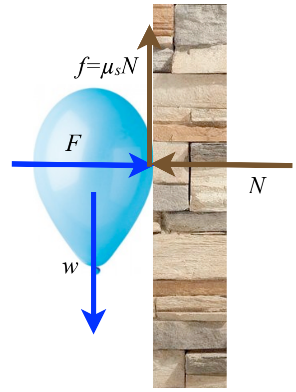
Quiz 01: Electrostatics

Answer each of the following questions. If a numerical answer is required, please show your work, express the answer with the correct number of significant digits, and include the algebraic sign where appropriate. Each question is worth 1 point, unless otherwise noted. There is no partial credit.

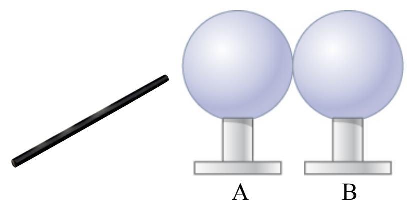


1. True or **false**: When the balloon sticks to the wall (assuming it sticks to the wall), it is because the balloon is negatively charged and the wall carries an extra positive charge.
2. True or **false**: The negative balloon polarizes the surface of the wall by pushing protons away, deep into the wall.
3. (2 points) If the balloon has a weight $w = mg$, and there is a coefficient of static friction μ_s between the wall and the balloon, then how much electrostatic force F is required to keep the balloon stationary and stuck to the wall?

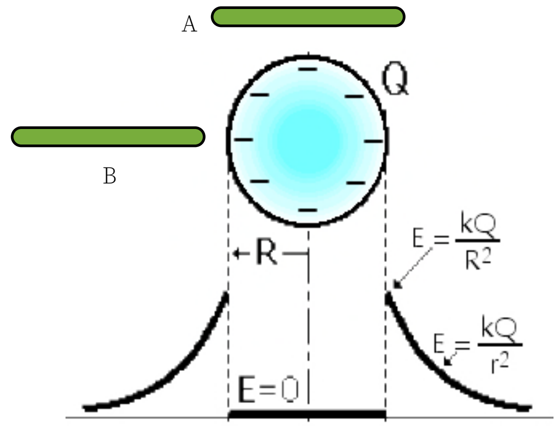
$$\sum F_x = F - N = 0 \quad \text{and} \quad \sum F_y = \mu_s N - mg = 0$$
$$F = N \quad \text{and} \quad N = \frac{mg}{\mu_s} \implies F = \frac{mg}{\mu_s}$$

4. True or **false**: The foil leaves of the electroscope separate because they are oppositely charged.
5. True or **false**: The leaves of the electroscope will not separate unless the charged rod actually touches the metal knob.
6. When the ebonite (black) rod is rubbed with the wool, it always ends up negative. You rub the rod, then touch it to the ball of the electroscope. If the glass rod can be charged at all, it is frequently positive. How would you know if it was (+)?
   A) You wouldn't. There's no way to tell what the sign of the charge is.
   B) It cannot be (+). Whenever you use friction, the object you rub will always gain extra electrons.
   C) If it was (+), the separated leaves of the electroscope would come back together when the glass rod approached.
   D) If it was (+), the separated electroscope leaves would spread farther apart.

You perform an induction experiment with two conducting spheres (A and B, initially in contact) and the ebonite rod. You use friction to charge the rod, then bring it close to *Sphere*$_A$, but you do not touch it.



7. **True** or false: *Sphere*$_A$ will become positively charged.
8. (2 points) While you are still holding the rod close to *Sphere*$_A$, your lab partner slides *Sphere*$_B$ (touching the base, not the sphere) about 30cm to the right. What can you say about the charge on each of the spheres?
   A) Nothing. Each sphere started with zero net charge, and since you never actually touched the rod to either sphere, the spheres both remain at zero net charge.
   B) The negative rod repelled some electrons from *Sphere*$_A$ to *Sphere*$_B$. Those extra electrons remain on *Sphere*$_B$ when it is moved over, so *Sphere*$_B$ carries extra negative charge, and *Sphere*$_A$ now has a net positive charge.
   C) Answer B is backwards; sphere *Sphere*$_B$ donates electrons to *Sphere*$_A$, so that when *Sphere*$_B$ gets moved away, it has a positive charge. The extra electrons give *Sphere*$_A$ a negative charge.
9. (2 points) Start over, with uncharged spheres initially in contact. What happens when you touch your charged rod to *Sphere*$_A$, hold it in contact for a few seconds, then remove the rod and separate the spheres?
   A) Nothing. The rod cannot transfer charge to the spheres. The rod keeps all of its charge, and the spheres remain with zero charge.
   B) Electrons transfer from the rod to *Sphere*$_A$, and repel each other until they are distributed evenly over the surfaces. Separating them will result in each sphere carrying half of the transferred charge, both spheres negative.
   C) Electrons transfer from the rod to *Sphere*$_A$, and that's where they stay. Charge cannot move from *Sphere*$_A$ to *Sphere*$_B$. When separated, *Sphere*$_A$ will be negative and *Sphere*$_B$ will have zero net charge.
10. So...what is really happening with that salt & pepper demonstration?
   A) Nothing. Neither particles are attracted to a negatively charged object.
   B) Something. Both salt and pepper are attracted, but the pepper more so. This is because the grains of pepper have extra protons, but the grains of salt have extra electrons.
   C) Both salt and pepper are attracted, but neither the salt grains nor the pepper particles are carrying excess charge. The grains of both can be polarized, but the lighter-weight pepper requires less force to overcome gravity.
   D) Meh. The effect is totally random, because you can *never* be sure whether particles of *anything* (salt, pepper, flour, sand, whatever) are carrying excess positive (protons) or excess negative (electrons) charge.
11. Which side of the adhesive tape will become positively charged when you pull a strip from the roll?
   A) The sticky side literally pulls some electrons from the flat side, leaving the flat side positively charged.
   B) The sticky side leaves extra electron stuck to the flat side, making it positive and the flat side negatively charged.
   C) Trick question! Both sides of the tape are neutral. There is no transfer of charge when tape is pulled from the roll.



Let's have some van de Graaff fun! Assume that when the van de Graaff is charged up, there are a billion ($n = 1\times10^9$) electrons (the charge on a single electron is $e^- = -1.6\times10^{-19}$ C) distributed over the surface of the hollow sphere. While we're at it, let's also assume that it is actually a perfect sphere, and a closed sphere. The sphere has a radius R = 10cm (0.10m), and $k = 9\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$.

12. True or **false**: If you stand with your hand on the uncharged van de Graaff, as soon as the generator is switched on, you will get a wicked shock, so you are better off waiting for the generator to charge up, then putting your hand on it after the charge has accumulated.

13. The direction of the electric field generated by the sphere is
    A) radial toward the center of the sphere.
    B) radial, away from the center of the sphere.
    C) horizontal (field lines parallel to each other in the x-direction).
    D) vertical (field lines parallel to each other in the y-direction).
    E) circular (concentric circles centered at the center of the sphere)>

14. (4points) What is the magnitude (strength) of the electric field E at the surface of the sphere (R = 10 cm from the center of the sphere)? Answer numerically with three sig figs.

$$E=\frac{kQ}{R^2}=\frac{k(ne^-)}{R^2}=\frac{(9\times10^9\text{N}\cdot\text{m}^2/\text{C}^2)(1\times10^9)(1.6\times10^{-19}\text{C})}{(0.10\text{m})^2}=144\text{N/C}$$

Notice there's no negative! The magnitude is the absolute value, and any sign (+) or (–) tells you about the direction of the vector. In this case, the vector direction is radially inward, toward the center of the sphere.

15. (4points) When the bulb is held at position B, what is the difference in field strength from one end of the bulb to the other? Assume the bulb is 30cm long, and the near end is held 15cm from the center of the sphere. Answer numerically with three sig figs.

$$E_1=\frac{k(ne^-)}{r_1^2}=\frac{(9\times10^9\text{N}\cdot\text{m}^2/\text{C}^2)(1\times10^9)(1.6\times10^{-19}\text{C})}{(0.30+0.15\text{m})^2}=7.11\text{N/C}$$

$$E_2=\frac{k(ne^-)}{r_2^2}=\frac{(9\times10^9\text{N}\cdot\text{m}^2/\text{C}^2)(1\times10^9)(1.6\times10^{-19}\text{C})}{(0.15\text{m})^2}=64\text{N/C}$$

$$\Delta E=E_2\text{-}E_1=64\text{–}7.1=56.9\text{N/C}$$

16. The fluorescent tube lights up when it is held
    A) in position A, but not in position B.
    B) at B, but not when it is at A.
    C) anywhere; either position A or B works.
    D) never. It cannot light at either position because it is not touching the sphere.