Electricity – Lesson 1

SP5a Develop and use mathematical models and generate diagrams to compare and contrast the electric and gravitational forces between two charged objects.

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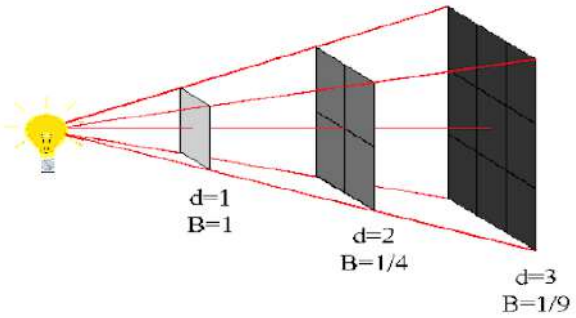
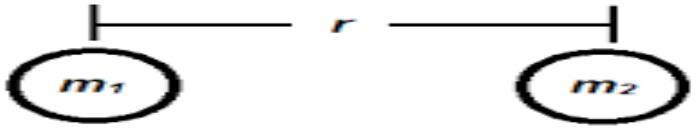
Inverse Square Law



Electrical and Gravitational Forces
1. Gravitational Force

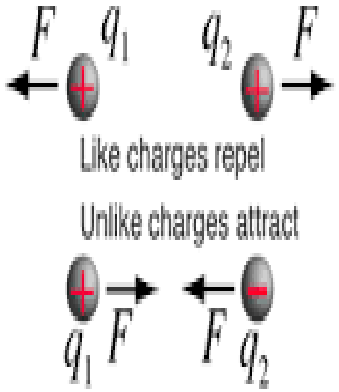
$$F_G = \frac{Gm_1m_2}{r^2}$$



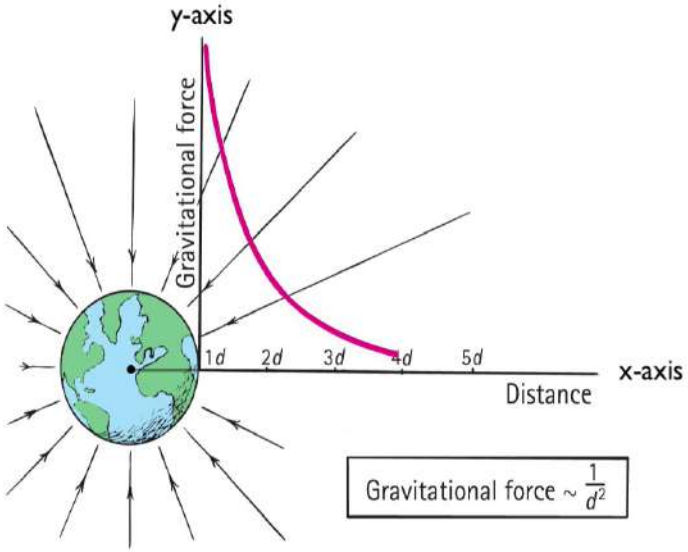
$$G = 6.67x10^{-11}\ \frac{N \cdot m^2}{kg^2}$$

Just like objects that have mass exert **gravitational forces** on each other, objects that are **charged** will also exert electric **forces** on each other. The electric **force** is directly proportional to the **charge** of the two objects and inversely proportional to the distance **between** them squared.

Electrical and Gravitational Forces
2. Electrical Force



$$F = \frac{kq_1q_2}{r^2} = \frac{q_1q_2}{4\pi\varepsilon_0 r^2}$$ Coulomb's Law



$$F_e = \frac{kq_1q_2}{r^2}$$

- Coulomb's law states that the electrical force between two charged objects is **directly** proportional to the product of the **quantity of charge** on the objects and **inversely** proportional to the **square of the separation distance** between the two objects.
- The force value is **positive** (***repulsive***) when q_1 and q_2 are of **like charge** - either both "+" or both "-".
- The force value is **negative** (**attractive**) when q_1 and q_2 are of opposite charge - one is "+" and the other is "-".

Your Task: What is the value of k?

Coulomb's Law

The Force between two point charges is **directly proportional to the product of the CHARGES** and **inversely proportional to the square of their distance apart.**

$$F \propto Q_1 Q_2 \qquad F \propto \frac{1}{r^2}$$

$$F = k\frac{Q_1 Q_2}{r^2}$$

$k = 9 \times 10^{-9}\ Nm^2C^{-2}$

Newton's Law

The Force between two point masses is **directly proportional to the product of the MASSES** and **inversely proportional to the square of their distance apart.**

$$F \propto m_1 m_2 \qquad F \propto \frac{1}{r^2}$$

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

$G = 6.6742 \times 10^{-11}\ m^3kg^{-1}s^{-2}$

Although there are various similarities between electrostatic force and gravitational force like

1.Both are conservative.

2.Both these forces follow Newton's third law(make action reaction pair).

3.Have 1/r^2 dependence.

4.Are Central forces.

There are various differences as well

1.Gravitational force is independent of the medium between the masses. Electrostatic force whereas depends on the material between the charges

2.Gravitational force is always attractive whereas electrostatic force may be both attractive as well as repulsive.

3.In any system containing masses gravitational force is always present but electrostatic force may or may not be present.

4.The magnitude of gravitational force is very small in comparison to the electrostatic force.

CWS-2 Coulomb's Law

2.3 The Electrical vs. the gravitational force in the Hydrogen Atom

Electron $e^- = -1.6 \times 10^{-19}$ C

proton $e^+ = 1.6 \times 10^{-19}$ C

$m_{electron} = 9.11 \times 10^{-31}$ kg

$m_{proton} = 1.67 \times 10^{-27}$ kg

$r = 0.53 \times 10^{-10}$ m

$$G = 6.67 \times 10^{-11}\,\mathrm{N \cdot m^2/kg^2}$$

$$k = 9.0 \times 10^{9}\,\mathrm{N \cdot m^2/C^2}$$

(a) Calculate the magnitude of the electrical force on the electron. Is it attractive or repulsive?

$$F_{1\,on\,2} = F_{2\,on\,1} = \frac{K|q_1||q_2|}{r_{12}^2}$$

(b) Calculate magnitude of the gravitational force on the electron. Is it attractive or repulsive?

$$F_{1\,on\,2} = F_{2\,on\,1} = \frac{Gm_1m_2}{r_{12}^2}$$

(c) Which is larger? By what factor (i.e. take the ratio of larger to smaller)? Which force are you more aware of on a daily basis?

1. Calculate the gravitational force (in Newtons) between Earth ($m_E = 5.972 \times 10^{24}$ Kg) and its moon ($m_M = 7.348 \times 10^{22}$ Kg). The average distance between Earth and its only moon is 3.844×10^{8} meters.

Determine the Electrical and Gravitational Forces between the following charged bodies

Two charged bodies of mass 3.135 x 10^-9 kg and 6.270 x 10^-7 kg and of charges. 2.123 x 10 ^-34 C and 8.492 x 10^-19 C

(10%) Problem 4: A solid aluminum sphere of radius $r_1 = 0.038$ m is charged with $q_1 = +4.2$ μC of electric charge. It is surrounded concentrically by a spherical copper shell of inner radius $r_2 = 0.065$ m and outer radius $r_3 = 0.078$ m. An electric charge of $q_2 = -9.5$ μC is placed on the copper shell. The situation is static.

EXAMPLE 23.1 The Hydrogen Atom

The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately 5.3×10^{-11} m. Find the magnitudes of the electric force and the gravitational force between the two particles.

$$F_e = k_e \frac{|e|^2}{r^2} = \left(8.99 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right) \frac{(1.60 \times 10^{-19}\ \text{C})^2}{(5.3 \times 10^{-11}\ \text{m})^2}$$

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

Using Newton's law of gravitation

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

$$= \left(6.7 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2}\right)$$

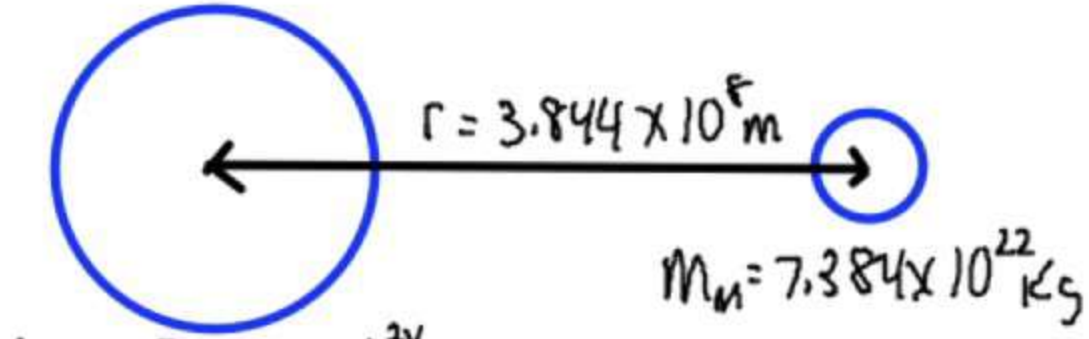
$$= \times \frac{(9.11 \times 10^{-31}\ \text{kg})(1.67 \times 10^{-27}\ \text{kg})}{(5.3 \times 10^{-11}\ \text{m})^2}$$

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

The ratio $F_e / F_g \approx 2 \times 10^{39}$.

Thus, the gravitational force between charged atomic particles is negligible when compared with the electric force.

1. Calculate the gravitational force (in Newtons) between Earth ($m_E = 5.972 \times 10^{24}$ Kg) and its moon ($m_M = 7.348 \times 10^{22}$ Kg). The average distance between Earth and its only moon is 3.844×10^8 meters.



$$F = \frac{G m_1 m_2}{r_2}$$

$$F = \frac{\left(6.674 \times 10^{-11} \frac{m^3}{Kg\,s^2}\right)(5.972 \times 10^{24} Kg)(7.384 \times 10^{22} Kg)}{3.844 \times 10^8 m}$$

$G = 6.674 \times 10^{-11}\ m^3\,Kg^{-1}\,s^{-2}$