PHYSICS IN MOTION
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Unit 5A
Introduction to Electricity
Practice Problems TEACHER

Work each of the following problems. SHOW ALL WORK.

1. **What are four similarities between electrostatic and gravitational forces? What are two differences?**

Similarities:

1. *Both forces decrease with the square of the distance between objects.*
2. *Both forces increase with a corresponding increase in charge or mass.*
3. *Both forces depend on fundamental physical constants: the gravitational constant for gravitational force (G) and Coulomb's constant for electrostatic force (k).*
4. *Both forces act on a line between the objects involved, either directly towards or directly away from one another.*
5. *Both forces are mediated by fields rather than by physical contact.*
6. *Both forces are additive, meaning the total force on one object is the sum of the forces between that object and every other object.*

Differences:

1. *Electrostatic force can both attract and repel, while gravitational force can only attract.*
2. *Electrostatic force depends on charge, while gravitational force depends on mass.*
3. *All objects have a net mass and therefore experience gravitational force. However, not all objects have a net charge and therefore might not experience electrostatic force.*

2. **Determine both the mass and the charge of a block of material consisting of 3 x 10^{27} protons, 3 x 10^{37} neutrons, and 3.1 x 10^{27} electrons.**

A proton's mass is 1.6 x 10^{-27} kg. A neutron's mass is also 1.6 x 10^{-27} kg.

An electron's mass is 9.1 x 10^{-31} kg. The total mass of the block is:

$$m_{block} = m_p(\#\ of\ protons) + m_n(\#\ of\ neutrons) + m_e(\#\ of\ electrons)$$
$$m_{block} = (1.6 \times 10^{-27}\ kg)(3 \times 10^{27}\ protons) + (1.6 \times 10^{-27}\ kg)(3 \times 10^{27}\ neutrons) + (9.1 \times 10^{-31}\ kg)(3.1 \times 10^{27}\ electrons)$$
$$m_{block} = 9.6\ kg$$

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Work each of the following problems. SHOW ALL WORK.

A proton's charge is 1.6×10^{-19} C. A neutron has no charge.

An electron's charge is -1.6×10^{-19} C. The total charge of the block is:

$$q_{block} = q_p + q_e$$

$$q_{block} = q_p(\#\ of\ protons) + q_e(\#\ of\ electrons)$$

$$q_{block} = (1.6 \times 10^{-19} C)(3 \times 10^{27} protons) + (-1.6 \times 10^{-19} C)(3.1 \times 10^{27} electrons)$$

$$q_{block} = -1.6 \times 10^{7} C$$

3. A proton is placed 100 μm from a helium nucleus. The gravitational force pulls the proton and nucleus together, while the electric force pushes them apart. Which force is stronger and by how much?

A helium nucleus has two protons. The charge of a single proton is 1.6×10^{-19} C,

and its mass is 1.6×10^{-27} kg. A neutron's mass is equal to a proton's mass.

The electric force pushing the proton and nucleus apart is:

$$F_{electric} = \frac{k|q_{proton}\, q_{nucleus}|}{r^2}$$

$$F_{electric} = \frac{(9 \times 10^{9}\ Nm^2/C^2)(1.6 \times 10^{-19}\ C)(2)(1.6 \times 10^{-19}\ C)}{(1 \times 10^{-4}\ m)^2}$$

$$F_{electric} = 4.6 \times 10^{-20}\ N$$

The gravitational force pulling the proton and nucleus together is:

$$F_{gravity} = \frac{Gm_{proton}\, m_{nucleus}}{r^2}$$

$$F_{gravity} = \frac{(6.6 \times 10^{-11}\ m^3/kgs^2)(1.6 \times 10^{-27}\ kg)(4)(1.6 \times 10^{-27}\ kg)}{(1 \times 10^{-4}\ m)^2}$$

$$F_{gravity} = 1.7 \times 10^{-56}\ N$$

$$\frac{F_{electric}}{F_{gravity}} = \frac{4.6 \times 10^{-20}\ N}{1.7 \times 10^{-56}\ N} = 2.7 \times 10^{35}$$

The electric force is stronger by roughly a trillion trillion trillion times!

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4. How far apart are a proton and an electron if they exert an attractive force of 3 N on each other?

A proton's charge is 1.6 x 10^{-19} C and an electron's charge is -1.6 x 10^{-19} C.

The electric charge between them is:

$$F_{electric} = \frac{k|q_{proton}\, q_{electron}|}{r^2}$$

Rearranging for r, the distance between the charges is:

$$r = \sqrt{\frac{kq_{proton}\,|q_{electron}|}{F_{electric}}}$$

$$r = \sqrt{\frac{(9 \times 10^9\ Nm^2/C^2)(1.6 \times 10^{-19}\ C)(|-1.6 \times 10^{-19}\ C|)}{3\ N}}$$

$$r = 8.8 \times 10^{-15}\ m$$

5. If the total charge of an atom's nucleus is +3 and the total charge of the surrounding electrons is -3, the atom is which one of the following:

a. positively charged

b. negatively charged

c. electrically neutral

d. unstable

c. electrically neutral

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6. **An object with charge 4.3 x 10^{-5} C pushes another object 0.31 μm away with a force of 7 N. What is the total charge of the second object?**

Refer to Coulomb's law:

$$F_{electric} = \frac{k|q_1 q_2|}{r^2}$$

$$q_2 = \frac{F_{electric}\, r^2}{k q_1}$$

$$q_2 = \frac{(7\ N)(3.1 \times 10^{-7}\ m)^2}{(9 \times 10^9\ Nm^2/C^2)(4.3 \times 10^{-5}\ C)}$$

$$q_2 = 1.7 \times 10^{-18}\ C$$

7. **A balloon, which is initially neutral, is rubbed with fur until it acquires a net charge of -0.40 nC.**

   a. **Assuming that only electrons are transferred, were electrons removed from the balloon or added to it?**

   The balloon started neutral and ended with a net negative charge,

   indicating that electrons were transferred to it.

   b. **How many electrons were transferred?**

   The charge of an electron is -1.6 x 10^{-19} C.

$$\text{\# of electrons transferred} = \frac{-0.40 \times 10^{-9}\ C}{-1.6 \times 10^{-19}\ C}$$

$$= 2.5 \times 10^9 \quad \textit{or two and a half billion electrons}$$

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Work each of the following problems. SHOW ALL WORK.

8. Two +1 C charges are separated by 3,000 m. What is the magnitude of the electric force between them?

Refer to Coulomb's law: $$F_{electric} = \frac{k|q_1 q_2|}{r^2}$$

$$q_1 = 1C$$
$$q_2 = 1C$$
$$r = 3000\,m$$

$$F_{electric} = \frac{9 \times 10^9\,Nm^2/C^2(1C)(1C)}{(3000\,m)^2}$$

$$F_{electric} = 1000\,N$$