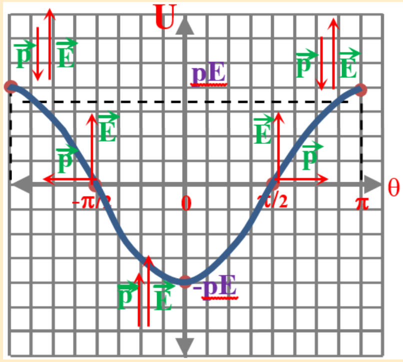
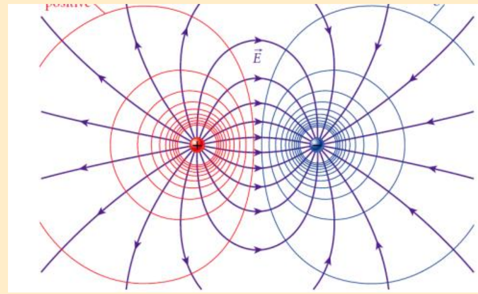


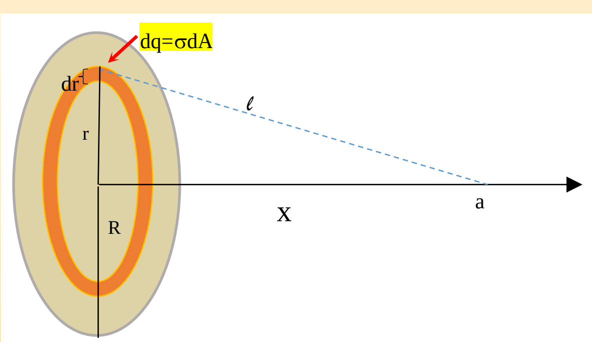


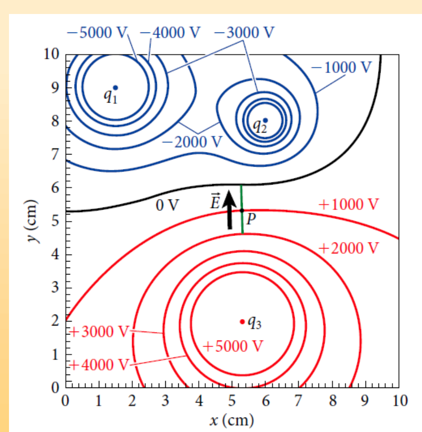
PYSICS FOR G12 ADVANCED

ELECTRIC potential

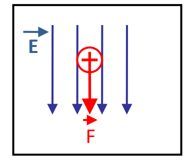
2020-2021

EXERCISES AND ADDITIONAL PROBLEMS





Electric potential.



1- Electric potential energy of a charge: U

"The energy gained by a charge because of its position in an electric field."

Change in potential energy of a charge: ΔU

It equals negative the work done by the electric force to transfer the charge from one point to the another point in the electric field.

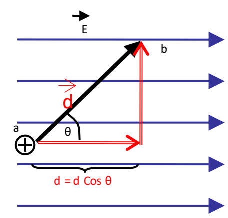
$$\Delta U_{a\text{-}b} = -W_{a\text{-}b} \qquad (\text{where: } \Delta U_{a\text{-}b} = U_b - U_a)$$

The potential energy of a charge: U_b

It equals negative the work done by the electric force to transfer the charge from infinity to a point in the electric field.

$$\Delta U_{\infty\text{-}b} = U_b - U_\infty = U_b = -W_{\infty\text{-}b} \qquad (\text{considering } U_\infty = 0 \text{ at } \infty)$$

Change in potential energy of a charge in a uniform electric field:



When a charge is transferred with a constant velocity in a uniform electric field, the change of its potential energy will be given by:

$$\Delta U_{a\text{-}b} = U_b - U_a = -q\,E\,d$$

Change in potential energy of a charge

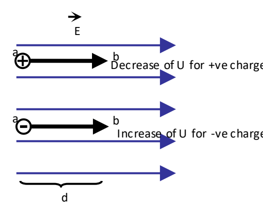
The transferred charge

The electric field

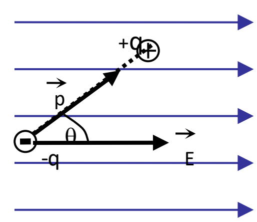
The displacement parallel to the field

Note: -The potential energy of a positive charge decreases in the direction of the electric field.

-The potential energy of a negative charge decreases opposite to the direction of the electric field.



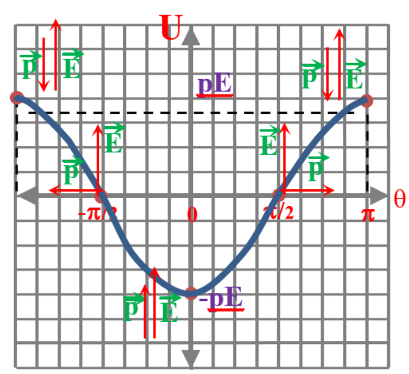
Change in potential energy of an electric dipole in a uniform electric field:



When an electric dipole is rotated in a uniform electric field, the torque exerts work on the dipole: $W_e = \int_{\theta_\circ}^{\theta} \vec{\tau}(\theta')d\theta' = \int_{\theta_\circ}^{\theta} -pE\sin(\dot\theta)d\dot\theta = -pE\int_{\theta_\circ}^{\theta}\sin(\dot\theta)d\dot\theta = pE(\cos\theta - \cos\theta_\circ)$

and the change of its potential energy will be given by:

$$\Delta U = U - U_\circ = -p\,E\cos\theta \qquad (\text{considering } U_\circ = 0 \text{ at } \theta_\circ = 90^\circ)$$



Note:

-The potential energy of a dipole equals zero when the dipole is perpendicular to the field.

-The potential energy of a dipole is minimum ($U=-pE$) when the dipole is parallel to the field.

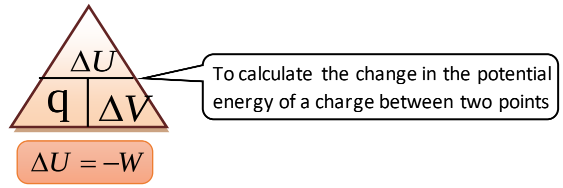
-The potential energy of a dipole is maximum ($U=+pE$) when the dipole is antiparallel to the field.

2- Change in electric potential and the electric potential:

-Change in electric potential: ΔV

"The change in potential energy of a positive test charge divided by the test charge."

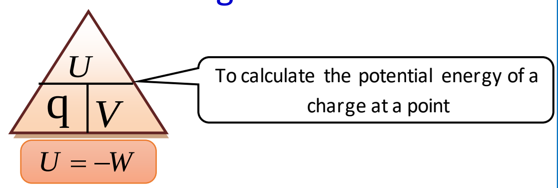
$$\Delta V = \frac{\Delta U}{q}$$



-Electric potential: V

"The potential energy of a positive test charge divided by the test charge."

$$V = \frac{U}{q}$$



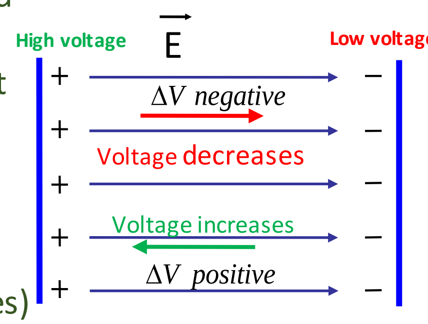
Notes:

-The electric potential and the potential difference both are measured in volt(Jule/Coulomb).

-The electric potential, like the electric field is a property independent of the charge at the point.

-The electric potential decreases in the direction of the field, and increases in a direction opposite to the field.

-The electric potential has the same value at all points on any line parallel to the charged planes (perpendicular to the electric field lines)



-In a uniform electric $\Delta V = \frac{\Delta U}{q} = \frac{-qEd}{q} \Rightarrow \Delta V = -Ed$

Example:

An electron is accelerated from rest between two points, through a potential difference of 20 V, in a uniform electric field 5000 V/m .

Solution:

1-Calculate the change in kinetic energy of the electron between these two points .

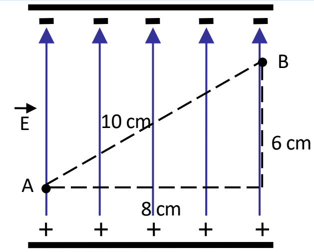
$$\Delta k = -\Delta U = -q\Delta V \quad \Rightarrow \quad \Delta k = -1.6\times10^{-19}(-20) = 3.2\times10^{-18}\,J$$

2-Find the distance after which the electron gains this kinetic energy.

$$\Delta V = -Ed \quad \Rightarrow \quad -20 = -5000d \quad \Rightarrow \quad d = 0.004m$$

3-Find the speed of the electron at the end of this distance.

$$\Delta k = \frac{1}{2}mv^2 \quad \Rightarrow \quad v = \sqrt{\frac{2\Delta k}{m}} \quad \Rightarrow \quad v = \sqrt{\frac{2\times3.2\times10^{-18}}{9.11\times10^{-31}}} \quad \Rightarrow \quad v = 2.65\times10^{6}m/s$$



Example: **In the figure A, and B, are two pointe in a uniform electric field 4×10^4 V/m . Using information on the figure, calculate:**

1-Calculate the change in electric potential from A to B.

Solution: $\Delta V = -E\,d \;\Rightarrow\; \Delta V_{A\to B} = -4\times10^4 \times 0.06 = -2400\ v$

2- Calculate the change in electric potential from B to A.

Solution: $\Delta V = -E\,d \;\Rightarrow\; \Delta V_{B\to A} = -4\times10^4 \times (-0.06) = +2400\ v$

3- Calculate the change in electric potential energy of a proton when transferred from A to B.

Solution: $\Delta P.E_{A\to B} = q\,\Delta V \;\Rightarrow\; \Delta P.E_{A\to B} = 1.6\times10^{-19} \times (-2400) = -3.84\times10^{-16}\ j$

4- Calculate the change in electric potential energy of a proton when transferred from B to A.

Solution: $\Delta P.E_{B\to A} = q\,\Delta V \;\Rightarrow\; \Delta P.E_{B\to A} = 1.6\times10^{-19} \times (+2400) = +3.84\times10^{-16}\ j$

Batteries:

"A battery is basically a device that converts chemical energy directly into electrical energy."

The weight of the batteries needs to be as small as possible.

They need to be rapidly rechargeable for hundreds of cycles.

They need to deliver as constant a potential difference as possible.

They need to be available at an affordable price.

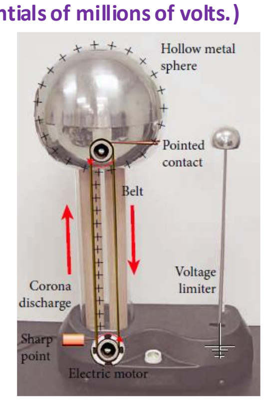
Lithium ion batteries:

	Advantages	Disadvantages
1	Has a much higher energy density, than conventional batteries	If a lithium ion battery is completely discharged, it can no longer be recharged.
2	They can be recharged hundreds of times.	Rising temperature decreases the efficiency of a lithium ion battery.
3	They have no "memory" effect and thus, do not need to be conditioned to hold their charge.	If the batteries are discharged too quickly, the constituents can catch fire or explode.

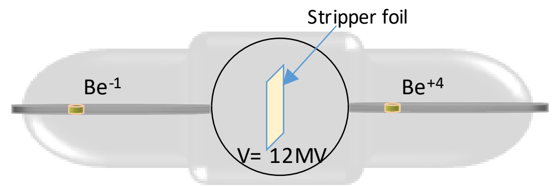
Van de Graaff generator:

A device creates large electric potentials. (Large Van de Graaff generators can produce electric potentials of millions of volts.)

Putting a high positive voltage on the sharp point ionize air molecules. The positive charges repelled away from the sharp point and deposited on the rubber belt. The moving belt, driven by an electric motor, carries the charge up into a hollow metal sphere, where the charge is taken from the belt by a pointed contact connected to the metal sphere. The charge that builds up on the metal sphere distributes itself uniformly around the outside of the sphere. On the Van de Graaff generator shown in Figure a voltage limiter is used to keep the generator from producing sparks larger than desired.



Example: Tandem Van de Graaff accelerator.



What is the highest kinetic energy that beryllium nuclei can attain in the tandem accelerator shown in figure?

1-Measured in Jules.

2-Measured in electron volts

Solution:

1- $\Delta k = |\Delta U| = |q_1 \Delta V| + |q_1 \Delta V| \Rightarrow \Delta k = |-e\Delta V| + |4e\Delta V| = 5e\Delta V = 5\times(1.6\times10^{-19})\times(12\times10^{6}) = 9.6\times10^{-12}\,J$

2- $\Delta k = \dfrac{9.6\times10^{-12}}{1.6\times10^{-19}} = 6\times10^{7}\,eV$

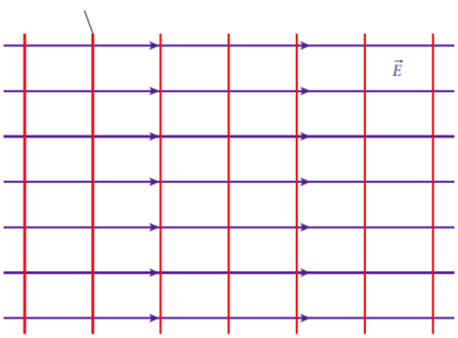
Equipotential Surfaces and lines:

Surfaces each of which contain all points that have the same electric potential.

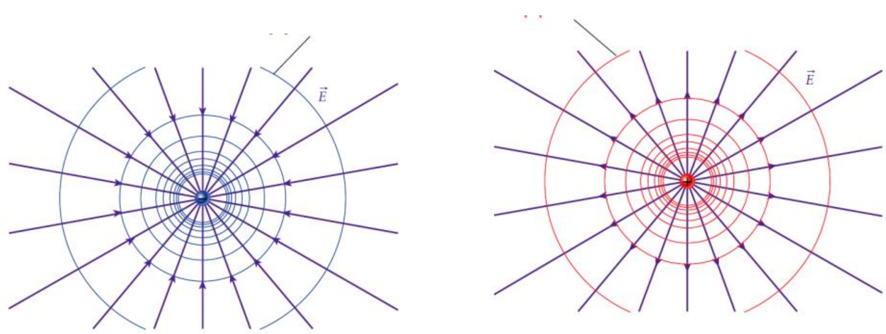
-The surface of any conductor forms an equipotential surface.

-Equipotential surfaces are always perpendicular to the electric field lines at any point in space.

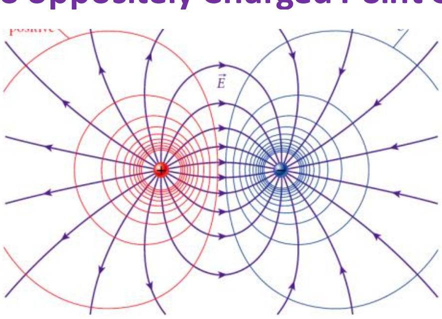
1- Constant electric Field:



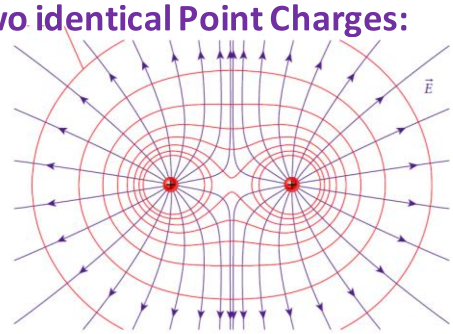
2- Single Point Charge:



3- Two oppositely Charged Point Charges:



4- Two identical Point Charges:



3- Electric Potential of Various Charge Distributions:

$$W=\int_{r_i}^{r_f} dw=\int_{r_i}^{r_f}\vec{F}\bullet d\vec{s}=q\int_{r_i}^{r_f}\vec{E}\bullet d\vec{s}$$

$$\Delta V=\frac{\Delta U_e}{q}=-\frac{W_e}{q}=-\int_{r_i}^{r_f}\vec{E}\bullet d\vec{s}$$

$$V(\vec{r})=-\int_{\infty}^{r}\vec{E}\bullet d\vec{s}$$

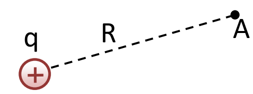
The electric potential can be calculated from the electric field:

$$V(\vec{r})=-\int_{\infty}^{r}\vec{E}\bullet d\vec{s}$$

Electric Potential for a point charge:

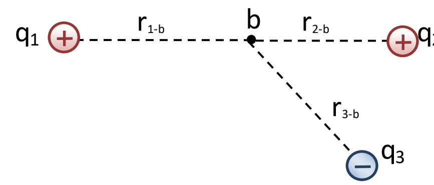
$$V(R)=-\int_{\infty}^{R}\vec{E}\bullet d\vec{s}=-\int_{\infty}^{R}\frac{kq}{r^2}dr=\left[\frac{kq}{r}\right]_{\infty}^{R}=\frac{kq}{R}$$

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



Electric Potential for a system of point charges:

$$V_{at\ b}=\frac{kq_1}{r_{1\to b}}+\frac{kq_2}{r_{2\to b}}+\frac{kq_3}{r_{3\to b}}+.......$$



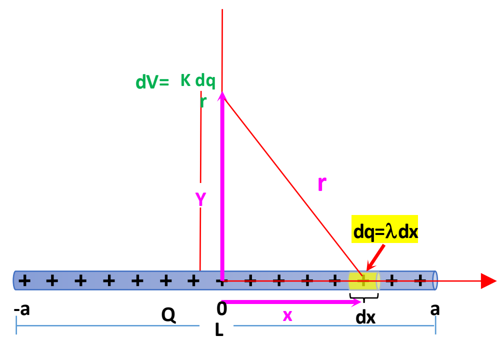
Continuous Charge Distribution:

Electric Potential a distance y from a finite charged wire:

$$V=\int_{-a}^{a}dV=\int_{-a}^{a}\frac{kdq}{r}=k\lambda\int_{-a}^{a}\frac{dx}{\sqrt{x^2+y^2}}=k\lambda\left[\ln(\sqrt{x^2+y^2}+x)\right]_{-a}^{+a}$$

$$V=k\lambda\left[\ln(\sqrt{a^2+y^2}+a)-\ln(\sqrt{(-a)^2+y^2}+(-a))\right]$$

$$V=k\lambda\left[\ln(\frac{\sqrt{a^2+y^2}+a}{\sqrt{a^2+y^2}-a})\right]$$

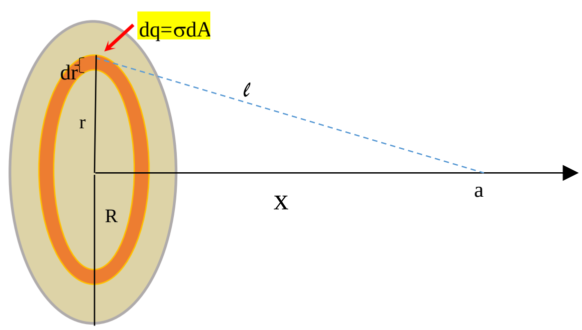


Electric Potential a distance x on the axis of a charged desk:

$$V=\int dV=\int\frac{kdq}{\ell}=\int\frac{k\sigma dA}{\sqrt{x^2+r^2}}=\int\frac{k\sigma 2\pi rdr}{\sqrt{x^2+r^2}}=\int\frac{k\frac{q}{\pi R^2}2\pi rdr}{\sqrt{x^2+r^2}}$$

$$V=\frac{2kq}{R^2}\int_0^R\frac{rdr}{\sqrt{x^2+r^2}}=\frac{2kq}{R^2}\left[\sqrt{x^2+r^2}\right]_0^R$$

$$V=\frac{2kq}{R^2}\left[\sqrt{x^2+R^2}-x\right]$$



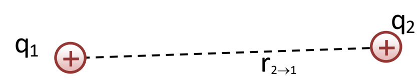
Finding the electric field from the electric potential:

The electric field can be calculated from the electric potential:

$$\vec{E}(\vec{r}) = -\nabla V = -\left(\frac{\partial V}{\partial x}\hat{x} + \frac{\partial V}{\partial y}\hat{y} + \frac{\partial V}{\partial z}\hat{z}\right)$$

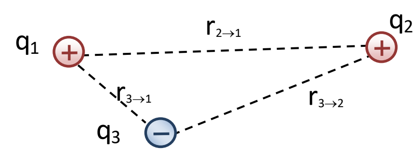
The potential energy in a system of point charges:

1- A system of two charges:



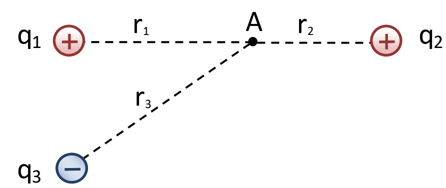
$$U = \frac{kq_2q_1}{r_{2\to1}}$$

2- A system of three charges:



$$U = \frac{kq_2q_1}{r_{2\to1}} + \frac{kq_3q_1}{r_{3\to1}} + \frac{kq_3q_2}{r_{3\to2}}$$

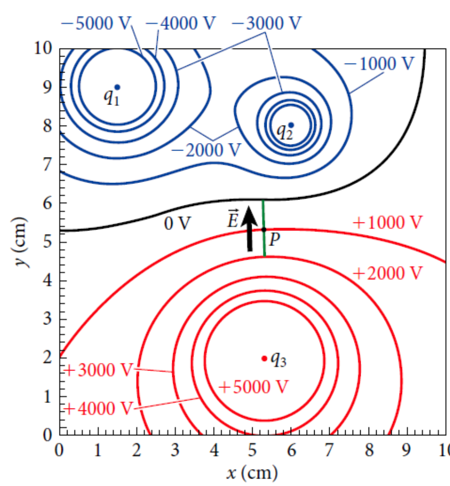
3- A system of four charges:



$$U = \frac{kq_2q_1}{r_{2\to1}} + \frac{kq_3q_1}{r_{3\to1}} + \frac{kq_3q_2}{r_{3\to2}} + \frac{kq_4q_1}{r_{4\to1}} + \frac{kq_4q_2}{r_{4\to2}} + \frac{kq_4q_3}{r_{4\to3}}$$

Graphical extraction of the electric field:

The electric field can be calculated graphically from the equipotential lines. $E_s = \left|-\frac{\Delta V}{\Delta s}\right|$



Example: Consider a system of three point charges. The electric potential, V(x,y), resulting from these charges is represented as shown in Figure.

Calculate the magnitude of the electric field at point P .

Solution:

$$E_s = \left|-\frac{\Delta V}{\Delta s}\right| \Rightarrow E_s = \left|-\frac{0-2000}{0.015}\right| \Rightarrow E_s = 1.3\times10^5 \ V/m$$

Choose the correct answer:

1- Which of the following is not a vector?

☐ electric force ☐ electric field ☐ electric potential ☐ electric line of force

2- One joule per coulomb is a

☐ newton ☐ volt ☐ electron-volt ☐ farad

3- Two identical aluminum objects are insulated from their surroundings. Object A has a net charge of excess electrons. Object B is grounded. Which object is at a higher potential?

☐ A ☐ Both are at the same potential.

☐ B ☐ cannot be determined without more information

4- For a proton moving in the direction of the electric field

☐ its potential energy increases and its electric potential decreases.

☐ its potential energy decreases and its electric potential increases.

☐ its potential energy increases and its electric potential increases.

☐ its potential energy decreases and its electric potential decreases.

5- For an electron moving in a direction opposite to the electric field

☐ its potential energy increases and its electric potential decreases.

☐ its potential energy decreases and its electric potential increases.

☐ its potential energy increases and its electric potential increases.

☐ its potential energy decreases and its electric potential decreases.

6- Several electrons are placed on a hollow conducting sphere. They

☐ clump together on the sphere's outer surface.

☐ clump together on the sphere's inner surface.

☐ become uniformly distributed on the sphere's outer surface.

☐ become uniformly distributed on the sphere's inner surface.

7- A small charged ball is accelerated from rest to a speed v by a 500 V potential difference. If the potential difference is changed to 2000 V, what will the new speed of the ball be?

☐ 1v ☐ 2v ☐ 4v ☐ 16v

8- A surface on which all points are at the same potential is referred to as

☐ a constant electric force surface. ☐ an equipotential surface.

☐ a constant electric field surface. ☐ an equivoltage surface.

9- A negative charge is moved from point A to point B along an equipotential surface.

☐ The negative charge performs work in moving from point A to point B.

☐ Work is required to move the negative charge from point A to point B.

☐ Work is both required and performed in moving the negative charge from point A to point B.

☐ No work is required to move the negative charge from point A to point B.

10- The energy acquired by a particle carrying a charge equal to that on the electron as a result of moving through a potential difference of one volt is referred to as

☐ a joule. ☐ an electron-volt. ☐ a proton-volt. ☐ a coulomb.

11- The absolute potential at a distance of 2.0 m from a positive point charge is 100 V. What is the absolute potential 4.0 m away from the same point charge?

☐ 25 v ☐ 50 v ☐ 200 v ☐ 400 v

12- The absolute potential at a distance of 2.0 m from a positive point charge is -100 V. What is the absolute potential 4.0 m away from the same point charge?

☐ -25 v ☐ -50 v ☐ -200 v ☐ -400 v

13- The absolute potential at the exact center of a square is 3.0 V when a charge of +Q is located at one of the square's corners. What is the absolute potential at the square's center when each of the other corners is also filled with a charge of +Q?

☐ zero ☐ 3 v ☐ 9 v ☐ 12 v

14- The absolute potential at the center of a square is 3.0 V when a charge of +Q is located at one of the square's corners. What is the absolute potential at the square's center when a second charge of -Q is placed at one of the remaining corners?

☐ zero ☐ 3 v ☐ 9 v ☐ 12 v

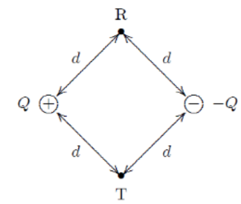
15- If 500 J of work are required to carry a charged particle between two points with a potential difference of 20V, the magnitude of the charge on the particle is:

☐ 0.04 C ☐ 12.5 C ☐ 20 C ☐ none of these

16- During a lightning discharge, 30C of charge move through a potential difference of 1.0×10^{8} V in 2.0×10^{-2} s. The energy released by this lightning bolt is:

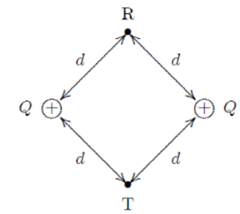
☐ 1.5×10^{11} J ☐ 3.0×10^{9} J ☐ 6.0×10^{7} J ☐ 1500 J

17- Points R and T are each a distance d from each of two particles with charges of equal magnitudes and opposite signs as shown, the work required to move a particle with a negative charge q from R to T is:



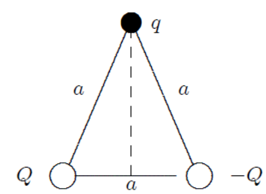
☐ $\frac{kqQ}{d}$ ☐ $\frac{kqQ}{\sqrt{2}d}$ ☐ $\frac{kqQ}{2d}$ ☐ 0.0

18- Points R and T are each a distance d from each of two particles with charges of equal magnitudes and opposite signs as shown, the work required to move a particle with a negative charge q from R to T is:



☐ $\frac{kqQ}{d}$ ☐ $\frac{kqQ}{\sqrt{2}d}$ ☐ $\frac{kqQ}{2d}$ ☐ 0.0

19- Two particle with charges Q and −Q are fixed at the vertices of an equilateral triangle with sides of length a, the work required to move a particle with charge q from the other vertex to the center of the line joining the fixed particles is:



☐ $\frac{\sqrt{2}kqQ}{a}$ ☐ $\frac{kqQ}{a}$ ☐ $\frac{2kqQ}{a}$ ☐ 0.0

20- A conducting sphere with radius R is charged until the magnitude of the electric field just outside its surface is E. The electric potential of the sphere, relative to the potential far away, is:

☐ 0 ☐ E/R ☐ ER ☐ E/R^2

21- A 5-cm radius conducting sphere has a surface charge density of 2×10^{-6} C/m^2 on its surface. Its electric potential, relative to the potential far away, is:

☐ 1.1×10^{4} V ☐ 2.2×10^{4} V ☐ 2.3×10^{5} V ☐ 3.6×10^{5} V

22- A hollow metal sphere is charged to a potential V. The potential at its center is:

☐ -V ☐ 0 ☐ V ☐ 2V

23- Positive charge is distributed uniformly throughout a non-conducting sphere. The highest electric potential occurs:

☐ at the center ☐ at the surface ☐ far from the sphere ☐ just outside the surface

24- A total charge of 7×10^{-8} C is uniformly distributed throughout a non-conducting sphere with a radius of 5 cm. The electric potential at the surface, relative to the potential far away, is about:
☐ -1.3×10^{4} V ☐ 1.3×10^{4} V ☐ 7.0×10^{5} V ☐ -6.3×10^{4} V

25- Eight identical spherical raindrops are each at a potential V, relative to the potential far away. They coalesce to make one spherical raindrop whose potential is:
☐ $V/8$ ☐ $V/2$ ☐ $2V$ ☐ $4V$ ☐ $8V$

26- A metal sphere carries a charge of 5×10^{-9} C and is at a potential of 400V, relative to the potential far away. The potential at the center of the sphere is:
☐ 400V ☐ −400V ☐ 2 × 10−6 V ☐ 0

27- A 5-cm radius isolated conducting sphere is charged so its potential is +100V, relative to the potential far away. The charge density on its surface is:
☐ $+2.2\times10^{-7}$ C/m^2 ☐ -2.2×10^{-7} C/m^2 ☐ $+3.5\times10^{-7}$ C/m^2 ☐ $+1.8\times10^{-8}$ C/m^2

28- The potential difference between the ends of a 2-meter stick that is parallel to a uniform electric field is 400V. The magnitude of the electric field is:
☐ 100 V/m ☐ 200 V/m ☐ 400 V/m ☐ 800 V/m

29- If the electric field is in the positive x direction and has a magnitude given by $E = Cx^2$, where C is a constant, then the electric potential is given by V =:
☐ $2Cx$ ☐ $-2Cx$ ☐ $Cx^3/3$ ☐ $-Cx^3/3$

30- The work required to carry a particle with a charge of 6.0C from a 5.0-V equipotential surface to a 6.0-V equipotential surface and back again to the 5.0-V surface is:
☐ 0.0 ☐ 1.2×10^{-5} J ☐ 3.0×10^{-5} J ☐ 6.0×10^{-5} J

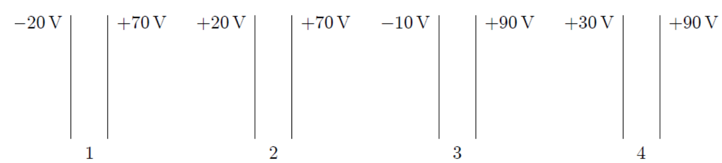
31- The equipotential surfaces associated with the charged point particles are:
☐ vertical planes ☐ radially outward from the particle
☐ horizontal planes ☐ concentric spheres centered at the particle

32- The electric field in a region around the origin is given by $\vec{E} = C(x\,\hat{\imath} + y\,\hat{\jmath})$, where C is a constant. The equipotential surfaces in that region are:
☐ concentric cylinders with axes along the z axis

□ concentric cylinders with axes along the x axis
□ concentric spheres centered at the origin
□ planes parallel to the xy plane

33- The electric potential in a certain region of space is given by $V = -7.5x^2 + 3x$, where V is in volts and x is in meters. In this region the equipotential surfaces are:
□ planes parallel to the x axis
□ planes parallel to the yz plane
□ concentric spheres centered at the origin
□ concentric cylinders with the x axis as the cylinder axis

34- The diagram shows four pairs of large parallel conducting plates. The value of the electric potential is given for each plate. Rank the pairs according to the magnitude of the electric field between the plates, least to greatest.



□ 4, 3, 2, 1 □ 2, 3, 1, 4 □ 2, 4, 1, 3 □ 3, 2, 4, 1

35- It takes 50 J of energy to move 10 C of charge from point A to point B. What is the potential difference between points A and B?
□ 500 V □ 50 V □ 5 V □ 0.5 V

36- The net work done in moving an electron from point A, where the potential is -50 V, to point B, where the potential is +50 V, is
□ $+1.6\times10^{-17}$ J. □ -1.6×10^{-17} J. □ Zero □ none of these

37- A proton, initially at rest, is accelerated through an electric potential difference of 500 V. What is the kinetic energy of the proton?
□ 500 J □ $+1.6\times10^{-19}$ J. □ $+8.0\times10^{-17}$ J. □ zero

38- A proton, initially at rest, is accelerated through an electric potential difference of 500 V. What is the speed of the proton?
□ 2.2×10^{5} m/s □ 3.1×10^{5} m/s □ 9.6×10^{10} m/s □ zero

39- How much work does 9.0 V do in moving 8.5×10^{18} electrons?
□ 12 J □ 7.7 J □ 1.4 J □ 1.1 J

40- Starting from rest, a proton falls through a potential difference of 1200 V. What speed does it acquire?

☐ 1.2×10^5 m/s ☐ 2.4×10^5 m/s ☐ 3.6×10^5 m/s ☐ 4.8×10^5 m/s

41- An electron (charge -1.6×10^{-19} C) moves on a path perpendicular to the direction of a uniform electric field of strength 3.0 N/C. How much work is done on the electron as it moves 15 cm?

☐ 4.8×10^{-20} J ☐ -4.8×10^{-20} J ☐ 1.6×10^{-20} J ☐ zero

42- A proton ($+1.6\times10^{-19}$ C) moves 10 cm on a path in the direction of a uniform electric field of strength 3.0 N/C. How much work is done on the proton by the electrical field?

☐ 4.8×10^{-20} J ☐ -4.8×10^{-20} J ☐ 1.6×10^{-20} J ☐ zero

43-

44- A stationary electron is accelerated through a potential difference of 500 V. What is the velocity of the electron afterward?

☐ 1.3×10^6 m/s ☐ 2.6×10^6 m/s ☐ 1.3×10^7 m/s ☐ 2.6×10^7 m/s

45- A 4.0-g ball carries a charge of 20 μC. The ball is accelerated from rest through a potential difference, and afterward the ball is moving at 2.0 m/s. What is the magnitude of the potential difference?

☐ 800 KV ☐ 400 KV ☐ 800 V ☐ 400 V

46- A 6.0-V battery maintains the electrical potential difference between two parallel metal plates separated by 1.0 mm. What is the electric field between the plates?

☐ 6.0 V ☐ 600 V ☐ 6000 V ☐ zero

47- A uniform electric field, with a magnitude of 500 V/m, is directed parallel to the +x axis. If the potential at x = 5.0 m is 2500 V, what is the potential at x = 2.0 m?

☐ 500 V ☐ 1000 V ☐ 2000 V ☐ 4000 V

48- A uniform electric field, with a magnitude of 600 N/C, is directed parallel to the positive x-axis. If the potential at x = 3.0 m is 1 000 V, what is the potential at x = 1.0 m?

☐ 400 V ☐ 1600 V ☐ 2200 V ☐ 2500 V

49- Consider a uniform electric field of 50 N/C directed toward the east. If the voltage measured relative to ground at a given point is 80 V, what is the voltage at a point 1.0 m directly west of that point?

☐ 30 V ☐ 50 V ☐ 80 V ☐ 130 V

50- A proton moves 0.10 m along the direction of an electric field of magnitude 3.0 V/m. What is the change in kinetic energy of the proton?

☐ 4.8×10^{-20} J ☐ 3.2×10^{-20} J ☐ 1.6×10^{-20} J ☐ 8.0×10^{-21} J

51- Two parallel plates, separated by 0.20 m, are connected to a 12-V battery. An electron released from rest at a location 0.10 m from the negative plate. When the electron arrives at a distance 0.050 m from the positive plate, what is the potential difference between the initial and final points?

☐ 2.4 V ☐ 3.0 V ☐ 4.8 V ☐ 6.0 V

52- Two parallel plates, separated by 0.20 m, are connected to a 12-V battery. An electron released from rest at a location 0.10 m from the negative plate. When the electron arrives at a distance 0.050 m from the positive plate, much kinetic energy does the electron gain?

☐ 2.4×10^{-19} J ☐ 4.8×10^{-19} J ☐ 7.2×10^{-19} J ☐ 9.6×10^{-19} J

53- Two parallel plates, separated by 0.20 m, are connected to a 12-V battery. An electron released from rest at a location 0.10 m from the negative plate. When the electron arrives at a distance 0.050 m from the positive plate, what is the speed of the electron?

☐ 5.0×10^{5} m/s ☐ 1.0×10^{6} m/s ☐ 5.0×10^{6} m/s ☐ 1.0×10^{7} m/s

54- A 5.0-nC charge is at (0, 0) and a -2.0-nC charge is at (3.0 m, 0). If the potential is taken to be zero at infinity, what is the electric potential energy of a 1.0-nC charge at point (0, 4.0 m)?

☐ 1.5×10^{-8} J ☐ 3.6×10^{-9} J ☐ 1.1×10^{-8} J ☐ 7.7×10^{-9} J

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

☐ lower potential and lower potential energy.

☐ lower potential and higher potential energy.

☐ higher potential and lower potential energy.

☐ higher potential and higher potential energy.

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

□ remain at rest.

□ move toward point B with constant velocity.

□ accelerate toward point A.

□ accelerate toward point B.

□ move toward point A with constant velocity.

57- What would be the consequence of setting the potential at +100 V at infinity, rather than taking it to be zero there?

□ Nothing; the field and the potential would have the same values at every finite point.

□ The electric potential would become infinite at every finite point, and the electric field could not be defined.

□ The electric potential everywhere would be 100V higher, and the electric field would be the same.

□ It would depend on the situation. For example, the potential due to a positive charge would drop off more slowly with distance, so the magnitude of the electric field would be less.

58- In which situation is the electric potential the highest?

□ at a point 1 m from a point charge of 1 C

□ at a point 1 m from the center of a uniformly charged spherical shell of radius 0.5 m with a total charge of 1 C

□ at a point 1 m from the center of a uniformly charged rod of length 1 m and with a total charge of 1 C

□ at a point 2 m from a point charge of 2 C

□ at a point 0.5 m from a point charge of 0.5 C

59- The amount of work done to move a positive point charge q on an equipotential surface of 1000 V relative to that on an equipotential surface of 10 V is

□ the same.

□ less.

□ more.

□ dependent on the distance the charge moves.

60- A solid conducting sphere of radius R is centered about the origin of an xyz-coordinate system. A total charge Q is distributed uniformly on the surface of the sphere. Assuming, as usual, that the electric potential is zero at an infinite distance, what is the electric potential at the center of the conducting sphere?

☐ zero ☐ $Q/\varepsilon_\circ R$ ☐ $Q/2\pi\varepsilon_\circ R$ ☐ $Q/4\pi\varepsilon_\circ R$

61- Which of the following angles between an electric dipole moment and an applied electric field will result in the most stable state?

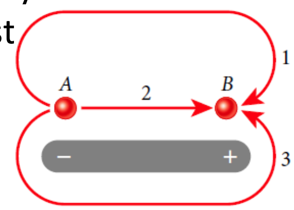
☐ 0 rad

☐ π/2 rad

☐ π rad

☐ The electric dipole moment is not stable under any condition in an applied electric field.

62- 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 being done by the dipole's electric field on the point charge?



☐ path 1 ☐ path 2

☐ path 3 ☐ The work is the same on all three paths.

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

☐ +5 C and +3 C ☐ +5 C and –3 C

☐ –5 C and +3 C ☐ All pairs have the same potential energy.

64- A negatively charged particle revolves in a clockwise direction around a positively charged sphere. The work done on the negatively charged particle by the electric field of the sphere is

☐ positive ☐ negative ☐ zero ☐ can not be determined

65- A hollow conducting sphere of radius R is centered about the origin of xyz-coordinate system. A total charge Q is distributed uniformly over the surface of the sphere. Assuming as, usual, that the electric potential is zero at infinite distance, what is the electric potential at the center of the sphere?

☐ zero ☐ kQ/R ☐ $kQ/2R$ ☐ $kQ/4R$

66- A solid conducting sphere of radius R has charge Q evenly distributed over its surface producing an electric potential $V_\circ$ at the surface. How much charge must be added to the sphere to increase the potential at the surface to $2V_\circ$?

☐ Q/2 ☐ Q ☐ 2Q ☐ Q^2

67- Which one of the following statements is not true?
- □ Equipotential lines are parallel to the electric field lines.
- □ Equipotential lines for a point charge are circular.
- □ Equipotential surfaces exist for any charge distribution.
- □ When a charge moves on an equipotential surface, the work done on the charge is zero.

68- If a proton and an alpha particle (composed of two protons and two neutrons) are each accelerated from rest through the same potential difference, how do their resulting speeds compare?
- □ The proton has twice the speed of the alpha particle.
- □ The proton has the same speed as the alpha particle.
- □ The proton has half the speed of the alpha particle.
- □ The speed of the proton is $\sqrt{2}$ times the speed of the alpha particle.
- □ The speed of the alpha particle is $\sqrt{2}$ times the speed of the proton.

69- If a positive charge moves in the direction of an electric field, its potential energy
- □ increases
- □ remains the same
- □ decreases
- □ increases rabidly then decreases.

70- If a negative charge moves in the direction of an electric field, its potential energy
- □ increases
- □ remains the same
- □ decreases
- □ increases rabidly then decreases.

71- When a charge +3C is transferred from point “a” to point “b” in a uniform electric field, its potential energy decreased by 27J, so, we conclude that the electric potential at “b”
- □ is 9 times less than the electric potential at “a”
- □ is 81 times less than the electric potential at “a”
- □ is 9 times greater than the electric potential at “a”
- □ is 81 times greater than the electric potential at “a”

72- When a proton is transferred a distance (2×10^{-2} m) in a uniform electric field, its potential energy increased by (2.4×10^{-19} J). What is the magnitude of the electric field.
- □ 75 N/C
- □ 33 N/C
- □ 0.03 N/C
- □ 1.3×10^{-2} N/C

73- Two points a distance (3.2 cm) apart on the same electric field line in a uniform field. The measured potential difference between them is (4.8 V).What is the magnitude of the electric field?

□ 150 V/m □ 1.5 V/m □ 0.15 V/m □ 6.7×10^{-3} V/m

74- When a positive charge moves, from point to another, in the direction of the electric field

□ its electric potential energy decreases and the electric potential at the point decreases.
□ its electric potential energy decreases and the electric potential at the point increases.
□ its electric potential energy increases and the electric potential at the point decreases.
□ its electric potential energy increases and the electric potential at the point increases.

75- When a negative charge moves, from point to another, in the direction of the electric field

□ its electric potential energy decreases and the electric potential at the point decreases.
□ its electric potential energy decreases and the electric potential at the point increases.
□ its electric potential energy increases and the electric potential at the point decreases.
□ its electric potential energy increases and the electric potential at the point increases.

76- The change in the potential energy of a charge divided by the charge itself is

□ the electric potential □ the electric potential difference
□ the electric potential energy □ the electron volt

77- If the potential energy of a proton thrown in a uniform electric field decreases by (1.5×10^{-8}J), what is the change in the kinetic energy of the proton?

□ -1.5×10^{-8}J □ zero □ $+1.5\times10^{-8}$J □ can not be determined

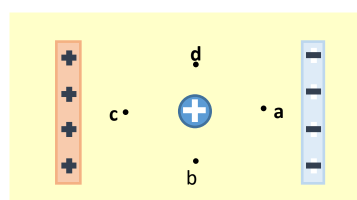
78- If a charge q_1=1μC is placed a distance 0.10 m from a charge q_2= 5μC , what is the relation between the potential energies of the two charges?

□ $U_2=5U_1$ □ $U_2=0.2\,U_1$ □ $U_2= -U_1$ □ $U_2= +U_1$

79- If the electric potential a distance "r" from a point charge is (800 V) and the electric field at the same point is (400 N/C), what is the distance "r" from the point charge?

□ 0.25 m □ 0.50 m □ 1.0 m □ 2.0 m

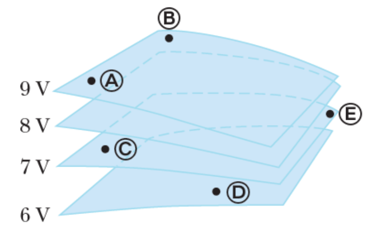
80- A light positively charged ball is released from rest in a uniform electric field as shown in figure, to which point should it be moved to increase its potential energy?



□ a □ b
□ c □ d

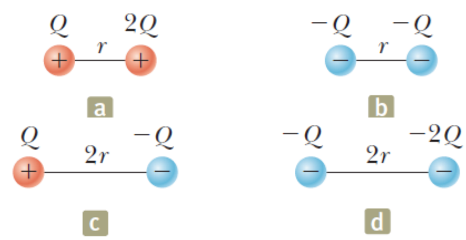
81- In a certain region of space, the electric field is zero. From this fact, what can you conclude about the electric potential in this region?
☐ It is zero. ☐ It does not vary with position. ☐ It is positive.
☐ It is negative. ☐ None of those answers is necessarily true.

82- Consider the equipotential surfaces shown in figure. In this region of space, what is the approximate direction of the electric field?
☐ It is out of the page. ☐ It is into the page.
☐ It is toward the top of the page. ☐ The field is zero.
☐ It is toward the bottom of the page.



83- The electric potential at x = 3.00 m is 120 V, and the electric potential at x = 5.00 m is 190 V. What is the x component of the electric field in this region, assuming the field is uniform?
☐ 140 N/C ☐ 2140 N/C ☐ 35.0 N/C ☐ 235.0 N/C
☐ 75.0 N/C

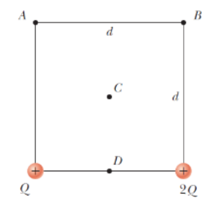
84- Rank the potential energies of the four systems of particles shown in figure from largest to smallest. Include equalities if appropriate.
☐ a=d>b>c ☐ a=b>d>c
☐ a>b=d>c ☐ d>b>c>a



85- In a certain region of space, a uniform electric field is in the x direction. A particle with negative charge is carried from x = 20.0 cm to x = 60.0 cm. Does the electric potential energy of the charge–field system
☐ increase? ☐ remain constant? ☐ decrease? ☐ change unpredictably?

86- In a certain region of space, a uniform electric field is in the x direction. A particle with negative charge is carried from x = 20.0 cm to x = 60.0 cm. Has the particle moved to a position where the electric potential is
☐ higher than before? ☐ lower than before?
☐ unchanged? ☐ unpredictable?

87- Rank the electric potentials at the four points shown in figure from largest to smallest.

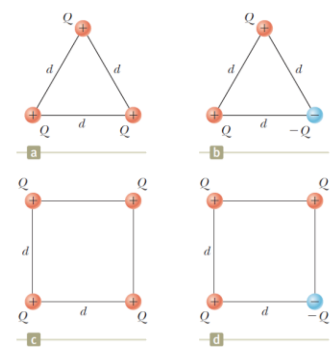


☐ D>C>B>A ☐ D>C>A>B
☐ A>B>C>D ☐ B>A>C>D

88- An electron in an x-ray machine is accelerated through a potential difference of 1.00×10^{4} V before it hits the target. What is the kinetic energy of the electron in electron volts?

☐ 1.00×10^{4} eV ☐ 1.60×10^{-15} eV ☐ 1.60×10^{-22} eV ☐ 6.25×10^{22} eV
☐ 1.60×10^{-19} eV

89- Rank the electric potential energies of the systems of charges shown in figure from largest to smallest. Indicate equalities if appropriate.



☐ c>d>a>b
☐ c>a>d>b
☐ c>a=b>d
☐ c=d>a=b
☐ b>a>d>c

90- Four particles are positioned on the rim of a circle. The charges on the particles are +0.500 μC, +1.50 μC, -1.00 μC, and -0.500 μC. If the electric potential at the center of the circle due to the +0.500 μC charge alone is 4.50×10^{4} V, what is the total electric potential at the center due to the four charges?

☐ 18.0×10^{4} V ☐ 4.50×10^{4} V ☐ 0.00 ☐ -4.50×10^{4} V
☐ 9.00×10^{4} V

91- A proton is released from rest at the origin in a uniform electric field in the positive x direction with magnitude 850 N/C. What is the change in the electric potential energy of the proton–field system when the proton travels to x = 2.50 m?

☐ $+3.40\times10^{-16}$ J ☐ -3.40×10^{-16} J ☐ $+2.50\times10^{-16}$ J ☐ -2.50×10^{-16} J
☐ -1.60×10^{-19} J

92- A particle with charge -40.0 nC is on the x axis at the point with coordinate x = 0. A second particle, with charge -20.0 nC, is on the x axis at x = 0.500 m.

(i) Is the point at a finite distance where the electric field is zero

☐ to the left of x = 0 ☐ between x = 0 and x = 0.500 m ☐ to the right of x 5 0.500 m?

(ii) Is the electric potential zero at this point?

☐ No; it is positive. ☐ Yes. ☐ No; it is negative.

(iii) Is there a point at a finite distance where the electric potential is zero?

☐ Yes; it is to the left of x = 0. ☐ Yes; it is between x = 0 and x =0.500 m.
☐ Yes; it is to the right of x 5 0.500 m. ☐ No.

93- A filament running along the x axis from the origin to x = 80.0 cm carries electric charge with uniform density. At the point "P" with coordinates (x = 80.0 cm, y = 80.0 cm), this filament creates electric potential 100 V. Now we add another filament along the y axis, running from the origin to y = 80.0 cm, carrying the same amount of charge with the same uniform density. At the same point "P", is the electric potential created by the pair of filaments

☐ greater than 200 V? ☐ 200 V? ☐ 100 V?
☐ between 0 and 200 V? ☐ 0?

94- In different experimental trials, an electron, a proton, or a doubly charged oxygen atom (O^{--}), is fired within a vacuum tube. The particle's trajectory carries it through a point where the electric potential is 40.0 V and then through a point at a different potential. Rank each of the following cases according to the change in kinetic energy of the particle over this part of its flight from <u>the largest increase</u> to <u>the largest decrease</u> in kinetic energy. In your ranking, display any cases of equality.

(a) An electron moves from 40.0 V to 60.0 V. ($\Delta k=+20e$)
(b) An electron moves from 40.0 V to 20.0 V. ($\Delta k=-20e$)
(c) A proton moves from 40.0 V to 20.0 V. ($\Delta k=+20e$)
(d) A proton moves from 40.0 V to 10.0 V. ($\Delta k=+30e$)
(e) An (O^{--}) ion moves from 40.0 V to 60.0 V. ($\Delta k=+40$)

☐ b>a>c>d>e ☐ e>d>a=c>b ☐ d>a=c=e>b ☐ d>e>c>a>b

95- A helium nucleus (charge=2e, mass=6.63×10^{-27} kg) traveling at 6.20×10^{5} m/s enters an electric field, traveling from point A, at a potential of 1.50×10^{3} V, to point B, at 4.00×10^{3} V. What is its speed at point B?

☐ 7.91×10^{5} m/s ☐ 4.91×10^{5} m/s ☐ 2.13×10^{5} m/s ☐ 3.78×10^{5} m/s
☐ 3.01×10^{8} m/s

96- How much energy is necessary to place three charges, each of 2.0 mC, at the corners of an equilateral triangle of side 2.0 cm?

☐ 4.5 J ☐ 5.4 J ☐ 6.7 J ☐ 7.6 J

97- A particle with a charge of 5.5×10^{-8} C is 3.5 cm from a particle with a charge of -2.3×10^{-8} C. The potential energy of this two-particle system, relative to the potential energy at infinite separation, is:

☐ 3.2×10^{-4} J ☐ -3.2×10^{-4} J ☐ 9.3×10^{-3} J ☐ -9.3×10^{-3} J

98- A particle with a charge of 5.5×10^{-8} C is fixed at the origin. A particle with a charge of -2.3×10^{-8} C is moved from x = 3.5 cm on the x axis to y = 4.3 cm on the y axis. The change in potential energy of the two-particle system is:

☐ 3.1×10^{-3} J ☐ -3.1×10^{-3} J ☐ 6.0×10^{-5} J ☐ -6.0×10^{-5} J

99- Three particles lie on the x axis: particle 1, with a charge of 1×10^{-8} C is at x = 1 cm, particle 2, with a charge of 2×10^{-8} C, is at x = 2 cm, and particle 3, with a charge of -3×10^{-8} C, is at x = 3 cm. The potential energy of this arrangement, relative to the potential energy for infinite separation, is:

☐ 4.9×10^{-4} J ☐ -4.9×10^{-4} J ☐ 8.5×10^{-4} J ☐ -8.5×10^{-5} J

100- If the distance between two negative point charges is increased by a factor of three, the resultant potential energy is what factor times the initial potential energy?

☐ 3.0 ☐ 9.0 ☐ ⅓ ☐ $\frac{1}{9}$

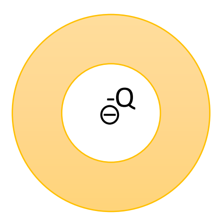
101- Two point-charges of values +3.4 and +6.6 μC, respectively, are separated by 0.20 m. What is the potential energy of this 2-charge system?

☐ +0.34 J ☐ -0.75 J ☐ +1.0 J ☐ -3.4 J

102- Two protons, each of charge 1.60×10^{-19} C, are 2.00×10^{-5} m apart. What is the change in potential energy if they are brought 1.00×10^{-5} m closer together?

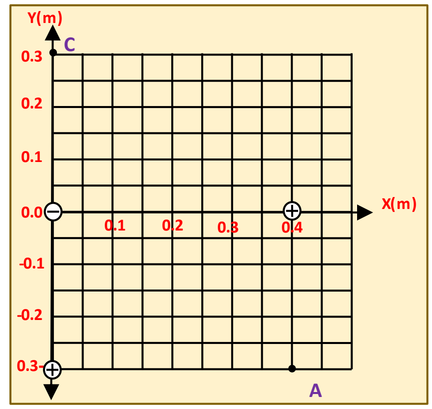
☐ 1.15×10^{-23} J ☐ 3.20×10^{-19} J ☐ 3.20×10^{-16} J ☐ 1.60×10^{-14} J

103- There is a hollow, conducting, uncharged sphere with a negative charge inside the sphere. Consider the electrical potential at the inner and outer surfaces of the sphere. Which of the following is true?

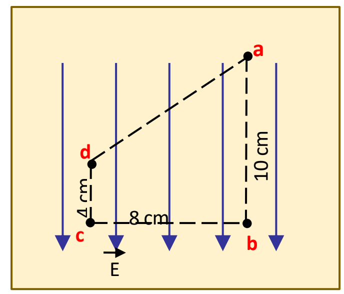


☐ The potential on the inner surface is greater.
☐ The potential on the outer surface is greater.
☐ The potentials on both surfaces are zero.
☐ The potentials on both surfaces are equal but not zero.

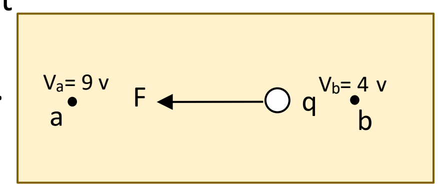
Solve the following problems:



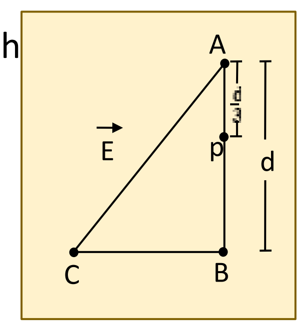
1) Three charges q_1=-8 nC , q_2=+2 nC , and q_3=+15 nC are located as shown in figure.
   1- Calculate the electric potential at the two points "A" and "C"
   2- Find the change in potential when moving from "A" to "C"
   3- Calculate the change in the electric potential energy of a proton when transferred from "A" to "C"



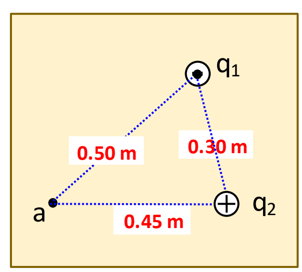
2) In the figure shown, the magnitude of the electric field equals 5 N/C.
   1- At which of the given point is the electric potential greater?
   2- Name two points have the same potential.
   3- Calculate the change in the electric potential from "a" to "d"
   4- Calculate the change in the electric potential energy of a charge 2μC when transferred from "c" to "d"



3) In the figure shown, a charge q is moving from point "b" to point "a" in a uniform electric field.
   1- Draw on the figure the electric field lines showing its direction.
   2- Calculate the change in the electric potential energy of the charge (1.6×10^{-12}) when transferred from "b" to "a"

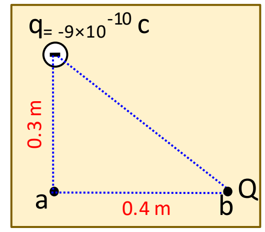


4) The points "A" , "B" , and "C" are the corners of right angle triangle in a uniform electric field. The electric potential at "A" equals 4 V and at both "B" and "C" equals 10V.
   1- Draw the direction of the electric field lines on the figure.
   2- What happens to the electric potential energy of an electron when transferred from "A" to "B"? Explain your answer.
   3- If an electron is released from rest at point "p" , in which direction would it move? Explain your answer.
   4- Calculate the electric potential at point "p".



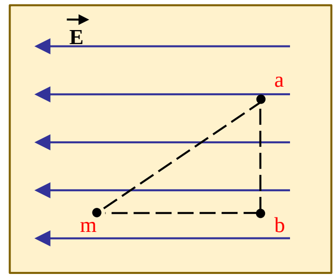
5) In the figure shown, the point "a" in the electric field of the two charges (q_1= -2.0×10^{-8} C), and (q_2= $+2.0\times10^{-8}$ C).
   1- Calculate the electric potential at point "a".
   2- Find the work exerted by the electric force to transfer the charge q_2 from "b" to "a".

6) In the figure shown, the electric potential at point "a" equals zero.
   1- Find the charge Q.
   2- What is the electric potential at point "b" ?



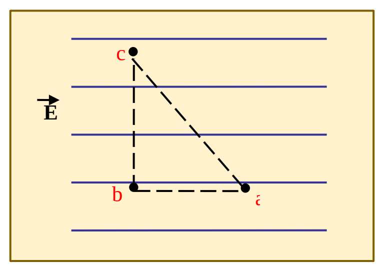
7) An electron is released from rest in a uniform electric field ($+5.0\times10^3$ V/m), it moves on y-axis from y_i=8 cm to y_f= -2 cm .
   1- Calculate the change in electric potential acting on the electron through this displacement.
   2- Find the change in electric potential energy between these two points.

8) A charge (2.0×10^{-9} C) loses ($+4.2\times10^{-8}$ J) of its potential energy when transferred in a uniform electric from "a" to "b" as shown in figure.
   1- Find the change in electric potential from "a" to "b".
   2- If an electron is transferred from "m" to "a", then to "b".
   What happens to its potential energy:
   * From : "m" to "a" * From : "a" to "b"

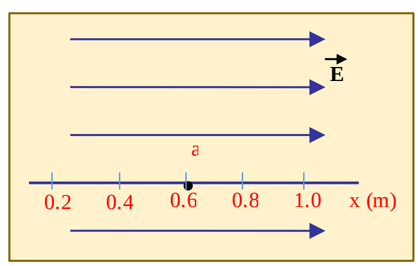


9) An electron is released in a uniform electric field, moves from rest at point x_i = +8 cm to point x_f = +18 cm, where its potential energy decreased by ($+2.0\times10^{-18}$ J).
   1- Find the magnitude of the electric field and determine its direction.
   2- If the electric potential energy of the electron at "x_i" equals ($+2.0\times10^{-18}$ J), what is the total mechanical energy of the electron at point "x_f".

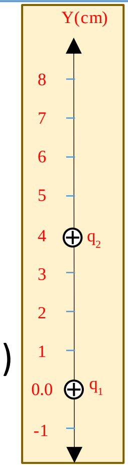
10) Three points "a" , "b" , and "c" in a uniform electric field (200N/C) as shown in figure. Knowing that $V_a<V_b$:
   1- Compare the electric potential energy of a proton at point "a", to that at each of the other points "b" , and "c".
   2- Determine and draw on figure the direction of the electric field.



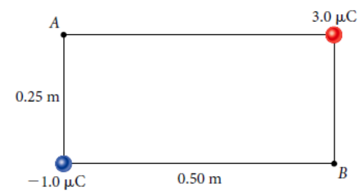
11) In the figure point "a" located at x=0.6 m , in a uniform electric field 2000 N/C .If another point "b" on x-axis has an electric potential 800 V greater than that at "a", find the distance from "b" to "a" and locate the position of the point "b" on the figure.



12) In the figure shown, two charges $q_1 = 4\ \mu C$, and $q_2 = 9\mu C$ are fixed in space on the y-axis.
Answer the following:
1- Determine the point "P" on y-axis at which the electric potential from both of the charges has a minimum.
2- Calculate the electric potential at "P".
3- Find the change in potential energy of a proton if transferred from point O(0,3cm) to point "P".



13) Two point-charges are located at two corners of a rectangle, as shown in the figure.
a) What is the electric potential at point A?
b) What is the potential difference between points A and B?



14) In molecules of gaseous sodium chloride, the chloride ion has one more electron than proton, and the sodium ion has one more proton than electron. These ions are separated by about 0.24 nm. How much work would be required to increase the distance between these ions to 1.0 cm?

15) A metal ball with a mass of 3.00×10^{-6} kg and a charge of +5.00 mC has a kinetic energy of 6.00×10^{8} J. It is traveling directly at an infinite plane of charge with a charge distribution of $+4.00\ C/m^2$. If it is currently 1.00 m away from the plane of charge, how close will it come to the plane before stopping?

16) An electron is accelerated from rest through a potential difference of 370 V. What is its final speed?

17) 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?

18) Two protons at rest and separated by 1.00 mm are released simultaneously. What is the speed of either at the instant when the two are 10.0 mm apart?

19) A proton with a speed of $1.23 \cdot 10^4$ m/s is moving from infinity directly toward a second proton. Assuming that the second proton is fixed in place, find the position where the moving proton stops momentarily before turning around.

20) What potential difference is needed to give an alpha particle (composed of 2 protons and 2 neutrons) 200 keV of kinetic energy?

21) A proton, initially at rest, is accelerated through a potential difference of 500. V. What is its final velocity?

22) 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.
a) What kinetic energy does the electron have just as it reaches the positive plate?
b) What is the speed of the electron just as it reaches the positive plate?

23) A particle with a charge of +5 μC is released from rest at a point on the x-axis, where x = 0.1 m. It begins to move as a result of the presence of a +9.0-μC charge that remains fixed at the origin. What is the kinetic energy of the particle at the instant it passes the point x = 0.20 m?

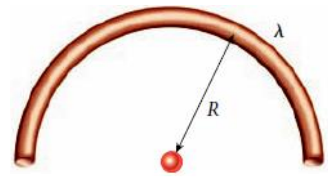
24) proton gun fires a proton from midway between two plates, A and B, which are separated by a distance of 10.0 cm; the proton initially moves at a speed of 150.0 km/s toward plate B. Plate A is kept at zero potential, and plate B at a potential of 400.0 V.
a) Will the proton reach plate B?
b) If not, where will it turn around?
c) With what speed will it hit plate A?

25) The ammonia molecule (NH_3) has a dipole moment of 5.0×10^{-30} C.m. Ammonia molecules in the gas phase are placed in a uniform electric field $\vec{E}$ with magnitude 1.6×10^{6} N/C.
(a) What is the change in electric potential energy when the dipole moment of a molecule changes its orientation with respect to $\vec{E}$ from parallel to perpendicular?
(b) At what absolute temperature T is the average translational kinetic energy ($\frac{2}{3}\ kT$) of a molecule equal to the change in potential energy calculated in part (a)? (Note: Above this temperature, thermal agitation prevents the dipoles from aligning with the electric field.)
$(Poltzmann\ constant\ is{:}\quad k = 1.38\times10^{-23}\ J/k)$

26) Fully stripped (all electrons removed) sulfur ($^{32}S_{16}$) ions are accelerated in an accelerator from rest using a total voltage of 1.0×10^{9} V. ($^{32}S_{16}$) has 16 protons and 16 neutrons. The accelerator produces a beam consisting of $6.61\cdot10^{12}$ ions per second. This beam of ions is completely stopped in a beam dump. What is the total power the beam dump has to absorb?

27) If a Van de Graff generator has an electric potential of 1.00×10^5 V and a diameter of 20.0 cm, find how many more protons than electrons are on its surface.

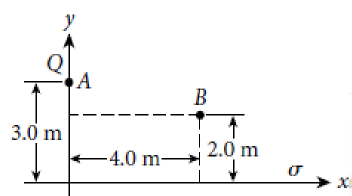
28) Find the potential at the center of curvature of the (thin) wire shown in the figure. It has a (uniformly distributed) charge per unit length of $\lambda = 3.00 \times 10^{-8}$ C/m and a radius of curvature of R = 8.00 cm.



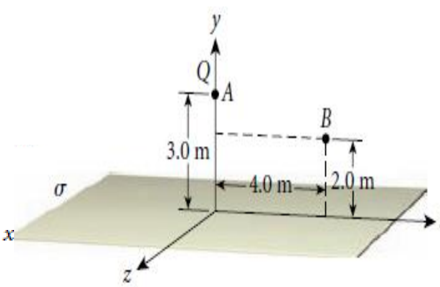
29) A 12-V battery is connected between a hollow metal sphere with a radius of 1 m and a ground, as shown in the figure. What are the electric field and the electric potential inside the hollow metal sphere?

30) A solid metal ball with a radius of 3.00 m has a charge of 4.00 mC. If the electric potential is zero far away from the ball, what is the electric potential at each of the following positions?
a) at r = 0 m, the center of the ball
b) at r = 3.00 m, on the surface of the ball
c) at r = 5.00 m

31) An insulating sheet in the xz-plane is uniformly charged with a charge distribution $\sigma = 3.5 \times 10^{-6}$ C/m. What in is the change potential when a charge of Q = 1.25 μC is moved from position A to position B in the figure?

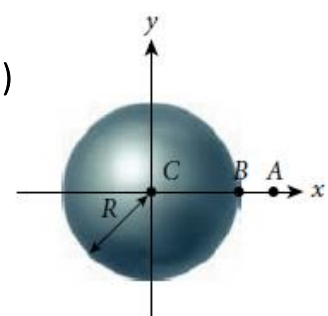


Side view



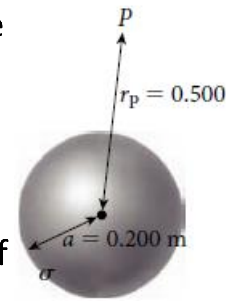
32) Suppose that an electron inside a cathode ray tube starts from rest and is accelerated by the tube's voltage of 21.9 kV. What is the speed with which the electron (mass = 9.11×10^{-31} kg) hits the screen of the tube?

33) A conducting solid sphere (radius of R = 18 cm, charge of $q = 6.1 \times 10^{-6}$ C) is shown in the figure. Calculate the electric potential at a point 24 cm from the center (point A), a point on the surface (point B), and at the center of the sphere (point C). Assume that the electric potential is zero at points infinitely far away from the origin of the coordinate system.



34) A classroom Van de Graaff generator accumulates a charge of 1.00×10^{-6} C on its spherical conductor, which has a radius of 10.0 cm and stands on an insulating column. Neglecting the effects of the generator base or any other objects or fields, find the potential at the surface of the sphere. Assume that the potential is zero at infinity.

35) The solid metal sphere of radius a = 0.200 m shown in the figure has a surface charge distribution of σ. The potential difference between the surface of the sphere and a point P at a distance P = 0.500 m from the center of the sphere is $\Delta V = V_{surface} - V_P = +4\pi$ V = +12.566 V. Determine the value of σ.



36) A point charge of +2.0 μC is located at (2.5 m,3.2 m). A second point charge of located at (–2.1 m,1.0 m).
a) What is the electric potential at the origin?
b) Along a line passing through both point charges, at what point(s) is (are) the electric potential(s) equal to zero?

37) Two fixed point charges are on the x-axis. A charge of –3.00 mC is located at x = +2.00 m and a charge of +5.00 mC is located at x = –4.00 m.
a) Find the electric potential, V(x), for an arbitrary point on the x-axis.
b) At what position(s) on the x-axis is V(x) = 0?
c) Find E(x) for an arbitrary point on the x-axis.

38) 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.
b) An electron is initially placed halfway between the plates. Find its kinetic energy when it hits the positive plate.

39) An electric field is established in a nonuniform rod. A voltmeter is used to measure the potential difference between the left end of the rod and a point a distance x from the left end. The process is repeated, and it is found that the data are described by the relationship ($\Delta V = 270x^2$), where ΔV has the units V/m^2. What is the x-component of the electric field at a point 13 cm from the left end?

40) A 2.50-mg dust particle with a charge of 1.00 μC falls at a point x = 2.00 m in a region where the electric potential varies according to $V(x) = (2.00 \text{ V/m}^2)x^2 - (3.00 \text{ V/m}^3)x^3$. With what acceleration will the particle start moving after it touches down?

41) The electric potential in a volume of space is given by $V(x, y, z) = x^2 + xy^2 + yz$. Determine the electric field in this region at the coordinate (3,4,5).

42) The electric field strength between two parallel conducting plates separated by 4.00 cm is 7.50×10^4 V/m .
(a) What is the potential difference between the plates?
(b) The plate with the lowest potential is taken to be zero volts. What is the potential 1.00 cm from that plate and 3.00 cm from the other?

43) The voltage across a membrane forming a cell wall is 80.0 mV and the membrane is 9.00 nm thick. What is the electric field strength? (The value is surprisingly large, but correct.) You may assume a uniform electric field.

44) Two parallel conducting plates are separated by 10.0 cm, and one of them is taken to be at zero volts.
(a) What is the electric field strength between them, if the potential 8.00 cm from the zero volt plate (and 2.00 cm from the other) is 450 V?
(b) What is the voltage between the plates?

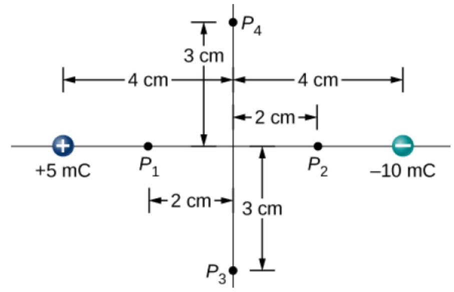
45) Find the maximum potential difference between two parallel conducting plates separated by 0.50 cm of air, given the maximum sustainable electric field strength in air to be 3.0×10^6 V/m .

46) An electron is to be accelerated in a uniform electric field having a strength of 2.00×10^6 V/m.
(a) What energy in keV is given to the electron if it is accelerated through 0.400 m?
(b) Over what distance would it have to be accelerated to increase its energy by 50.0 GeV?

47) In nuclear fission, a nucleus splits roughly in half.
(a) What is the potential 2.00×10^{-14} m from a fragment that has 46 protons in it?
(b) What is the potential energy in MeV of a similarly charged fragment at this distance?

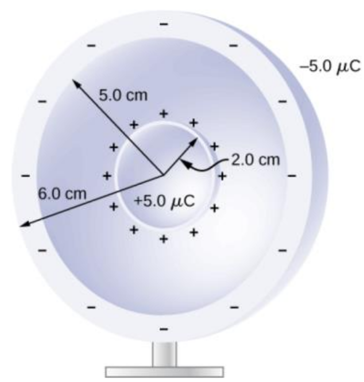
48) A research Van de Graaff generator has a 2.00-mdiameter metal sphere with a charge of 5.00 mC on it.
(a) What is the potential near its surface?
(b) At what distance from its center is the potential 1.00 MV?
(c) An oxygen atom with three missing electrons is released near the Van de Graaff generator. What is its energy in MeV when the atom is at the distance found in part b?

49) Find the potential at points P_1, P_2, P_3, and P_4 in the diagram due to the two given charges.



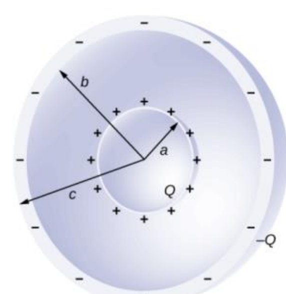
50) A very large sheet of insulating material has had an excess of electrons placed on it to a surface charge density of –3.00 nC/m^2.
(a) As the distance from the sheet increases, does the potential increase or decrease? Can you explain why without any calculations? Does the location of your reference point matter?
(b) What is the shape of the equipotential surfaces?
(c) What is the spacing between surfaces that differ by 1.00 V?

51) A metallic sphere of radius 2.0 cm is charged with +5.0-μC charge, which spreads on the surface of the sphere uniformly. The metallic sphere stands on an insulated stand and is surrounded by a larger metallic spherical shell, of inner radius 5.0 cm and outer radius 6.0 cm. Now, a charge of −5.0-μC is placed on the inside of the spherical shell, which spreads out uniformly on the inside surface of the shell. If potential is zero at infinity, what is the potential of (a) the spherical shell, (b) the sphere, (c) the space between the two, (d) inside the sphere, and (e) outside the shell?



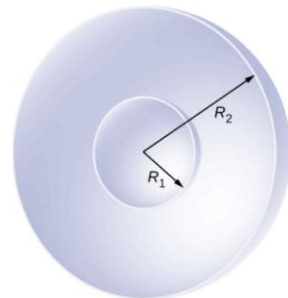
52) A point charge of q = 5.0 × 10^{-8} C is placed at the center of an uncharged spherical conducting shell of inner radius 6.0 cm and outer radius 9.0 cm. Find the electric potential at (a) r = 4.0 cm, (b) r = 8.0 cm, (c) r = 12.0 cm.

53) Concentric conducting spherical shells carry charges Q and –Q, respectively. The inner shell has negligible thickness. What is the potential difference between the shells?



54) A small spherical pith ball of radius 0.50 cm is painted with a silver paint and then −10 µC of charge is placed on it. The charged pith ball is put at the center of a gold spherical shell of inner radius 2.0 cm and outer radius 2.2 cm. (a) Find the electric potential of the gold shell with respect to zero potential at infinity. (b) How much charge should you put on the gold shell if you want to make its potential 100 V?

55) Shown below are two concentric spherical shells of negligible thicknesses and radii R_1 and R_2. The inner and outer shell carry net charges q_1 and q_2, respectively, where both q_1 and q_2 are positive. What is the electric potential in the regions (a) $r < R_1$, (b) $R_1 < r < R_2$, and (c) $r > R_2$?



56) Two large charged plates of charge density ±30 µC/m² face each other at a separation of 5.0 mm.
(a) Find the electric potential everywhere.
(b) An electron is released from rest at the negative plate; with what speed will it strike the positive plate?

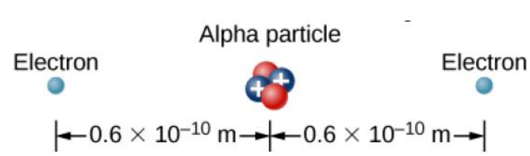
57) Throughout a region, equipotential surfaces are given by z = constant . The surfaces are equally spaced with V = 100 V for z = 0.00 m, V = 200 V for z = 0.50 m, V = 300 V for z = 1.00 m. What is the electric field in this region?

58) In a particular region, the electric potential is given by $V = -xy^2z + 4xy$. What is the electric field in this region?

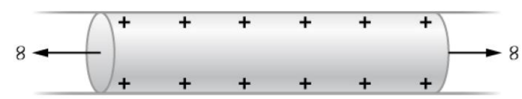
59) Calculate the electric field of an infinite line charge, throughout space.

60) Two parallel plates 10 cm on a side are given equal and opposite charges of magnitude 5.0×10^{-9} C. The plates are 1.5 mm apart. What is the potential difference between the plates?

61) To form a helium atom, an alpha particle that contains two protons and two neutrons is fixed at one location, and two electrons are brought in from far away, one at a time. The first electron is placed at 0.600×10^{-10} m from the alpha particle and held there while the second electron is brought to 0.600×10^{-10} m from the alpha particle on the other side from the first electron. See the final configuration below.
(a) How much work is done in each step?
(b) What is the electrostatic energy of the alpha particle and two electrons in the final configuration?



62) The surface charge density on a long straight metallic pipe is σ. What is the electric potential outside and inside the pipe? Assume the pipe has a diameter of 2a.



63) The probability of fusion occurring is greatly enhanced when appropriate nuclei are brought close together, but mutual Coulomb repulsion must be overcome. This can be done using the kinetic energy of high temperature gas ions or by accelerating the nuclei toward one another.
(a) Calculate the potential energy of two singly charged nuclei separated by 1.00×10^{-12} m.
(b) At what temperature will atoms of a gas have an average kinetic energy ($\frac{2}{3}\ kT$) equal to this needed electrical potential energy? $(Poltzmann\ constant\ is: \quad k = 1.38 \times 10^{-23}\ J/k)$

64) A bare helium nucleus has two positive charges and a mass of 6.64×10^{-27} kg.
(a) Calculate its kinetic energy in joules at 2.00% of the speed of light. ($c=3\times10^{8}$ m/s)
(b) What is this in electron-volts?
(c) What voltage would be needed to obtain this energy?

65) In one of the classic nuclear physics experiments at the beginning of the twentieth century, an alpha particle was accelerated toward a gold nucleus, and its path was substantially deflected by the Coulomb interaction. If the energy of the doubly charged alpha nucleus was 5.00 MeV, how close to the gold nucleus (79 protons) could it come before being deflected?

66) A CD disk of radius (R = 3.0 cm) is sprayed with a charged paint so that the charge varies continually with radial distance r from the center in the following manner: $\sigma = -(6.0\ C/m)r/R$. Find the potential at a point 4 cm above the center.

67) (a) What is the final speed of an electron accelerated from rest through a voltage of 25.0 MV by a negatively charged Van de Graff terminal?
(b) What is unreasonable about this result?
(c) Which assumptions are responsible?

68) Two parallel conducting plates, each of cross-sectional area 400 cm^2, are 2.0 cm apart and uncharged. If 1.0×10^{12} electrons are transferred from one plate to the other,
(a) what is the potential difference between the plates?
(b) What is the potential difference between the positive plate and a point 1.25 cm from it that is between the plates?

69) A large metal plate is charged uniformly to a density of $\sigma = 2.0 \times 10^{-9}$ C/m^2. How far apart are the equipotential surfaces that represent a potential difference of 25 V?

70) A point charge q_1 is held stationary at the origin. A second charge q_2 is placed at point a, and the electric potential energy of the pair of charges is $+5.4\times10^{-8}$ J. When the second charge is moved to point b, the electric force on the charge does -1.9×10^{-8} J of work. What is the electric potential energy of the pair of charges when the second charge is at point b?

71) Energy of the Nucleus. How much work is needed to assemble an atomic nucleus containing three protons (such as Li) if we model it as an equilateral triangle of side 2.00×10^{-15} m with a proton at each vertex? Assume the protons started from very far away.

72) (a) How much work would it take to push two protons very slowly from a separation of 2.00×10^{-10} m (a typical atomic distance) to 3.00×10^{-15} m (a typical nuclear distance)?
(b) If the protons are both released from rest at the closer distance in part (a), how fast are they moving when they reach their original separation?

73) Three equal 1.20 μC point charges are placed at the corners of an equilateral triangle with sides 0.400 m long. What is the potential energy of the system? (Take as zero the potential energy of the three charges when they are infinitely far apart.)

74) Three point-charges, which initially are infinitely far apart, are placed at the corners of an equilateral triangle with sides d. Two of the point charges are identical and have charge q. If zero net work is required to place the three charges at the corners of the triangle, what must the value of the third charge be?

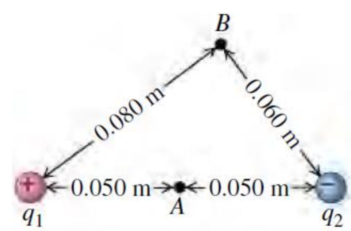
75) An object with charge $q = -6.00\times10^{-9}$ C is placed in a region of uniform electric field and is released from rest at point A. After the charge has moved to point B, 0.500 m to the right, it has kinetic energy 3.00×10^{-7} J. (a) If the electric potential at point A is +30.0 V, what is the electric potential at point B?

76) A small particle has charge -5.00 μC and mass 2.00×10^{-4} kg. It moves from point A, where the electric potential is $V_A = +200$ V, to point B, where the electric potential is $V_B = +800$ V. The electric force is the only force acting on the particle. The particle has speed 5.00 m/s at point A. What is its speed at point B? Is it moving faster or slower at B than at A? Explain.

77) A particle with charge +4.20 nC is in a uniform electric field $\vec{E}$ directed to the left. The charge is released from rest and moves to the left; after it has moved 6.00 cm, its kinetic energy is $+2.20\times10^{-6}$ J. What are (a) the work done by the electric force, (b) the potential of the starting point with respect to the end point, and (c) the magnitude of $\vec{E}$?

78) A charge of 28.0 nC is placed in a uniform electric field that is directed vertically upward and has a magnitude of 4.00×10^{4} V/m. What work is done by the electric force when the charge moves (a) 0.450 m to the right; (b) 0.670 m upward; (c) 2.60 m at an angle of 45 $^\circ$ downward from the horizontal?

79) Two point-charges q_1 =+2.40 nC and q_2 = -6.50 nC are 0.100 m apart. Point A is midway between them; point B is 0.080 m from q_1 and 0.060 m from q_2. Take the electric potential to be zero at infinity. Find:



(a) the potential at point A.
(b) the potential at point B.
(c) the work done by the electric field on a charge of 2.5nC that travels from point B to point A.

80) A total electric charge of 3.50 nC is distributed uniformly over the surface of a metal sphere with a radius of 24.0 cm. If the potential is zero at a point at infinity, find the value of the potential at the following distances from the center of the sphere: (a) 48.0 cm; (b) 24.0 cm; (c) 12.0 cm.

81) A uniformly charged, thin ring has radius 15.0 cm and total charge +24.0 nC. An electron is placed on the ring's axis a distance 30.0 cm from the center of the ring and is constrained to stay on the axis of the ring. The electron is then released from rest.
(a) Describe the subsequent motion of the electron.
(b) Find the speed of the electron when it reaches the center of the ring.

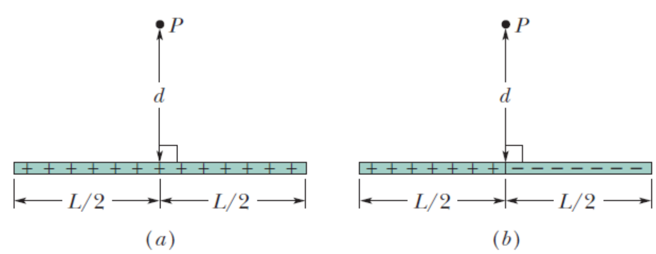
82) A ring of diameter 8.00 cm is fixed in place and carries a charge of +5.00 μC uniformly spread over its circumference.
(a) How much work does it take to move a tiny +3.00 μC charged ball of mass 1.50 g from very far away to the center of the ring?
(b) Is it necessary to take a path along the axis of the ring? Why?

83) A thin spherical shell with radius R_1 = 3.00 cm is concentric with a larger thin spherical shell with radius R_2 = 5.00 cm. Both shells are made of insulating material. The smaller shell has charge q_1 = +6.00 nC distributed uniformly over its surface, and the larger shell has charge q_2 = -9.00 nC distributed uniformly over its surface. Take the electric potential to be zero at an infinite distance from both shells.
(a) What is the electric potential due to the two shells at the following distance from their common center: (i) r = 0; (ii) r = 4.00 cm; (iii) r = 6.00 cm?
(b) What is the magnitude of the potential difference between the surfaces of the two shells? Which shell is at higher potential: the inner shell or the outer shell?

84) Charge Q = 5.0 μC is distributed uniformly over the volume of an insulating sphere that has radius R = 12.0 cm. A small sphere with charge q = +3.0 μC and mass 6.0×10^{-5} kg is projected toward the center of the large sphere from an initial large distance. The large sphere is held at a fixed position and the small sphere can be treated as a point charge. What minimum speed must the small sphere have in order to come within 8.0 cm of the surface of the large sphere?

85) A very long wire carries a uniform linear charge density λ. Using a voltmeter to measure potential difference, you find that when one probe of the meter is placed 2.50 cm from the wire and the other probe is 1.00 cm farther from the wire, the meter reads 575 V.
(a) What is λ?
(b) If you now place one probe at 3.50 cm from the wire and the other probe 1.00 cm farther away, will the voltmeter read 575 V? If not, will it read more or less than 575 V? Why?
(c) If you place both probes 3.50 cm from the wire but 17.0 cm from each other, what will the voltmeter read?

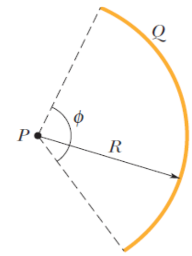
86) (a) Figure (a) shows a nonconducting rod of length L = 6.00 cm and uniform linear charge density λ=+3.68 pC/m. Assume that the electric potential is defined to be V = 0 at infinity. What is V at point P at distance d = 8.00 cm along the rod's perpendicular bisector?



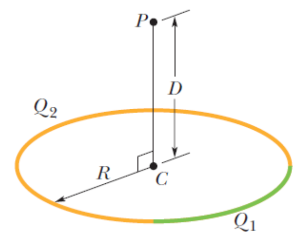
(b) Figure (b) shows an identical rod except that one half is now negatively charged. Both halves have a linear charge density of magnitude 3.68 pC/m. With V=0 at infinity, what is V at P?

87) A solid conducting sphere has net positive charge and radius R = 0.400 m. At a point 1.20 m from the center of the sphere, the electric potential due to the charge on the sphere is 24.0 V. Assume that V = 0 at an infinite distance from the sphere. What is the electric potential at the center of the sphere?

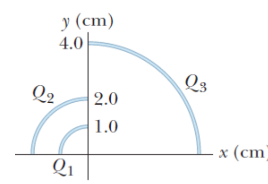
88) In figure, a plastic rod having a uniformly distributed charge Q=-25.6 pC has been bent into a circular arc of radius R = 3.71 cm and central angle $\phi = 120^{\circ}$. With V = 0 at infinity, what is the electric potential at P, the center of curvature of the rod?



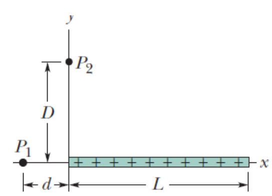
89) A plastic rod has been bent into a circle of radius R= 8.20 cm. It has a charge Q_1=+4.20 pC uniformly distributed along one quarter of its circumference and a charge Q_2 =-6Q1 uniformly distributed along the rest of the circumference. With V =0 at infinity, what is the electric potential at (the center C of the circle and (b) point P, on the central axis of the circle at distance D = 6.71 cm from the center?



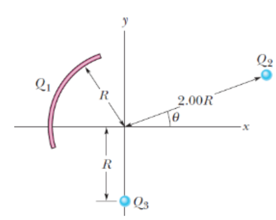
90) In the figure, three thin plastic rods form quarter-circles with a common center of curvature at the origin. The uniform charges on the three rods are Q_1=+30 nC, Q_2 =+3.0Q_1, and Q_3=-8.0Q_1. What is the net electric potential at the origin due to the rods?



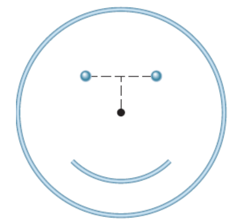
91) The figure shows a thin plastic rod of length L= 12.0 cm and uniform positive charge Q =6.1 fC lying on an x axis. With V = 0 at infinity, find the electric potential at point P_1 on the axis, at distance d = 2.50 cm from the rod.



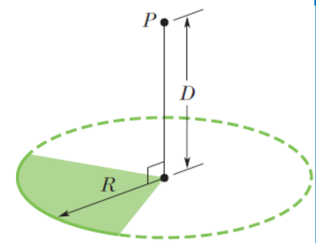
92) In the fig. 24-48, what is the net electric potential at the origin due to the circular arc of charge Q_1=+7.21 pC and the two particles of charges Q_2=4.00Q_1 and Q_3=-2.00Q_1? The arc's center of curvature is at the origin and its radius is R = 2.00 m; the angle indicated is $\theta = 20^{\circ}$.



93) The smiling face of Figure consists of three items:
1. a thin rod of charge -3.0 μC that forms a full circle of radius 6.0 cm.
2. a second thin rod of charge 2.0 μC that forms a circular arc of radius 4.0 cm, subtending an angle of 90° about the center of the full circle.
3. an electric dipole with a dipole moment that is perpendicular to a radial line and has a magnitude of 1.28×10^{-21} C.m. What is the net electric potential at the center?



94) A plastic disk of radius R=4.0 cm is charged on one side with a uniform surface charge density σ=7.73 fC/m^2, and then three quadrants of the disk are removed. The remaining quadrant is shown in figure. With V = 0 at infinity, what is the potential due to the remaining quadrant at point P, which is on the central axis of the original disk at distance D=25.9 cm from the original center?



95) Two large parallel metal plates are 1.5 cm apart and have charges of equal magnitudes but opposite signs on their facing surfaces. Take the potential of the negative plate to be zero. If the potential halfway between the plates is then +5.0 V, what is the electric field in the region between the plates?

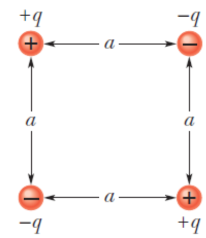
96) The electric potential at points in an xy plane is given by $V = \left(2.0\frac{V}{m^2}\right)x^2 - \left(3.0\ \frac{V}{m^2}\right)y^2$. In unit-vector notation, what is the electric field at the point (3.0 m, 2.0 m)?

97) The electric potential V in the space between two flat parallel plates 1 and 2 is given (in volts) by $V = 1500x^2$, where x (in meters) is the perpendicular distance from plate 1. At x =1.3 cm, (a) what is the magnitude of the electric field and (b) is the field directed toward or away from plate 1?

98) What is the magnitude of the electric field at the point $(3\hat{x} - 2\hat{y} + 4\hat{z})m$ if the electric potential in the region is given by $V = 2.00xyz^2$, where V is in volts and coordinates x, y, and z are in meters?

99) A particle of charge +7.5 μC is released from rest at the point x = 60 cm on an x axis. The particle begins to move due to the presence of a charge Q that remains fixed at the origin. What is the kinetic energy of the particle at the instant it has moved 40 cm if:
(a) Q=+20 μC and (b) Q=-20 μC?

100) How much work is required to set up the arrangement of the figure shown, if q = 2.30 pC, a= 64.0 cm, and the particles are initially infinitely far apart and at rest?



101) (a) What is the electric potential energy of two electrons separated by 2.00 nm?
(b) If the separation increases, does the potential energy increase or decrease?

102) A particle of charge q is fixed at point P, and a second particle of mass m and the same charge q is initially held a distance r_1 from P. The second particle is then released. Determine its speed when it is a distance r_2 from P. Let q=3.1 μC, m=20 mg, r_1=0.90 mm, and r_2=2.5 mm.

103) Sphere 1 with radius R_1 has positive charge q. Sphere 2 with radius $2R_1$ is far from sphere 1 and initially uncharged. After the separated spheres are connected with a wire thin enough to retain only negligible charge, (a) is potential V_1 of sphere 1 greater than, less than, or equal to potential V_2 of sphere 2? What fraction of q ends up on (b) sphere 1 and (c) sphere 2? (d) What is the ratio s_1/s_2 of the surface charge densities of the spheres?

104) Two isolated, concentric, conducting spherical shells have radii R_1=0.500 m and R_2=1.00 m, uniform charges q_1=+2.00 μC and q_2=+1.00 μC, and negligible thicknesses. What is the magnitude of the electric field E at radial distance (a) r=4.00 m, (b) r=0.700 m, and (c) r=0.200 m? With V=0 at infinity, what is V at (d) r=4.00 m, (e) r=1.00 m, (f) r=0.700 m, (g) r=0.500 m, (h) r=0.200 m, and (i) r=0? (j) Sketch E(r) and V(r).

105) In a certain region of space the electric potential is given by $V = +Ax^2y - Bxy^2$, where A = 5.00 V/m^3 and B = 8.00 V/m^3. Calculate the magnitude and direction of the electric field at the point in the region that has coordinates x = 2.00 m, y = 0.400 m, and z = 0.

106) The electric potential V in a region of space is given by

$$V(x, y, z) = A(x^2 - 3y^2 + z^2)$$

where A is a constant.
(a) Derive an expression for the electric field $\vec{E}$ at any point in this region.
(b) The work done by the field when a 1.50 μC test charge moves from the point (x, y, z) = (0, 0, 0.250 m) to the origin is measured to be 6.00×10^{-5} J. Determine A.
(c) Determine the electric field at the point (0, 0, 0.250 m).