

Remember: $W_{\text{external}} = \Delta U = q\Delta V = -\Delta KE = -\frac{1}{2}m(v_f^2 - v_i^2)$, $E = \frac{V}{d}$

Practice Questions: Topic 3- Electric Potential

1. Which of the following is the equivalent unit for the unit of electric field, N/C ?

A. Vm

B. V/m

C. J/m

D. Jm

$$\Delta V = Ed$$

$$E = \frac{\Delta V}{d} \rightarrow \text{volt} \rightarrow \text{meter}$$

2. Which of the following quantities are scalar?

I. Electric force *vector*

II. Electric field *vector*

III. Electric potential

IV. Electric potential Energy

A. I and II

B. II and IV

C. II and III

D. III and IV

3. Which of the following gives the correct conversion of eV to joules?

A. $1eV = \frac{1}{1.6 \times 10^{-19}} J$

B. $1eV = 1.6 \times 10^{-19} J$

C. $1eV = \frac{1}{8.99 \times 10^9} J$

D. $1eV = 8.99 \times 10^9 J$

$$1eV = 1.6 \times 10^{-19} J$$

$$eV \xrightarrow{\times 1.6 \times 10^{-19}} J$$

$$J \xrightarrow{\div 1.6 \times 10^{-19}} eV$$

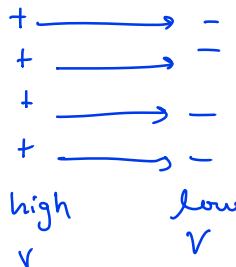
4. Electric field lines always point

A. from higher potential to lower potential

B. from lower potential to higher potential

C. in the same direction as the equipotential lines

D. in the opposite direction as the equipotential lines



5. A positive charge is released and moves along an electric field line. This charge moves to a position of ____.

It goes to negative side

A. lower potential and lower potential energy

B. lower potential and higher potential energy

C. higher potential and lower potential energy

D. higher potential and higher potential energy

Not doing work

6. A negative charge is released and moves along an electric field line. This negative charge moves to a position of ____.

A. lower potential and lower potential energy

B. lower potential and higher potential energy

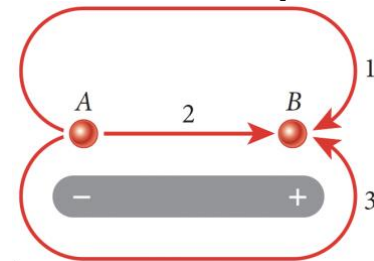
C. higher potential and lower potential energy

D. higher potential and higher potential energy

going to positive side

no work

7. A positive point charge is to be moved from point A to point B in the vicinity of an electric dipole. Which of the three paths shown in the figure will result in the most work being done by the dipole's electric field on the point charge?



A. path 1

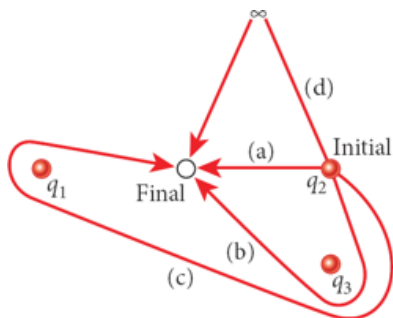
B. path 2

C. path 3

D. The work is the same on all three paths

** Work doesn't depend on path, only final & initial positions.*

8. Three identical positive point charges are located at fixed points in space. Then charge q_2 is moved from its initial location to a final location as shown in the figure. Four different paths, marked (a) through (d), are shown. Path (a) follows the shortest line; path (b) takes q_2 around q_3 ; path (c) takes q_2 around q_3 and q_1 ; path (d) takes q_2 out to infinity and then to the final location.



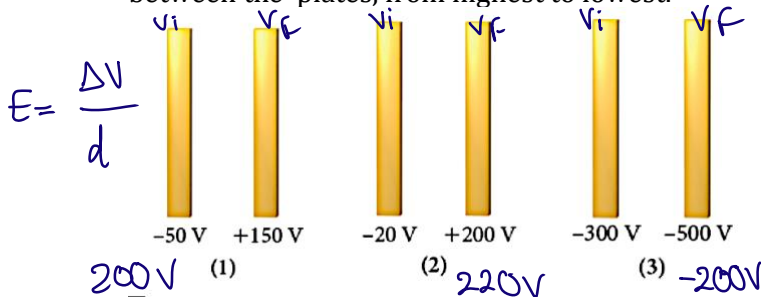
Which path requires the least work?

- A. path (a)
- B. path (b)
- C. path (c)
- D. path (d)

* Work doesn't depend on path, only final & initial positions.

E. The work is the same for all the paths

9. Three pairs of parallel plates have the same plate separation and potentials on each plate as indicated in the drawing. The electric field, E , is uniform between each pair of plates and perpendicular to them. Rank the magnitude of E between the plates, from highest to lowest.



- A. $1 > 2 > 3$
- B. $3 > 2 > 1$
- C. The magnitudes for 3 and 2 are equal and greater than the magnitude for 1
- D. The magnitude for 2 is greater than that for 1 and 3, which are the same

10. Two parallel plates are held at a potential of +220 V and +130 V. If the plates have area of 44 cm² and are separated by a distance of 7.3 mm, what is the magnitude of the electric field between the plates?

$$E = \frac{\Delta V}{d} = \frac{220 - 130}{0.0073 \text{ m}} \approx 12000 \text{ N/C}$$

- A. 54 V/m
- B. 132 N/C
- C. 12 000 N/C
- D. 20 000 V/m

11. A proton is placed midway between points A and B. The potential at point A is -20 V, and the potential at point B is +20 V. The potential at the midpoint is 0 V. The proton will ____.

- A. remain at rest
- B. accelerate toward point A
- C. accelerate toward point B
- D. move toward point A with constant velocity
- E. move toward point B with constant velocity

* when proton is released, it will go to lower potential

12. An electron is accelerated from rest through a potential difference of 450 V. What is its final speed?

- A. $0.81 \times 10^7 \text{ m/s}$
- B. $1.3 \times 10^7 \text{ m/s}$
- C. $2.9 \times 10^7 \text{ m/s}$
- D. $4.1 \times 10^7 \text{ m/s}$

$$\Delta V = \frac{-\Delta KE}{q} = \frac{-\frac{1}{2}mv_f^2}{q}$$

$$450(-1.6 \times 10^{-19}) = \frac{-\frac{1}{2}(9.1 \times 10^{-31})v_f^2}{-1.6 \times 10^{-19}}$$

$$v_f \approx 1.3 \times 10^7 \text{ m/s}$$

13. A 5.0 V battery is connected to two parallel metal plates placed in a vacuum. An electron is accelerated from rest from the negative plate toward the positive plate. What kinetic energy does the electron have as it just reaches the positive plate?

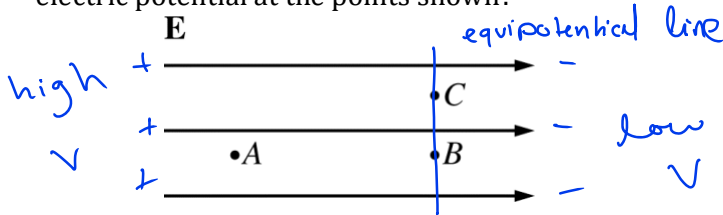
- A. $5.6 \times 10^{-19} \text{ J}$
- B. $6.1 \times 10^{-19} \text{ J}$
- C. $8.0 \times 10^{-19} \text{ J}$
- D. $8.9 \times 10^{-19} \text{ J}$

$$-eE = q\Delta V$$

$$KE = -q\Delta V = -(-1.6 \times 10^{-19})(5) = 8 \times 10^{-19} \text{ J}$$

$$KE = -q\Delta V = (1.6 \times 10^{-19})(5) = 8 \times 10^{-19} \text{ J}$$

14. The diagram below shows a uniform horizontal electric field and three points that lie in the field. Which of the following is true of the electric potential at the points shown?

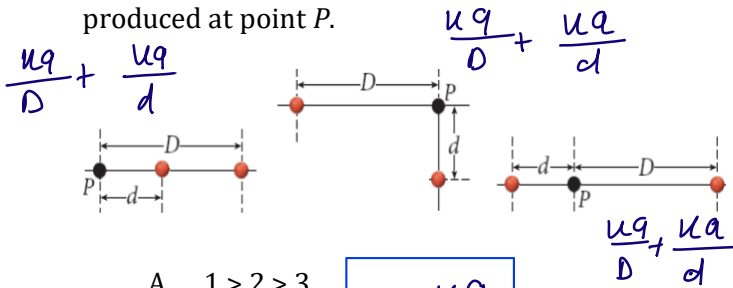


- I. It is lower at point A than at point B
- II. It is lower at point A than at point C
- III. It is the same at points A and B
- IV. It is the same at points B and C

- A. I only
- B. III only
- C. IV only
- D. II and III only

$$A > C = B$$

15. Two protons are located in space in the three ways shown in the figure. Rank the three cases from highest to lowest net electric potential, V , produced at point P .



- A. $1 > 2 > 3$
- B. $2 > 3 > 1$
- C. $3 > 2 > 1$

D. All three potentials are the same

$$V = \frac{kq}{r}$$

16. Suppose an electric potential is described by, $V(x, y, z) = -(5x^2 + y + z)$ in volts. Which of the following expressions describes the associated electric field, in units of volts per meter?

- A. $E = 5\hat{x} + 2\hat{y} + 2\hat{z}$
- B. $E = 10x\hat{x}$
- C. $E = 5\hat{x} + 2\hat{y}$
- D. $E = 10x\hat{x} + \hat{y} + \hat{z}$

$$E_x = -\frac{dv}{dx} = 10x\hat{x}$$

$$E_y = -\frac{dv}{dy} = \hat{y}$$

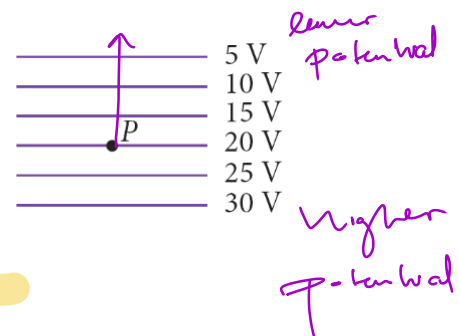
$$E_z = -\frac{dv}{dz} = \hat{z}$$

17. Which one of the following statements is not true?

- A. Equipotential lines are parallel to the electric field lines
- B. Equipotential lines for a point charge are circular
- C. Equipotential surfaces exist for any charge distribution
- D. When a charge moves on an equipotential surface, the work done on the charge is zero

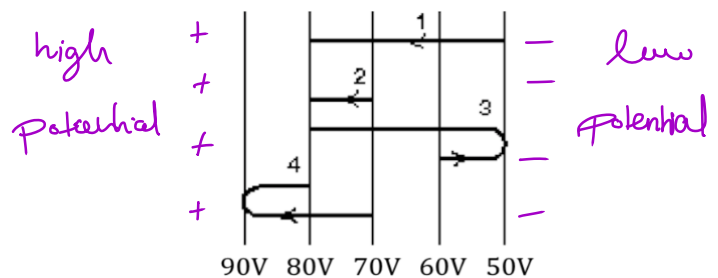
perpendicular

18. In the figure, the lines represent equipotential lines. What is the direction of the electric field at point P ?



- A. Up
- B. Down
- C. Left
- D. Right

19. An electron goes from one equipotential surface to another along one of the four paths shown below.



Rank the paths according to the work done by the electric field, from least to greatest.

- A. $1 < 2 < 3 < 4$
- B. $1 < 3 < 4 = 2$
- C. $4 < 3 < 2 < 1$
- D. $4 = 2 < 3 < 1$

look at initial & final displacement

$$1: 80 - 50 = 30$$

$$2: 80 - 70 = 10$$

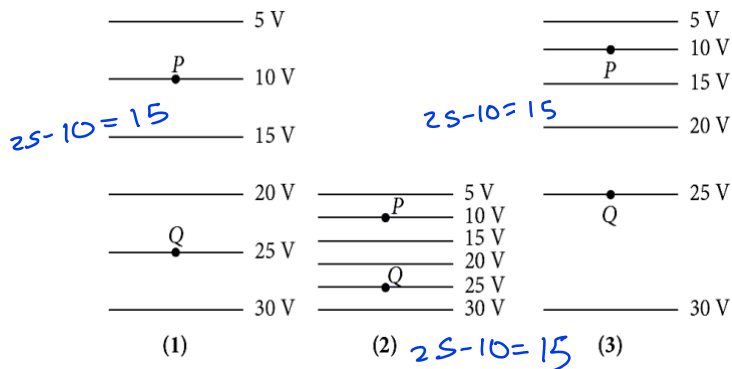
$$3: 80 - 60 = 20$$

$$4: 80 - 80 = 0$$

$$W = q \Delta V$$

$$\Delta V \uparrow = W \uparrow$$

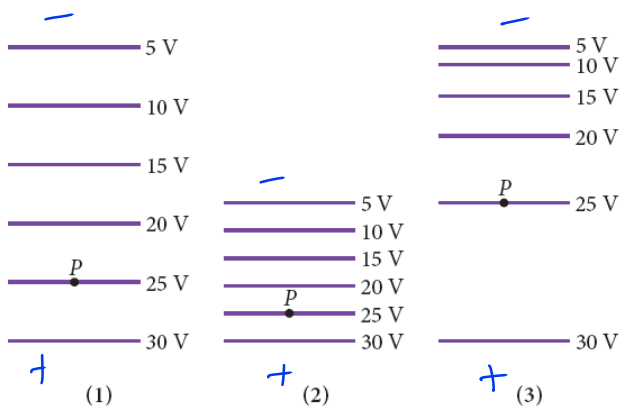
20. In the figure, the lines represent equipotential lines. A charged object is moved from point P to point Q . How does the amount of work done on the object compare for these three cases?



$W = q\Delta V$

- A. All three cases involve the same work
 B. The most work is done in case 1
 C. The most work is done in case 2
 D. The most work is done in case 3

21. In the figure, the lines represent equipotential lines. How does the magnitude of the electric field, E , at point P compare for the three cases?

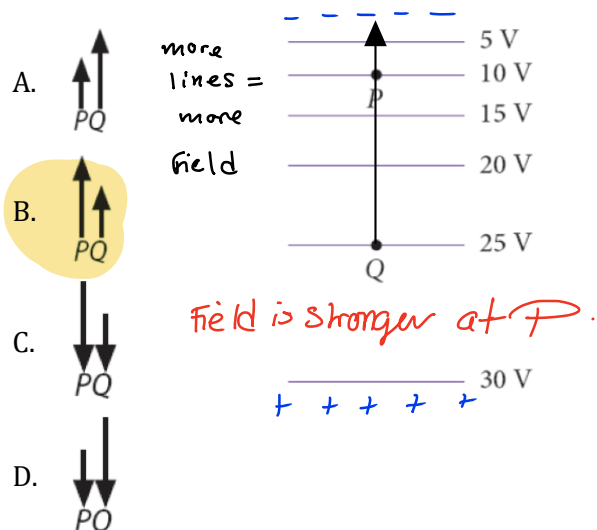


- A. $E_1 > E_2 > E_3$
 B. $E_1 < E_2 < E_3$
 C. $E_3 > E_1 > E_2$
 D. $E_3 < E_1 < E_2$

$E = \frac{\Delta V}{d}$ ← constant

less distance
 = Greater
 electric
 field

22. In the figure, the lines represent equipotential lines. A positive charge is placed at point P , and then another positive charge is placed at point Q . Which set of vectors best represents the relative magnitudes and directions of the electric forces exerted on the positive charges at P and Q ?



23. The amount of work done to move a positive point charge q on an equipotential surface of 1000 V relative to that done to move the charge on an equipotential surface of 10 V is ____.

- A. the same
 B. less
 C. more
 D. dependent on the distance the charge moves

Both cases
 work = 0

24. The amount of work done to move a positive charge Q on an equipotential surface of 1000 V compared to that on an equipotential surface of 10 V is ____.

- A. the same
 B. less
 C. more
 D. dependent on distance travelled

$W = 0$

25. What is the electric potential 45.5 cm away from a point charge of 12.5 pC?

A. 0.247 V

B. 1.45 V

C. 4.22 V

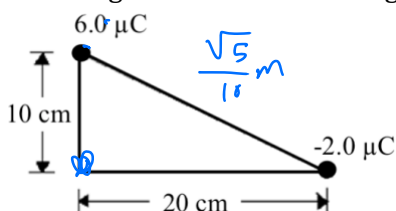
D. 10.2 V

$$V = \frac{kQ}{r}$$

$$V = \frac{(8.99 \times 10^9)(12.5 \times 10^{-12})}{0.455}$$

$$V \approx 0.247 \text{ V}$$

26. Two point charges are located at two corners of a triangle as shown. What is the electric potential at the right corner of the triangle?



A. $2.1 \times 10^5 \text{ V}$

B. $4.5 \times 10^5 \text{ V}$

C. $6.3 \times 10^5 \text{ V}$

D. $7.2 \times 10^5 \text{ V}$

$$V_1 = \frac{kQ}{r}$$

$$= \frac{(8.99 \times 10^9)(6 \times 10^{-6})}{0.1}$$

$$V_2 = \frac{kQ}{r} = \frac{(8.99 \times 10^9)(-2 \times 10^{-6})}{0.2}$$

$$= -89900 \approx 4.5 \times 10^5 \text{ V} \leftarrow \text{add normally}$$

27. At a distance d from a charge, the electric potential is V . What would be the electric potential a distance $d/4$ from the same charge?

A. $V/4$

B. $V/2$

C. $2V$

D. $4V$

$$V = \frac{kQ}{r} = \frac{kQ}{\frac{r}{4}} = 4\left(\frac{kQ}{r}\right)$$

* There is a mistake in answer key.

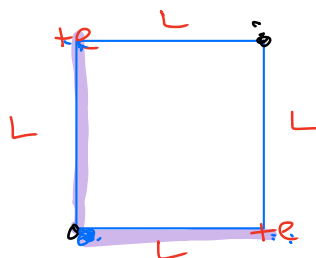
28. In the opposite corners of a square there are two identical ions. Each has a charge of $+e$. The length of one side of the square is L . What is the net electric potential caused by the two positive ions at both of the empty corners of the square?

A. $ke/2L$

B. ke/L

C. $\sqrt{2}ke/L$

D. $2ke/L$



$$V = \frac{kQ}{r}$$

$$V = \frac{kQ}{r} + \frac{kQ}{r} = \frac{ke}{L} + \frac{ke}{L} = \frac{2ke}{L}$$

* At both corners, V will be the same.

29. The potential energy of a system of three equal charges arranged in an equilateral triangle is 0.54 J. If the length of one side of this triangle is 33 cm, what is the charge of one of the three charges?

A. 1.7 μC

B. 2.0 μC

C. 2.6 μC

D. 4.3 μC

$$U = 3 \frac{kq^2}{r}$$

$$0.54 = 3 \left[\frac{(8.99 \times 10^9) q^2}{0.33} \right]$$

$$q \approx 2.6 \times 10^{-6}$$

30. When two charges are separated by a distance d , their electric potential energy is equal to U . What would be their electric potential energy if the separation distance was $d/2$?

A. $U/4$

B. $U/2$

C. $2U$

D. $4U$

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

$$U = \frac{kq_1q_2}{\frac{r}{2}} = 2 \left[\frac{kq_1q_2}{r} \right]$$

$$U = 2U$$

31. Each of the following pairs of charges are separated by a distance d . Which pair has the highest potential energy?

A. +5 C and +3 C

B. +5 C and -3 C

C. -5 C and +3 C

D. All pairs have the same potential energy

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

will want to repel

$$= \frac{2ke}{L}$$

formulas: $W_{\text{external}} = q\Delta V = \Delta U = -\Delta KE$ $E = \frac{\Delta V}{d}$ $V = \frac{kQ}{r}$ $\Delta V = -\int E \cdot ds$

Free Response:

$$W_{\text{field}} = -W_{\text{external}}$$

$$E = \frac{-dV}{ds}$$

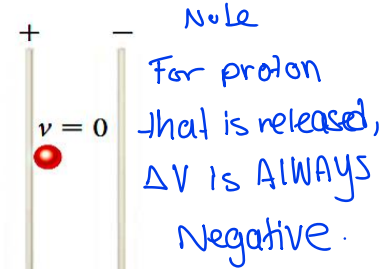
1. How much work would be done by an electric field in moving a proton from a point at a potential of +180 V to a point at a potential of -60.0 V?

$$W_{\text{field}} = -W_{\text{external}} = -(q\Delta V) = -(1.6 \times 10^{-19} \times (-60 - 180)) = 3.84 \times 10^{-17} \text{ J}$$

2. A proton is placed between two parallel conducting plates in a vacuum as shown below. The difference in electric potential between the two plates is 450 V. The proton is released from rest close to the positive plate. What is the kinetic energy of the proton when it reaches the negative plate?

$$\Delta KE = KE_f - KE_i = -\Delta U = -q\Delta V$$

$$KE_f = -q\Delta V = -1.6 \times 10^{-19} (-450) = 7.2 \times 10^{-17} \text{ J}$$



3. A proton, initially at rest, is accelerated through a potential difference of 500 V. What is its final velocity? → Taken as negative

$$KE_i = 0$$

$$\Delta V = 500 \text{ V}$$

$$v_f = ?$$

$$q\Delta V = -\Delta KE = -(KE_f - KE_i) = -KE_f$$

$$-\frac{1}{2}mv^2 = q\Delta V$$

$$v = \sqrt{\frac{-2q\Delta V}{m}} = \sqrt{\frac{-2 \times 1.6 \times 10^{-19} \times -500}{1.67 \times 10^{-27}}} \approx 3.1 \times 10^5 \text{ m/s}$$

4. A 10.0 V battery is connected to two parallel metal plates placed in a vacuum. An electron is accelerated from rest from the negative plate toward the positive plate.

$$KE_i = 0$$

a. What kinetic energy does the electron have just as it reaches the positive plate?

$$\Delta KE = KE_f - KE_i = -\Delta U = -q\Delta V$$

$$KE_f = -(-1.6 \times 10^{-19})(10) = 1.6 \times 10^{-18} \text{ J}$$

* ΔV for electron ALWAYS positive (if it accelerates)

b. What is the speed of the electron just as it reaches the positive plate?

$$KE_f = 1.6 \times 10^{-18} = \frac{1}{2}mv^2$$

$$v_f = \sqrt{\frac{2 \times (1.6 \times 10^{-18})}{9.11 \times 10^{-31}}} \approx 1.88 \times 10^6 \text{ m/s}$$

REMINDER

mass of proton:

mass of electron: $9.11 \times 10^{-31} \text{ kg}$

$$\Delta V = 5 \times 10^3 \text{ V}$$

5. A cathode ray tube uses a potential difference of 5.0 kV to accelerate electrons and produce an electron beam that makes images on a phosphor screen. What is the speed of these electrons as a percentage of the speed of light?

$$KE = \frac{1}{2}mv^2 = -q\Delta V$$

$$\frac{1}{2}(9.1 \times 10^{-31})v^2 = -(-1.6 \times 10^{-19})(5 \times 10^3)$$

$$v \approx 4.2 \times 10^7 \text{ m/s}$$

$$\rightarrow \text{Speed of light} = c \approx 3 \times 10^8 \text{ m/s}$$

$$\frac{v}{c} = \frac{4.2 \times 10^7}{3 \times 10^8} = 0.14$$

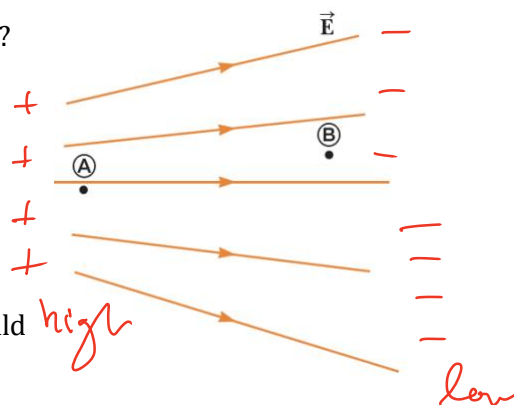
$\therefore v = 14\%$ of speed of light

6. In the figure below, two points A and B are located within a region in which there is an electric field.

a. How would you describe the potential difference $\Delta V = V_B - V_A$?

Tick the appropriate box.

- ☐ It is positive
☒ It is negative
☐ It is zero



b. A negative charge is placed at A and then moved to B. How would you describe the change in potential energy of the charge-field system for this process? Tick the appropriate box.

- ☒ It is positive
☐ It is negative
☐ It is zero

$$U = \frac{kq_1q_2}{r} = q \Delta V$$

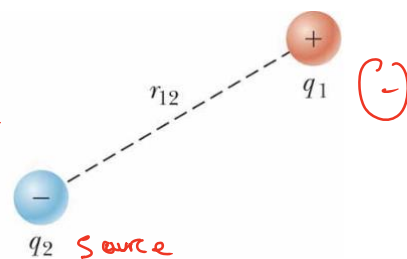
negative
negative

= positive

7. In the figure, take q_2 to be a negative source charge and q_1 to be a second charge whose sign can be changed. If q_1 is initially positive and is changed to a charge of the same magnitude but negative, what happens to the potential at the position of q_1 due to q_2 ?

- ☐ It increases
☐ It decreases
☒ It remains the same

potential talks about a location only



$$V = \frac{kq_2}{r} \text{ won't change}$$

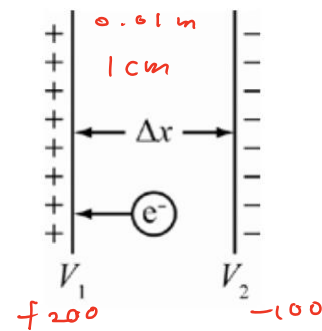
8. Two parallel plates are held at potentials of +200.0 V and -100.0 V. The plates are separated by 1.00 cm.

- a. Find the electric field between the plates.

$$E = \frac{\Delta V}{d} = \frac{200 - (-100)}{0.01} = 3 \times 10^4 \text{ V/m}$$

- b. An electron is initially placed halfway between the plates. Find its kinetic energy when it hits the positive plate.

$$KE = -q \Delta V \longrightarrow$$



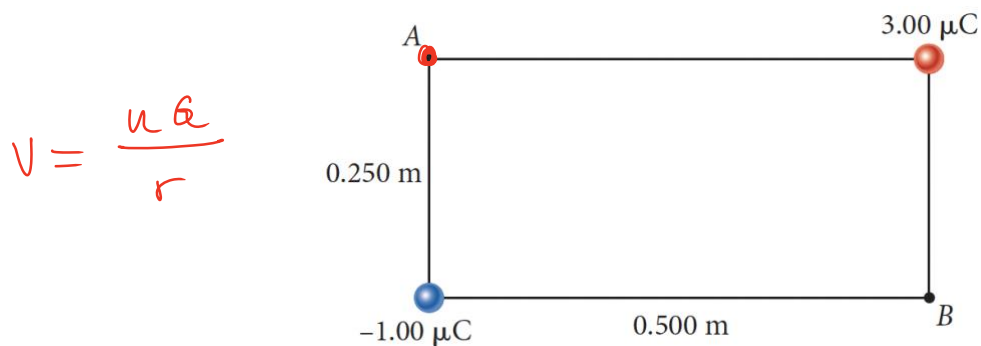
$$KE = -(-1.6 \times 10^{-19})(150)$$

$$\Delta V = Ed = 3 \times 10^4 \left(\frac{0.01}{2} \right)$$

$$= 2.4 \times 10^{-17} \text{ J}$$

$$\Delta V = 150$$

9. Two point charges are located at two corners of a rectangle, as shown in the figure.



$$V = \frac{kq}{r}$$

- a. What is the electric potential at point A?

$$V_{\text{Total}} = V_1 + V_2 = \frac{8.99 \times 10^9 (-1 \times 10^{-6})}{0.25} + \frac{8.99 \times 10^9 (3 \times 10^{-6})}{0.5}$$

$$V_{\text{Total}} = 17980 \text{ V}$$

- b. What is the potential difference between points A and B?

$$V_{AB} = V_B - V_A = k \left[\frac{q_1}{r_1} + \frac{q_2}{r_2} \right] - V_A$$

$$= 8.99 \times 10^9 \left[\frac{-1 \times 10^{-6}}{0.5} + \frac{3 \times 10^{-6}}{0.25} \right] - 17980$$

$$= 89900 - 17980 = 71920 \text{ V}$$

10. A $2.50 \mu\text{g}$ dust particle with a charge of $1.00 \mu\text{C}$ falls at a point $x = 2.00 \text{ m}$ in a region where the electric potential varies according to:

$$V(x) = (2.00 \text{ V/m}^2)x^2 - (3.00 \text{ V/m}^3)x^3$$

a. What is the electric field at $x = 2.00 \text{ m}$?

$$E(x) = -\frac{dV}{dx} = -\frac{(2x^2 - 3x^3)}{dx} = -4x + 9x^2$$

$$E(2) = -4(2) + 9(2)^2 = -8 + 36 = 28 \text{ V/m}$$

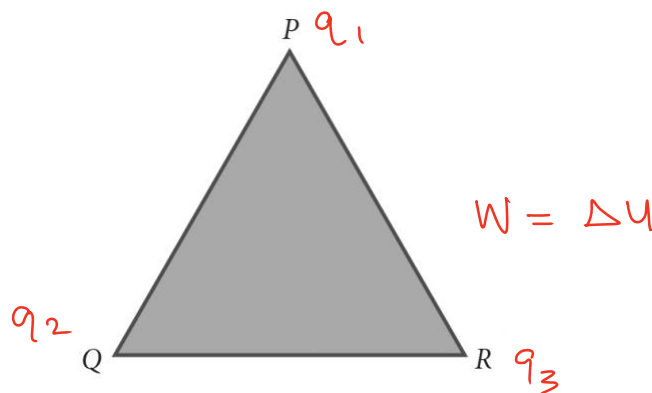
b. With what acceleration will the particle start moving after it touches down?

$$F = ma$$

$$F = qE$$

$$a = \frac{qE}{m} = \frac{(1 \times 10^{-6})(28)}{2.5 \times 10^{-6}} = 11.2 \text{ m/s}^2$$

11. Three charges, q_1 , q_2 , q_3 , are located at the corners of an equilateral triangle with side length of 1.20 m .



* To bring any charge from infinity

$$U_i = 0$$

$$W = U_f - U_i$$

$$W = U_f$$

Find the work done in each of the following cases:

a. to bring the first particle, $q_1 = 1.00 \text{ pC}$, to P from infinity.

No other particle to interact with so $U_1 = W_1 = 0 \text{ J}$

b. to bring the second particle, $q_2 = 2.00 \text{ pC}$, to Q from infinity.

$$\begin{aligned} W_2 = U_2 &= \frac{kq_1q_2}{r} \\ &= \frac{(8.99 \times 10^9)(1 \times 10^{-12})(2 \times 10^{-12})}{1.2} \\ &\approx 1.5 \times 10^{-14} \text{ J} \end{aligned}$$

c. to bring the last particle, $q_3 = 3.00 \text{ pC}$, to R from infinity.

$$W_3 = U_3 = \frac{kq_1q_3}{r} + \frac{kq_2q_3}{r} = \frac{k}{r} (q_1q_3 + q_2q_3)$$

$$= \frac{8.99 \times 10^9}{1.2} (1 \times 10^{-12} \times 3 \times 10^{-12}) + (2 \times 10^{-12} \times 3 \times 10^{-12})$$

$$\approx 6.74 \times 10^{-14} \text{ J}$$

d. Find the total potential energy stored in the final configuration of q_1 , q_2 , and q_3 .

$$U_{\text{Total}} = U_1 + U_2 + U_3$$

$$= 0 + (1.5 \times 10^{-14}) + (6.74 \times 10^{-14}) = 8.24 \times 10^{-14} \text{ J}$$

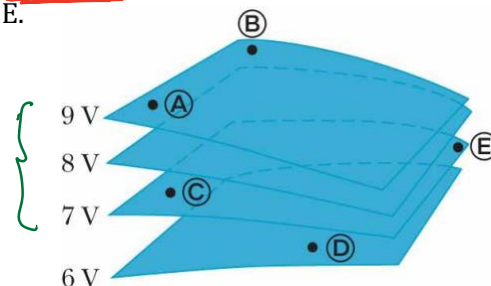
12. The labeled points in the figure are on a series of equipotential surfaces associated with an electric field. Rank (from greatest to least) the work done by the electric field on a positively charged particle that moves from A to B, from B to C, from C to D, and from D to E.

B to C 2V $W_{\text{electric}} = -q\Delta V$

C to D 1V $W_{\text{external}} = q\Delta V$

A to B zero

D to E Negative



13. Can two equipotential lines cross? Why or why not?

Equipotential lines, by definition, are lines of constant potential. The equipotential at a given point in space can only have a single value. If they intersect, then the point of intersection will have two different potentials at the same point which is not possible. Therefore, two equipotential lines cannot cross.