Coulomb's Law

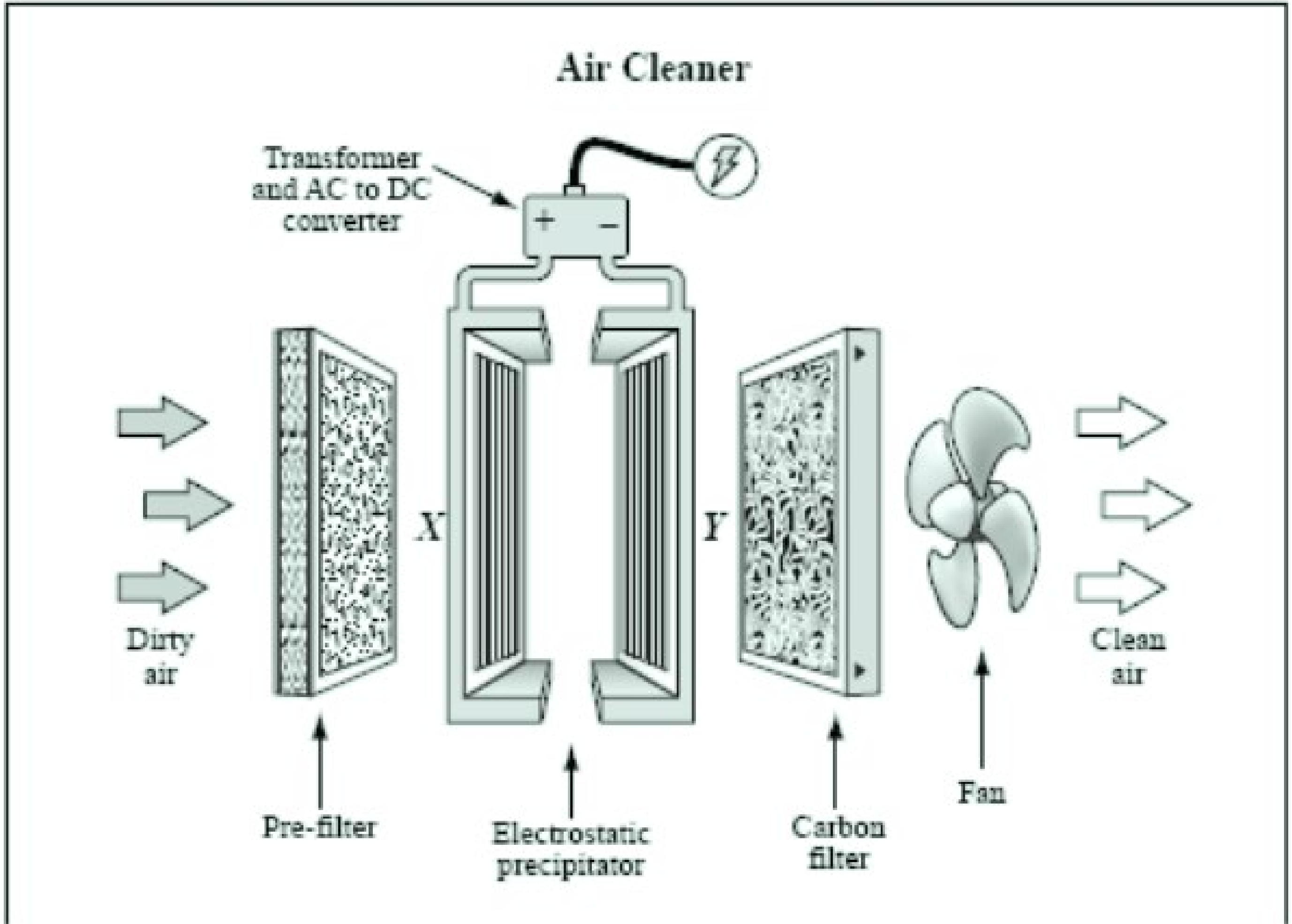
Lesson 2

Objectives

- explain, qualitatively, the principles pertinent to Coulomb's torsion balance experiment.
- apply Coulomb's law, quantitatively, to analyze the interaction of two point charges.
- compare, qualitatively and quantitatively, the inverse square relationship as it is expressed by Coulomb's law and by Newton's universal law of gravitation.

Diploma Question Alert!

Use the following information to answer the next two questions.



One type of air cleaner uses a single-stage electrostatic precipitator to remove very fine particles, such as cigarette smoke and pollen, from the air in a room. The first grid, marked as *X* in the diagram, removes electrons from the particles through a combination of friction and electrostatic action. The particles pass through grid *X* and leave with a positive charge. The positively charged particles are then removed from the air stream by a negatively charged grid, marked as *Y* in the diagram. This cleaner also contains a pre-filter and a carbon filter to help remove dust and odours.

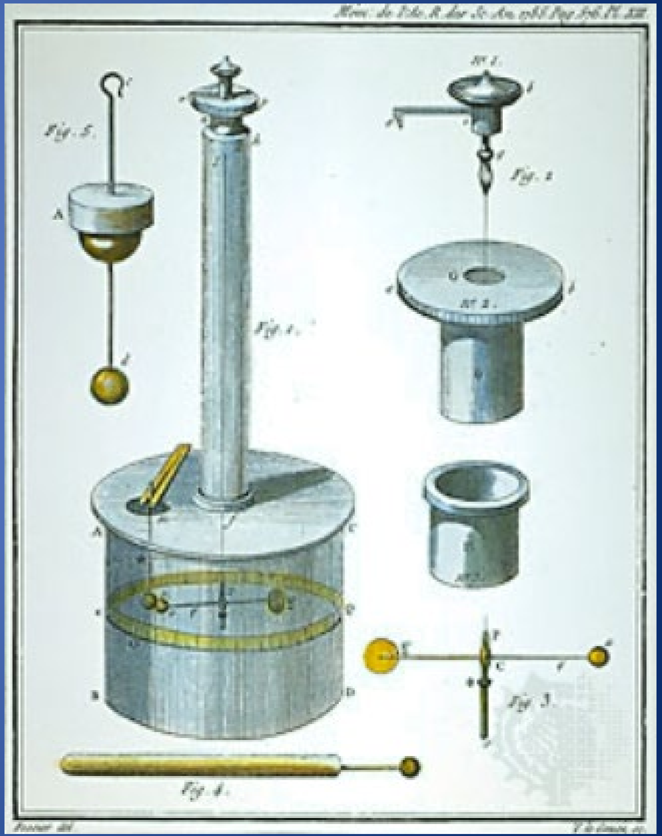
12. When particles are between grids *X* and *Y*, they are repelled by

A. grid *X* and each other, but are attracted to grid *Y*
B. grid *Y* and each other, but are attracted to grid *X*
C. grid *X* but are attracted to each other and grid *Y*
D. grid *Y* but are attracted to each other and grid *X*

Coulomb's Law

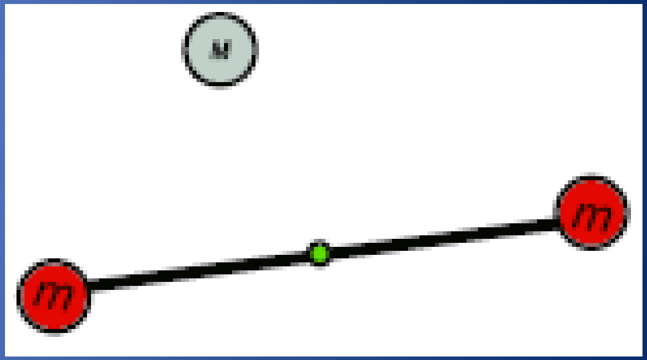
- The problem of the electric force puzzled a great physicist: Charles Coulomb (1736-1806).
- Coulomb wanted a way of measuring the force acting between two charged objects.
- But because the force was quite small (he could only generate charge by friction), he had to use a very delicate apparatus...
- What kind of apparatus should he use?

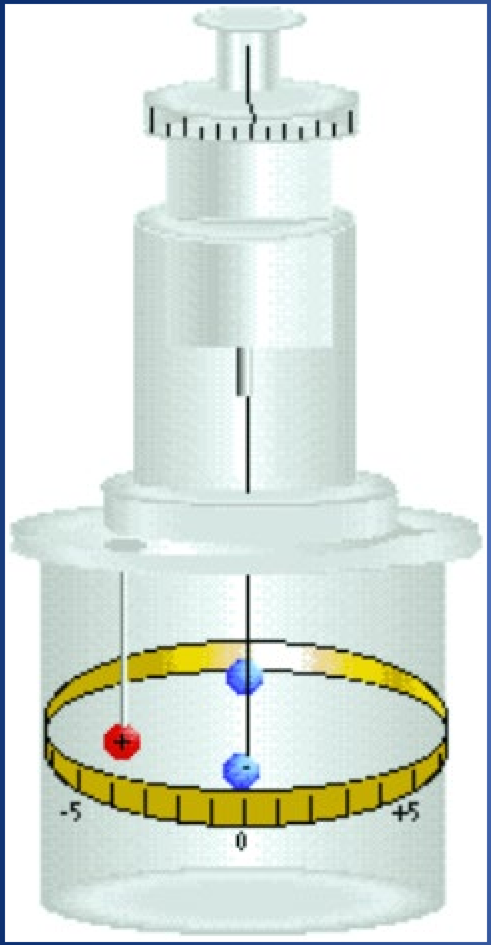
- Coulomb needed a way of measuring very small forces between objects: his idea for measuring was called a torsion balance (1777).
- A similar apparatus was used again in 1798 by Henry Cavendish in order to determine the density of the Earth and, eventually, G.



How did the Torsion Balance Work?

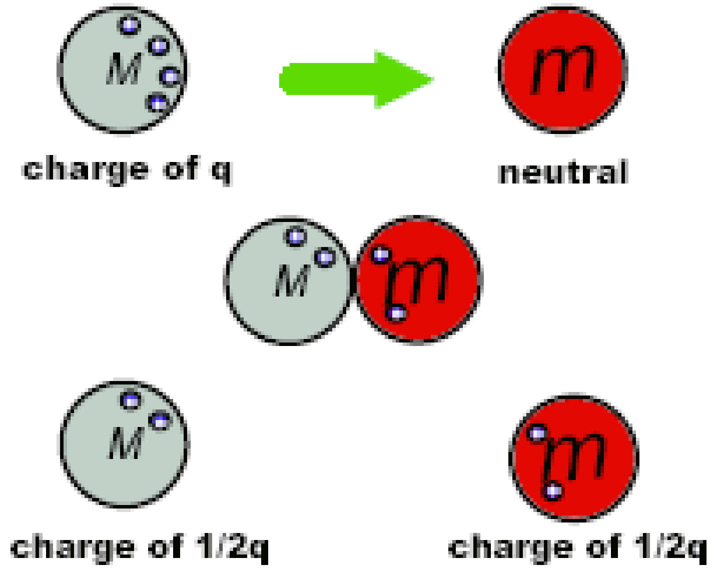
- Coulomb would charge the balls by friction.
- The red balls are attached to an axis which is suspended by a wire and are free to rotate.
- As the red balls are either attracted or repulsed from the grey ball, the axis and wire twists. By measuring the twist in the wire, the force can be determined.





Coulomb's Torsion Balance

- Because Coulomb had no way of measuring the actual charge on each ball, he used the concept of charge sharing to determine the relative charge on each.



- He placed some charge on one ball. He did not know how much charge was on it, so he just called it q.
- Through this method, he was able to vary the charge in fractions of some original charge q and could use these relative values in his calculations.

Q – So What Did Coulomb Find?

- Coulomb made two observations:
- Observation 1:
  - There is an inverse square relationship between the magnitude of the force and the separation of the objects.

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

- where r = distance between charged objects.

Observation 2:

- There is a direct relationship between the magnitude of the charges and the force.

$$\vec{F} \propto q_1 q_2$$

- Together, Coulomb was able to write a proportionality for the electric force:

$$\vec{F}_e \propto \frac{q_1 q_2}{r^2}$$

Note the similarity…

$$\vec{F}_e \;\alpha\; \frac{q_1 q_2}{r^2}$$

Coulomb's Law
of
Electrostatic Repulsion or Attraction

$$\vec{F}_g \;\alpha\; \frac{m_1 m_2}{r^2}$$

Newton's Law
of
Universal Gravitation

This is the beauty of the natural world of physics!

- Any proportionality can be made into an equation by introducing a constant.
- For Coulomb's Law, the constant k is used.

k = electrostatic constant = 8.99×10^9 Nm^2/C^2

When substituted, we get:

$$\vec{F}_e = \frac{kq_1q_2}{r^2}$$

- where: F_e = electric force between charged objects (N)
- k = electrostatic constant (Nm^2/C^2)
- q_1 = charge on object 1 (C)
- q_2 = charge on object 2 (C)
- r = distance between charges (m)

Examples

- ex) Determine the magnitude of the electrostatic force between each object.

*What is the direction of the force?

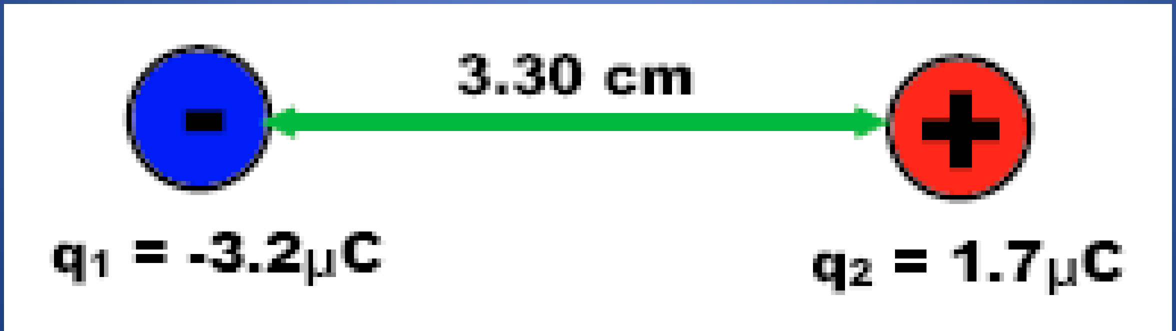
- Because each charge is +ive, it is a repulsive force. Which means q_1 moves left at 26 N and q_2 moves right at 26 N.

Examples

- ex) Determine the magnitude and direction of the electrostatic force between each object.

Examples

- ex) The two charges below are now brought into contact with one another then separated. What is the electrostatic force between the objects?



Examples

- ex) The electrostatic force between 2 small charged objects is 5.0×10^{-5} N. Find Fe if:
- distance is doubled.
- charge on one object is tripled, while the charge on the other is halved.

Examples

- ex) In a hydrogen atom, the average separation distance between the nucleus and electron is 5.3×10^{-11} m. Using your data sheet, compare the gravitational and electric forces at work.

The Coulomb (C)

- Let's talk a little about the unit of C...
- 1 C is the amount of charge on 6.25×10^{18} individual electrons (the amount of charge passing through a 60 W light bulb in 2.0 s).
- ex) What is the charge on a single electron?
- This amount is called the elementary charge.

Examples

- Ex) How many free electrons are on this charged object?