Workshop Tutorials for Introductory Physics

EI1: **Charge and Coulomb's Law**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
Coulomb's, 1.6×10^{-19} C, electric, removing, neutral, negative, conserved, positive

Charge and electrostatic force

Electrical interactions play a key role in the chemical bonding of matter and in most biological processes such as seeing, feeling, moving and thinking. Electrical interactions occur between bodies and particles which have ________ charge which, like mass, is a fundamental property of matter.

Charge comes in discrete amounts and, like energy, it is always _________. The SI unit of charge is the coulomb (symbol C). The smallest possible discrete amount of charge, the elementary charge e, has a magnitude of _________. There are two types of electric charge, which have been arbitrarily labelled _______ and negative. Every electron has a __________ charge, of $-1e$ (-1.6×10^{-19} C), and every proton has a charge of $+1e$. An atom or molecule which has acquired a net electric charge by the addition or removal of a whole number of electrons always has a charge which is some positive or negative integer multiple of e.

__________ law describes the interaction between two charged particles which are not chemically bound to each other and which are at rest. The interaction involves a pair of forces as described by Newton's third law of motion. Particle 1 exerts a force on particle 2 at the same time as particle 2 exerts a force on particle 1. These two forces have exactly the same magnitude but they act in opposite directions along the line joining the particles. If both charges have the same sign the two forces are repulsive but opposites attract each other. The common magnitude of the two forces is given by the formula: $F = k\dfrac{q_1 q_2}{r^2}$.

where q_1 and q_2 are the magnitudes of the two charges and r is the distance between them; k is a universal constant; $k = 9.0 \times 10^9$ N.m^2.C^{-2}. Even if the charges are different the two forces still have the same magnitude.

The total amounts of negative and positive charge in the universe seem to be exactly balanced. Most objects normally have the same amount of positive charge as they do negative charge, and so are overall electrically _________. However it is possible to "charge up" an object by adding or _________ some charged particles such as electrons or ions. When you make an object negative by adding extra electrons, you must be getting those electrons from something which is becoming positive. The total amount of charge is conserved, it is just moved around.

Discussion Question
Why do you think it is easier to charge something up by the transfer of electrons rather than protons?

B. Activity Questions:

1. Tape Charge
Stick two strips of tape on to the desk, then peel them off.
Hang them close to each other and see what happens. Explain your observations.

2. van de Graaff generator
Stand on the insulating block and place your hand on the generator.
What do you feel?
What can you see when someone else is touching the generator?
Explain your observations.

3. Charged rods
Charge up the various rods using different materials.
How do the items become charged?
Balance a charged rod on a watch glass. How can you accelerate it without touching or blowing on it?

C. Qualitative Questions:

1. Newton's law of gravitation says that the force between any two objects with masses m_1 and m_2 is proportional to the product of the masses and decreases with the square of the distance between them:

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

How is Newton's law of gravitation similar to Coulomb's law? How is it different? What about the force between charges and masses?

2. In a simple (but not very accurate) model of the helium atom, two electrons (each of charge = *-e)* orbit a nucleus consisting of two protons (charge = +2*e*) and two neutrons (charge = 0). Is the magnitude of the force exerted on the nucleus by one of the two electrons less than the force exerted on the electron by the nucleus? Explain your answer.

D. Quantitative Question:

You are at the college ball and are about to impress all the girls with your levitating cat trick. You take a pair of identical, 2.0 kg, unconscious Persian cats from your bag and rub them vigorously against a glass table top. You then carefully place one cat on the (non-conducting) floor and hold the other a metre above it. There is an expectant hush as you let go of the raised cat.
a. How much charge will you need to have accumulated on each cat's fur (assuming the same on each) for the cat to levitate at 1 m above the other?
b. How many excess (or deficit) electrons is this required charge equivalent to?