 = 6\ \mu C$ is at the origin and the net Force on q_3 is zero. what is the x-coordinate of q_3.

$$F_{31} = F_{32}$$

$$\frac{K q_3 q_1}{r_{31}^2} = \frac{K q_3 q_2}{r_{32}^2}$$

$$\frac{15}{(2-x)^2} = \frac{6}{x^2}$$

$$15x^2 = 6(2-x)^2$$

$$2.5x^2 = (2-x)^2$$

$$1.58x = (2-x)$$

$$2.58x = 2$$

$$x = 0.775 \text{ m}$$

Ex (23.4)
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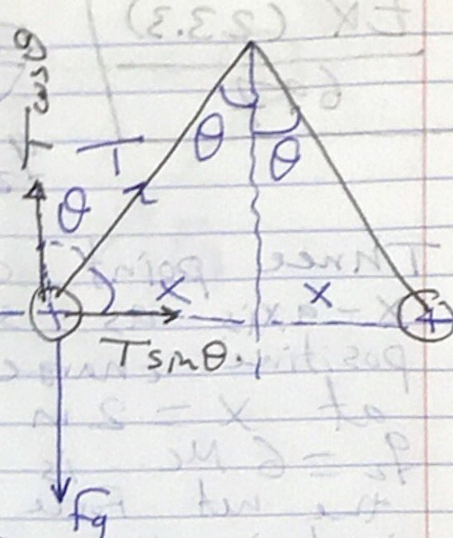
Two identical small charged spheres each having a mass of 3×10^{-2} kg hang in equilibrium as shown in Fig. The length L of each string is 0.15 m and the angle θ is 5°. Find the magnitude of each charge?



$\Sigma F_x = 0$

$T\sin\theta = F_e$ —— (1)

$\Sigma F_y = 0$

$T\cos\theta = F_g$ —— (2)

$\frac{(1)}{(2)} \Rightarrow \tan\theta = \frac{F_e}{F_g}$

$\sin\theta = \frac{x}{L}$

$x = L\sin\theta$
$= 0.15\sin 5$
$= 0.013$

$F_e = mg\tan\theta$

$F_e = 3\times10^{-2}\times10\times\tan 5 = 26.25\times10^{-3}$

but

$F_e = \frac{Kq^2}{(2x)^2}$

$26.25\times10^{-3} = \frac{9\times10^{9}\times q^2}{(2\times0.013)^2}$

$q = 4.65\times10^{-8}$ C or $q = 46.5\times10^{-9}$ C

$q = 46.5$ nC

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