Key Concepts

Chapter 6

Voltage

Electrical potential energy

Conservation of energy

Takeaways

Problems involving charged particles that move around near other charged particles (or in electric fields) are solved most easily using the conservation of energy equation. Do these problems just as you would for gravity. Find the change in potential energy, set that equal to the negative of the change in kinetic energy, and solve for the quantity of interest.

Electrostatics and Velocity

A particle with a mass of 1 g and a charge of +1 μC is released from rest at a distance of 20 cm from another particle with a charge of +20 μC, which is held fixed. How fast is the moving particle traveling when it is 150 cm away from the fixed particle? ($k = 9 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$)

1) Determine the electrical potential energy at the points of interest.

point 1: $U_1 = \frac{kq_1q_2}{r_1} = \frac{(9\times10^9)(20\times10^{-6})(1\times10^{-6})}{(0.2)} = 0.9\ \text{J}$

point 2: $U_2 = \frac{kq_1q_2}{r_2} = \frac{(9\times10^9)(20\times10^{-6})(1\times10^{-6})}{(1.5)} = 0.12\ \text{J}$

Generic: $U = \frac{kq_1q_2}{r}$

Potential energy can only be defined as a relative value, but in these types of problems, it is easiest to use the definition that the potential energy is zero at infinite distance. This way, you can use the formula $U = \frac{kq_1q_2}{r}$, which saves time compared to using $\Delta U = q\Delta V$ by bypassing the step of first calculating V.

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2) Determine the change in potential energy and kinetic energy.

$\Delta U = U_2 - U_1 = -0.78\ \text{J} = -\Delta K$

$\Delta K = 0.78\ \text{J}$

There is a negative change in potential energy. From the conservation of energy equation, this means that there must be a positive change in kinetic energy because the total energy must remain constant. In these types of problems, $\Delta U = -\Delta K$.

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3) Determine the velocity of the particle from the kinetic energy.

$\Delta K = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$; ($v_1 = 0$, so $\Delta K = \frac{1}{2}mv_2^2$)

$0.78\ \text{J} = \frac{1}{2}(1 \times 10^{-3})v^2$

$v^2 = \frac{0.78(2)}{(1\times10^{-3})} = 1{,}560$

$v = 39.50\ \text{m/s}$

Because the initial velocity is 0, the change in kinetic energy equals the kinetic energy that the particle has at point 2. Set them equal and solve.

Things to Watch Out For

These problems can be presented in several different ways. If you are given the potential at two points, simply multiply by the magnitude of the charge in motion to determine the electrical potential energy at those points. A common mistake is to multiply by the source charge. Remember, the q in the equation $U = qV$ refers to the charge that is moving. Work is often tested with these problems, so remember that work is equal to the change in kinetic energy. For problems involving point charges and speed, you will always use the work energy theorem.

Similar Questions

1) A proton initially at rest is accelerated through a potential difference of 100 V. What is the proton's final speed? ($e = 1.6 \times 10^{-19}$ C; $m_p = 1.67 \times 10^{-27}$)
2) How much work is done in moving an electron from a distance of 1 nm to a distance of 10 nm away from a hydrogen nucleus?
3) What voltage is required to accelerate protons to a speed of 10^4 m/s?