CH 17-1 – Electric Potential Energy

Important Ideas

- If two charged particles interact (via the electric or gravitational force perhaps), the energy associated with the interaction of a pair of interacting particles is called *potential energy.* The electric potential energy of two charged particles of charge q_1 and q_2 is

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

  The potential energy is negative for particles that attract and positive for particles that repel.

- For more than two charged particles, the total potential energy is the sum of the potential energy of each pair of particles.

- In a uniform electric field, the change in potential energy for a particle of charge q as it is displaced a distance Δr between two points is:

$$\Delta U = -qE|\Delta\vec{r}|\cos(\theta)$$

  where $|\Delta\vec{r}|$ is the magnitude of the displacement of the particle and θ is the smallest angle between the particle's displacement and the uniform electric field.

  If a particle's displacement is in the same direction as the electric field, then $\theta = 0$ and

$$\Delta U = -qE|\Delta\vec{r}|$$

  If a particle's displacement is opposite the electric field, then $\theta = 180°$ and

$$\Delta U = qE|\Delta\vec{r}|$$

  Remember that q can be either positive or negative in this equation.

  - If a positively charged particle moves in the direction of the electric field, the system loses potential energy.
  - If a negatively charged particle moves in the direction of the electric field, the system gains potential energy.
  - If a positively charged particle moves opposite the electric field, the system gains potential energy.
  - If a negatively charged particle moves opposite the electric field, the system loses potential energy.

  For a uniform electric field (only), you can define zero for the potential energy to be at any location.

- The total energy of a system of charged particles is conserved. Thus for a closed system in which no outside forces do work, then

$$\Delta U + \Delta K = 0$$
$$U_i + K_i = U_f + K_f$$

Examples

1. A roller coaster is nearly at rest at the top of a hill of height 40 m. Define zero potential energy to be the bottom of the hill. If your mass is 60 kg and if friction is negligible, what is your:

   (a) potential energy at the top of the hill

   (b) your kinetic energy at the bottom of the hill

   (c) your speed at the bottom of the hill

2. (a) Suppose that a positively charge particle $+q$ can be at point A or at point B. At which point does the system have a greater potential energy?

   (a) A

   (b) B

   (c) Neither, because A and B are at the same potential.

   (b) If a particle of negative charge $-q$ is at point A or point B, at which point does the system have a greater potential energy?

   (a) A

   (b) B

   (c) Neither, because A and B are at the same potential.

3. (a) Suppose that a positively charge particle $+q$ can be at point A or at point B. At which point does the system have a greater potential energy?

   (a) A

   (b) B

   (c) Neither, because A and B are at the same potential.

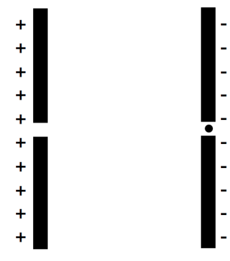
   (b) If a particle of negative charge $-q$ is at point A or point B, at which point does the system have a greater potential energy?

   (a) A

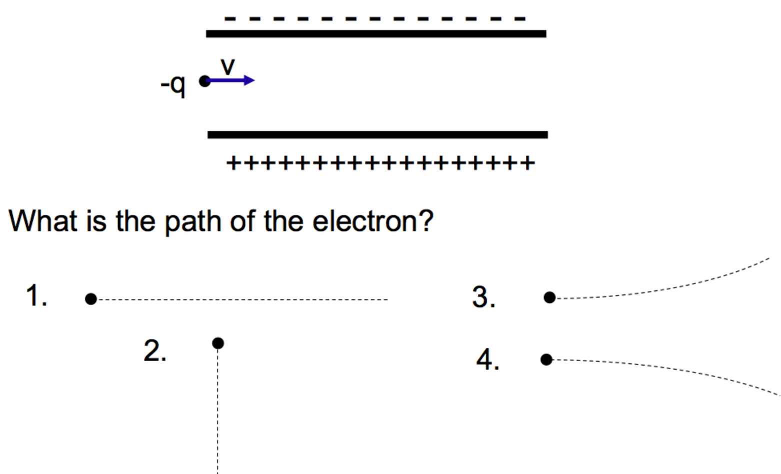
   (b) B

   (c) Neither, because A and B are at the same potential.

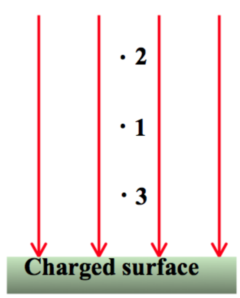
4. Two oppositely charged plates (called a capacitor) separated 2 cm are used to accelerate an electron. The electric field between the plates is 25,000 N/C. An electron is released from rest in a hole at the negatively charged plate. How fast is the electron moving when it reaches a slit in the other plate that is 2 cm away?



5.



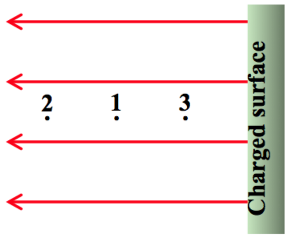
6. The electric field near a charged surface is shown.



A negative charge carrier released from rest at point 1 will

(a) travel past point 2, gaining PE as it goes
(b) travel past point 2, losing PE as it goes
(c) travel past point 3, gaining PE as it goes
(d) travel past point 3, losing PE as it goes

7. The electric field near a charged surface is shown.



A positive charge carrier is given an initial velocity v_0 to the right at point 1. Which of the following states all the possibilities?

(a) The charge carrier can reach point 2 and gain PE.

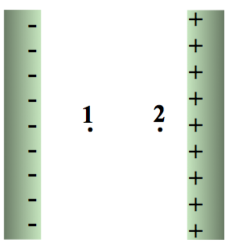
(b) The charge carrier can reach point 2 and lose PE.

(c) The charge carrier can reach point 3 and gain PE.

(d) The charge carrier can reach point 3 and lose PE.

(e) Two of the above are possible.

8. An electron going from point 1 to point 2



(a) moves toward increasing potential and gains PE.

(b) moves toward increasing potential but loses PE.

(c) moves toward decreasing potential and gains PE.

(d) moves toward decreasing potential but loses PE.

9. An alpha particle very far away and traveling at a speed of 1×10^7 m/s "collides" head on with a gold nucleus and rebounds backward as a result of the collision. (Note, this is unlikely but possible.) An alpha particle is a helium nucleus with 2 protons and 2 neutrons; thus, its mass is about 6.646×10^{-27} kg and its charge is $+2e$. A gold nucleus has 79 protons and 118 neutrons and a mass of 3.2707×10^{-25} kg. Its charge is $+79e$. What is the closest distance between the alpha particle and the gold nucleus? How does this compare to the approximate diameter of a gold atom (which is approximately 1 fm)?

10. A charged sphere, shown in Figure **??** has a net positive charge of 1 nC.

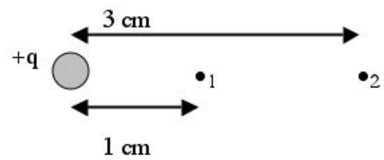


Figure 1:

(a) What is the speed of a proton at point 2 if it is moving to the right with a speed of 4×10^5 m/s at point 1?

(b) What is the speed of a proton at point 2 if it is moving to the left with a speed of 4×10^5 m/s at point 1?

(c) What is the speed of an electron at point 2 if it is moving to the right with a speed of 4×10^5 m/s at point 1?