UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

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Quiz 1: Solution

1. An electron (of charge $-e$ and mass m_e) enters a region of uniform electric field $\vec{\mathbf{E}} = 200\,\hat{\mathbf{x}}$ [N/C] with velocity $\vec{\mathbf{v}}_i = 3.0 \times 10^6\,\hat{\mathbf{x}}$ [m/s]. What is magnitude the acceleration $|\vec{\mathbf{a}}|$ of the electron due to the electric field?

- ■ $-3.5 \times 10^{13}\ \left[\text{m/s}^2\right]$
- □ $4.6 \times 10^{8}\ \left[\text{m/s}^2\right]$
- □ $-1.4 \times 10^{15}\ \left[\text{m/s}^2\right]$
- □ $6.8 \times 10^{12}\ \left[\text{m/s}^2\right]$

The presence of an electric field gives rise to an acceleration through the electric force:

$$\vec{\mathbf{F}}_e = q\vec{\mathbf{E}} = m\vec{\mathbf{a}}$$

Since $\vec{\mathbf{E}}$ is in the $\hat{\mathbf{x}}$ direction, the acceleration $\vec{\mathbf{a}}$ due to that field will be in the $\hat{\mathbf{x}}$ direction as well, we can drop the vector notation. Using the quantities given, and rearranging the above:

$$a = \frac{qE}{m} = \frac{-eE}{m_e} = \frac{\left(-1.6 \times 10^{-19}\,[\text{C}]\right)\left(200\,[\text{N/C}]\right)}{9.11 \times 10^{-31}\,[\text{kg}]} = -3.5 \times 10^{13}\,[\text{N/kg}] = -3.5 \times 10^{13}\,\text{m/s}^2$$

2. A test charge of $3\ [\mu\text{C}]$ is at a point P where an external electric field is directed to the right and has a magnitude of $4 \times 10^6\ [\text{N/C}]$ If the test charge is replaced with another test charge of $-3\ [\mu\text{C}]$, the external electric field at P:

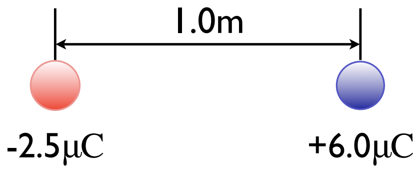
- ■ is unaffected
- □ reverses direction
- □ changes in a way that cannot be determined

The electric field is unaffected by the presence of the test charge - it is merely a fictitious probe to help us imagine what the electric force on a charge *would* be at that point, but it is not actually present.

3. A "free" electron and a "free" proton are placed in an identical electric field. Which of the following statements are true? *Check all that apply.* Note that the electron mass is 9.11×10^{-31} kg, and the proton mass is 1.67×10^{-27} kg.

- □ Each particle is acted on by the same electric force and has the same acceleration.
- □ The electric force on the proton is greater in magnitude than the force on the electron, but in the opposite direction.
- ■ The electric force on the proton is equal in magnitude to the force on the electron, but in the opposite direction.
- ■ The magnitude of the acceleration of the electron is greater than that of the proton.
- □ Both particles have the same acceleration.

Since both particles have the same magnitude of charge $|e|$, they both feel the same electric force F_e. The forces must be in opposite directions, since protons and electrons have charges of opposite sign. However, since the electron is far lighter than the proton, it feels a much larger acceleration, $a = F_e/m$



4. Determine the point (other than infinity) at which the total electric field is zero.

- □ 1.8 m to the right of the negative charge
- □ 0.61 m to the right of the positive charge
- □ 0.39 m to the right of the negative charge
- ■ 1.8 m to the left of the negative charge

By symmetry, we can figure out on which side the field should be zero. In between the two charges, the field from the positive and negative charges *add together*. The force on a fictitious positive test charge placed in between the two would experience a force to the left due to the positive charge, and another force to the left due to the negative charge. There is no way the fields can cancel here.

If we place a positive charge to the *right of the positive charge*, it will feel a force to the right from the positive charge, and a force to the left from the negative charge. The directions are opposite, but the fields still cannot cancel because the test charge is closest to the larger charge.

This leaves us with points to the left of the negative charge. The forces on a positive test charge will be in opposite directions here, and we are closer to the smaller charge. What position gives zero field? First, we will call the position of the negative charge $x=0$, which means the positive charge is at $x=1$ m. We will call the position where electric field is zero x. The distance from this point to the negative charge is just x, and the distance to the positive charge is $1+x$. Now write down the electric field due to each charge:

$$\begin{aligned} E_{\text{neg}} &= \frac{k_e(-2.5\,\mu\text{C})}{x^2} \\ E_{\text{pos}} &= \frac{k_e(6\,\mu\text{C})}{(1+x)^2} \end{aligned}$$

The field will be zero when $E_{\text{neg}} + E_{\text{pos}} = 0$

$$\begin{aligned} E_{\text{neg}} + E_{\text{pos}} &= 0 \\ \frac{k_e(-2.5\,\mu\text{C})}{x^2} + \frac{k_e(6\,\mu\text{C})}{(1+x)^2} &= 0 \\ \frac{\cancel{k_e}(-2.5\,\cancel{\mu\text{C}})}{x^2} + \frac{\cancel{k_e}(6\,\cancel{\mu\text{C}})}{(1+x)^2} &= 0 \\ \frac{-2.5}{x^2} + \frac{6}{(1+x)^2} &= 0 \\ \Rightarrow \qquad \frac{2.5}{x^2} &= \frac{6}{(1+x)^2} \end{aligned}$$

Cross multiply, apply the quadratic formula.

$$\begin{aligned} 2.5(1+x)^2 &= 6x^2 \\ 2.5 + 5x + 2.5x^2 &= 6x^2 \\ 3.5x^2 - 5x - 2.5 &= 0 \\ \Rightarrow \qquad x &= \frac{-(-5) \pm \sqrt{5^2 - 4(-2.5)(3.5)}}{2(3.5)} \\ x &= \frac{5 \pm \sqrt{25+35}}{7} \\ x &= \frac{5 \pm 7.75}{7} = 1.82, -0.39 \end{aligned}$$

Which root do we want? We wrote down the distance x the distance to the *left* of the negative charge. A negative value of x is then in the wrong direction, in between the two charges, which we already ruled out. The positive root, $x = 1.82$, means a distance 1.82 m to the *left* of the negative charge. This is what we want.

5. Which of the following is true for the electric force, but not the gravitational force? Check all that apply.

- □ The force propagates at a speed of c
- □ The force acts at a distance without any intervening medium

- □ The force between two bodies depends on the square of the distance between them
- ■ The force between two bodies can be repulsive as well as attractive.

This one should be clear . . . the math is precisely the same for both forces, but while we do have negative charge, there is no negative mass.