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← PHYS-2B, section 34945, Spring 2020

Potential and Potential Energy (Homework)

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Current Score

QUESTION	1	2	3	4	5	6	7	8	9	10	11	12
POINTS	4/4	1/1	5/5	4/4	5/5	3/3	2/2	1/1	3/3	1/1	1/1	3/3

TOTAL SCORE

33/33	100.0%

Due Date Past Due

THU, FEB 6, 2020
11:59 PM PST

Request Extension

Assignment Submission & Scoring

Assignment Submission

For this assignment, you submit answers by question parts. The number of submissions remaining for each question part only changes if you submit or change the answer.

Assignment Scoring

Your last submission is used for your score.

The due date for this assignment has passed.

Your work can be viewed below, but no changes can be made.

Important! Before you view the answer key, decide whether or not you plan to request an extension. Your Instructor may not grant you an extension if you have viewed the answer key. Automatic extensions are not granted if you have viewed the answer key.

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1. 4/4 points Previous Answers **SERCP11 16.1.OP.001.**

My Notes Ask Your Teacher

Inside a particular cathode ray tube, there is a uniform electric field with a magnitude 402 N/C pointing in the positive x-direction. An electron, initially at rest, moves a distance of 2.60 cm in this field.

(a) How much work (in J) does the electric field do on the electron?

1.67e-18 ✔ 1.67e-18 J

(b) What is the change in potential energy (in J) of the entire system (cathode ray tube plus electron)?

-1.67e-18 ✔ -1.67e-18 J

(c) What is the velocity (in m/s) of the electron after it moves the 2.60 cm distance?

magnitude 1.91e6 ✔ 1.92e+06 m/s

direction $-x$ ✔ $-x$

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

(a) Because the electron has a negative charge, it experiences a force in the direction opposite to the field and, when released from rest, will move in the negative x-direction. The work done on the electron by the field is

$$W = F_x(\Delta x) = (qE_x)\Delta x = (-1.60 \times 10^{-19}\ \text{C})(402\ \text{N/C})(-2.60 \times 10^{-2}\ \text{m})$$
$$= 1.67 \times 10^{-18}\ \text{J}$$

(b) The change in the electric potential energy is the negative of the work done on the particle by the field. Thus,

$$\Delta PE = -W = -1.67 \times 10^{-18}\ \text{J}$$

(c) Since the Coulomb force is a conservative force, conservation of energy gives

$$\Delta KE + \Delta PE = 0,$$

or

$$KE_f = \frac{1}{2}m_e v_f^{\,2} = KE_i - \Delta PE = 0 - \Delta PE,$$

and

$$v_f = \sqrt{\frac{-2(\Delta PE)}{m_e}} = \sqrt{\frac{-2(-1.67 \times 10^{-18}\ \text{J})}{9.11 \times 10^{-31}\ \text{kg}}} = 1.92 \times 10^{6}\ \text{m/s in the } -x\text{-direction}$$

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2. 1/1 points Previous Answers **SERCP11 16.1.OP.003.**

My Notes Ask Your Teacher

Animal cells have a membrane that separates the interior of the cell from the outside environment. Typically, an electric potential difference exists between the inner and outer surfaces of the membrane.

Consider one such cell where the magnitude of the potential difference is 55 mV, and the inner surface of the membrane is at a higher potential than the outer surface. A potassium ion (K^+) is initially just outside the cell membrane (initially at rest). How much work (in J) is required for a cell to absorb the ion, so that it moves from the exterior of the cell to the interior?

8.80e-21 ✔ 8.80e-21 J

Solution or Explanation

Note that the positively charged ion is moving from a region of lower potential to a region of higher potential. This means it is moving against the direction of the electric field, and therefore, because the charge is positive, against the direction of the electric force on it. Therefore, the potential energy of the system is increasing. This means a positive quantity of external work must be supplied to the system. The work can be found from conservation of energy.

$$\Delta KE + \Delta PE = W_{\text{input}}$$

The initial kinetic energy is zero. The minimum work required will be for the case where the final kinetic energy is also zero. (We model the ion as moving very slowly through the membrane, so the change in kinetic energy is essentially zero.)

$$\Delta PE = W_{\text{input}}$$

The change in potential energy is related to the charge and change in potential by

$$\Delta PE = q\Delta V.$$

So,

$$W_{\text{input}} = q\Delta V = (1.60 \times 10^{-19}\ \text{C})(0.055\ \text{V}) = 8.80 \times 10^{-21}\ \text{J}.$$

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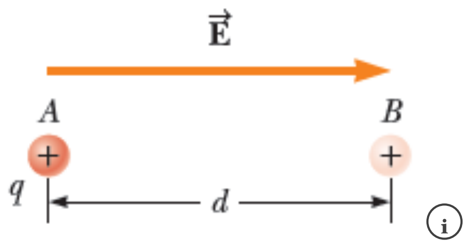
3. 5/5 points Previous Answers **SERCP11 16.1.OP.006.**

My Notes Ask Your Teacher

The figure below shows a small, charged sphere, with a charge of q = +39.0 nC, that moves a distance of d = 0.186 m from point A to point B in the presence of a uniform electric field $\vec{\mathbf{E}}$ of magnitude 250 N/C, pointing right.



(a) What is the magnitude (in N) and direction of the electric force on the sphere?

magnitude 9.75e-6 ✓ 9.75e-06 N

direction toward the right ✓ toward the right

(b) What is the work (in J) done on the sphere by the electric force as it moves from A to B?

1.81e-6 ✓ 1.81e-06 J

(c) What is the change of the electric potential energy (in J) as the sphere moves from A to B? (The system consists of the sphere and all its surroundings.)

$PE_B - PE_A$ = -1.81e-6 ✓ -1.81e-06 J

(d) What is the potential difference (in V) between A and B?

$V_B - V_A$ = -46.4 ✓ -46.5 V

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

(a) The electric force is given by $\vec{\mathbf{F}} = q\vec{\mathbf{E}}$. The magnitude is

$$F = |q|E = (39.0 \times 10^{-9}\ \text{C})(250\ \text{N/C}) = 9.75 \times 10^{-6}\ \text{N}.$$

Because the charge is positive, the force is in the same direction as the electric field, or to the right.

(b) The work is given by $W = Fd\cos(\theta)$, where θ is the angle between the force F and displacement d. In this case both are in the same direction, so $\theta = 0$ and $\cos(\theta) = 1$. So,

$$W = Fd = (9.75 \times 10^{-6}\ \text{N})(0.186\ \text{m}) = 1.81 \times 10^{-6}\ \text{J}.$$

(c) The change in electric potential energy of the system is defined to be the negative of the work done by the electric force, or,

$$PE_B - PE_A = -W = -1.81 \times 10^{-6}\ \text{J}.$$

The negative sign is consistent with the fact that the electric field tends to accelerate the charge over the given displacement—its kinetic energy increases, so its potential energy must decrease.

(d) The change in electric potential is related to the change in potential energy by

$$\Delta V = \frac{\Delta PE}{q}, \text{ or}$$

$$V_B - V_A = \frac{PE_B - PE_A}{q}.$$

So, $V_B - V_A = \dfrac{-1.81 \times 10^{-6}\ \text{J}}{39.0 \times 10^{-9}\ \text{C}} = -46.5\ \text{V}.$

The negative sign is consistent with the fact that the electric field and the path from A to B are in the same direction.

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4. 4/4 points Previous Answers **SERCP11 16.1.P.001.**

My Notes Ask Your Teacher

A uniform electric field of magnitude 436 N/C pointing in the positive x-direction acts on an electron, which is initially at rest. The electron has moved 3.10 cm.

(a) What is the work done by the field on the electron?

2.16e-18 ✔ 2.17e-18 J

(b) What is the change in potential energy associated with the electron?

-2.16e-18 ✔ -2.17e-18 J

(c) What is the velocity of the electron?

magnitude 2.18e6 ✔ 2.18e+06 m/s

direction -*x* ✔ -*x*

Solution or Explanation

(a) Because the electron has a negative charge, it experiences a force in the direction opposite to the field and, when released from rest, will move in the negative *x*-direction. The work done on the electron by the field is

$$W = F_x(\Delta x) = (qE_x)\Delta x = (-1.60 \times 10^{-19}\text{ C})(436\text{ N/C})(-3.10 \times 10^{-2}\text{ m})$$
$$= 2.17 \times 10^{-18}\text{ J}$$

(b) The change in the electric potential energy is the negative of the work done on the particle by the field. Thus,

$$\Delta PE = -W = -2.17 \times 10^{-18}\text{ J}$$

(c) Since the Coulomb force is a conservative force, conservation of energy gives

$$\Delta KE + \Delta PE = 0,$$

or

$$KE_f = \frac{1}{2}m_e v_f^2 = KE_i - \Delta PE = 0 - \Delta PE,$$

and

$$v_f = \sqrt{\frac{-2(\Delta PE)}{m_e}} = \sqrt{\frac{-2(-2.17 \times 10^{-18}\text{ J})}{9.11 \times 10^{-31}\text{ kg}}} = 2.18 \times 10^{6}\text{ m/s in the } -x\text{-direction}$$

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5. 5/5 points Previous Answers **SERCP11 16.1.P.002.**

My Notes Ask Your Teacher

A proton is released from rest in a uniform electric field of magnitude 346 N/C.

(a) Find the electric force on the proton.

magnitude 5.54e-17 ✓ 5.54e-17 N

direction in the direction of the electric field ✓ in the direction of the electric field

(b) Find the acceleration of the proton.

magnitude 3.32e10 ✓ 3.31e+10 m/s^2

direction in the direction of the electric field ✓ in the direction of the electric field

(c) Find the distance it travels in 2.08 μs.

7.18 ✓ 7.17 cm

Solution or Explanation

(a) $\vec{\mathbf{F}} = q\vec{\mathbf{E}} = (1.60 \times 10^{-19}\ \text{C})(346\ \text{N/C}) = 5.54 \times 10^{-17}\ \text{N}$ in the direction of the electric field

(b) $\vec{\mathbf{a}} = \dfrac{\vec{\mathbf{F}}}{m_p} = \dfrac{5.54 \times 10^{-17}\ \text{N}}{1.67 \times 10^{-27}\ \text{kg}} = 3.31 \times 10^{10}\ \text{m/s}^2$ in the direction of the electric field

(c) $\Delta x = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(3.31 \times 10^{10}\ \text{m/s}^2)(2.08 \times 10^{-6}\ \text{s})^2$

$= 7.17 \times 10^{-2}\ \text{m} = 7.17\ \text{cm}$

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6. 3/3 points Previous Answers **SERCP11 16.3.P.025.**

My Notes Ask Your Teacher

Calculate the speed (in m/s) of an electron and a proton with a kinetic energy of 1.35 electron volt (eV). (The electron and proton masses are m_e = 9.11 × 10^{-31} kg and m_p = 1.67 × 10^{-27} kg. Boltzmann's constant is k_B = 1.38 × 10^{-23} J/K.)

HINT

(a) an electron

6.89e5 ✔ 6.89e+05 The electron volt is a unit of energy, defined as the kinetic energy that an electron gains when accelerated through a potential difference of 1 V: 1 eV = 1.60 × 10^{-19} J. m/s

(b) a proton

1.61e4 ✔ 16100 m/s

(c) Calculate the average translational kinetic energy in eV of a 3.13 × 10^2 K ideal gas particle. (Recall from Topic 10 that $\frac{1}{2}m\overline{v^2} = \frac{3}{2}k_BT$.)

.0405 ✔ 0.0404 eV

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

Use the conversion factor 1 eV = 1.60 × 10^{-19} C · V to find the kinetic energy in joules.

$$KE = (1.35\text{ eV})\left(\frac{1.60 \times 10^{-19}\text{ J}}{1\text{ eV}}\right) = 2.16 \times 10^{-19}\text{ J}$$

(a) Solve for the electron's speed from the definition of kinetic energy.

$$KE = \frac{1}{2}m_e v_e^{\,2} \rightarrow v_e = \sqrt{\frac{2(KE)}{m_e}} = \sqrt{\frac{2(2.16 \times 10^{-19}\text{ J})}{9.11 \times 10^{-31}\text{ kg}}} = 6.89 \times 10^5\text{ m/s}$$

(b) Follow the same steps to find the proton's speed.

$$KE = \frac{1}{2}m_p v_p^{\,2} \rightarrow v_p = \sqrt{\frac{2(KE)}{m_p}} = \sqrt{\frac{2(2.16 \times 10^{-19}\text{ J})}{1.67 \times 10^{-27}\text{ kg}}} = 1.61 \times 10^4\text{ m/s}$$

(c) Use $KE_{av} = \frac{1}{2}m\overline{v^2} = \frac{3}{2}k_BT$ to find the average translational kinetic energy in joules.

$$KE_{av} = \frac{3}{2}k_BT = \frac{3}{2}(1.38 \times 10^{-23} \text{ J/K})(313 \text{ K})$$
$$= 6.48 \times 10^{-21} \text{ J}$$

Convert to eV to find the following.

$$KE_{av} = (6.48 \times 10^{-21} \text{ J})\left(\frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}\right) = 0.0404 \text{ eV}$$

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7. 2/2 points Previous Answers **SERCP11 16.3.P.026.**

My Notes Ask Your Teacher

An electric field does 1.75×10^3 eV of work on a carbon nucleus of charge 9.61×10^{-19} C. Find the change in the nucleus' electric potential and electric potential energy in joules.

HINT

(a) change in electric potential (in V)

-291 ✔ -292 V

(b) change in electric potential energy in joules

-2.80e-16 ✔ -2.80e-16 Be careful not to confuse the two terms *electric potential* and *electric potential energy*. They represent different physical quantities, related by $\Delta V = \frac{\Delta PE}{q}$: electric *potential* is a measure of the change in electric *potential energy* per unit charge. As ΔV increases, potential energy can either increase (for $q > 0$) or decrease (for $q < 0$). J

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

Convert the given work into the SI unit of joules.

$$W = (1.75 \times 10^{3}\ \text{eV})\left(\frac{1.60 \times 10^{-19}\ \text{J}}{1\ \text{eV}}\right) = 2.80 \times 10^{-16}\ \text{J}$$

(a) Work done by the electric force is related to the changes in electric potential and potential energy by the relation $W = -\Delta PE = -q\Delta V$.

Solve for the potential difference ΔV and substitute values to find the following.

$$\Delta V = -\frac{W}{q} = -\frac{2.80 \times 10^{-16}\ \text{J}}{9.61 \times 10^{-19}\ \text{C}}$$
$$= -292\ \text{V}$$

(b) The change in electric potential energy is the following.

$$\Delta PE = -W = -2.80 \times 10^{-16}\ \text{J}$$

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8. 1/1 points Previous Answers **SERCP11 15.CQ.001.**

My Notes Ask Your Teacher

A glass object receives a positive charge by rubbing it with a silk cloth. In the rubbing process, have protons been added to the object or have electrons been removed from it?

- ○ Protons have been added.
- ◉ Electrons have been removed. ✓

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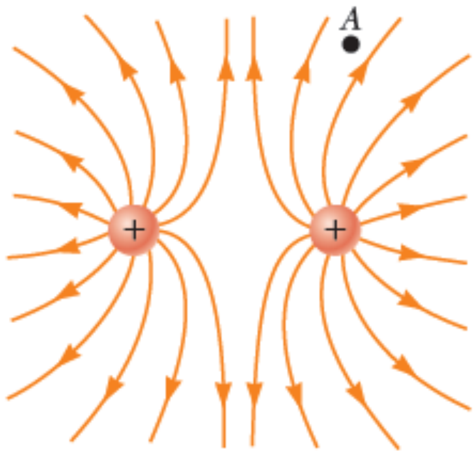
9. 3/3 points Previous Answers **SERCP11 15.CQ.008.**

My Notes Ask Your Teacher

Consider point *A* in the figure below located an arbitrary distance from two point charges in otherwise empty space.



(a) Is it possible for an electric field to exist at point *A* in empty space?

- (selected) Yes
- No

(b) Does charge exist at this point?

- Yes
- (selected) No

(c) Does a force exist at this point?

- Yes
- (selected) No

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10. 1/1 points Previous Answers **SERCP11 15.CQ.015.**

My Notes Ask Your Teacher

If more electric field lines leave a Gaussian surface than enter it, what can you conclude about the net charge enclosed by that surface?

- ○ The surface must enclose a negative net charge.
- ○ Not enough information is given to decide.
- ● The surface must enclose a positive net charge.

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11. 1/1 points Previous Answers **SERCP11 15.CQ.017.**

My Notes Ask Your Teacher

What happens when a charged insulator is placed near an uncharged metallic object?

- They repel each other.
- They exert no electrostatic force on each other.
- They may attract or repel each other, depending on whether the charge on the insulator is positive or negative.
- The charged insulator always spontaneously discharges.
- They attract each other.

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12. 3/3 points Previous Answers **SERCP11 15.CQ.002.**

My Notes Ask Your Teacher

The fundamental charge is $e = 1.60 \times 10^{-19}$ C. Identify whether each of the following statements is true or false.

HINT

(a) It's possible to transfer electric charge to an object so that its net electric charge is 8.5 times the fundamental electric charge, *e*.

- True
- False ✓

Electric charge is quantized in chunks of magnitude equal to the fundamental charge, *e*. Protons have a charge of $+e$ and electrons have a charge of $-e$. (Quarks are fundamental particles with charges of $\frac{\pm e}{3}$ or $\frac{\pm 2e}{3}$. They combine in groups of 2 or 3 to form particles with charges of $0, \pm e, \pm 2e$, etc. Quarks are discussed in Topic 30.)

(b) All protons have a charge of $+e$.

- True ✓
- False

(c) Electrons in a conductor have a charge of $-e$ while electrons in an insulator have no charge.

- True
- False ✓

Solution or Explanation

(a) False. Electric charge is said to be quantized, meaning that charge occurs in discrete chunks that can't be further subdivided. An object may have a charge of $0, \pm e, \pm 2e, \pm 3e$, and so on, but never a fractional charge such as $3.25e$ or $8.5e$.

(b) True. All protons have a positive charge equal to the fundamental charge, $+e$.

(c) False. All electrons have a negative charge equal to $-e$.

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