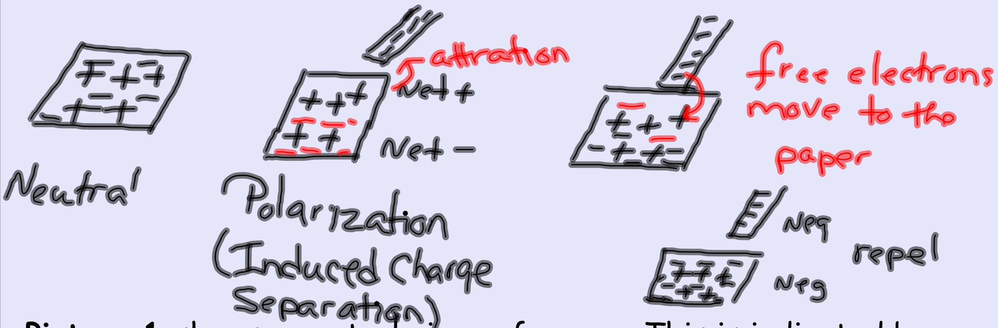
Section IV: Charging by Friction (Continued)

Question: Why is it that an electric force of attraction exists between some neutral objects and a charged object?

Consider: If we tear a scrap of paper into tiny pieces and bring a charged rubber balloon (rub it in your hair) near the pieces of paper, the paper will be attracted to the balloon. Why?



Picture 1 shows a neutral piece of paper. This is indicated by an equal number of protons and electrons.

Picture 2 shows how free electrons move away from the top of the piece of paper because of the repelling force caused by the negatively charged rod (like charges repel). The paper is now **polarized**; the top of the paper has a net positive charge and the bottom of the paper has a net negative charge. Note the paper is still neutral and the protons did not move.

Polarization is defined as an **induced charge separation**. (This is sometimes referred to as **charging by induction to cause a temporary rearrangement of charge.**)

Picture 3 shows a force of attraction between the electrons on the rod and the protons of the paper. There is, of course, a repelling force between the electrons on the rod and the electrons of the paper. But these electrons are further away from the rod than are the protons of the paper. Because of this, the repelling force is smaller than the attraction force. Therefore, the neutral paper moves toward the charged rod.

Picture 4 shows that some of the free electrons on the rod are attracted to the piece of paper. This causes the paper to become negative.

Picture 5 shows that both the paper and the rod have a negative charge and since like charges repel the paper flies away from the rod.

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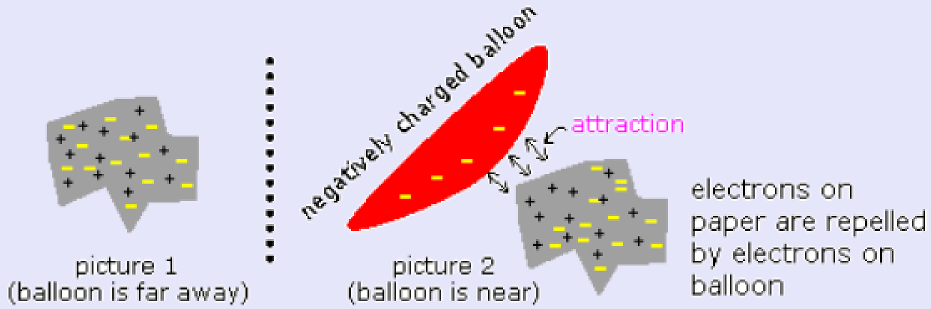
Much Shorter Version

As shown in the picture 1 below, each piece of paper has equivalent numbers of positive and negative charges and is therefore neutral. Generally, the charge will be more or less evenly distributed throughout the paper.



Then in picture 2 a negatively charged balloon is brought near. (There are, of course, trillions of + charges on the balloon but usually we just show the excess charge, which in this case is a negativ charge.)

What will the negative charges on the balloon do to nearby negative charges on the paper?

Push them away! But that leaves the near side of the paper to be positive. So, there will be a force of attraction between the balloon and the near side of the paper, and the paper will be attracted to the balloon.

Note that overall the paper is still neutral--no charge was added or taken away. The charge was simply re-arranged. We say that a charge was **temporarily induced on the paper**.

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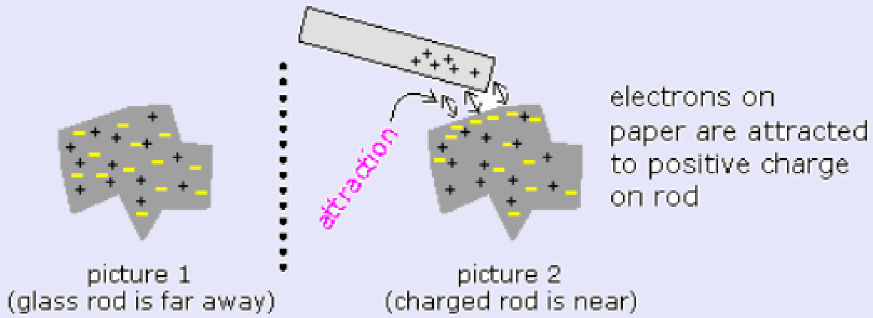
Question: Is it possible for a neutral object to be repelled by a charged object?

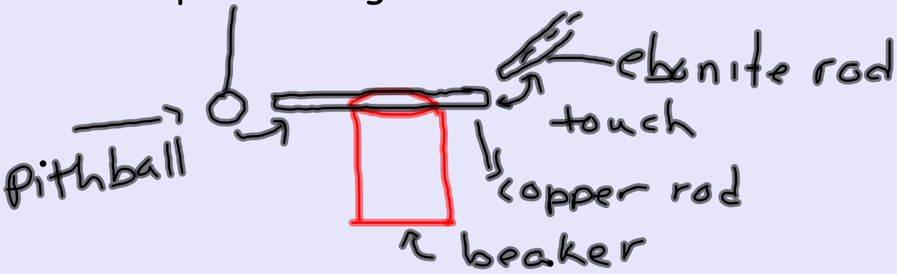
We already know that the answer to this question is "no" as far as a negatively charged object is concerned because we just showed how it is that a negatively charged balloon will always attract a neutral piece of paper. But what will happen if a positively charged object is brought near a piece of paper? The next pictures answer the question. (Glass acquires a positive charge if rubbed with wool or silk--see the table in your textbook, p. 530).



What does the positive charge on the glass rod do to the negative charge on the paper? Attract them so that some electrons migrate to the side of the paper near the glass rod. The paper will be attracted by the glass rod. Therefore we must conclude that a neutral object (such as the paper) can never be repelled by a charged object.

There is something very important that you should have noticed: in the solids that we have been working with the positive charge never, never, never, moves. That's because all positive charge is bound up in the nucleus. So, you say, how is that we can give an object a positive charge? Answer: by taking away some electrons!

Question: How do we put a charge on a conductor?



Answer: If we try holding a copper rod (which is a conductor) and rubbing it with a piece of wool, any charge that we might succeed in transferring to the rod is immediately conducted back to the wool because copper is such a good conductor. Even if we could put a charge in the rod, it would immediately leak off through your hand to the ground.

So, to charge a copper rod, we must put an insulator under it. (Example: a glass beaker) Because glass is an insulator, any charge that we put on the copper rod cannot leak off. (Still, we cannot use wool to charge the copper rod because the electrons will still travel back to the wool.)

To charge the copper rod, place the copper rod on an insulator, such as a glass beaker. Charge an ebonite rod (which is an insulator) with wool. The ebonite rod becomes negatively charged because some of the electrons leave the wool and move over to the ebonite rod. Then touch the copper rod with the ebonite rod. Some of the electrons from the ebonite rod move over to the copper rod. The electrons on the copper rod cannot move back to the ebonite rod because ebonite is an insulator nor can the electrons leak off onto the glass beaker since glass is also an insulator. Hence the copper is charged negatively.

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Section V: Properties of Electric Force

The properties of electric forces are:

1. An attractive force exists between electrified objects and neutral objects.

2. Objects with like charges repel each other.

3. Objects with unlike charges attract each other.

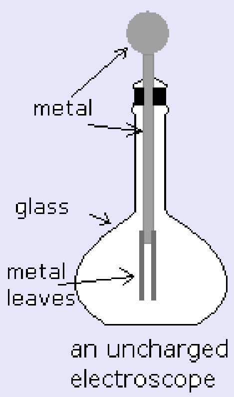
4. The electric force decreases as the distance between the object's increases. (It follows an inverse square law: ($F_E \propto 1/d^2$)

5. The electric force can act through a vacuum.

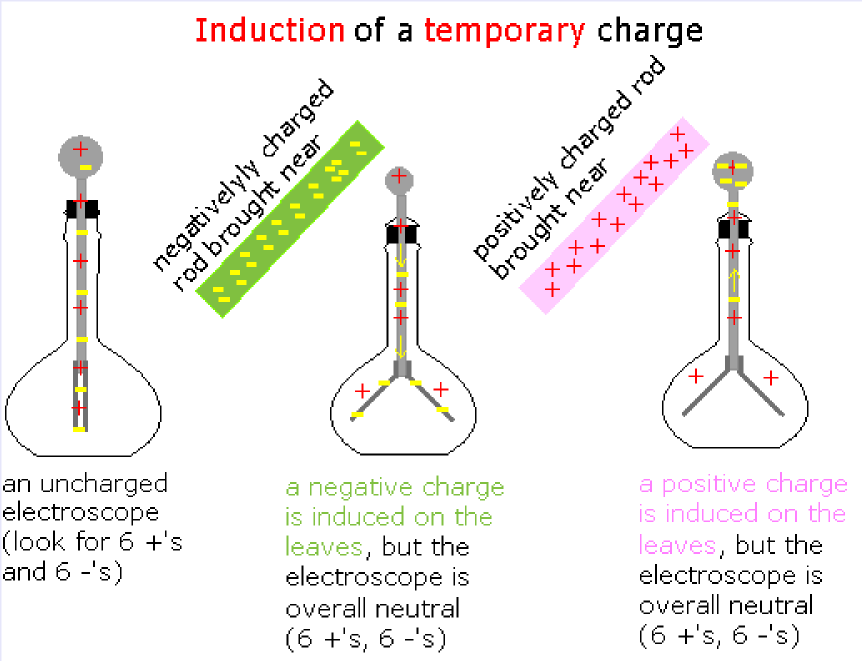
6. The electric force is much, much greater than the gravitational force.

Section VI: The Electroscope

The **electroscope** is a device that is used to **detect the presence and sign of an electric charge**. It is made from an isolated conducting rod (a conductor) connected to two metal foil leaves and supported by a glass structure. Since glass is an insulator, any charge placed on the metal rod will not escape.



When a charged object comes near the electroscope, it causes the electrons on the conducting rod to either **repel (negative charge near)** so most of the **electrons move to the foil leaves** at the bottom; or to **attract (positive charge near)** so most of the **electrons move to the knob at the top**. In both cases, the **leaves in the bottom have the same charge** which causes the **leaves to repel (move apart).** The farther apart the move the greater the charge present.



We can **determine the sign of the charge on the electroscope** by:

1. Observing the different effects that different charges have on the leaves of the electroscope.

2. We know that a charge is present by the fact that the leaves on the bottom of the electroscope separate.

3. This is due to the deficit of electrons on the conducting rod and the leaves and the fact that like charges repel.

Example: An electroscope has an unknown charge. When a negative rod is brought near the knob of the electroscope, the leaves diverge further apart. What is the charge on the electroscope? Explain.

When a negatively charged rod is brought near an electroscope with an unknown charge, free electrons on the electroscope are repelled down to the leaves. (Like charges repel.) These electrons cause the leaves to move further apart. This means the leaves have a larger charge than before. This could only occur if the electroscope was negative.

Example: An electroscope has an unknown charge. When a negative rod is brought near the knob of the electroscope, the leaves collapse (move closer together) and then diverge again. What is the charge on the electroscope? Explain.

When a negatively charged rod is brought near an electroscope with an unknown charge, free electrons on the electroscope are repelled down to the leaves. These electrons cause the leaves to collapse. This means that the leaves had an excess of protons. Thus the electroscope was positively charged. As the rod is brought closer, even more electrons are forced down on the leaves and the leaves separate again.