



Chapter 1

Electric Charge and Coulomb's Law



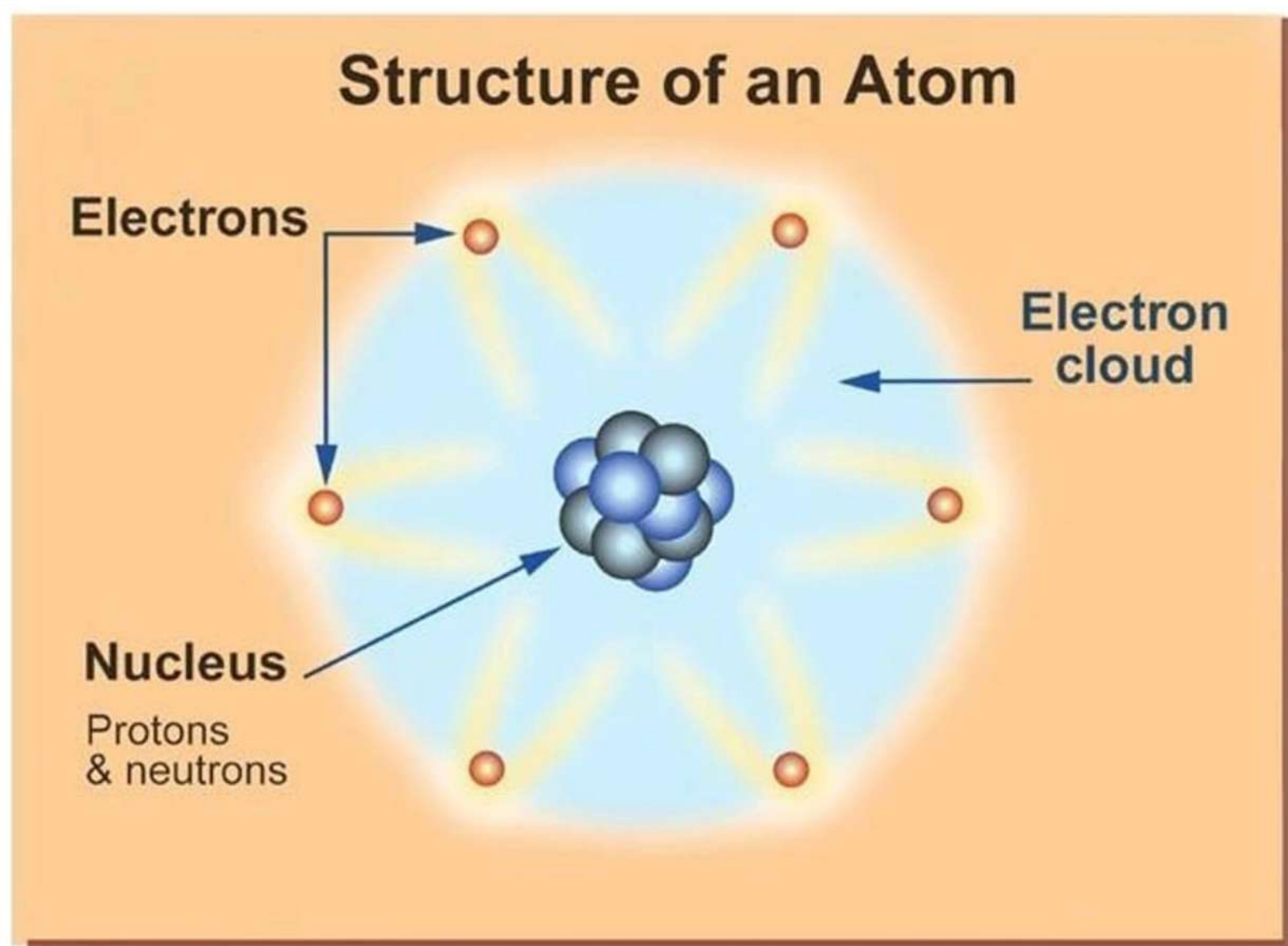
Electric Charge and Coulomb's Law

In this chapter we will describe the following properties of charge:

- Types of electric charges
- Electric charge and its conservation
- Forces among two charges (Coulomb's law)
- Force from many charges



ELECTRIC CHARGE





ELECTRIC CHARGE

- All ordinary matter contains both **positive** and **negative** charge.
- You do not usually notice the charge because most matter contains the exact same number of positive and negative charges.
- An object is **electrically neutral** when it has equal amounts of both types of charge.

This object is neutral



positive charge	+8
negative charge	-8
total	0



ELECTRIC CHARGE

- Objects can lose or gain electric charges.
- The **net charge** is also sometimes called **excess charge** because a charged object has an excess of either positive or negative charges.
- A tiny imbalance in either positive or negative charge on an object is the cause of **static electricity**.



ELECTRIC CHARGE

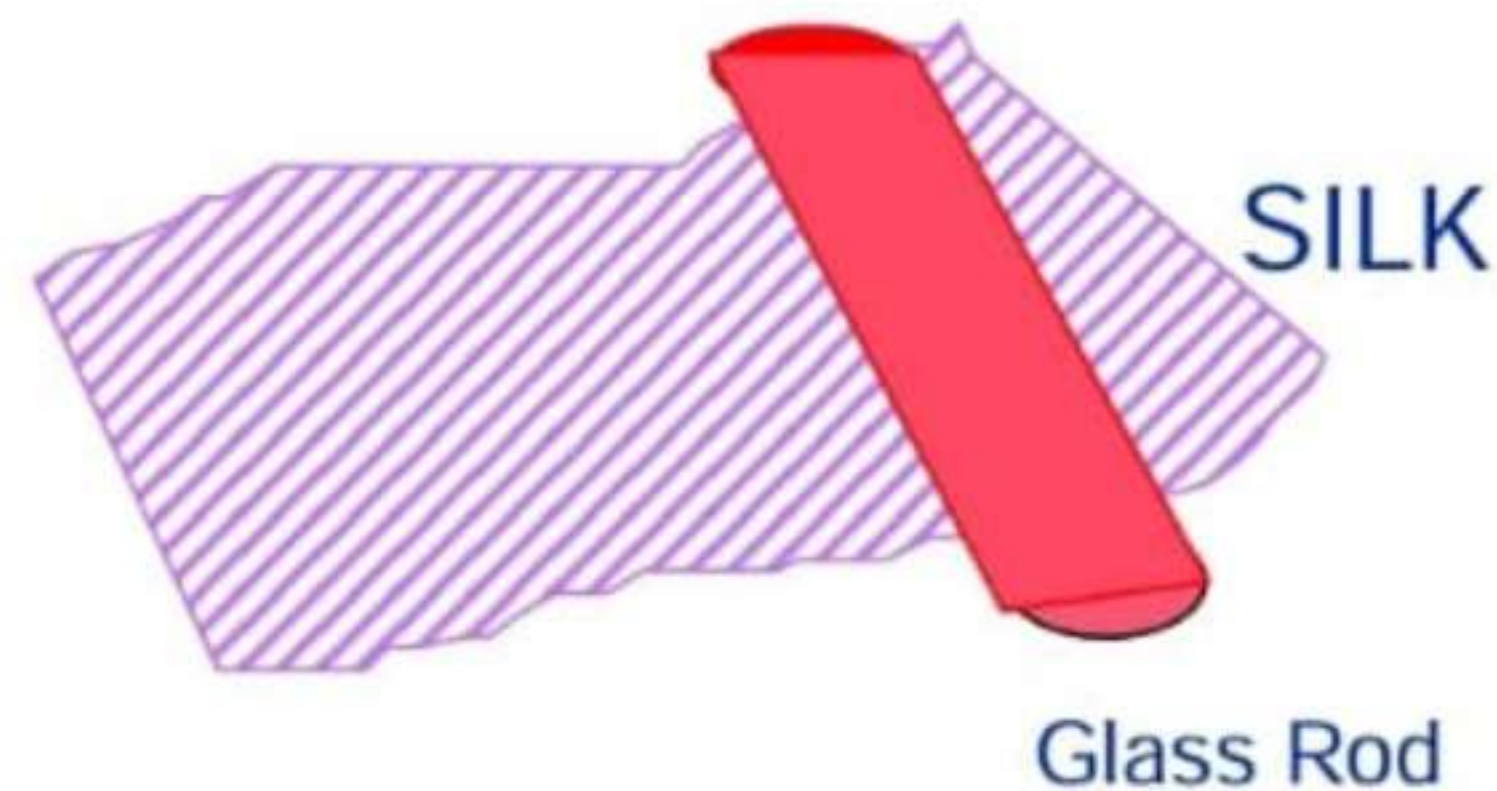
- Electric charge is a property of tiny particles in atoms.
- A quantity of charge should always be identified with a positive or a negative sign.
- The unit of electric charge is the **coulomb** (C).

Mass (kg)	Charge (coulombs)
 Electron	
9.109×10^{-31}	-1.602×10^{-19}
 Proton	
1.673×10^{-27}	$+1.602 \times 10^{-19}$
 Neutron	
1.675×10^{-27}	0



ELECTRIC CHARGE

The Transfer of Charge

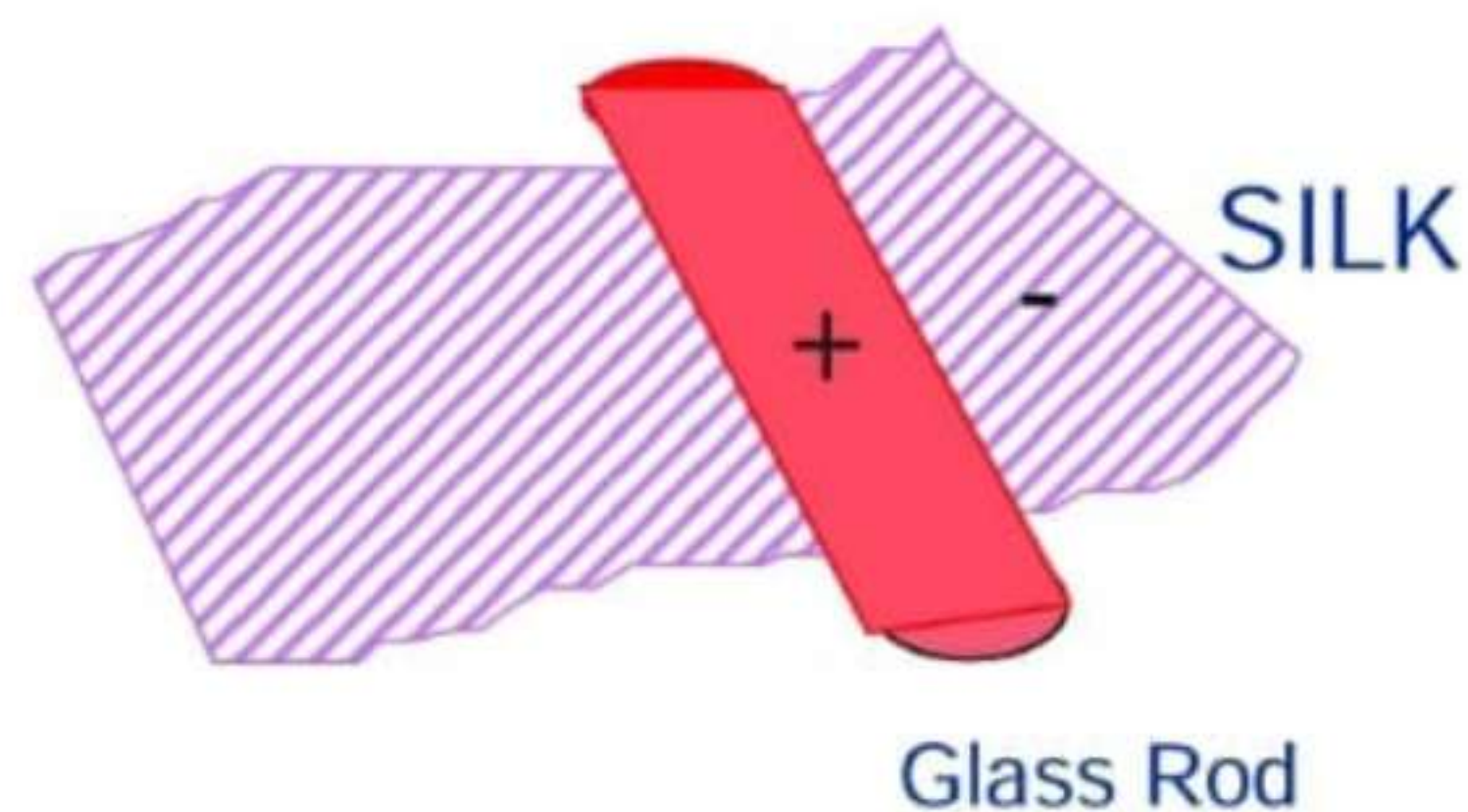


Some materials attract electrons more than others.



ELECTRIC CHARGE

The Transfer of Charge

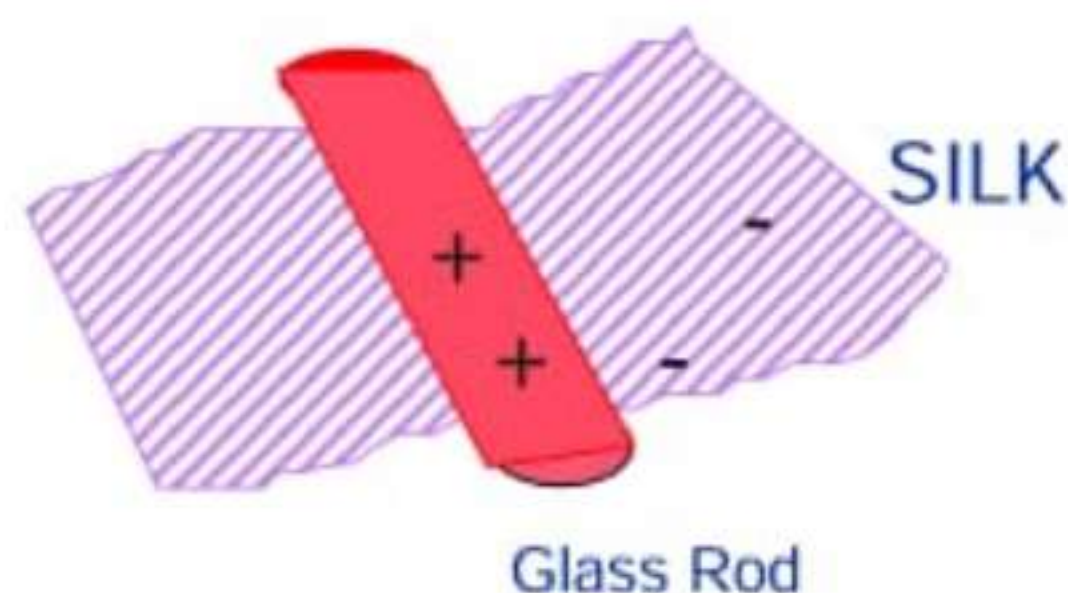


As the glass rod is rubbed against silk, electrons are pulled off the glass onto the silk.



ELECTRIC CHARGE

The Transfer of Charge

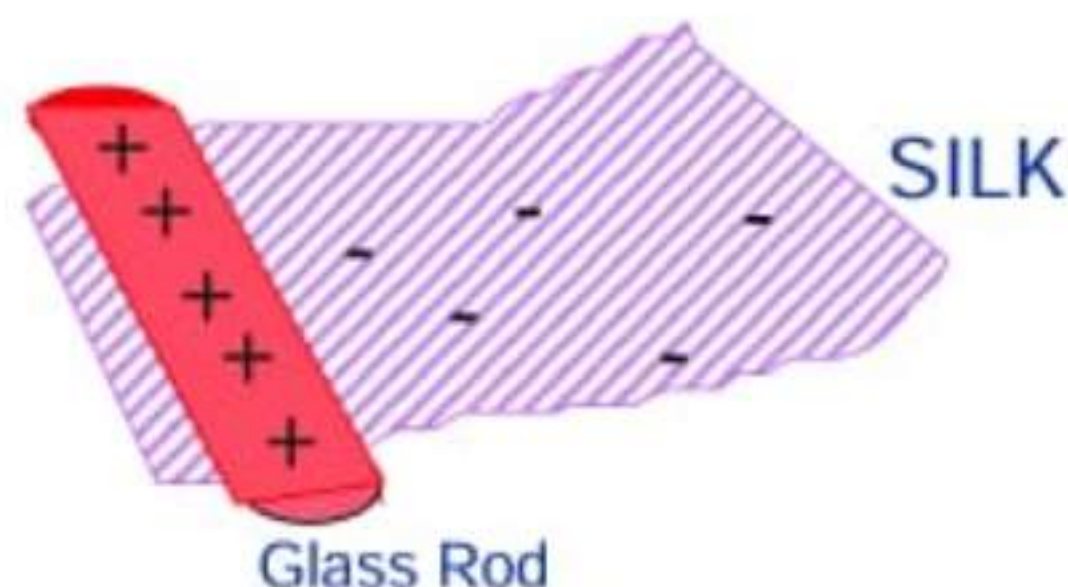


Usually matter is charge neutral, because the number of electrons and protons are equal. But here the silk has an excess of electrons and the rod a deficit.



ELECTRIC CHARGE

The Transfer of Charge



Glass and silk are insulators: charges stuck on them stay put.



Electric Charge and Its Conservation

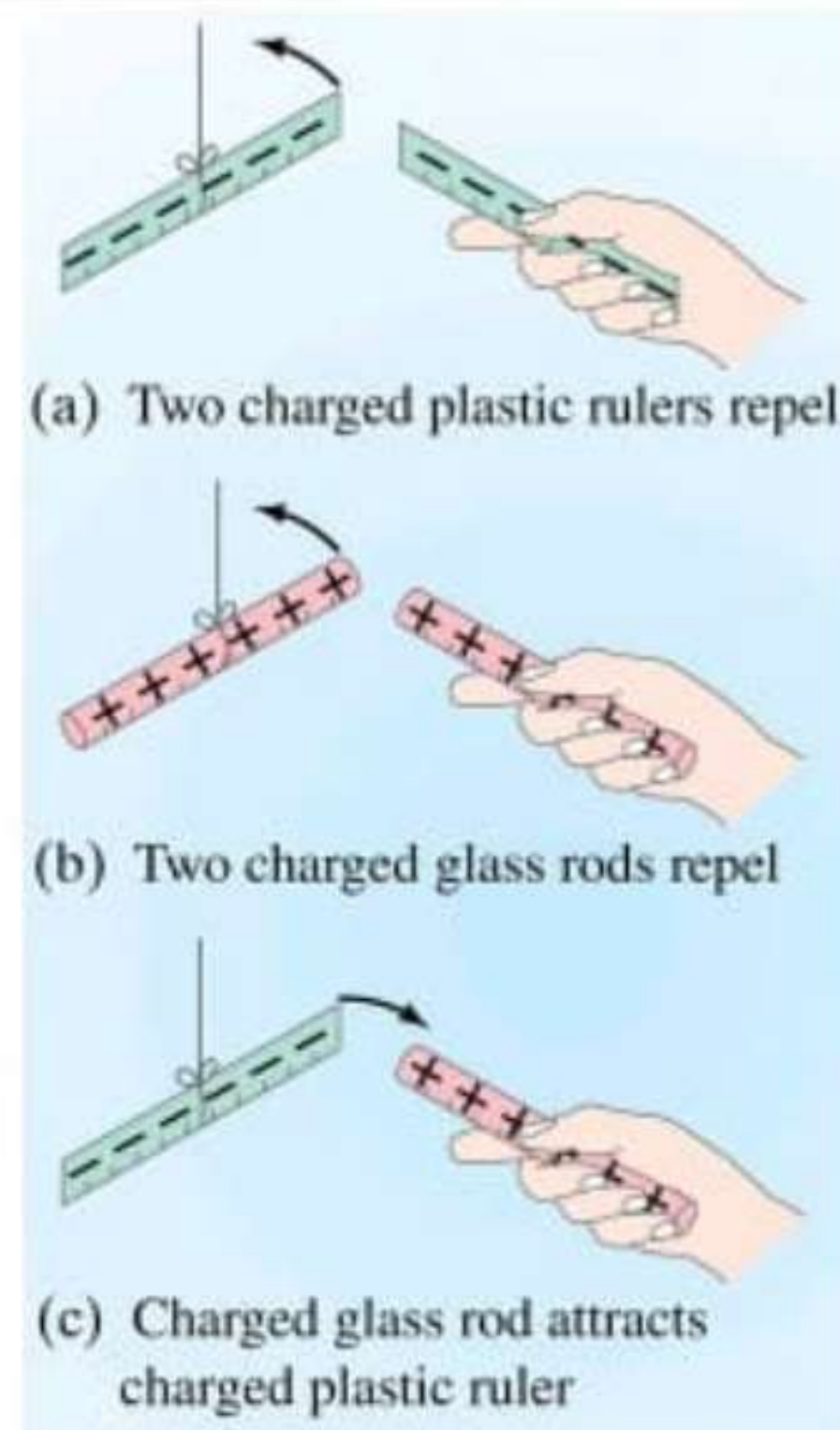
Macroscopic objects can be charged by rubbing





Electric Charge and Its Conservation

Charge comes in two types, positive and negative; like charges repel and opposite charges attract

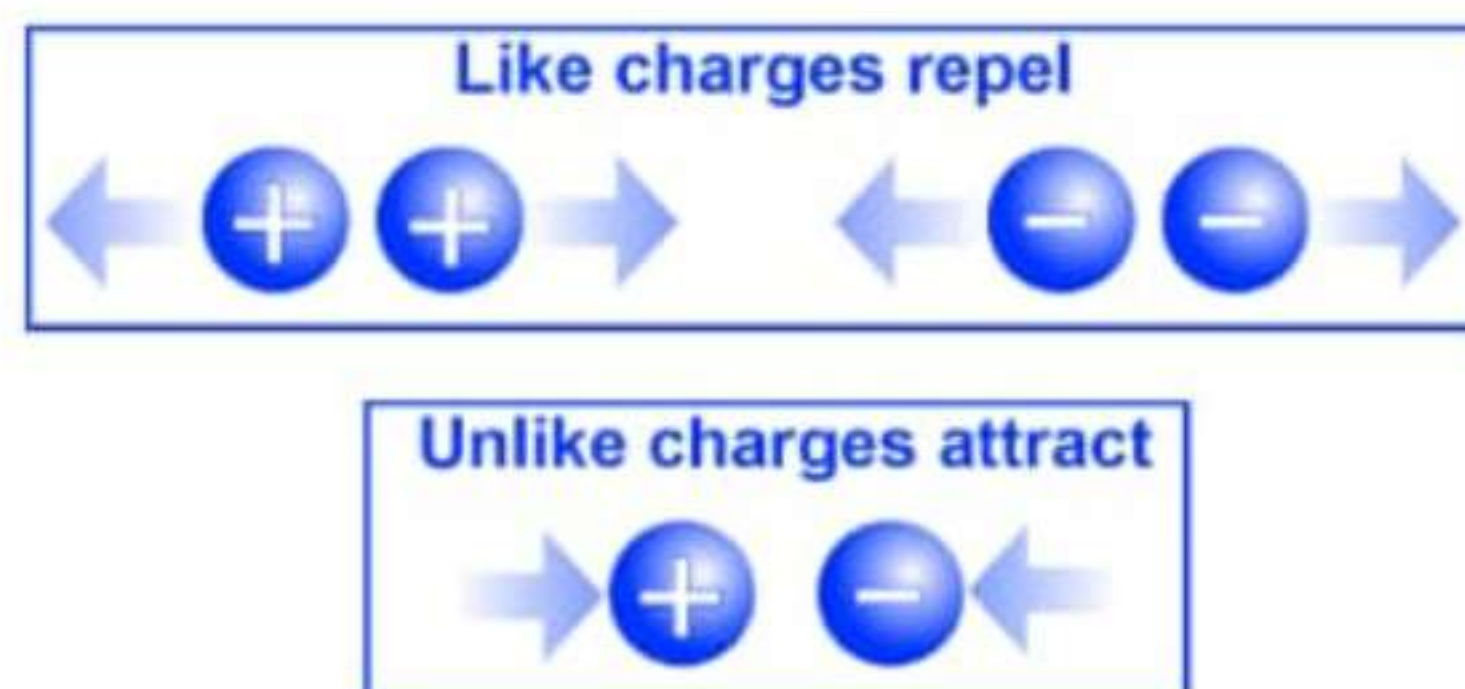


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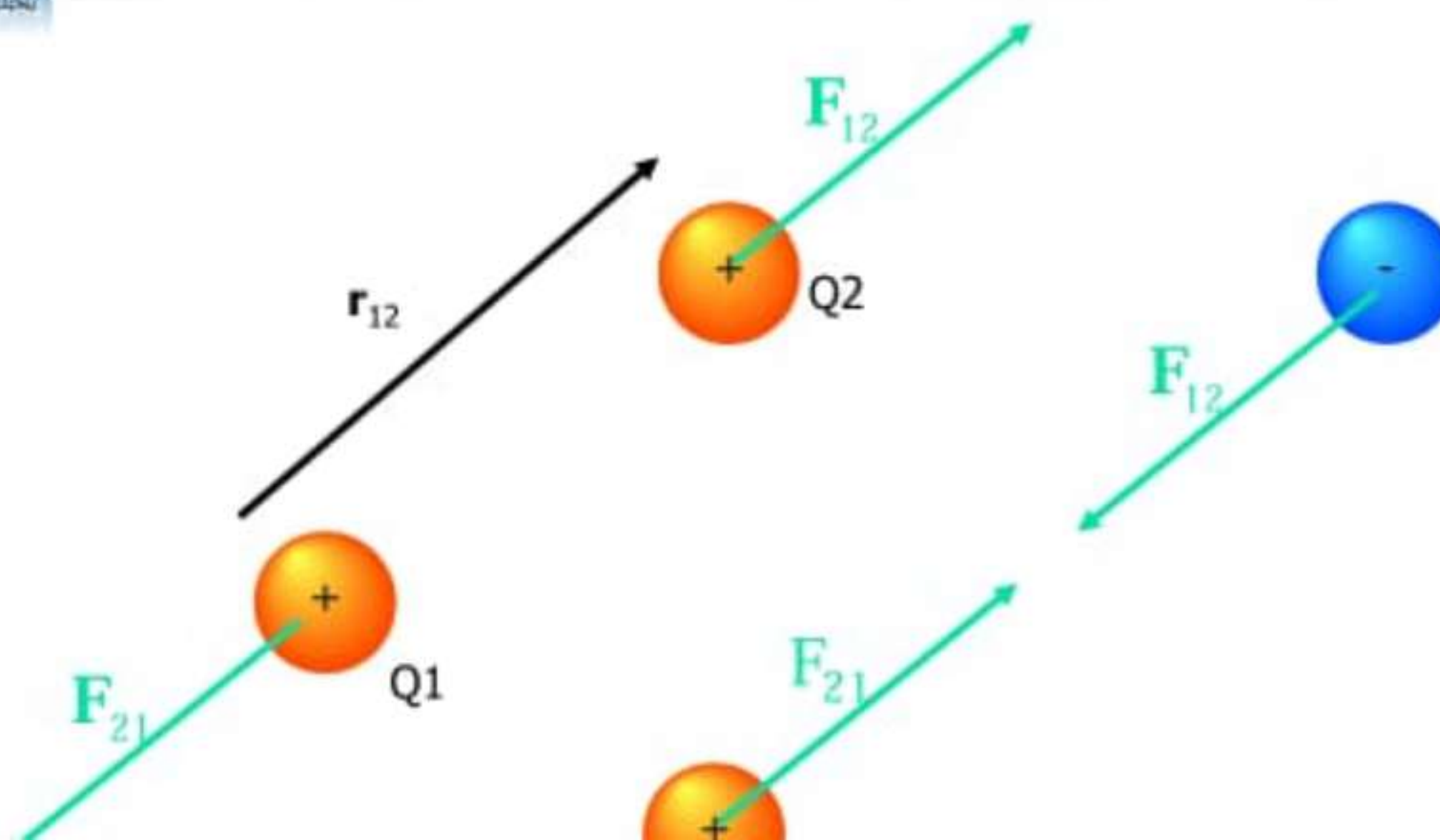


Charges and Forces

- Electric forces are created between all electric charges.
- Because there are two kinds of charge (positive and negative) the electrical force between charges can **attract** or **repel**.
- In any process the charge at the beginning equals the charge at the end of the process.

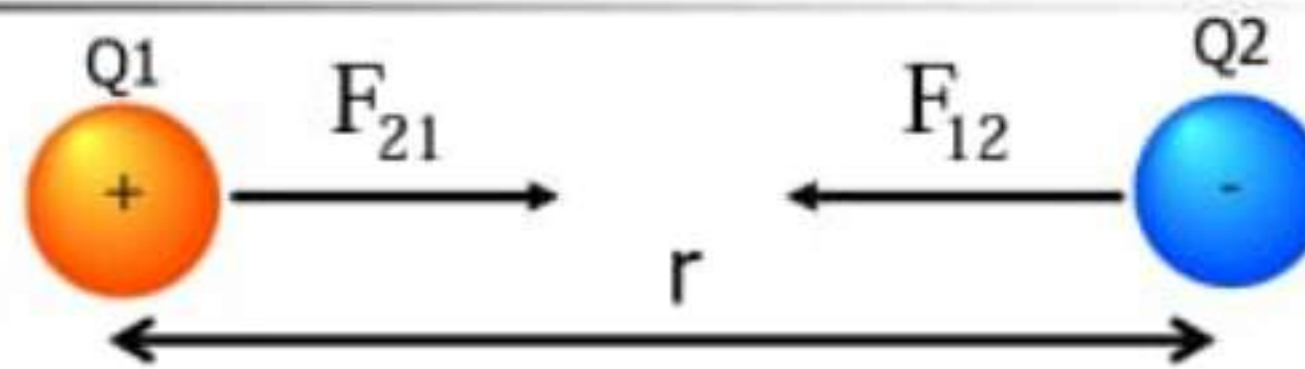


Charges and Forces





Coulomb's Law

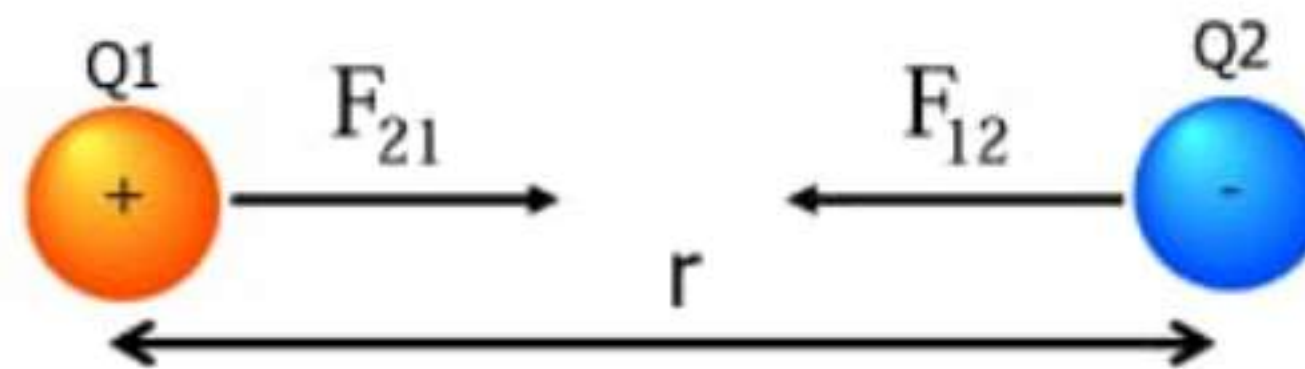


■ Coulomb determined

- Force is proportional to the product of the charges q_1 and q_2 along the lines joining them
- Force inversely proportional square of the distance
- I.e.
 - $|F_{12}| \propto |Q_1| |Q_2| / r_{12}^2$
 - or
 - $|F_{12}| = k |Q_1| |Q_2| / r_{12}^2$



Coulomb's Law



- The force on Q_1 due to Q_2 is equal in magnitude but opposite in direction to the force on Q_2 due to Q_1 .

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

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Coulomb's Law

The magnitude of the force of interaction between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them

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

$$K = \frac{1}{4\pi\epsilon_0}, \quad K = 9 \times 10^9 \text{ Nm}^2 / \text{C}^2$$



Example 1

A $-3\mu\text{C}$ charge is placed 100 mm from a $+3\mu\text{C}$ charge
calculate the force between two charges



- First we convert to appropriate units

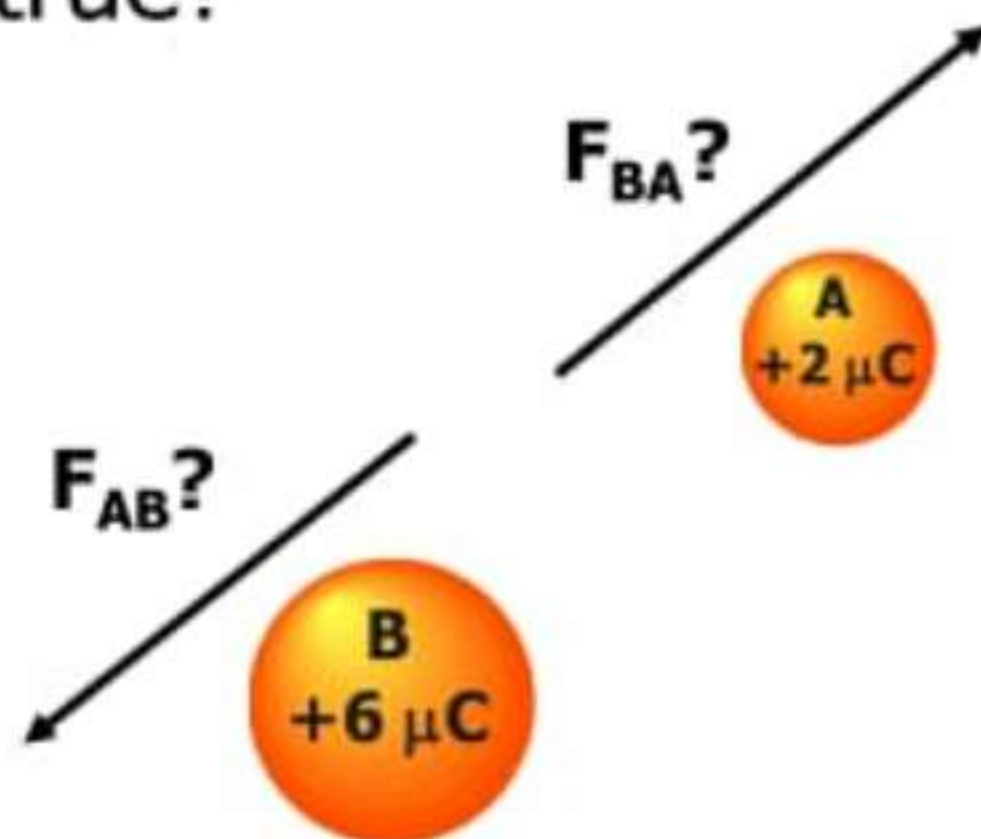
$$3\mu\text{C} = 3 \times 10^{-6}\text{C}, 100\text{ mm} = 100 \times 10^{-3}\text{m} = 0.1\text{ m}$$

$$F = K \frac{|q_1 q_2|}{r^2} = (9 \times 10^9 \text{ N.m}^2 / \text{C}^2) \frac{(3 \times 10^{-6} \text{ C})(3 \times 10^{-6} \text{ C})}{(0.1 \text{ m})^2}$$
$$= 8.1 \text{ N (Attraction force)}$$



Quiz 1

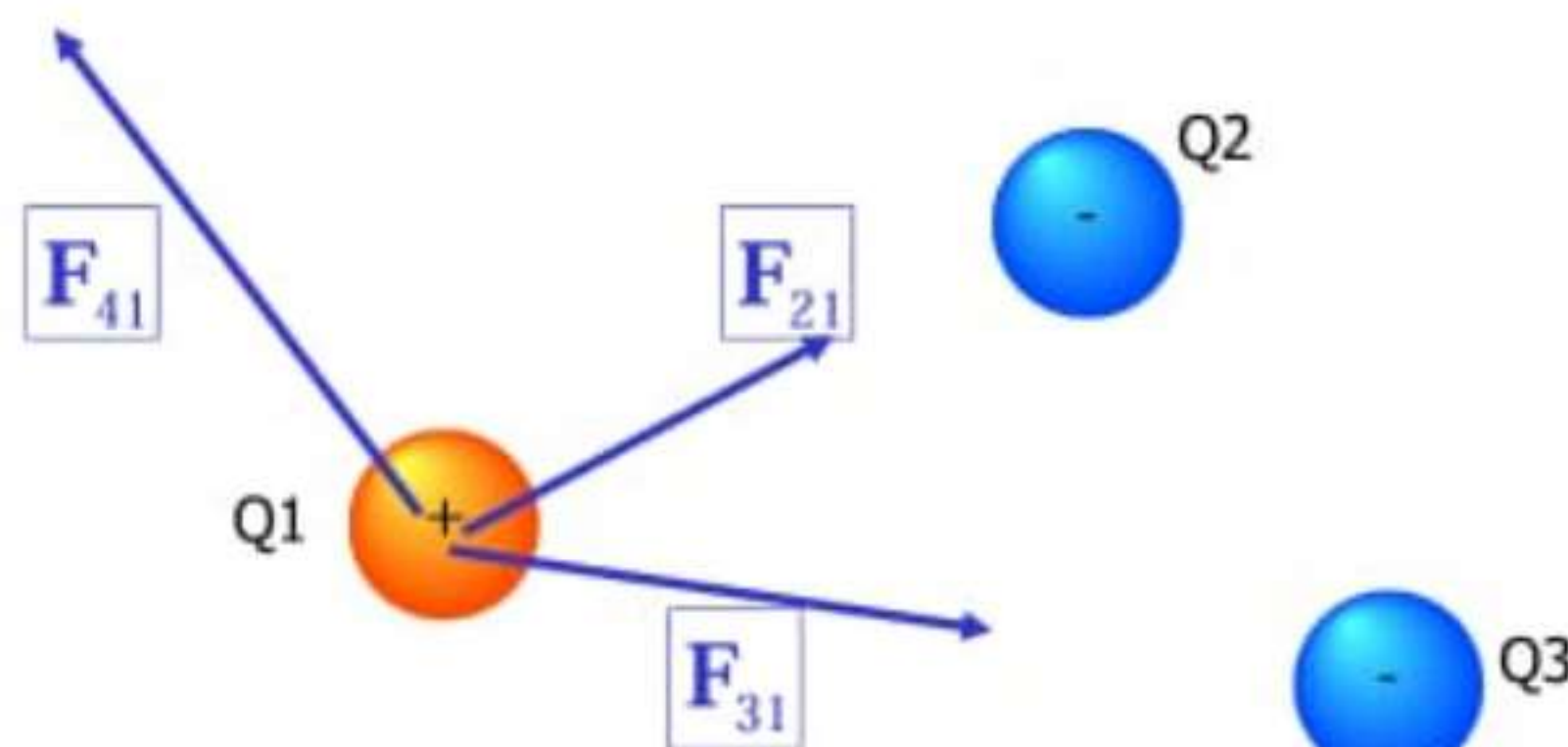
Object A has a charge of $+2\mu\text{C}$ and Object B has a charge of $+6\mu\text{C}$. Which statement is true?



- A:** $F_{AB} = -3F_{BA}$
- B:** $F_{AB} = -F_{BA}$
- C:** $3F_{AB} = -F_{BA}$
- D:** $F_{AB} = 12F_{BA}$



Force from many charges



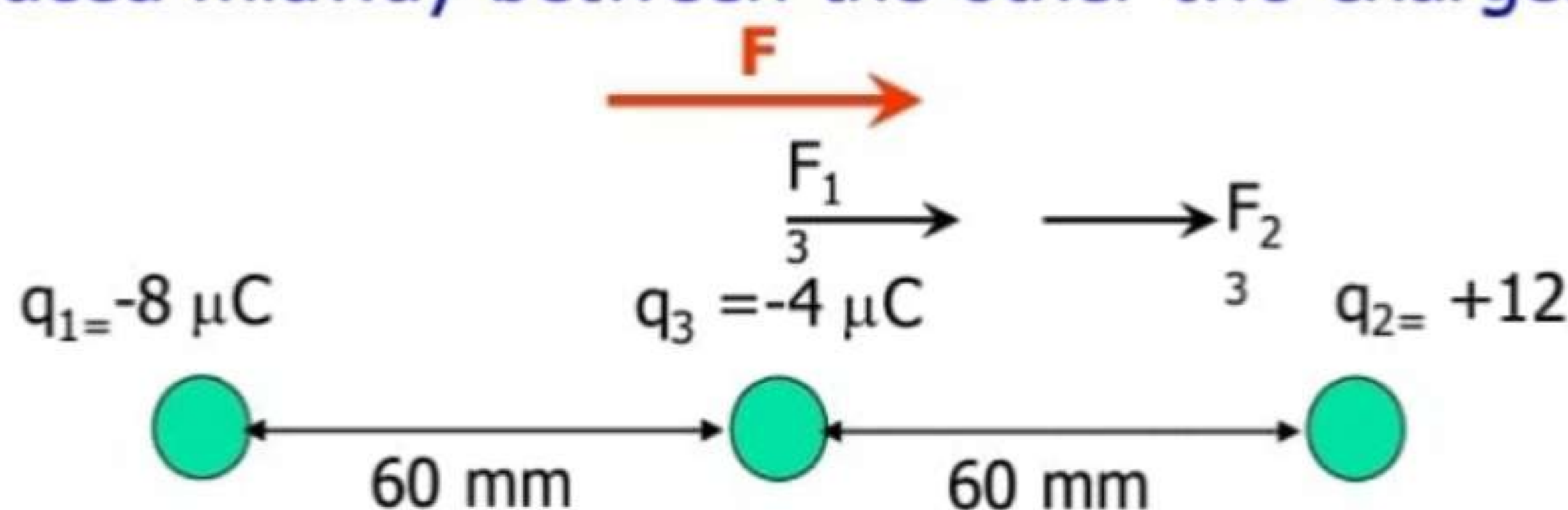
Principle of

Force on charge is vector sum of forces from all charges



Example 2

Two charges $q_1 = -8 \mu\text{C}$ and $q_2 = +12 \mu\text{C}$ are placed 120 mm apart in the air as shown. What is the resultant force on a third charge $q_3 = -4 \mu\text{C}$ placed midway between the other two charges?



$$F_{13} = K \frac{|q_1 q_3|}{r^2} = (9 \times 10^9 \text{ N.m}^2 / \text{C}^2) \frac{(8 \times 10^{-6} \text{ C})(4 \times 10^{-6} \text{ C})}{(0.06 \text{ m})^2} = 80 \text{ N (Repulsion, to the right).}$$

$$F_{23} = K \frac{|q_2 q_3|}{r^2} = (9 \times 10^9 \text{ N.m}^2 / \text{C}^2) \frac{(12 \times 10^{-6} \text{ C})(4 \times 10^{-6} \text{ C})}{(0.06 \text{ m})^2} = 120 \text{ N (Attraction, to the right).}$$

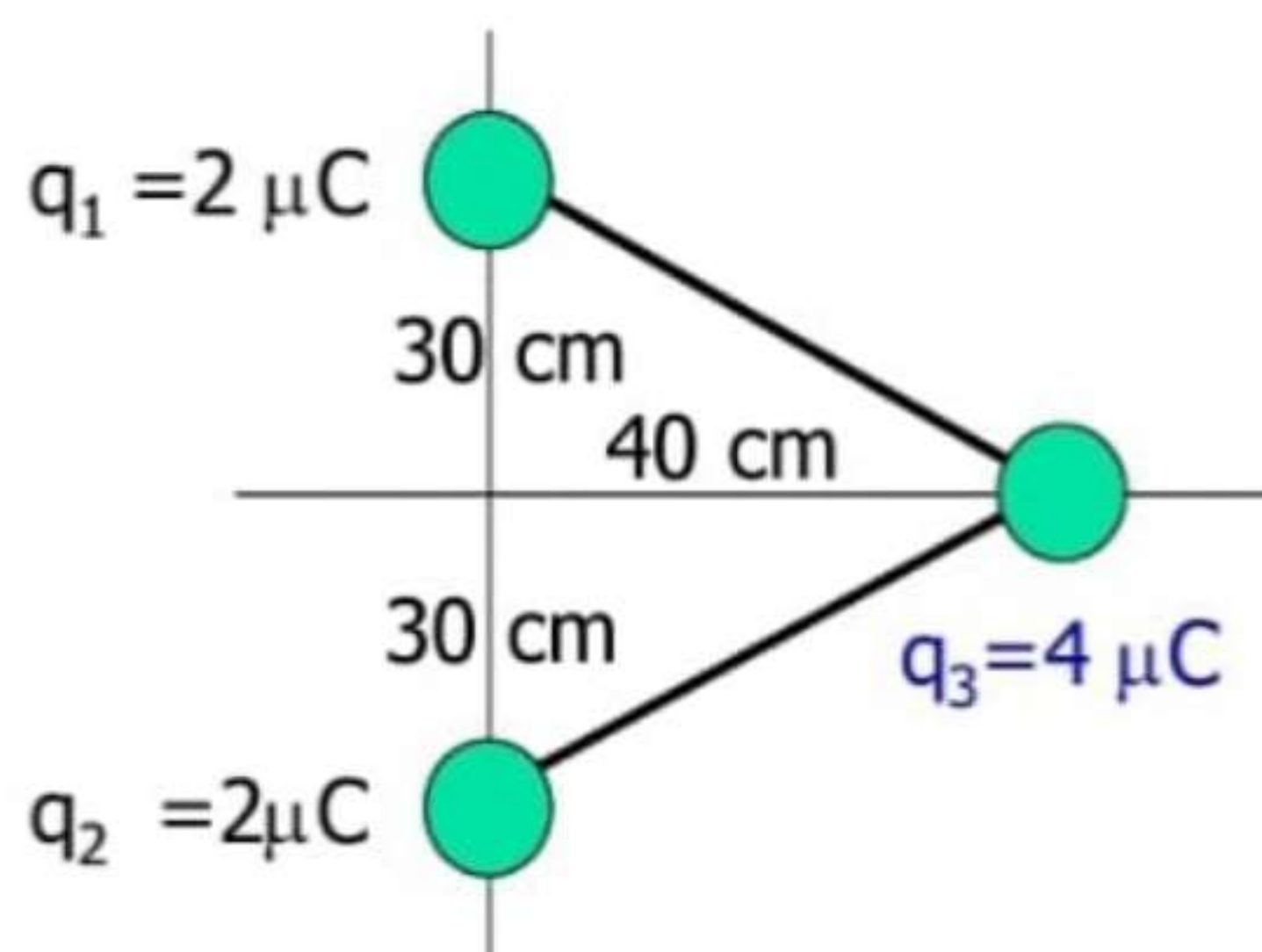
The resultant force F is the vector sum of F_{13} and F_{23} . Thus
 $F = 80 \text{ N} + 120 \text{ N} = 200 \text{ N}$ (Directed to the right)



Homework

Example 3

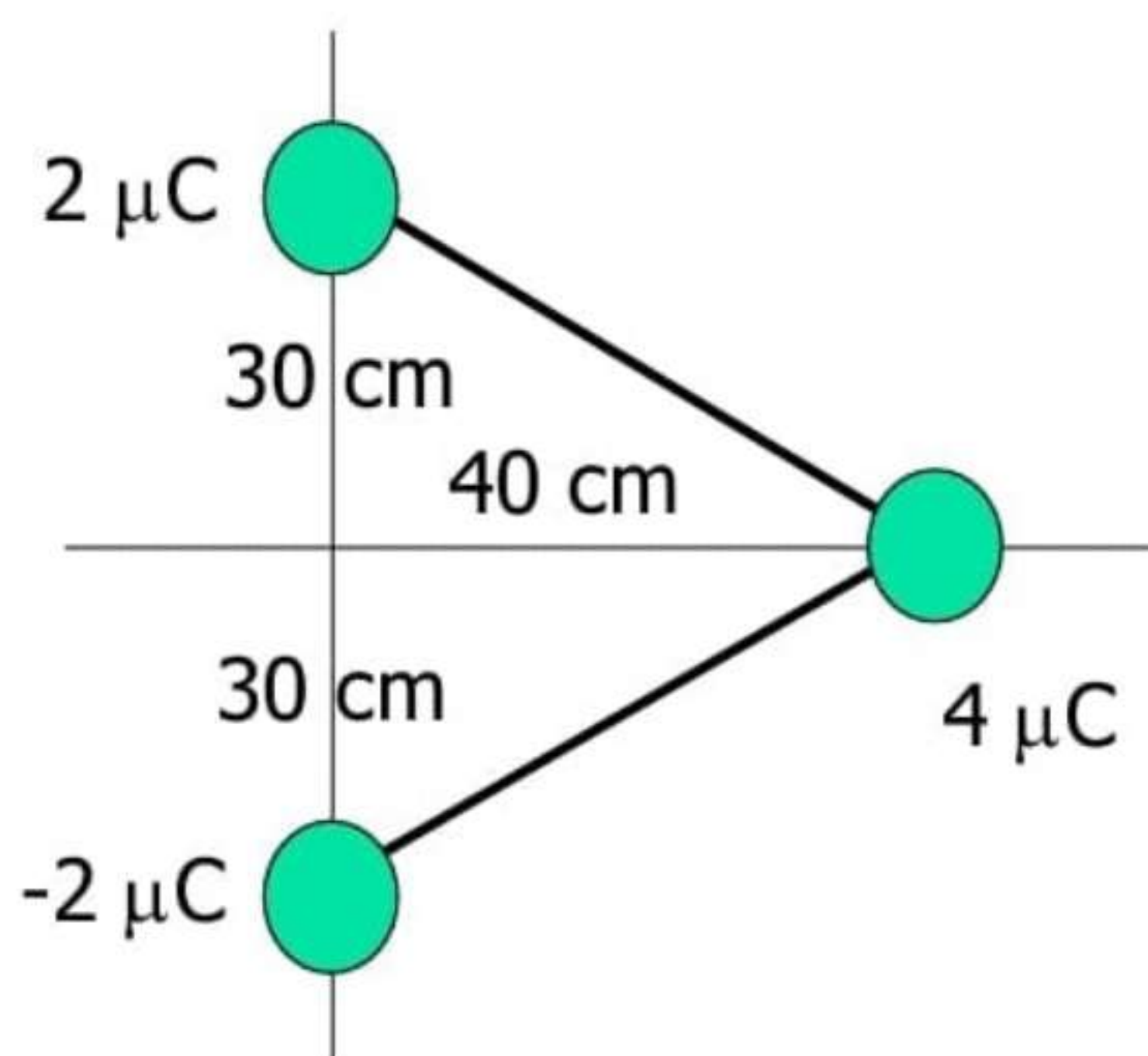
Two equal positive point charges $q_1 = q_2 = 2 \mu\text{C}$ interact with a third point charge $q_3 = 4 \mu\text{C}$. Find the magnitude and direction of the resultant force on q_3 .





Homework Example 4

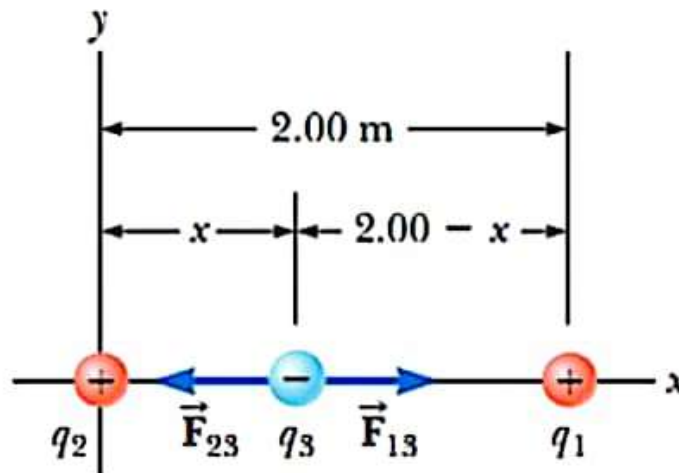
Solve the example 3 if the lower charge is negative.



Example 5



Three point charges lie along the x axis as shown in Figure. The positive charge $q_1 = 15.0 \mu\text{C}$ is at $x = 2 \text{ m}$, the positive charge $q_2 = 6.00 \mu\text{C}$ is at the origin, and the net force acting on q_3 is zero. What is the distance x coordinate of q_3 ?



Example 5



As shown in the figure

$$F_3 = F_{13} - F_{23} = 0$$

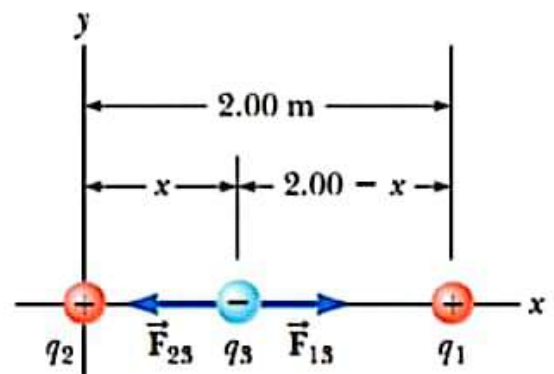
$$F_{13} = F_{23}$$

$$K \frac{|q_1 q_3|}{r_{13}^2} = K \frac{|q_2 q_3|}{r_{23}^2}$$

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

$$\therefore 6(2-x)^2 = 15x^2 \Rightarrow 3x^2 + 8x - 8 = 0$$

$$\therefore x = 0.775 \text{ m}, \quad x = -3.44 \text{ m (refused)}$$

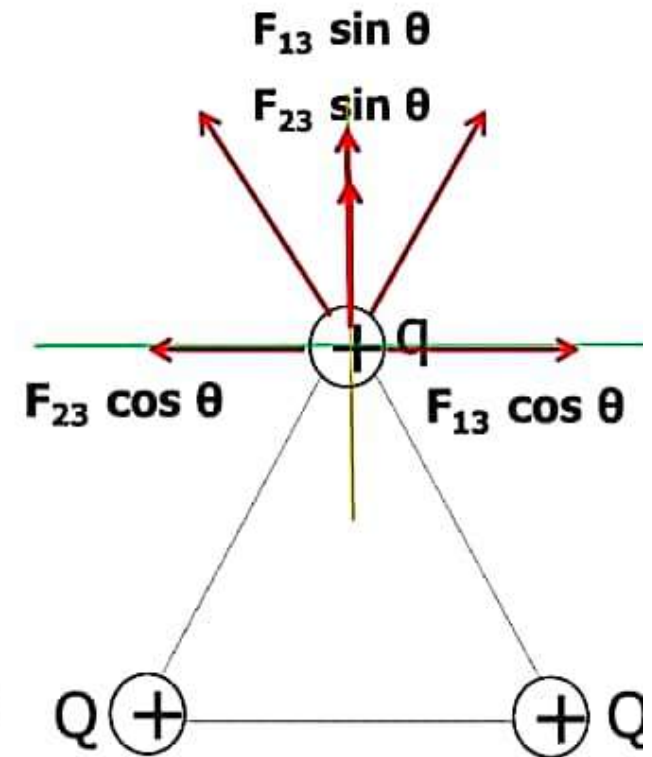




Example 6

Two particles, each with charge Q , and a third particle, with charge q , are placed at the vertices of an equilateral triangle as shown. The total force on the particle with charge q is:

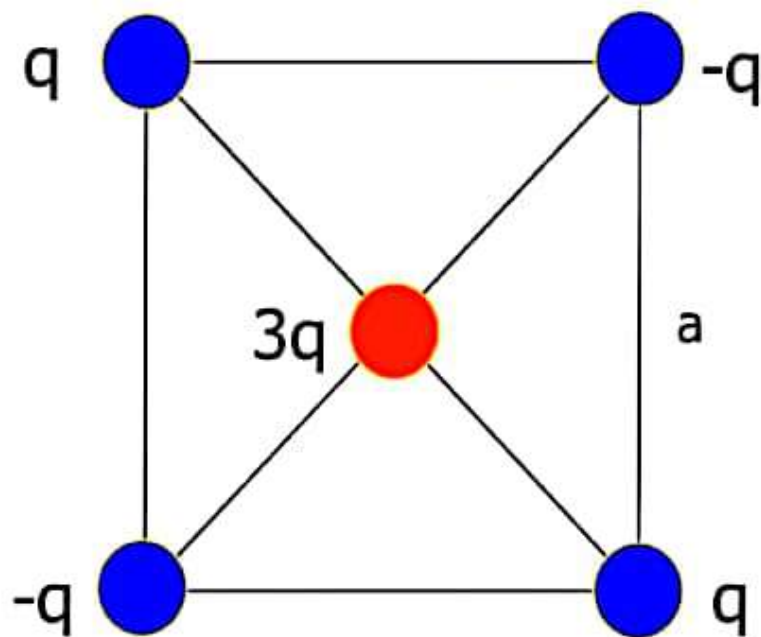
- A. parallel to the left side of the triangle
- B. parallel to the right side of the triangle
- C. parallel to the bottom side of the triangle
- D. perpendicular to the bottom side of the triangle
- E. perpendicular to the left side of the triangle





Quiz 1

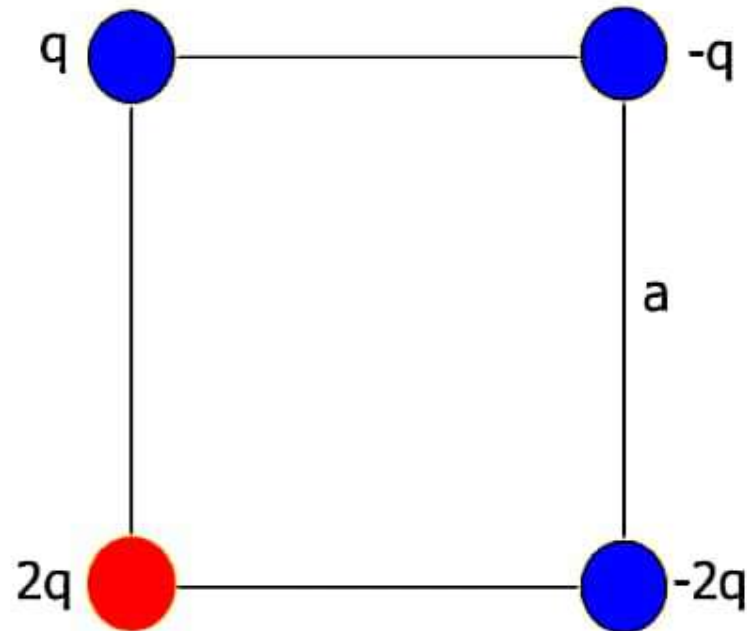
what is the resultant force on the charge in the center of the square? ($q=1 \times 10^{-7}$ C and $a = 5$ cm).





Example 7

what is the resultant force on the charge in the lower left corner of the square? ($q=1 \times 10^{-7}$ C and $a = 5$ cm).



(The resultant force equals = 0.175 N, with the direction -15.5° with respect to the x-axis)



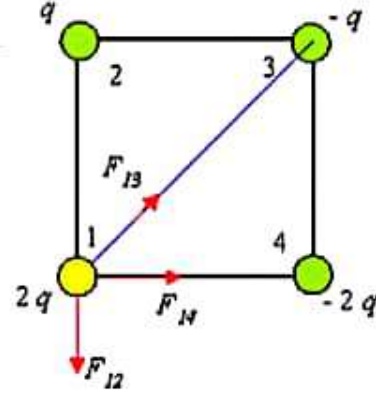
Solution

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

$$F_{12} = K \frac{2qq}{a^2}$$

$$F_{13} = K \frac{2qq}{2a^2}$$

$$F_{14} = K \frac{2q2q}{a^2}$$



لاحظ هنا أننا أهملنا التعويض عن إشارة الشحنات عند حساب مقدار القوى. وبالتعويض في المعادلات ينتج أن:

$$F_{12} = 0.072 \text{ N}, \quad F_{13} = 0.036 \text{ N}, \quad F_{14} = 0.144 \text{ N}$$

لاحظ هنا أننا لا نستطيع جمع القوى الثلاث مباشرة لأن خط عمل القوى مختلف، ولذلك لحساب المحصلة نفرض محورين متعامدين x, y ونحلل القوى التي لا تقع على هذين المحورين أي متجه القوة F_{13} ليصبح



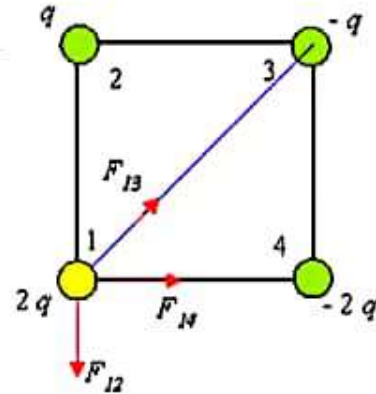
Solution

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

$$F_{12} = K \frac{2qq}{a^2}$$

$$F_{13} = K \frac{2qq}{2a^2}$$

$$F_{14} = K \frac{2q2q}{a^2}$$



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$$F_{13x} = F_{13} \sin 45 = 0.025 \text{ N}$$

$$F_{13y} = F_{13} \cos 45 = 0.025 \text{ N}$$

$$F_x = F_{13x} + F_{14} = 0.025 + 0.144 = 0.169 \text{ N}$$

$$F_y = F_{13y} - F_{12} = 0.025 - 0.072 = -0.047 \text{ N}$$

الإشارة السالبة تدل على أن اتجاه مركبة القوة في اتجاه محور y السالب.

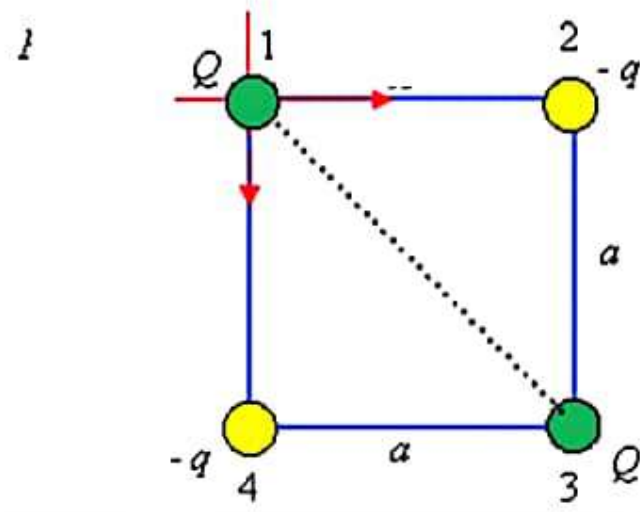
- The resultant force equals

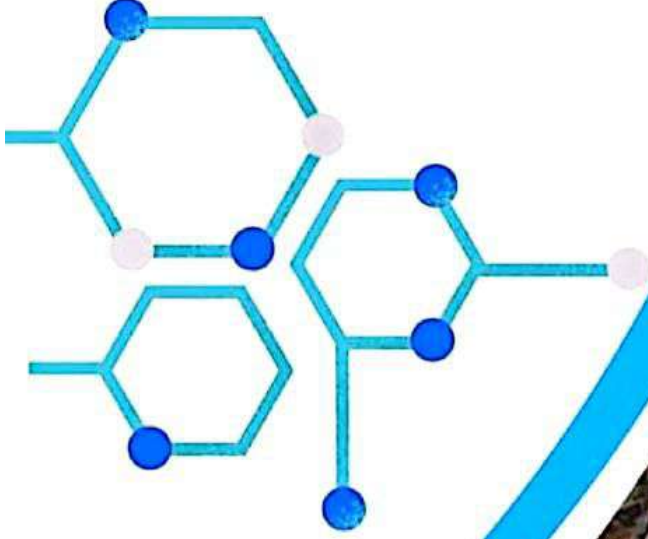
$$F_1 = \sqrt{(F_x)^2 + (F_y)^2} = 0.175 \text{ N}$$



Quiz 2

- A charge Q is fixed at each of two opposite corners of a square as shown in figure 2.6. A charge q is placed at each of the other two corners. (a) If the resultant electrical force on Q is Zero, how are Q and q related.





Lecture: محاضره 3 كهربيه

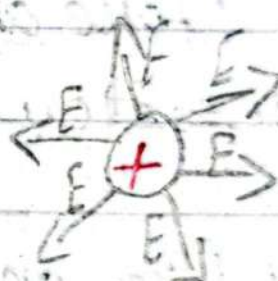
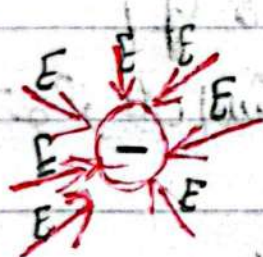
By: Anas Mohammed

اللَّهُمَّ انْفَعْنِي
بِمَا عَلَّمْتَنِي
وَعَلَّمْنِي مَا
يَنْفَعُنِي وَزِدْنِي
عِلْمًا

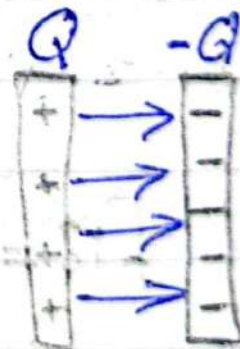
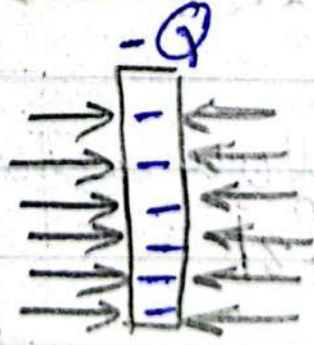
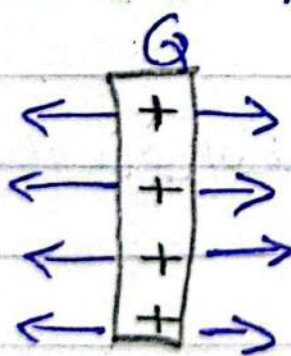
ch2: Electric field:

يعرف المجال بأنه: القوة المؤثرة على وحدة الشحنات الموجبة
في هذا المجال

$$E = \frac{F}{Q_0} \quad , \quad F = k \frac{19.921}{r^2}$$
$$\rightarrow E = \frac{F}{Q_0} = k \frac{q}{r^2}$$



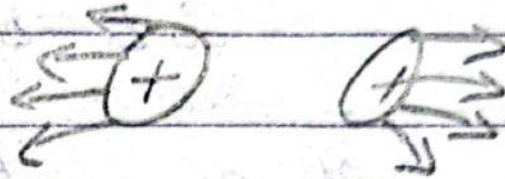
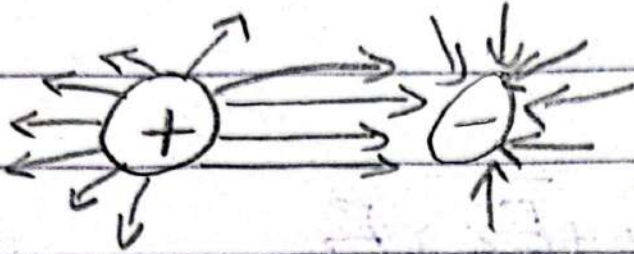
Electric field lines:



(2)- The electric field lines are always perpendicular to the surface of metal or conductor under electrostatic conditions.

« خطوط المجال الكهربائي عمودى على سطح الموصل أو الموصل »

3- No two field lines cross each other
 لا يمكن أن يتقاطع خطوط المجال الكهربائي أبدًا



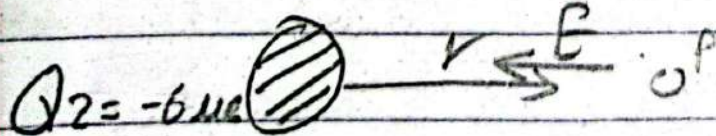
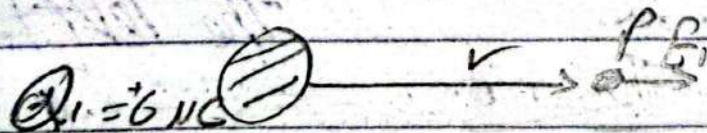
Example 1:



$$E = k \cdot \frac{q}{r^2}$$

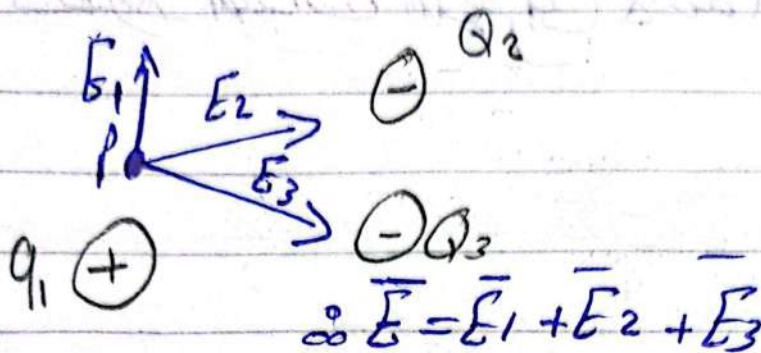
$$E = 9 \times 10^9 \times \frac{3 \times 10^{-9}}{(100 \times 10^{-3})^2} = 2700 \text{ N/C}$$

Quiz 1:

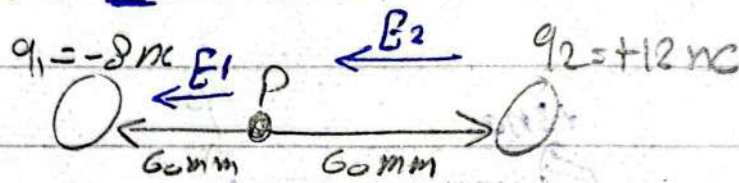


$$E_1 = -E_2$$

Electric field from many charges:-



Example 2: $\leftarrow E$

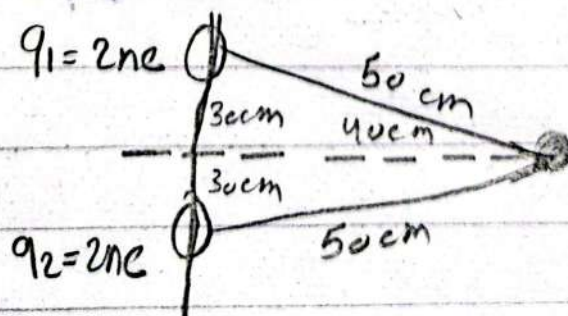


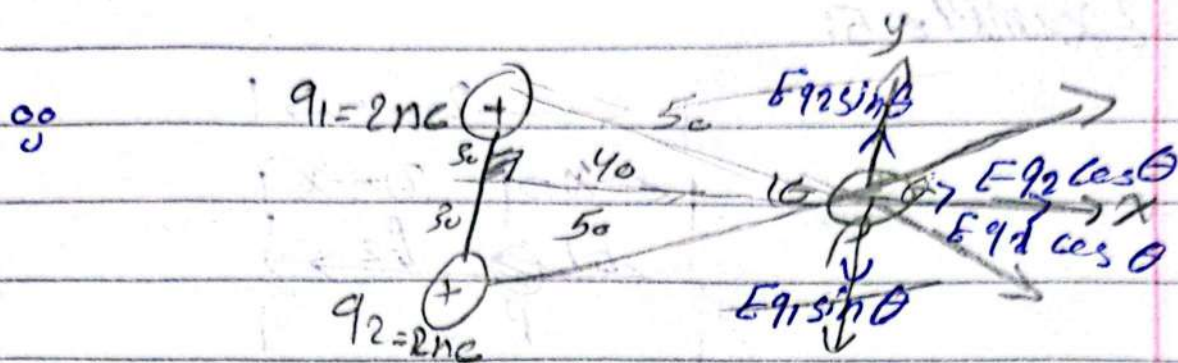
$$\therefore E_1 = 9 \times 10^9 \times \frac{|8 \times 10^{-9}|}{(60 \times 10^{-3})^2} = 20000 \text{ N/C (to the left)}$$

$$\therefore E_2 = 9 \times 10^9 \times \frac{|12 \times 10^{-9}|}{(60 \times 10^{-3})^2} = 30000 \text{ N/C (to the left)}$$

$$E = -20000 - 30000 = -50000 \text{ N/C (Directed to the left).}$$

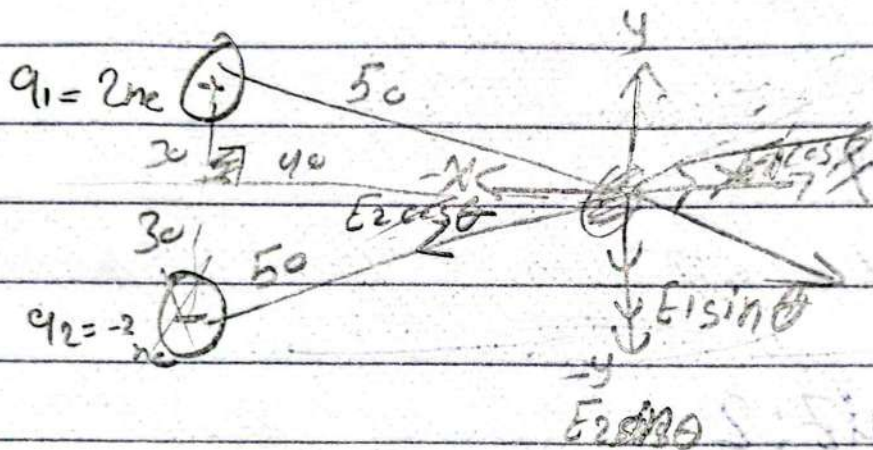
Example 3:





$$\begin{aligned} \therefore F_x &= E_2 \cos \theta + E_1 \cos \theta = 2 \times [72] \times \left(\frac{40}{50} \right) = 115,2 \text{ N/C} \\ \therefore E_1 = E_2 &= 9 \times 10^9 \times \frac{|2 \times 10^{-9}|}{(50 \times 10^{-2})^2} = 72 \text{ N/C} \end{aligned} \quad \text{in right}$$

Example 4:



$$\therefore F_x = 0$$

$$F_y = E_1 \sin \theta - E_2 \sin \theta = [72] \times \left(\frac{30}{50} \right) = -86,4 \text{ N/C}$$

$$\therefore E_1 = 9 \times 10^9 \times \frac{|2 \times 10^{-9}|}{(50 \times 10^{-2})^2} = 72$$

$E_2 = 72$

$$\therefore E = \sqrt{(-86,4)^2 + (0)^2} = 86,4 \text{ N/C}$$

The direct the total Electric field in (-y) with magnitude 86,4 N/C



Lecture: محاضرة الرابعة كهربيه

By: Mai Elrefaie

اللَّهُمَّ انْفَعْنِي
بِمَا عَلَّمْتَنِي
وَعَلَّمْنِي مَا
يَنْفَعُنِي وَزِدْنِي
عِلْمًا



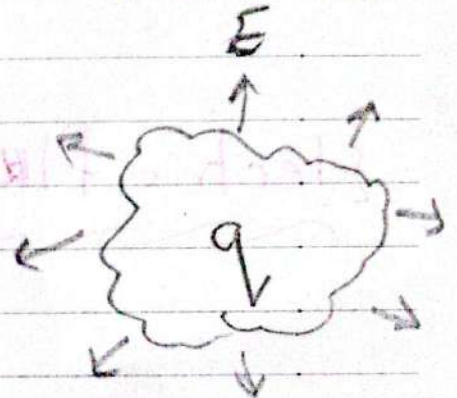
Gauss law

$$\Phi = \oint_{\text{surface}} \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$$

$$\epsilon_0 = 8,85 \times 10^{-12} \text{ F/m}$$

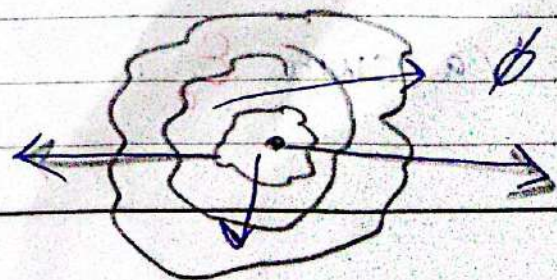
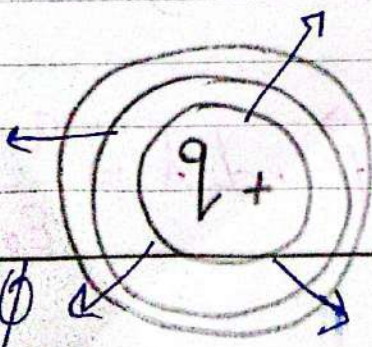
* Electric Flux

$$\begin{aligned} \Phi &= \int E A \cos \theta \\ &= E \int dA \cos \theta \\ &= E A \cos \theta \end{aligned}$$



* نجفت النظر على شكل السطح لجاوس

لا يتغير كمية الفيض الكهربيه الخارجيه



Gaussian surface

يتعامل مع الشحنة فقط ϕ يتغير مع الشكل أو عدد المستويات أو انتقال الشحنة.

* It deals with charge only and doesn't change with the shape, number of levels, or charge transfer

Electric Flux

Gauss's law.

The total Flux passing through a closed surface is equal to the net charge enclosed within that surface divided by Permittivity of the vacuum ϵ_0

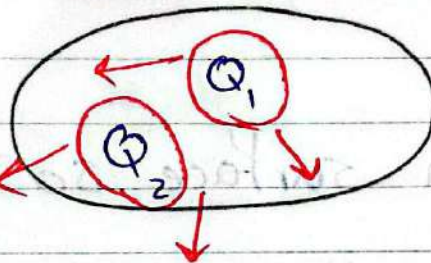
$$\phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$$

قانون جاوس

يُفهم على أن المنفذ المار خلال سطح مغلق يكون

مساوياً "للمقدار الشحنة داخل هذا السطح مقسوماً على ثباته

الفرانغ

 Φ_E عينة Φ_S ؟

المطلوب

since the flux is related to the number of field lines passing through a surface

→ the total flux is the total from each charge

$$\Phi_S = \frac{Q_1}{\epsilon_0} + \frac{Q_2}{\epsilon_0}$$

علشان نجد اى مسأله

* select Gauss's surface with symmetry

That matches the charge distribution

اختار سطح جاوس متماثل ومتناسب مع توزيع الشحنة

* Draw Gaussian surface so that the electric field is either constant or zero

ارسم سطح جاوس بحيث يكون قيمته ثابتة او صفر

* determine the direction of $\vec{E}$

حدد اتجاه الـ $\vec{E}$

* Evaluate the Electric Flux

محيط ϕ

* Determine the charge inside the Gaussian surface

ارسم الشحنات داخل السطح

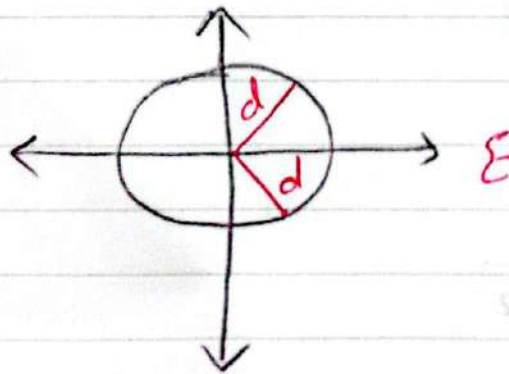
calculate Electric flux to point charge
with Gauss's law

المساحة الكلية لسطح غاوس

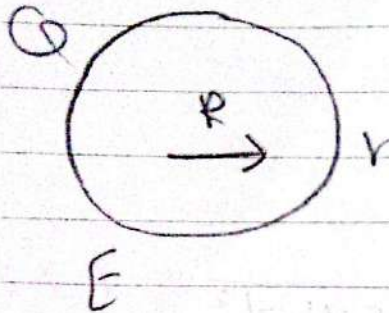
$$\Phi = \oint \vec{E} \cdot \frac{r}{2} \cdot 2\pi r^2 = \frac{q}{8,65 \times 10^{-12}} \quad (\times 2)$$

$$\Phi = \oint \vec{E} \cdot 4r^2\pi = \frac{q}{\epsilon_0}$$

$$E = \frac{q}{4\pi\epsilon_0 r^2} = k \frac{q}{r^2}$$



Conducting sphere



Q = total charge on its surface

1) $E, r < R$

$$E = 0$$

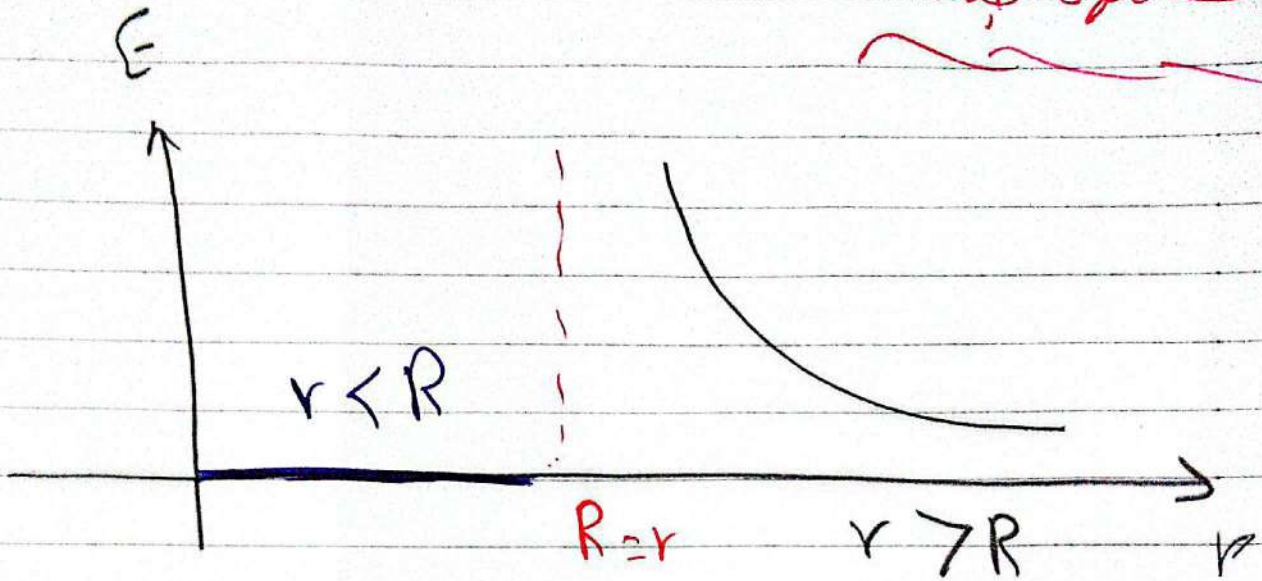
2) $r = R$

$$E = k \frac{Q}{R^2}$$

3) $r > R$

$$E = k \frac{Q}{r^2}$$

رسم جداول





Lecture: محاضرة 5 كهربية

By: Shahd Abdallah

اللَّهُمَّ انْفَعْنِي
بِمَا عَلَّمْتَنِي
وَعَلَّمَنِي مَا
يَنْفَعُنِي وَزِدْنِي
عِلْمًا



محاضرة 5 كهربية

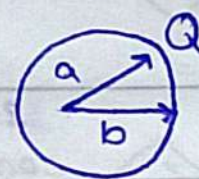
Example: Quiz 2 solution

consider uniformly charged spherical shell of hollow sphere inner radius a and outer radius b with a net charge Q on surface. use Gauss's Law to find electric field at (a) $r < a$ (b) $a < r < b$ (c) $r > b$

electric field for $r < a$ $\therefore E = 0$

electric field for $a < r < b$ $\therefore E = 0$

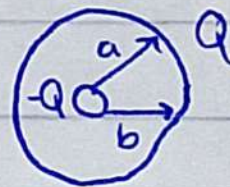
electric field for $r > b$ $\therefore E = k \frac{Q}{r^2}$



Quiz 3 solution

consider a spherical conducting shell with a charge Q . A particle with charge $-Q$ is placed at the center of the cavity as shown the figure. Use Gauss's Law to find the electric field at (a) $r < a$ (b) $a < r < b$ (c) $r > b$

(a) $r < a$ $\therefore E = k \frac{Q}{r^2}$ (directed radially inward)



(b) $a < r < b$ $\therefore E = 0$

(c) $r > b$ $\therefore E = 0$

MITKEES

Quiz 4 solution ← علينا برود

①

$$\vec{E} = 2\hat{i} + 3\hat{j} + 5\hat{k} \frac{N}{C}$$

$$\Phi = EA \quad E \perp A$$

$$\Phi = 5 \times 16 \times 10^{-4} = 8 \times 10^{-3} \text{ Nm}^2/C$$

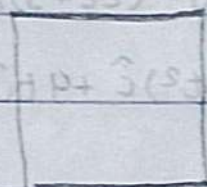
(الركبة العمودية الوحيدة التي يقطعها قيمة)

②

$$E = 28 \text{ kN/C}$$

$$\Phi = EA = 28 \times 10^3 \times 22 \times 10^{-2} \times 28 \times 10^{-2}$$

$$\text{if } \theta = 30^\circ \quad \Phi = EA \cos(30)$$



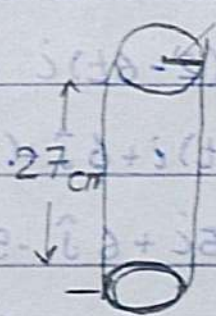
③

$$E = 4 \times 10^5 \text{ N/C} \quad \Phi = ??$$

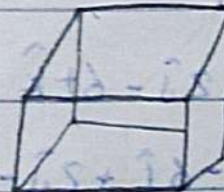
$$\Phi = EA = 4 \times 10^5 \times$$

A = (مساحة القاعدة) × الارتفاع

$$\Phi = \frac{q}{\epsilon} \quad q = \Phi \epsilon$$



$$\Phi = \frac{q}{\epsilon} = \frac{6 \times 10^{-9}}{8.85 \times 10^{-12}}$$



$$\Phi_{\text{Flax}} = \Phi/6$$



محاضره 6 كهريه: Lecture

By: *Omayma samy*

اللَّهُمَّ انْفَعْنِي
بِمَا عَلَّمْتَنِي
وَعَلَّمْنِي مَا
يَنْفَعُنِي وَزِدْنِي
عِلْمًا

13/4/2025

Date: / /

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Lee 6 :-

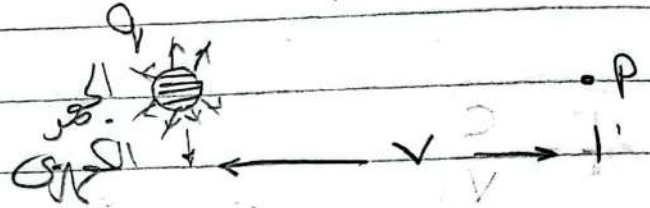
<< كهربية >>

$$W = \vec{F} \cdot \vec{d}$$

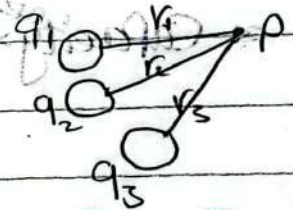
↳ scalar << قياسية >>

$$V_{AB} = V_B - V_A = \frac{W_{AB}}{q_0}$$

$$V_p = k \frac{q}{r} = \frac{1}{4\pi\epsilon_0} \frac{q}{r} = 9 \times 10^9 \frac{q}{r}$$



$$V_p = k \sum \frac{q_i}{r_i} = k \frac{q_1}{r_1} + k \frac{q_2}{r_2} + k \frac{q_3}{r_3}$$



الجهد الكهربي

مجال كهربائي

قوة كهربائية

$$V = k \frac{q}{r} = E \cdot r$$

لـ كمية قياسية

$$E = \frac{F}{q} = k \frac{q}{r^2}$$

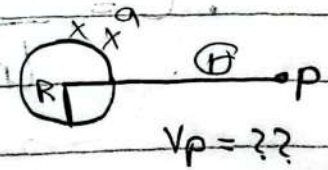
لـ كمية متجهة

$$F = k \frac{q_1 q_2}{r^2}$$

لـ كمية متجهة

$$E_p = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

$$\int dv = E \cdot \int dr$$

 $V_p = ??$

$$\int dv = \frac{1}{4\pi\epsilon_0} \int \frac{q}{r^2} dr$$

$$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r} + C$$

$$\Rightarrow r = \infty$$

$$V = 0$$

$$C = 0$$

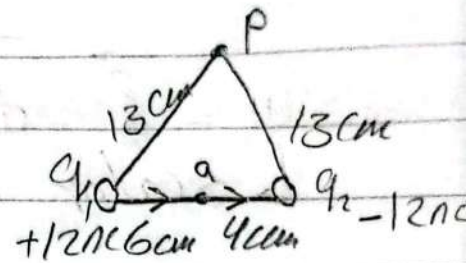
$$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$$

$$V_p = 9 \times 10^9 \left(\frac{12 \times 10^{-9}}{13} - \frac{12 \times 10^{-9}}{13} \right) = 0 \quad V_p = ??$$

$$V_a = ??$$

$$V_a = k \frac{q_1}{r_1} + k \frac{q_2}{r_2}$$

$$= k \left(\frac{q_1}{r_1} + \frac{q_2}{r_2} \right) = 9 \times 10^9 \times \left(\frac{12 \times 10^{-9}}{0.06} - \frac{12 \times 10^{-9}}{0.04} \right) = 900 \neq$$

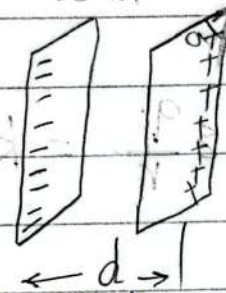


$$F = \frac{C}{V}$$

« Capacity »

$$C = \epsilon_0 \frac{A}{d}$$

$$C = \frac{q}{V}$$



« Parallel Plate capacity »

$$C = \frac{2\pi \epsilon_0 L}{\ln b - \ln a}$$

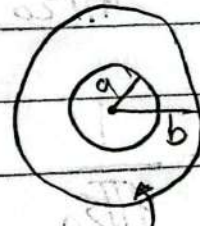
« Cylindrical capacity »



air dielectric

$$C = 4\pi \epsilon_0 \frac{ab}{b-a}$$

« spherical capacity »



air dielectric

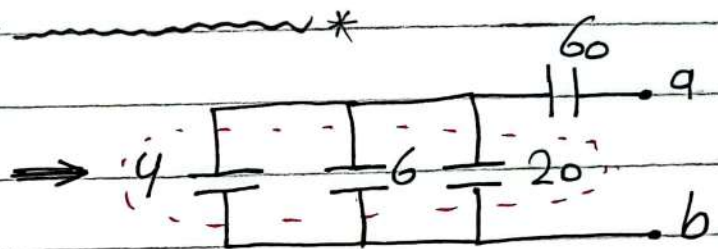
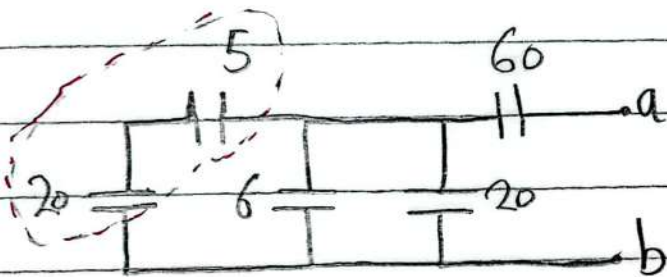
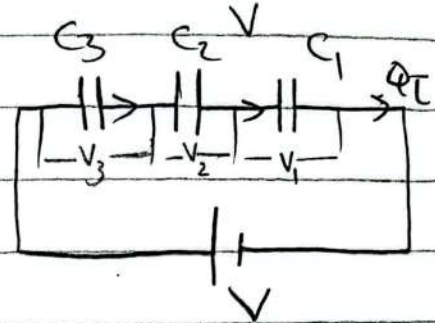
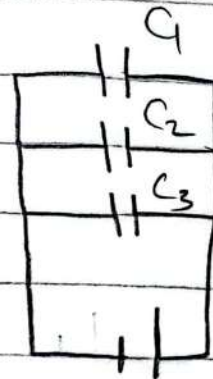
$$C_{eq} = C_1 + C_2 + C_3$$

$$Q_t = Q_1 + Q_2 + Q_3$$

* ~~~~~ *

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$V_{total} = V_1 + V_2 + V_3$$



→

