# Physics PreLab 212-1

## Electrical and Gravitational Force Laws

**Name** ______________________________

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**Section** ____________ **Date** ________

$$F_{12} = G\frac{m_1 m_2}{r^2}$$

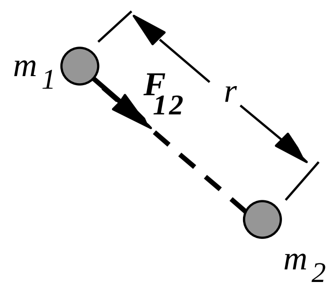


Figure 1. Newton's Universal Law of Gravitation

You are about to embark on a study of the electrical force. You will soon see that the electrical force behaves in a manner quite similar to a force you already studied in Physics 211, the gravitational force. The form and structure of Newton's Law of Gravitation are shown in Figure 1.

Consider Coulomb's law, which governs the force between charged objects held a distance apart. It turns out that Coulomb's Law is structurally identical to Newton's Universal Law of Gravitation. In Physics 211 you learned that the *magnitude* of the force experienced by a mass $m_1$ due to the presence of a mass $m_2$ a distance $r$ away, as in Figure 1, is given by:

$$F_{12} = G\frac{m_1 m_2}{r^2} \qquad \text{(Eq. 1)}$$

where $G$ is equal to $6.67 \times 10^{-11}$ N·m$^2$/kg$^2$. Thus, the force can be measured in Newtons if the masses are measured in kilograms and the distance is measured in meters.

Now compare Newton's Universal Law of Gravitation to Coulomb's Law. For charged objects, the *magnitude* of the force on a charge $q_1$ due to the presence of a charge $q_2$, as in Figure 2, is given by

$$F_{12} = \left| k \frac{q_1 q_2}{r^2} \right| \qquad \text{(Eq. 2)}$$

where $k$ is a constant that equals 9.0 x $10^9$ $N \cdot m^2/C^2$. The units of $k$ are chosen so that the force can be measured in Newtons if the charges are measured in Coulombs and the distance in meters. Note that one Coulomb of charge is equivalent to 6.3 x $10^{18}$ single electron charges!

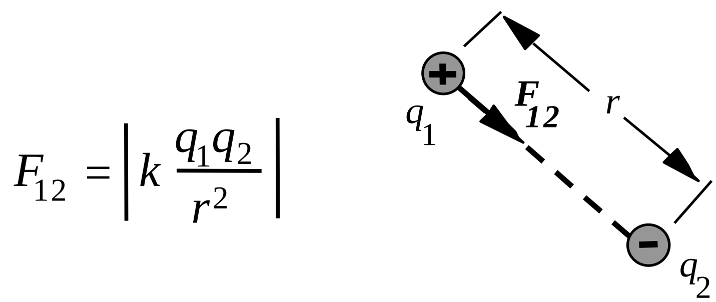


Figure 2. Coulomb's Law

**Q1[8']** What is the same about the two force laws? Give at least two common valuable features.

**Q2[8']** Is the gravitational force always attractive?[4'] The electrical force?[4']

You might be wondering if you can have both electrical and gravitational forces operating on objects at the same time. The answer is indeed "yes!" However, in many situations one force is dominant over the other. Take for example the simplest hydrogen atom, which is composed of one electron and one proton. How do the electrical and gravitational forces between these subatomic particles compare?

Figure 3 is a diagram of the Bohr model of a hydrogen atom. We will use it to make some calculations about the relative strength of gravitational and electrical forces.

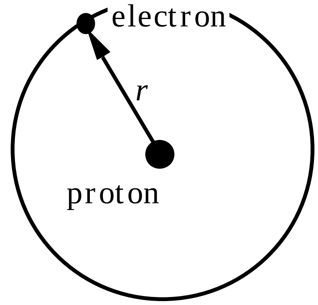


Figure 3. The hydrogen atom

The physical measurements of the system are:

| | | |
|---|---|---|
| Electron: | $m_e$ | = 9.1 x 10$^{-31}$ kg |
| | $q_e$ | = –1.6 x 10$^{-19}$ C |
| Proton: | $m_p$ | = 1.7 x 10$^{-27}$ kg |
| | $q_p$ | = +1.6 x 10$^{-19}$ C |
| Radius: | $r$ | = 5.3 x 10$^{-11}$ m |

**Q3[8']** What is the magnitude of the electrical force on the electron from the proton?[4'] Is it attractive or repulsive?[4']

$F_e$ = ________ [N]

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**Q4[8']** What is the magnitude of the gravitational force on the electron from the proton?[4'] Is it attractive or repulsive?[4']

$F_g$ = ________ [N]

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**Q5[8']** Which force is the dominant one in the hydrogen atom, the gravitational or the electrical?[4'] By what factor?[4']

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You have intimate contact with the force of gravity on a daily basis because you live on the surface of a planet that attracts all objects on and above it. Every time we take a step, or see something fall, we are experiencing a gravitational interaction. We rarely see electrical forces directly -- few of our lives are focused on static cling regardless of what TV commercials would have us believe! We have just seen, however, that electrical force is very much greater than gravitational force at the atomic level. Since everything is made up of atoms, we might therefore expect that electrical force would be dominant in our daily experiences.

**Q6[10']** Given that electrical force is so much stronger than gravitational force at atomic scales, why is it that it's the gravitational force between you and the earth that keeps you on the ground rather than the electrical force between you and the earth?

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## Reading materials

(https://www.phy.olemiss.edu/lab/genlab/labmanual/2020Manual/224/Electrostatics.pdf ):

There are two kinds of charges in nature: positive charge carried by protons and negative charge carried by electrons. An object that has an excess of either is said to be charged. Like charges repel each other, and unlike charges attract. Charge transfer is the exchange of charges between objects. In upcoming experiment, only electrons are exchanged while protons remain stationary. These electrons may move around within materials or move between materials, but they can never be created or destroyed. This is known as the law of conservation of charge. The law of conservation of electric charge states that the net amount of electric charge produced in any process is zero. A conductor is a material in which some loosely bound electrons can move freely (free electrons) while protons are tightly bound within the nucleus. An insulator is a material in which both electrons and protons are tightly bound. Conductors and insulators have the following properties:

Conductors

- Conductors are objects that allow the free flow of electrons throughout the object.

- Charges are easily transferred between conductors.

- Charge can collect at one end of an object in the presence of other charged objects.

Insulators

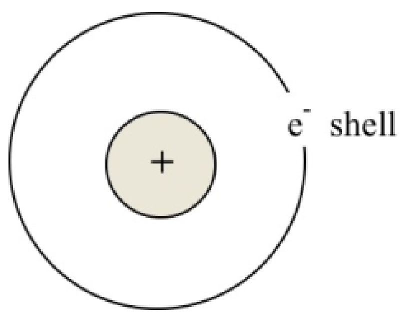
• An insulator is a material in which electrons are tightly bound to the nucleus.

• Transferring charge between insulators requires a force, e.g. friction, and direct contact.

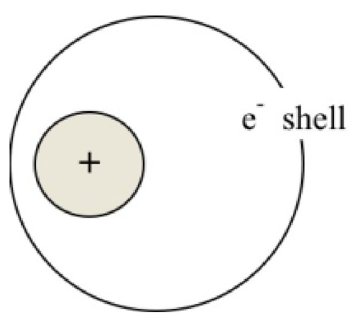
• Insulators brought near other charged objects experience polarization, a shifting of electrons to one side of an atom. (Fig. 4)

In the upcoming experiment, a glass rod or an ebonite rod (insulators) will be electrically charged by rubbing against another insulating material. Whether the rod gains or loses electrons will depend on the combination of materials used. The charged rod will be used to charge an electroscope (a conductor that indicates whether it is charged) by means of conduction and by means of induction.

To charge by conduction: Bring a charged rod close to, then touch, the electroscope. As the rod nears the electroscope, the free electrons in the electroscope are either attracted to or repelled by the charged rod (induction). When you touch the rod to the electroscope, the electroscope becomes charged as electrons transfer to (or from) the electroscope (charge transfer). To charge by induction: Bring a charged rod close to, but do not touch, the electroscope. While holding the rod near the electroscope (induction), touch the opposite side of the electroscope with the tip of your finger (charge transfer). Your body will act as a reservoir of charge (ground), either giving or receiving electrons to the electroscope. Remove your finger before moving the rod from the proximity of the electroscope.




*Atom charge distribution, normal*




*Atom charge distribution, polarized*

Figure 4. Polarization