29. Electric Field and Potential

Short Answer

Answer.1

No, it does not mean that the electron has a charge 3.2×10^{-19}C less than the charge of a proton. Electrons and Protons have same amount of charge just the nature of charge is different. Electron has negative charge and Proton has positive charge. If we keep an electron and a proton at a distance apart then attractive force will be observed as their nature of charge is different.Hence, magnitude of charge of both electron and a proton is1.6×10^{-19} C but nature is opposite.

Answer.2

Yes, there is a lower limit to the electric force between two particles.We know that electric force is given as:$F = \frac{kq_1q_2}{r^2}$This is Coulomb's Law. Here, k is a constant .k = $\frac{1}{4\pi\epsilon_0}$ = 9×10^9 Nm^2C^{-2}, q_1 and q_2 are the charges of two particles and r is the distance between two charges.The smallest possible charge would be that of an electron.r=1 cm = 0.01 mThus,$F = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{0.01^2}$

$\therefore F = 2.3 \times 10^{-24}\ N$Hence, lower limit to the electric force between two particles placed at a separation of 1 cm would be 2.3×10^{-24} N.

Answer.3

Yes, the force on particle B as well as particle A will increase when particle is A is displaced towards particle B.By Coulomb's Law, Electric force is inversely proportional to the square of the distance between the two charges.$F \propto 1/r^2$Thus, when A is displaced towards B, the distance between them decreases and hence the force on both the particles will increase.

Answer.4

No, gravitational field cannot be added vectorially to an electric field to get a total field. This is because Electric field comprises of influence due to electric charges whereas gravitational field comprises of influence due to masses of the bodies and thus, electric field and gravitational field have different dimensions. We can obtain net Force by adding Gravitational force and electric force.Hence, gravitational field cannot be added to electric field vectorially.

Answer.5

When a phonograph record is cleaned, electric charges are produced on the record due to induction. This happens as we rub a cloth on the record, friction causes the induction of charges on the record. This phenomenon is similar to a glass rod being rubbed by a cloth. Now, these deposited charges on the record attract dust particles having neutral charge.Hence, a phonograph-record attract dust particles just after it is cleaned.

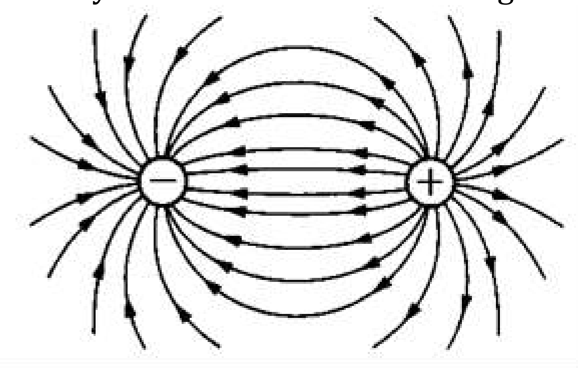
Answer.6

No, electric force between two charges or on any one of the two charges does not depends on the charges present nearby.According to Coulomb's Law,Electric force is given as: $F = \frac{kq_1q_2}{r^2}$Here, k is a constant and k = $\frac{1}{4\pi\epsilon_0}$ = 9×10^9 Nm^2C^{-2}, q_1 and q_2 are the two charges and r is the distance between two charges. As we see, the force on one charge depends only on the magnitude of the second charge and vice versa.Third charge won't affect the force between first two charges.The only thing that would affect the force on the charge is the **net force** due to superposition of all the individual forces.

Hence, the force on a charge due to another charge does not depend on the charges present nearby.

Answer.7

Here 4π is considered as a solid angle. Meaning the lines of force can subtend radially outward as shown in the figure below:



It does not mean that 4π lines will come out of a point charge, it means lines of force will move radially outwards from a positive charge having radial angle of 4π.

Answer.8

No, two equipotential surfaces cannot cut each other. When two equipotential surfaces intersect at a point, the potential at that point will have two values which is not possible. Also, electric field is perpendicular to the equipotential surface, when two surfaces intersect there will be two directions of the electric field (one of each equipotential surface) which is not possible either.Hence, two equipotential surfaces cannot cut each other.

Answer.9

Yes, when a charge is placed at rest in an electric field its path will be tangential the line of force. When the lines of forces are straight, the path of the charge would be in a straight line. When the lines of force are curved, the path of the charge would be tangential to the curve.

Answer.10

Lines of force are moving outwards from q_2, hence q_2 is positively charged: $+q_2$. Lines of force are going into q_1, hence q_1 is negatively charged : $-q_1$.From the diagram, 18 lines of electric field come out of q_2 and 6 lines of electric field get into q_1.Ratio of $\frac{q_1}{q_2} = \frac{6}{18} = \frac{1}{3} = 1:3$Hence, If the lines are drawn in proportion to the charge then q_1:q_2= 1:3

Answer.11

No, the work done by the electric field does not depend on the path of the charge.Work done is given as: W = Potential difference × charge.= $(V_A - V_B) \times q$Here, V_A and V_B is the potential at Points A and B respectively. And q is the charge.Thus, the position of the charge is important as potential difference will vary with position and so the work done will change.Hence, when a point is taken from A to a point B the work done on the charge due to electric field will not depend on the path.

Answer.12

The distance between the two charges forming the dipole must be small compared to the distance between the point of influence and the center of the dipole.

Answer.13

The basic difference between a conductor and an insulator is that conductor has many free electrons in its outer shell and an insulator has no free electrons. Free electrons are responsible for conduction of electricity in a material as they are not bound to the atom and are free to move. Whereas in an insulator electrons are tightly bound to the atom, thus no free electrons.

Answer.14

When a charged comb is brought near a small piece of paper, it attracts the piece because of induction. Induction is the process of redistribution of the charges on one body due to the presence of a charged body. Similarly, the charges are distributed on the paper from the comb. Thus when a charged comb is brought near a piece, the charges at the pointing end of the comb attracts the opposite charge on the piece of the paper which were introduced due to induction.Whole paper does not become charged, just the area near the charged comb contains induced electrons.

Hence When a charged comb is brought near a small piece of paper, it attracts the piece.

Objective I

Answer.1

At any given point in the electric field region, the electric flux (i.e. the number of field lines per unit area) determines the intensity of the field. The points in the region where the flux is more are associated with strong electric fields.

For a given area, field lines are dense and equal in number at point A and C.

Therefore, $E_A = E_C$

And at point B, the field lines are far away which indicates lesser intensity of electric field at point B than at point A and C.

Answer.2

Electric potential energy between two charges Q and Q’ kept at a distance R is given by:

$$U = \frac{1}{4\pi\epsilon}\frac{(Q)(Q')}{R}$$

If R is increased, then energy may decrease or increase depending on the charges involved.

∴ The potential energy may increase or decrease.

Answer.3

Electric potential energy of a system of point charges is defined as the work required in assembling this system of charges by bringing them close together, as in the system from infinite distance.

As we know,

$E=-\nabla V$

Electric field flows from high potential to low potential and a positive charge moves in the direction of electric field. In this process, it loses its energy.

But when a positive charge is moved from low potential to high potential i.e. in the direction opposite to the electric field, its energy increases as some work needs to be done to the particle. This work done gets stored as energy in the particle.

Answer.4

Potential due to a point charge at a distance r is given by:

$$V = \frac{1}{4\pi\epsilon}\frac{(Q)}{r}$$

Therefore, at a point very nearby to A and B, r → 0 ∴ V → ∞

i.e.

At a very nearby point right to A and a very nearby point left to B, potential will tend to ∞ (maximum possible value) as separation will tend to zero. That means at a point somewhere in the middle of path AB, the potential will acquire its minimum value.

Therefore, while moving from A to B, potential will first decrease and then increase.

Answer.5

As the electric field is in +X direction, that is field lines will flow from point C to point A. And as we already know that field lines flow from high potential to low potential, that means point A needs to be at a low potential region and point C needs to be at a high potential region.

Points B and D are equipotential.

The order of potentials is:

$V_C > V_B = V_D > V_A$

Therefore, potential is minimum at A.

Answer.6

On charging a body by rubbing it, there are two possibilities to happen: Either the body acquires a positive charge or a negative charge.

As $q=ne$ (where q is the amount of charge acquired on a body, n is the number of electrons transferred from or on the body and e is the charge on one electron.)

In case the body acquires a positive charge, there is loss of electrons from that body, therefore, its mass decreases.

In case the body acquires a negative charge, there is gain of electrons from that body, therefore, its mass increases.

So, on charging a body, its mass may increase or may decrease slightly.

Answer.7

An electric dipole consists of equal and opposite charges placed at some distance.

The dipole moment of this configuration is given as **p**=q(2**a**)

When the dipole is kept in an external electric field E, both its charges experience some force. Let the force on the positive charge(q) and negative charge(-q) be $\mathbf{F}_P$ and $\mathbf{F}_N$ respectively.

Therefore, $\mathbf{F}_P = q\mathbf{E}$ and $\mathbf{F}_N = -q\mathbf{E}$.

I.e. $\mathbf{F}_P = -\mathbf{F}_N$

that is force on the dipole is equal in magnitude but opposite in direction irrespective of its orientation.

Therefore, force on an electric dipole placed in an electric field is always zero.

Answer.8

Since electric field is a conservative field and therefore electric force is also a conservative force. Therefore, work done will not depend in the path taken.

As for a conservative force field, work done on a charge does not depend on the path taken by the charge but depends only on the initial and final points. Therefore, in this situation,

i.e. $W_A = W_B = W_C$

∴ The work done in taking a point charge from P to all the points A, B and C is the same.

Answer.9

If a force **F** applies on a body and it allows it to move an infinitely small distance d, then work done is given by dW=**F**.d**s** and for a path, integrate it putting lower limits (starting position) and upper limits (ending position).

Here, in the given question,

since a complete rotation is made i.e. net displacement is zero. i.e. $ds = 0$

$$\therefore\ w = \oint F.ds\ = 0\ (for\ one\ complete\ revolution)$$

i.e. The work done by the electric field on the rotating charge in one complete revolution is zero.

Objective II

Answer.1

Option (a) is correct because total charge of the universe is constant. It just gets transferred from one particle to another.

Option (b) is incorrect as the total positive charge of the universe is not constant. It is because the positive charges get converted into negative charges and vice-versa.

Option (c) is incorrect as the total negative charge of the universe is not constant. It is because the negative charges get converted into positive charges and vice-versa.

Option (d) is incorrect as in universe, the total number of charged particles is not a constant as a pair of positive and negative charges appear at the time of pair production and a pair of positive and negative charge combine to form a neutral particle at the time of pair annihilation.

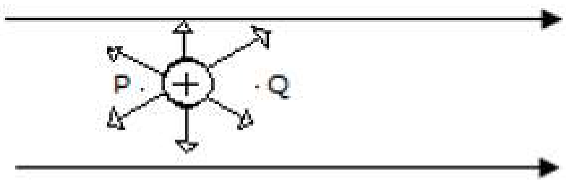
Answer.2

Option (c) is correct:

In an electric field, if a positive charge is placed, then the charge itself will generate some electric field on its own diverging from the point.

At a nearby point Q (towards the direction of external field), the field will increase as the field lines from the charge will also add to external field lines.

At a nearby point P (away from the direction of external field), the field will decrease as the field lines from the charge will cancel some of the external field lines.



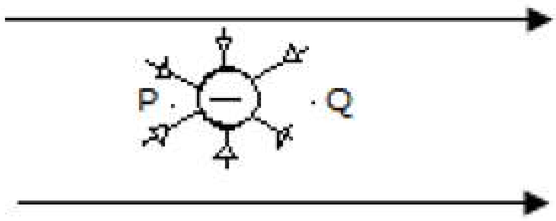
Therefore, at a nearby point, field can either increase or decrease.

Option (d) is correct:

In an electric field, if a negative charge is placed, then the charge itself will generate some electric field on its own converging to the point.

At a nearby point Q (towards the direction of external field), the field will decrease as the field lines from the charge will cancel some of the external field lines.

At a nearby point P (away from the direction of external field), the field will increase as the field lines from the charge will add on to the external field lines.



Therefore, at a nearby point, field can either increase or decrease.

Answer.3

We know that electric field is negative of the space rate of change of electric potential in a region. i.e.

$\boldsymbol{E} = -\nabla V$

Option (a) is incorrect as for E =0, V=0 is not the only condition. As we can see from the above equation, electric field is the negative of vector derivative of V that means

if V=constant, then also, E=0.

(As $\frac{d(constant)}{dr} = 0$)

Option (b) is incorrect as:

If at a point, the electric potential is zero, it doesn't imply electric field to be also zero.

Take an example of a dipole where somewhere between the two charges on its axial line, there exists a point where potential is zero but electric field is always non zero and directs in the direction from positive charge to negative charge.

Option (c) is incorrect as if E≠0, it doesn't mandate the potential to be non-zero. We can take again the example of a dipole where somewhere at a point on its axial line, there exists a point where E≠0 but V=0. So the statement "If E ≠ 0, V cannot be zero" is incorrect.

Option (d) is incorrect as:

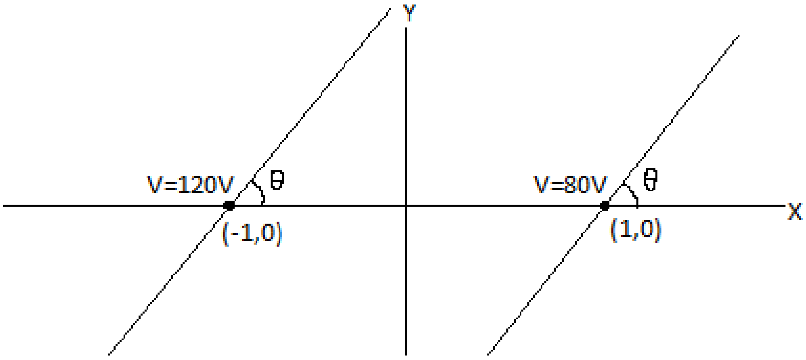
If V ≠ 0 (let's say V= non-zero constant)

Then E=0

Which is contradicted in the given statement.

Thus, none of the options is correct.

Answer.4



$V = -\int \boldsymbol{E}.d\boldsymbol{r}$

Here also, $\Delta V = \int_{-1}^{1} \boldsymbol{E}.d\boldsymbol{x}$ and $\Delta V = 120 - 80 = 40\ V$

Upon solving, we get $E = 20\ V/cm$ but it will also depend on the angle that equipotential surface makes with the X axis.

Therefore, the value of electric field may greater than 20V/cm (if the potential decreases uniformly) or equal to 20 V/cm (when equipotential surfaces are at right angles from X axis.)

Answer.5

Option (a) is incorrect because potential at a point depends on our choice of zero potential. Normally infinity is taken as reference point where potential is assumed to be zero.

If choice of zero potential is changed, then the potential at a point will also change.

Option (b) is correct as difference in potential between the two points doesn't depend on the choice of zero potential.

Option (c) is incorrect as the potential energy of the two-charge system also depends on the choice of zero potential in order to calculate the potential at the point where the two charges are kept.

Option (d) is correct as the change in potential energy of the two-charge system is independent of our choice of the zero-potential point.

Thus, we conclude that potential difference between two points and change in potential energy of a two-charge system don't depend on the choice of zero potential point.

Answer.6

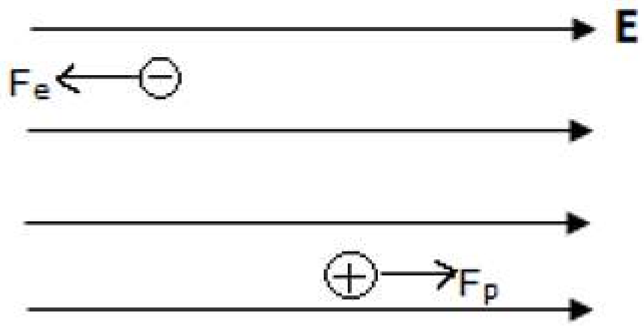
The field due a point charge is always radial (radially outwards for positive charge and radially inwards for negative charge). A dipole placed in that electric field will never feel equal and opposite forces due to the radial nature of the field. Therefore, option (a) and (b) are incorrect.

Torque on the dipole may be zero in the case when the dipole is placed along the electric field (as in that only case, $\boldsymbol{F}$ and $\boldsymbol{r}$ will be parallel or antiparallel, thus torque will be zero.)

C. Their accelerations will be equal.

D. The magnitudes of their accelerations will be equal

Answer.7



Let the force on the electron and proton is F_e (F) and F_p (F') respectively.

Then,

$F = -eE \text{ and } F' = eE$

Option (a) is incorrect as the forces are equal only in magnitude but not in direction.

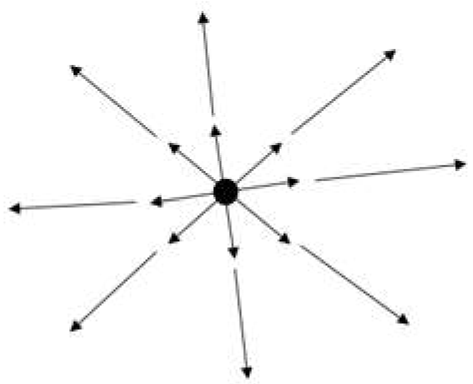
Option(b) is correct as magnitude of the forces are equal.

Option (c) is incorrect as the magnitude of accelerations for both particles is not equal and also the direction is also not the same.

Option (d) is incorrect as the magnitude of acceleration of both will be different as the masses of both are different.

Answer.8

The field around the origin will be like:



Where the intensity of the field will increase as we will move away from the charge placed at origin (as field is proportional to the distance r from the origin.)

Option (a) is incorrect as the field is not uniform in the region (can be perceived by the given situation and the diagram)

Field is given as:

$\boldsymbol{E} \propto \boldsymbol{r}$

$\boldsymbol{E} = k\boldsymbol{r}$ (where k is some positive constant)

Now,

$$V = -\int \boldsymbol{E}.d\boldsymbol{r} = \int Edr \cos\ 0$$

$$V = -\int krdr$$

$$V = -k\frac{r^2}{2} + c\ (c\ is\ constant\ of\ integration)$$

Option (b) is incorrect since V is not proportional to r.

Option (c) is correct since V is proportional to r.

Option (d) is incorrect. From the expression for V, we can say that the potential decreases as we move away. Alternatively, the field lines always flow from high potential to low potential. Therefore, we can say that the potential decreases with increase in r.

Exercises

Answer.1

We know that,

Electrostatic force, $F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$

Where

ϵ_0 is the permittivity of vacuum

q_1, q_2 is the magnitude of the charges on the charge particles

r is the distance between the two charge particles.

Taking the dimensions,

$$[F_e] = \frac{1}{[4\pi][\epsilon_0]}\frac{[q_1][q_2]}{[r^2]}$$

Note that Charge = Current × Time. Hence, its dimensional formula is $[Current][Time] = [A][T]$

Note that 4π is a dimensionless constant. Note that $F = ma$. Hence, $[F] = [m][a] = [MLT^{-2}]$. Also, r is just distance or length. Thus, $[r] = [L]$

$$[MLT^{-2}] = \frac{[AT][AT]}{[\epsilon_0][L^2]}$$

Rearranging, we get

$$[\epsilon_0] = [M^{-1}L^{-3}T^4A^2]$$

Answer.2

<u>Given:</u>

$q_1 = q_2 = 1.0C$

Distance between the charges, $r = 1.0km = 10^3 m$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

By Coulomb's law,

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$

$$F_e = \frac{9 \times 10^9 NC^{-2}m^2 \times 1.0C \times 1.0C}{(2 \times 10^3 m)^2}$$

$$= 2.25 \times 10^3 N$$

Formula used:

The weight of an object is given by

$$F_w = mg$$

where g is the acceleration due to gravity

and m is the mass of the object.

Let the mass of my body, m be 70 kg.

$$F_w = mg = 70kg \times 9.8ms^{-2} = 686N$$

Thus, dividing the Electrostatic force and the body weight, we get

$$\frac{F_e}{F_w} = \frac{2.25 \times 10^3 N}{686N} \approx 3.3$$

The electric force between the two charges is 3.3 times my weight.

Answer.3

Given:

Mass of the person , $m = 50kg$

Weight of the person, $w = mg = 50kg \times 9.8ms^{-2} = 490N$

Charges: $q_1 = q_2 = 1.0C$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

The magnitude of electric force is given by:

$$F_e = k\frac{q_1q_2}{r^2}$$

Rearranging, we get

$$r = \sqrt{k\frac{q_1q_2}{F_e}}$$

Note that $F_e = w = 490N$. Substituting all the values, we get

$$r = \sqrt{\frac{9 \times 10^9 NC^{-2}m^2 \times 1.0C \times 1.0C}{490N}}$$

$$\approx 4.3 \times 10^3 m$$

Answer.4

Given:

Mass of the person , $m = 50kg$

Weight of the person, $w = mg = 50kg \times 9.8ms^{-2} = 490N$

Let the magnitude of charge on both be q.

Here, $q_1 = q_2 = q$

Distance of separation, $r = 1.0m$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \mathrm{k}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

$$F_e = \mathrm{k}\frac{q_1 q_2}{r^2}$$

$$= k\frac{q^2}{r^2}$$

Rearranging, we get

$$q = \sqrt{\frac{F_e r^2}{k}}$$

Substituting the corresponding values, we get

$$q = \sqrt{\frac{490N \times (1.0m)^2}{9 \times 10^9 NC^{-2}m^2}}$$

$$\approx 2.3 \times 10^{-4}\ C$$

Answer.5

Given:

Charge on each proton, $q_1 = q_2 = 1.6 \times 10^{-19}$ C

Distance of separation, $r = 1\ fermi\ m = 10^{-15}m$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

The magnitude of electric force is given by:

$$F_e = k\frac{q_1 q_2}{r^2}$$

$$= \frac{9 \times 10^9 NC^{-2}m^2 \times 1.6 \times 10^{-19}C \times 1.6 \times 10^{-19}C}{(10^{-15}m)^2}$$

$$\approx 230\ N$$

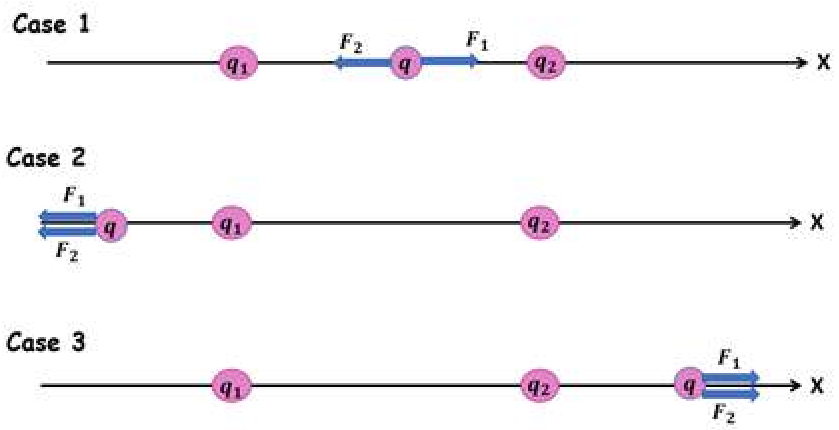
Answer.6

Given: Charges:

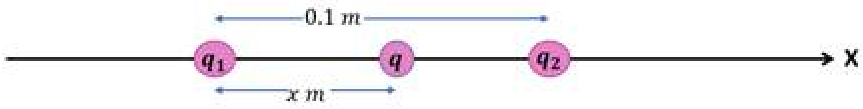
$$q_1 = 1.0 \times 10^{-6}C, q_2 = 2.0 \times 10^{-6}C$$

Distance between the charge is 10 cm

Let the third charge be q. There are three possible scenarios:



As we can see from the picture, the only possible location for q where net force on q is zero is between the two charges. Let it be x m away from q_1, x > 0.



Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \mathrm{k}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

Force on q due to q_1 is given by:

$$F_1 = k\frac{q_1 q}{x^2}$$

Force on q due to q_2 is given by:

$$F_2 = k\frac{q_2 q}{(0.1 - x)^2}$$

Now,

$$F_1 = F_2$$

$$\frac{(0.1 - x)^2}{x^2} = \frac{q_2}{q_1} = 2$$

$$\frac{(0.1 - x)}{x} = \pm\sqrt{2}$$

$$(0.1 - x) = \pm\sqrt{2}x$$

$$x = \frac{0.1}{1 \pm \sqrt{2}}$$

$$= -0.241 \; or \; 0.041$$

As x > 0. The correct option is 0.041.

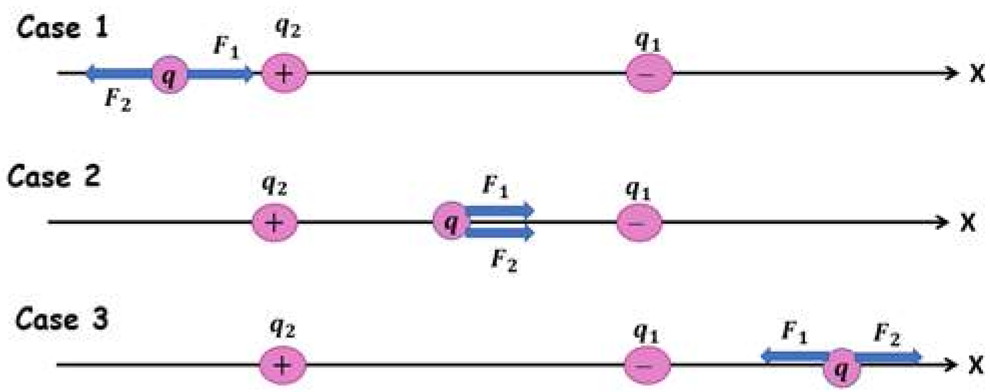
Distance from charge q_2 = 0.1 – 0.041 = 0.059 m

Hence, the charge q should be placed 5.9 cm from q_2.

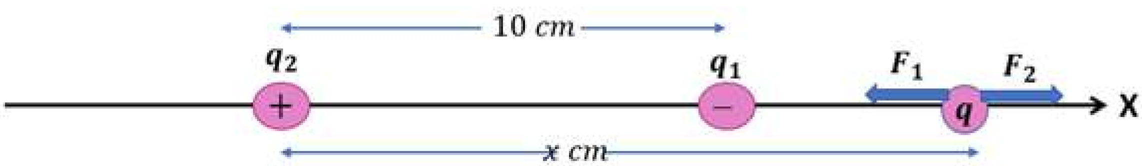
Answer.7

Given:

Charges: q_1=-1.0×10^{-6} C, q_2=2.0×10^{-6} C



Let the third charge q be at a distance x cm from q_2. As the forces must cancel, case II is not possible. Moreover, for forces to cancel, q must be near the smaller charge. Hence, only Case III is possible.



Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

Force on q due to q_1 is given by:

$$F_1 = \mathrm{k}\frac{|q_1|q}{((x-10)cm)^2}$$

Force on q due to q_2 is given by:

$$F_2 = k\frac{|q_2|q}{(x\ cm)^2}$$

Now,

$$F_1 = F_2$$

$$\frac{x^2}{(x-10)^2} = \left|\frac{q_2}{q_1}\right| = 2$$

$$\frac{x}{x-10} = \pm\sqrt{2}$$

$$x = \pm\sqrt{2}(x - 10)$$

$$x = \frac{10\sqrt{2}}{\sqrt{2}\pm 1}$$

$$= 5.86, 34.1$$

For Case III, x must be greater than 10. Hence, x = 34.14 cm

Thus, q should be placed *34.1 cm* from the larger charge on the side of the smaller charge.

Answer.8

Given: missing

For the electric force to be minimum, the magnitude of charge on the particles must be minimum. As both the particles are charged, they must have non-zero minimum charge.

Hence, they both must carry charge having magnitude of fundamental unit of charge i.e. 1.6×10^{19} C.

Magnitude of charges, $q_1 = q_2 = 1.6 \times 10^{19}$C

Distance between the charged particles, $r = 1.0cm = 0.01\ m$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \mathrm{k}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

The magnitude of electric force is:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

$$= \frac{9 \times 10^9 NC^{-2}m^2 \times 1.6 \times 10^{-19}C \times 1.6 \times 10^{-19}C}{(0.01m)^2} \approx 2.3 \times 10^{-24}N$$

Answer.9

<u>Given:</u>

Mass of water , $m = 100g$

Molar mass of water $M = 18\ gmol^{-1}$

Moles of water in 100g of water = $\frac{100g}{18gmol^{-1}}$

Number of electrons in 1 molecule of water = 2 times one electron each in hydrogen atom + 8 electrons in oxygen atom = 10 electrons

---

Formulas used:

The relation between molar mass M, mass of sample m and number of moles of sample n is given by:

$$n = \frac{m}{M}$$

1 mol of "something" contains N_A number of "something".

Number of electrons in 1 mol of electrons $= 10\ electrons \times N_A$= $10\ electrons \times 6.022 \times 10^{23} mol^{-1}$

Number of electrons in 1 g of water

$= 10$ electrons × N_a × $\frac{1g}{18\ g\ mol^{-1}}$

Number of electrons in 100 g of water

$$= 10\ electrons \times 6.022 \times 10^{23} mol^{-1} \times \frac{100g}{18gmol^{-1}}$$

$$= 3.34556 \times 10^{25} electrons$$

$$\approx 3.35 \times 10^{25} electrons$$

Negative charge on one electron = $1.6 \times 10^{-19} C$

Total negative charge in 100g of water
$= 3.34556 \times 10^{25} \times 1.6 \times 10^{-19} C \approx 5.35 \times 10^{6} C$

Answer.10

<u>Given:</u>

Mass of water , $m = 100g$

Molar mass of water $M = 18gmol^{-1}$

Moles of water in 100g of water = $\frac{100g}{18gmol^{-1}}$

Number of electrons in 1 molecule of water = 2 times one electron each in hydrogen atom + 8 electrons in oxygen atom = 10 electrons

---

Formulas used:

The relation between molar mass M, mass of sample m and number of moles of sample n is given by:

$$n = \frac{m}{M}$$

1 mol of "something" contains N_A number of "something".

Number of electrons in 1 mol of electrons $= 18\ electrons \times N_A$= $10\ electrons \times 6.022 \times 10^{23} mol^{-1}$

Number of electrons in 100 g of water

$$= 10\ electrons \times 6.022 \times 10^{23} mol^{-1} \times \frac{100g}{18gmol^{-1}}$$

$$= 3.34556 \times 10^{25} electrons$$

$$\approx 3.35 \times 10^{25} electrons$$

Negative charge on one electron = $1.6 \times 10^{-19} C$

Total negative charge $= 3.34556 \times 10^{25} \times 1.6 \times 10^{-19} C \approx 5.35 \times 10^{6} C$

We have,

Charges: $q_1 = -5.35 \times 10^{6} C, q_2 = 5.35 \times 10^{6} C$

Distance of separation, $r = 10cm = 0.1\ m$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \mathrm{k}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

The magnitude of electric force is:

$$F_e = \frac{k|q_1||q_1|}{r^2}$$

$$= \frac{9 \times 10^9 NC^{-2}m^2 \times (5.35 \times 10^6 C)^2}{(0.1m)^2}$$

$$\approx 2.57 \times 10^{25} N$$

Let my mass m be 70 kg.

$$F_w = mg = 70kg \times 9.8ms^{-2} = 686N$$

$$\frac{F_e}{F_w} = \frac{2.57 \times 10^{25} N}{686N} \approx 3.7 \times 10^{22}$$

The electric force between the two charges is about 10^{22} times my weight!

Answer.11

Given:

Largest Distance of Separation = Diameter of the nucleus ,
$d = 13.8 fermi = 13.8 \times 10^{-15} m$

Charge on each proton , $q_1 = q_2 = 1.6 \times 10^{-19} C$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

The electric force is repulsive and is given by:

$$F = k\frac{q_1 q_2}{d^2}$$

$$F = \frac{9 \times 10^9 NC^{-2}m^2 \times (1.6 \times 10^{-19}C)^2}{(13.8 \times 10^{-15}m)^2}$$

$\approx 1.21\ N$

The protons do not fly apart because there is also strong nuclear force which is attractive and balances the repulsive electric force.

Answer.12

Given,

Electric force between the two spheres, $F_e = 0.1N$

Distance between the two spheres, $r = 1cm = 0.01m$

We know that, magnitude of charge on electron, $e = 1.6 \times 10^{-19}$

Let n electrons be transferred from one sphere to another. Then, charge on one sphere is +ne and the other is -ne.

$q_1 = q_2 = ne$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

The magnitude of electric force is given by:

$$F_e = k\frac{q_1q_2}{r^2}$$

$$F_e = k\frac{(ne)^2}{r^2}$$

$$n = \frac{r}{e}\sqrt{\frac{F_e}{k}}$$

$$= \frac{0.01m}{1.6 \times 10^{-19}C}\sqrt{\frac{0.1N}{9 \times 10^9 NC^{-2}m^2}}$$

$$\approx 2.0 \times 10^{11}$$

Hence, about 2.0×10^{11} electrons are transferred.

Answer.13

Given:

Charge on Na^+ ion = $q = 1.6 \times 10^{-19}$

Charge on Cl^- ion = $-q = -1.6 \times 10^{-19}$

Distance between the ions, $r = 2.75 \times 10^{-8}cm = 2.75 \times 10^{-10}m$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \mathrm{k}\frac{q_1q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

We assume that the distance between the transferred electron and the sodium nucleus is the distance between the two ions.

$$F_e = k\frac{q \times q}{r^2}$$

$$= \frac{9 \times 10^9 NC^{-2}m^2 \times (1.6 \times 10^{-19}C)^2}{(2.75 \times 10^{-10}m)^2}$$

$$\approx 3.05 \times 10^{-9}N$$

Answer.14

Given:

Mass of proton, $m = 1.67 \times 10^{-27}$

Charge on proton, $q = 1.6 \times 10^{-19}$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \text{k}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

Formula used:

By Newton's law of gravitation, the gravitational force is given by:

$$F_g = \text{G}\frac{m_1 m_2}{r^2}$$

Where G is the Gravitational constant

m_1 and m_2 are the magnitude of charges r is the distance of separation between the masses

---

The electric force is given by:

$$F_e = k\frac{q^2}{r^2} \quad \text{.................................}(1)$$

The gravitational force is given by:

$$F_g = G\frac{m^2}{r^2} \quad \text{.................................}(2)$$

Dividing (2) by (1), we get

$$\frac{F_e}{F_g} = \frac{kq^2}{Gm^2}$$

$$= \frac{9 \times 10^9 NC^{-2}m^2 \times (1.6 \times 10^{-19}C)^2}{6.67 \times 10^{-11}Nkg^{-2}m^2 \times (1.67 \times 10^{-27}kg)^2}$$

$$\approx 1.23 \times 10^{36}$$

Hence the ratio of electric force to gravitational force between two protons is about 1.23×10^{36}.

Answer.15

<u>Given:</u>

The attractive nuclear force between two protons is, $F = \frac{CE^{-kx^2}}{r^2}$

(a)The power of e must be dimensionless.

Thus,

$$[k][r] = 1$$

$$[k] = \frac{1}{[r]} = [L^{-1}]$$

Hence, SI unit of k is m.

Now,

$$[F] = \frac{[C][e^{-kx}]}{[r^2]}$$

$$[MLT^{-2}] = [C][1][L^{-2}]$$

$$[C] = [ML^3T^{-2}]$$

Let us replace the formula with SI units

$$N = \frac{C}{m^2}$$

Hence, SI unit of C is Nm^2

(b)

Given,

Separation between the protons, r = 5fermi = 5×10^{-15} m.

We know that the charge on a proton is q = 1.6×10^{-19}C.

Now,

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = k\frac{q_1q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

The electric force between the two protons is given by:

$$F_e = k\frac{q^2}{r^2}$$

Also, the nuclear force between the protons is given by:

$$F_n = C\frac{e^{-kr}}{r^2}$$

These two forces balance each other.

$F_e = F_n$

$kq^2 = Ce^{-kr}$

$$C = \frac{kq^2}{e^{-kr}}$$

$$= \frac{9 \times 10^9 NC^{-2}m^2 \times (1.6 \times 10^{-19})^2\ C}{e^{-1fermi^{-1} \times 5fremi}}$$

$$\approx 3.4 \times 10^{-26} Nm^2$$

Answer.16

Given:

Let the force due to charge at corner B, C be $\mathbf{F_B}$, $\mathbf{F_C}$.

Charge at each corner, $q = 2.0 \times 10^{-6}$.

Note that the length of side of the triangle is, $a = 5cm = 0.05\ m$.

Formula used:

By Coulomb's law, the electric force is given by:

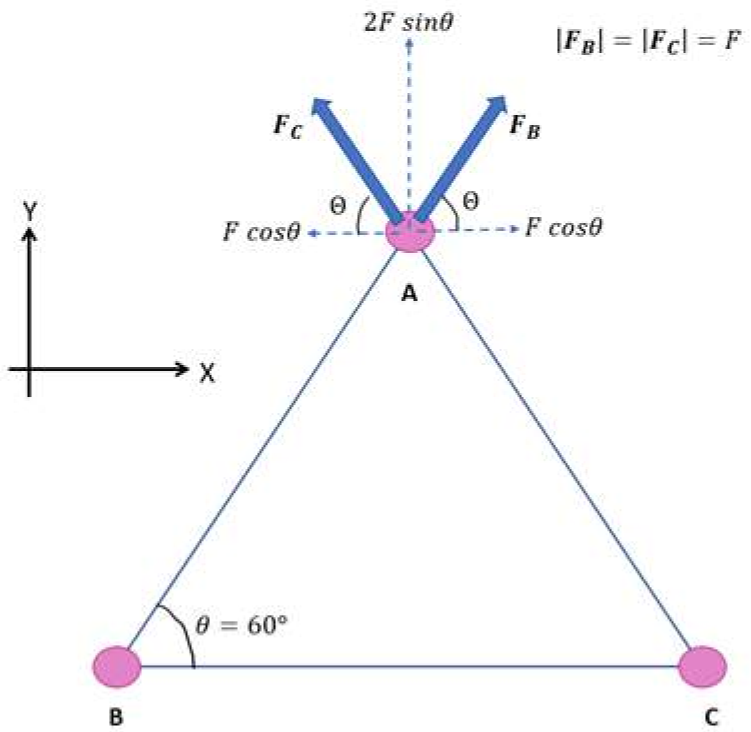
$$F_e = \mathrm{k}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges



$$F = |\vec{F_B}| = |\vec{F_C}| = k\frac{q^2}{a^2}$$

Putting the values in the above formula, we get

$$= \frac{9 \times 10^9 NC^{-2} m^2 \times (2.0 \times 10^{-6} C)^2}{(0.05m)^2} \approx 14.4N$$

We can see from the diagram that $\mathbf{F_C}$and $\mathbf{F_B}$cab be resolved into theirs x and y components.

$F_{c,x} = F \cos 60°$

$F_{c,y} = F \sin 60°$

$F_{b,x} = F \cos 60°$

$F_{b,y} = F \sin 60°$

The y's are in the same direction and add up but the x's are in the opposite direction, hence they cancel out.

Hence,

$$|\overrightarrow{F_{net}}| = F_{c,x} + F_{c,y} = 2F\ sin\,60°$$

$$|\overrightarrow{F_{net}}| = 2\ \times 14.4\,sin(60°)N \approx 24.9N$$

Answer.17

Given:

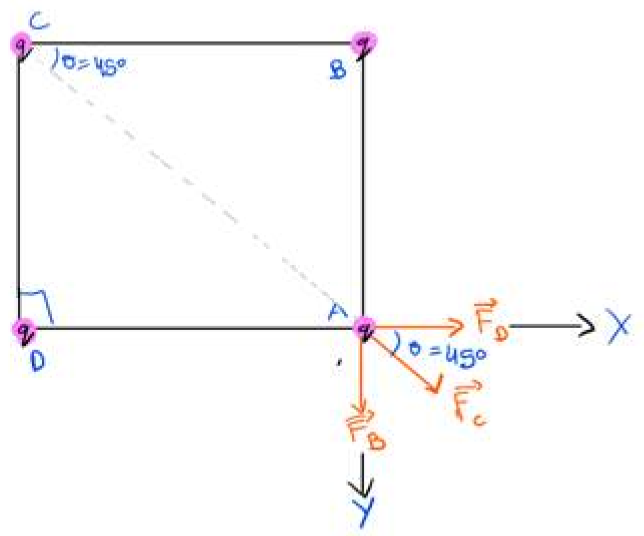
Let the force due to charge at corner B, C and D be $\mathbf{F_B}$, $\mathbf{F_C}$, $\mathbf{F_D}$.

Charge at each corner, $q = 2.0 \times 10^{-6}$.

The side of square is, $a = 5cm = 0.05\ m$.

By Pythagoras theorem,

The length of diagonal $= a\sqrt{2} = 0.05\sqrt{2}\ m$.



Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = k\frac{q_1q_2}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

k is the electrostatic constant

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

$$\overrightarrow{F_D} = k\frac{q^2}{a^2}\hat{\imath} = \frac{9\times10^9NC^{-2}m^2\times(2\times10^{-6}C)^2}{(0.05m)^2}\hat{\imath} = 14.4N\hat{\imath}$$

$$\overrightarrow{F_B} = k\frac{q^2}{a^2}\hat{\jmath} = \frac{9\times10^9NC^{-2}m^2\times(2\times10^{-6}C)^2}{(0.05m)^2}\hat{\jmath} = 14.4N\hat{\jmath}$$

$$|\overrightarrow{F_C}| = k\frac{q^2}{a^2} = \frac{9\times10^9NC^{-2}m^2\times(2\times10^{-6}C)^2}{\left(0.05\sqrt{2}m\right)^2} = 7.2N$$

Resolving $\mathbf{F_C}$, we get

$$F_x = |\overrightarrow{F_c}|\cos\theta = 7.2N\cos(45°) = \frac{7.2N}{\sqrt{2}}$$

$$F_y = |\overrightarrow{F_c}|\sin\theta = 7.2\mathrm{N}\sin(45°) = \frac{7.2N}{\sqrt{2}}$$

$$\overrightarrow{F_c} = F_x\hat{\imath} + F_y\hat{\jmath}$$

$$\overrightarrow{F_c} = \frac{7.2\mathrm{N}}{\sqrt{2}}(\hat{\imath}+\hat{\jmath}) = \frac{14.4}{2\sqrt{2}}(\hat{\imath}+\hat{\jmath})\mathrm{N}$$

The net force is:

$$\overrightarrow{F_{net}} = \overrightarrow{F_b} + \overrightarrow{F_c} + \overrightarrow{F_d}$$

$$\overrightarrow{F_{net}} = 14.4\left(1+\frac{1}{2\sqrt{2}}\right)(\hat{\imath}+\hat{\jmath})N \approx 19.49(\hat{\imath}+\hat{\jmath})N$$

We know that

$$|\overrightarrow{F_{net}}| = \sqrt{F_x^2 + F_y^2}$$

Hence, the magnitude of net force is

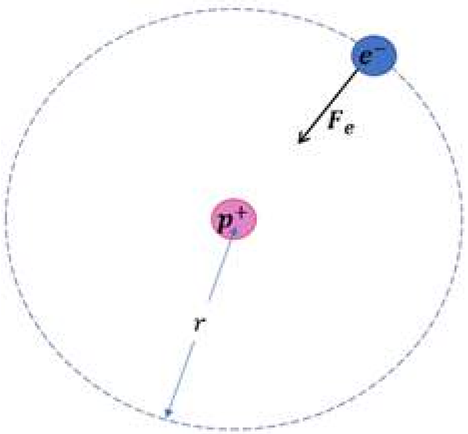
$$|\overrightarrow{F_{net}}| \approx \sqrt{19.49^2 + 19.49^2}N \approx 27.5N$$

Answer.18

Given:

Magnitude of charge on both proton and electron, $e = 1.6 \times 10^{-19} C$

The radius of the circular orbit, $r = 0.53 \times 10^{-10} m$



The radius of the circular orbit is the distance between the electron and the proton.

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

(Here, $q_1 = q_2 = e$)

The magnitude of electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2}$$

Putting the values in the above formula, we get

$$F_e = 9 \times 10^9 NC^{-2} m^2 \times \frac{(1.6 \times 10^{-19} C)^2}{(0.53 \times 10^{-10} m)^2} \approx 8.2 \times 10^{-8} N$$

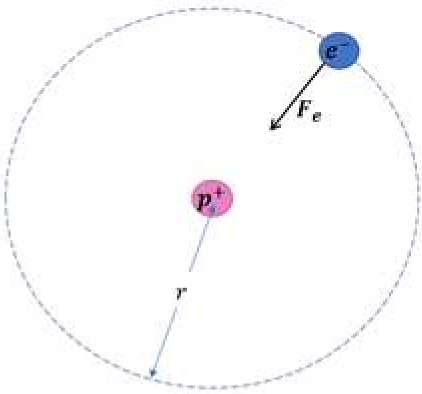
Answer.19

Given:

Magnitude of charge on both proton and electron, $e = 1.6 \times 10^{-19} C$

The radius of the circular orbit, $r = 0.53 \times 10^{-10} m$

Mass of electron , $m = 9.11 \times 10^{-31} kg$



The radius of the circular orbit is the distance between the electron and the proton.

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

(Here, $q_1 = q_2 = e$)

The magnitude of electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2}$$

$$F_e = 9 \times 10^9 NC^{-2} m^2 \times \frac{(1.6 \times 10^{-19} C)^2}{(0.53 \times 10^{-10} m)^2} \approx 8.2 \times 10^{-8} N$$

Formula used:

Centripetal force is given by

$$F_c = \frac{mv^2}{r}$$

Where m is the mass if the object, v is the speed of the object and r is the radius of the circular path.

Let F_c be the centripetal force on the electron.

$$F_c = \frac{mv^2}{r} \qquad ...(1)$$

Now, the electric force acts as centripetal force.

Hence,

$$F_e = F_c$$

Substituting (1) and rearranging, we get

$$v = \sqrt{\frac{F_e r}{m}}$$

Putting the values in the above formula, we get

$$v = \sqrt{\frac{8.2 \times 10^{-8} N \times 0.53 \times 10^{-10} m}{9.11 \times 10^{-31} kg}} \approx 2.18 \times 10^6 \ m/s$$

Answer.20

Given:

Charge on the ith particle ,$q_i = i^3 \times 10^{-8} C$

Distance of ith particle from origin, $r_i = 10icm = 0.1im$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

Magnitude of force on the 1C charge due to ithparticle is given by:

(Here, q_1 =$1C \times 10^{-8}$, $q_2 = q_i$ and $r = r_i$)

$$F_i = \frac{1}{4\pi\epsilon_0}\frac{1C \times 10^{-8} \times q_i}{(r_i)^2}$$

Substituting the values, we get

$$F_i = 9000N \ \times i$$

All the forces are in negative-x direction. Hence, we can simply add them up to get the magnitude of net force.

$$F_{x,net} = \sum_{i=1}^{10} 9000 \times i \ N$$

$$F_{x,net} = 9000N \sum_{i=1}^{10} i$$

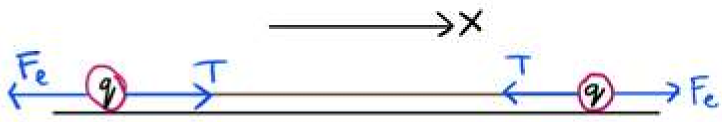
$$F_{x,net} = 9000N \times 55N = 4.95 \times 10^5 N$$

Answer.21
Given:

Given,

Charge on each particle, $q = 2.0 \times 10^{-8} C$

Distance between the two charges, $r = 1m$



The tension will adjust such that the net force is zero.

$$\sum F_x = F_e - T = 0$$

Formula used:

By Coulomb's law, the electric force id given by:

$$F_e = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

(Here, $q_1 = q_2 = q$.)

$$T = F_e = \frac{1}{4\pi\epsilon_0} \frac{q^2}{r^2}$$

Putting the values in the above formula, we get

$$T = \frac{9 \times 10^9 NC^{-2} m^2 \times (2 \times 10^{-8} C)^2}{(1m)^2} = 3.6 \times 10^{-6} N$$

Answer.22

Given, Mass,

$$m = 100g = 0.1kg$$

Length of strings, l = 50cm = 0.5 m

Distance between spheres,

$$r = 5cm = 0.05m$$

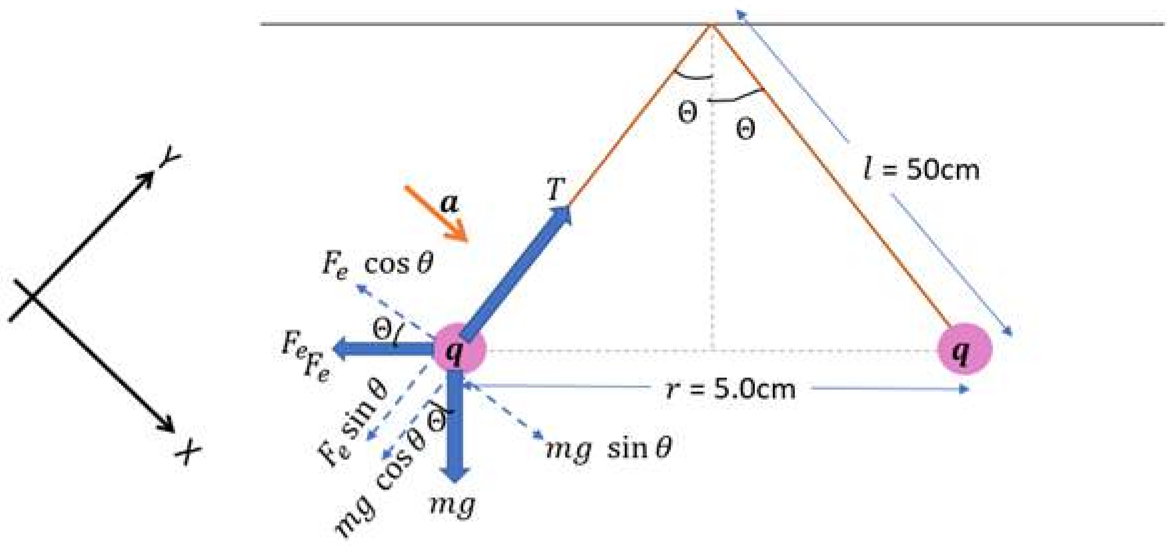
Magnitude of charge on each ball,

$$q = 2 \times 10^{-7} C$$

Let the magnitude of Tension be T. Let the magnitude of electric force between the spheres be F_e

.

Note that tension will adjust itself so that there is no acceleration along its direction.



(a)

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

(Here, $q_1 = q_2 = e$)

The magnitude of the electric force, F_e is given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q^2}{r^2} \quad ...(1)$$

$$F_e = \frac{9 \times 10^9 NC^{-2}m^2 \times (2 \times 10^{-7}C)^2}{(0.05m)^2} = 0.144\, N$$

Hence, the electric force is 0.144 N along the line joining the charges and away from the other charge.

(b)

By trigonometry,

$$sin\,\theta = \frac{12.5cm}{50cm} = 0.05$$

$$cos\,\theta = \sqrt{1 - sin^2\theta} \approx 0.99875$$

Now, along the string, there is component of acceleration. Hence,

$$\sum F_y = ma_y = m(0) = 0$$

Now, consider the direction perpendicular to the string,

$$\sum F_x = F_e\,cos\,\theta - mg\,sin\,\theta$$

$$= 0.144N \times 0.99875 - 0.1kg \times 9.8ms^{-2} \times 0.05$$

$$= 0.09482\,N \approx +0.095\,N$$

Hence, the component of net force perpendicular to the string is 0.095N and away from the other charge (indicated by positive sign)

(c)From the free body diagram,

$$\sum F_y = T - F_e\,sin\,\theta - mg\,cos\,\theta = 0$$

Rearranging to get the above expression, we get

$$T = F_e \sin\theta + mg\cos\theta$$

$$T = 0.144N \times 0.05 + 0.1kg \times 9.8ms^{-2} \times 0.99875 \approx 0.986\text{ N}$$

(d)

Applying Newton's second law along the y-direction,

$$\sum F_y = ma_y$$

$$a_y = \frac{\sum F_y}{m} \approx \frac{0.095N}{0.1kg} = 0.95ms^{-2}$$

$$\& \ a_x = 0$$

$$\therefore a = 0.95ms^{-2}$$

Thus the acceleration of one of the balls is $0.95ms^2$ perpendicular to the string and going away from the other charge.

Answer.23

Given,

Length of strings, $l = 20cm = 0.2\ m$

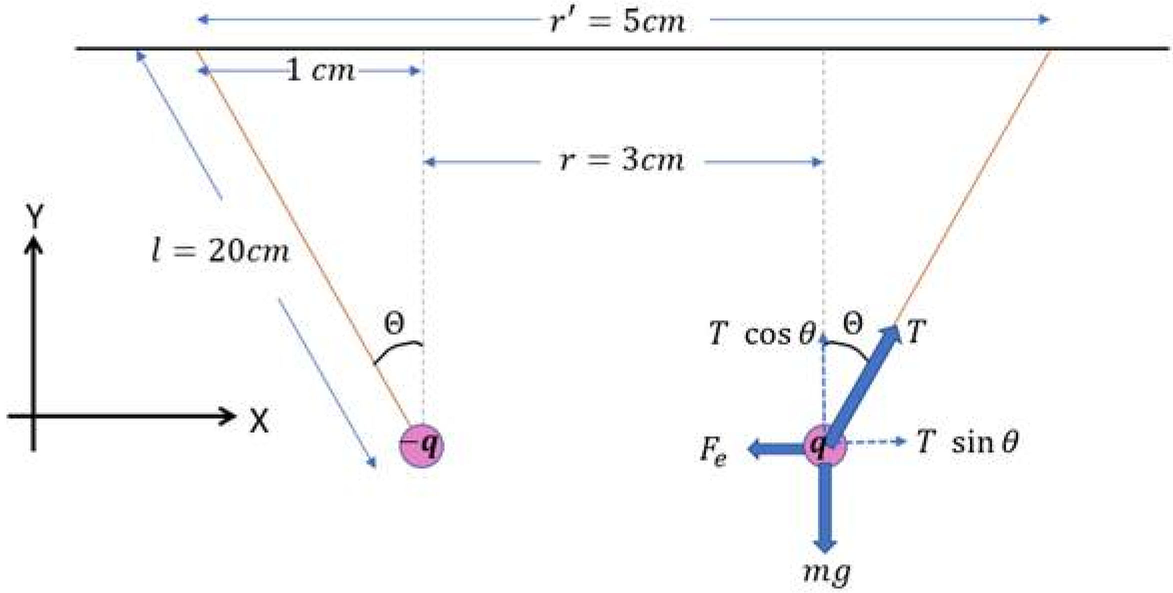
Distance between suspension points, $r' = 5cm = 0.05m$

Magnitude of charge on each ball, $q = 2 \times 10^{-8}C$

Distance between the two balls, $r = 3cm = 0.03m$

Let the mass of each ball be m. Let the magnitude of Tension be T and the electric force between the balls be F_e.

To be in accordance with the fact, $r' > r$, the balls must be attracted to each other. Hence, they are oppositely charged.



By trigonometry,

$$sin\ \theta = \frac{1\ cm}{20cm} = 0.05$$

$$cos\ \theta = \sqrt{1 - sin^2\theta} \approx 0.99875$$

At equilibrium, all forces must cancel out in accordance with newton's first law. Hence,

$$\sum F_x = T\,sin\,\theta\ - F_e = 0 \qquad \text{.............................(1)}$$

$$\sum F_y = T\cos\theta - mg = 0 \qquad \text{.............................(2)}$$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

(Here, $q_1 = q_2 = e$)

The magnitude of the electric force, F_e is given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q^2}{r^2} \quad \text{..................................(3)}$$

Substituting values in (3), we get

$$F_e = \frac{9 \times 10^9 NC^{-2}m^2 \times (2 \times 10^{-8}C)^2}{(0.03m)^2} = 0.004\ N$$

From equation (1), we get

$$T = \frac{F_e}{\sin\theta}$$

$$T \approx \frac{0.004N}{0.05} = 0.08\ N$$

From equation (2), we get

$$m = \frac{T\cos\theta}{g}$$

$$m \approx \frac{0.08\ N \times 0.99875}{9.8m/s^2} \approx 0.008153\ kg \approx 8.2\ g$$

Hence, mass of each of the balls is 8.2 grams and Tension in each of the ropes is 0.08N.

Answer.24

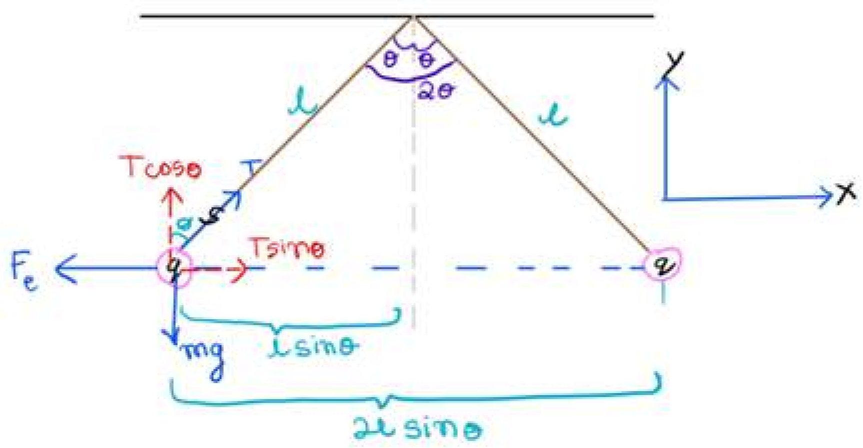
Given,

Mass, $m = 20g = 0.02kg$

Length of strings, l = 40cm = 0.4 m

Distance between spheres, $r = 4cm = 0.04m$

Let the magnitude of Tension be T. Let the electric force between the spheres be F_e. Let the magnitude of charge on each pitch ball be q.



By trigonometry,

$$sin\,\theta = \frac{2cm}{40cm} = 0.05$$

$$cos\,\theta = \sqrt{1 - sin^2\theta} \approx 0.99875$$

At equilibrium, all forces must cancel out in accordance with newton's first law. Hence,

$$\sum F_x = F_e - T\,sin\,\theta = 0 \quad \text{.............................(1)}$$

$$\sum F_y = T\cos\theta - mg = 0 \quad \text{.............................(2)}$$

Formula used:

By Coulomb's law, the electric force is given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

(Here, $q_1 = q_2 = e$)

The magnitude of the electric force, F_e is given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q^2}{r^2} \quad \text{.................................(3)}$$

From (2), we get,

$$T = \frac{mg}{\cos\theta} = \frac{0.02kg \times 9.8m/s^2}{0.99875} \approx 0.19625\,N$$

From (3) and (1), we get

$$\frac{1}{4\pi\epsilon_0}\frac{q^2}{r^2} = T\sin\theta$$

$$q^2 = 4\pi\epsilon_0 T\sin\theta\, r^2$$

$$q^2 \approx \frac{0.19625\,N \times 0.05 \times (0.04\,m)^2}{9 \times 10^9\,Nm^2C^{-2}}$$

$$q \approx 4.17 \times 10^{-8}C$$

Answer.25

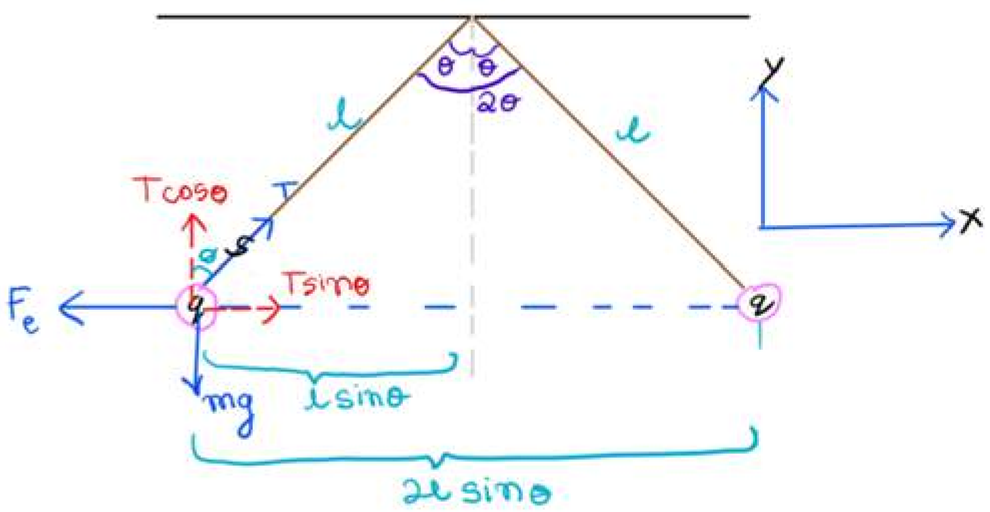
Given:

Charges on ball = q

Angle between the balls = 2θ

Length of the strings = l

Let the magnitude of Tension be T. Let the electric force between the pitch balls be F_e. Let the mass of each pitch ball be m. The free body diagram is as follows:



Now, let the distance between the two charges be r.

By trigonometry,

$$sin(\theta) = \frac{r/2}{l}$$

$$r = 2l\, sin\,\theta \quad ...(1)$$

By Coulomb's law, the electric force id given by:

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

Where ϵ_0 is the permittivity of free space

q_1 and q_2 are the magnitude of charges

r is the distance of separation between the charges

Here, $q_1 = q_2 = q$.

Now, let us find the magnitude of the electric force, F_e :

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q \cdot q}{r^2}$$

Substituting eq (1), we get

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{q^2}{4l^2\, sin^2(\theta)} \quad ...(2)$$

As the system is in equilibrium, all the forces in each direction must sum up to zero.

$$\sum F_x = T\, sin\,\theta \; - F_e = 0 \quad ...(3)$$

$$\sum \mathrm{F_y} = \mathrm{T}\cos\theta - \mathrm{mg} = 0 \quad ...(4)$$

Substituting (2) in (3), we get

$$T = \frac{1}{4\pi\epsilon_0}\frac{q^2}{4l^2\, sin^3\,\theta} \quad ...(5)$$

Substituting (4), we get

$$m = \frac{T\, cos\,\theta}{g} \quad ...(6)$$

Substituting (5) in (6), we get

$$m = \frac{q^2 \cot\theta}{16\pi\epsilon_0 g l^2 \sin^2\theta}$$

Answer.26

Given: Charge of the particle : q = 2.0 × 10^{-4} CDistance between charged particle and the bob:r =10 cm=0.1mMass of the bob : m = 100 g = 100 × 10^{-3} kg.**Formula used:**T = mgWhere T is the tension in the string and g is the acceleration due to gravity.∴ T = 0.1 × 9.8 ∴ T = 0.98 NNow let the charge on the bob be : q'Now the electrostatic force between the bob and the particle is given as:

$F = \left(\frac{1}{4\pi\epsilon_0} \times \left(\frac{qq'}{r^2}\right)\right)$This is the Coulomb's Law. Where ϵ_0 is the permittivity of free space and it's value is : ϵ_0 = 8.85418782 × 10^{-12} m^{-3} kg^{-1} s^4 A^2,q is the charge of the particle and q' is the charge of the bob, r is the distance between charged particle and the bob.Now, in order to have a loose string the tension in the string should be zero: T=0For tension to be zero, the particle must repel the bob along the direction of the tension.Also, weight of the bob is in opposite direction to the string.Thus the equation is:T + F = mg∴ $0 + \left(\frac{1}{4\pi\epsilon_0} \times \left(\frac{qq'}{r^2}\right)\right) = 0.1 \times 9.8$

$$\therefore \left(\frac{1}{4 \times \pi \times 8.85418782 \times 10^{-12}} \times \left(\frac{qq'}{0.1^2}\right)\right) = 0.98$$

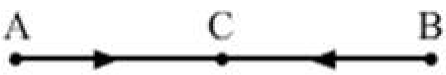
$$\therefore q' = \frac{0.98 \times 4 \times \pi \times 8.85418782 \times 10^{-12} \times 0.1^2}{2.0 \times 10^{-4}} \therefore \boldsymbol{q' = 5.4 \times 10^{-9}\ C}$$

Hence, the charge on the bob should be 5.4 × 10^{-4} C so that the string would become loose.

Answer.27

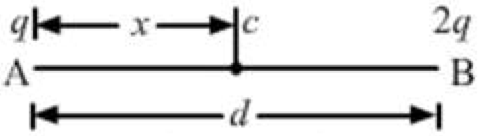
Given: Charge of the particle A : qCharge of the particle B : 2q

Distance between A and B : d**Formula used:**We will be using Coulomb's Law: $\left(\frac{1}{4\pi\epsilon_0} \times \left(\frac{qq'}{r^2}\right)\right)$Where ϵ_0 is the permittivity of free space and it's value is : ϵ_0 = 8.85418782 × 10^{-12} m^{-3} kg^{-1} s^4 A^2 and F is the electrostatic force between two charges. And r is the distance between two charges.The diagram below shows the given conditions:



C is the third particle clamped on the table. Let charge of point C be q'For A and B to remain at rest, the electrostatic forces from A and B must cancel out each other. Which means magnitude of force from A to C : $\bar{F}_{AC}$ should be equal and opposite to the force from B to C : $\bar{F}_{AB}$ as Point B has twice the charge of A.Thus the equation of rest is:

$\bar{F}_{AC} + \bar{F}_{AB} = 0$



Here x is the distance between charge A and C.From Coulomb's Law,

$F_{AC} = \left(\frac{1}{4\pi\epsilon_0} \times \left(\frac{qq'}{x^2}\right)\right) F_{AB} = \left(\frac{1}{4\pi\epsilon_0} \times \left(\frac{2qq}{(d)^2}\right)\right)$ Substituting we get,

$\left(\frac{1}{4\pi\epsilon_0} \times \left(\frac{qq'}{x^2}\right)\right) + \left(\frac{1}{4\pi\epsilon_0} \times \left(\frac{2q^2}{(d)^2}\right)\right) = 0 \ldots \ldots .. (1)$ Since we know that the magnitudes of F_{AC} and F_{BC} the forces are equal,

$\frac{1}{4\pi\epsilon_0} \times \left(\frac{qq'}{x^2}\right) = \frac{1}{4\pi\epsilon_0} \times \left(\frac{2qq'}{(d-x)^2}\right)$

$\frac{1}{x^2} = \frac{2}{(d-x)^2} \therefore (d-x)^2 = 2x^2 \therefore \sqrt{2}\,x = d - x \therefore \sqrt{2}\,x + x = d$

$\therefore (\sqrt{2}+1)x = d \therefore x = \left(\frac{d}{(\sqrt{2}+1)}\right)$ Rationalizing the denominator we get,

$\boldsymbol{x = (\sqrt{2}-1)d}$ Substituting value of x in the equation (1) we get,

$\left(\frac{1}{4\pi\epsilon_0} \times \left(\frac{qq'}{\left((\sqrt{2}-1)d\right)^2}\right)\right) + \left(\frac{1}{4\pi\epsilon_0} \times \left(\frac{2q^2}{(d)^2}\right)\right) = 0$

$\therefore \frac{1}{4\pi\epsilon_0} \times \left(\frac{qq'}{\left((\sqrt{2}-1)d\right)^2}\right) + \frac{1}{4\pi\epsilon_0} \times \left(\frac{2q^2}{d^2}\right) = 0 \therefore \frac{q'}{\left((\sqrt{2}-1)d\right)^2} + \frac{2q}{d^2} = 0$

$\therefore \frac{q'}{\left((\sqrt{2}-1)d\right)^2} = -\left(\frac{2q}{d^2}\right) \therefore q' = -\left(\frac{2q}{d^2}\right) \times (\sqrt{2}-1)^2 d^2$

$\therefore q' = -q \times 2(2 - 2\sqrt{2} + 1) \therefore q' = -q(4 - 4\sqrt{2} + 1) \therefore \boldsymbol{q' = -q(6 - 4\sqrt{2})C}$

Hence, the charge on the C is -q(6-4√2) C and it should be clamped at a distance of (√2-1)d .

Answer.28

Given: Natural Length of the spring: l = 10cm = 0.1m Spring Constant : K = 100 N m^{-1} Charge on each particle: q = 2.0 × 10^{-8} C Separation between two charges =

l**Formula used:** Let the extension be 'x' m. We use Coulomb's Law:

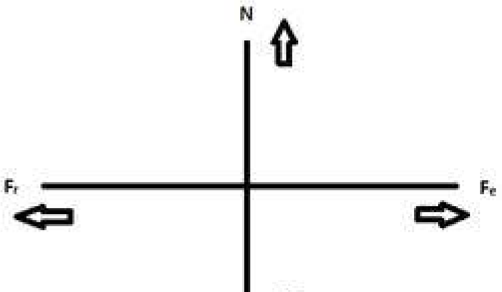
$F_e = \left(k \times \left(\frac{qq}{r^2}\right)\right)$ Where F_e is the electrostatic force, k is a constant .k = $\frac{1}{4\pi\epsilon_0}$ = 9× 10^9 Nm^2C^{-2} and r is the distance between two charges. Since the electrostatic force is repulsive in nature, the spring will exert a restoring spring force F_r. F= -Kx Here, K is the spring constant and x is the extension. Negative sign is because the restoring spring force us opposite to the applied force. The system would be in equilibrium when the Electrostatic force of repulsion between the two charges is equal to the spring force

$F_e + F_r = 0 \therefore \left(k \times \left(\frac{qq}{r^2}\right)\right) - Kx = 0 \therefore \left(k \times \left(\frac{qq}{r^2}\right)\right) = Kx \therefore k \times \left(\frac{q^2}{r^2}\right) = Kx$

$\therefore x = k \times \left(\frac{q^2}{r^2 K}\right) \therefore x = \left(9 \times 10^9 \times \frac{(2.0 \times 10^{-8})^2}{(0.1^2) \times 100}\right) \therefore \boldsymbol{x = 3.6 \times 10^{-6}\ m}$ Yes, the assumption is justified. When two similar charges are present at two ends, they will exert repulsive force on each other. The spring will extend due to its elastic nature. The repulsive force will have an opposite force called as restoring force in the spring. This force is directly proportional to the extension of the spring and depends on the elasticity if the material. If the extension is large compared to the natural length, then the restoring force would be proportional to the high powers of the extension.

Answer.29

Given: Charge of the particle A : $q_1 = 2.0 \times 10^{-6}$ C. Mass of the second charged particle i.e. B: m=80 g=80×10^{-3} kg. Separation between both the charged particles: r = 10 cm = 0.1 m Coefficient of friction between the table and this second particle: μ = 0.2



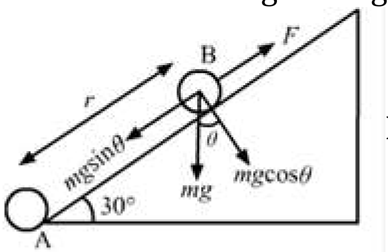
Formula used: Let the charge of the particle B be q_2 We use Coulomb's law: $\boldsymbol{F_e = k \times \left(\frac{q_1 q_2}{r^2}\right)}$ Where F_e is the electrostatic force on b due to A, k is a constant .k = $\frac{1}{4\pi\epsilon_0}$ = 9× 10^9 Nm^2C^{-2} and r is the distance between two charges. The Friction force is given as: F_r = μN= μmg Here, μ is the coefficient of friction, N is the normal reaction of table to the particle. N=mg. It is given that particle B is at equilibrium with the table,ThusF_e = F_r

$\therefore k \times \left(\frac{q_1 q_2}{r^2}\right) = \mu mg \therefore q_2 = \frac{\mu \times m \times g \times r^2}{k \times q_1}$

$\therefore q_2 = \frac{0.2 \times 80 \times 10^{-3} \times 9.8 \times (0.1)^2}{9 \times 10^9 \times 2.0 \times 10^{-6}} \therefore \boldsymbol{q_2 = 8.71 \times 10^{-8} C}$ Hence, the range within which the charge of the second particle lies is ± 8.71× 10^{-8} C. Since, charge can be positive or negative, thus ± .

Answer.30

Given: Charge of the particle A and B: q_1=q_2= q = 2.0 × 10^{-6} C.Mass of the particles A and B : m = 100 g =0.1 kg.Inclination of the inclined plain : θ = 30°



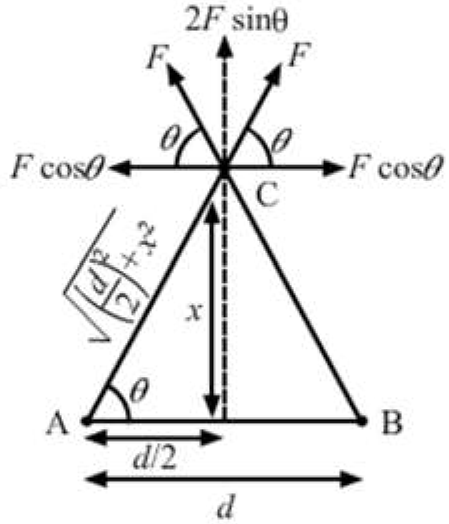
Formula used: The particle A and B will exert electrostatic repulsive forces on each other.This can be given by Coulomb's Law:We use Coulomb's law:$\boldsymbol{F_e = k \times \left(\frac{q_1 q_2}{r^2}\right)}$ Where F_e is the electrostatic force on b due to A, k is a constant .k = $\frac{1}{4\pi\epsilon_0}$ = 9× 10^9 Nm^2C^{-2} and r is the distance between two charges.Particle B would face a friction force opposite to the rolling force due to inclination. It is given as:F= mgsinθFor particle B to remain in equilibrium with the inclination and particle A. The electrostatic force of repulsion and the friction force must be equal.F_e = F.∴ $k \times \left(\frac{q_1 q_2}{r^2}\right) = mgsin\theta \therefore r^2 = \left(\frac{k}{mgsin\theta}\right) \times q^2$

$\therefore r^2 = \frac{9 \times 10^9}{0.1 \times 9.8 \times \sin(30)} \times (2.0 \times 10^{-6})^2 \therefore r^2 = 0.073\ m$

$\therefore \boldsymbol{r = \sqrt{0.073} = 0.2701\ m}$ Hence, particle b must be place at a distance of 0.2701m from particle A to remain in equilibrium.

Answer.31

Given: Charge on particles A and B: $q_1 = q_2 = Q$ Separation between A and B : d



here 'x' is the distance at which particle C of charge 'q' is place on the perpendicular bisector of AB. **Formula used:** From the figure we can find sinθ : $sin\theta = \frac{x}{\sqrt{\left(\frac{d}{2}\right)^2 + x^2}}$ The horizontal components of force cancel each other. Total vertical component of force is: $F' = 2F\sin\theta$ We use Coulomb's Law: $\boldsymbol{F = k \times \left(\frac{q_1 q_2}{r^2}\right)}$ Where F is the electrostatic force on b due to A, k is a constant .k $= \frac{1}{4\pi\epsilon_0} = 9\times 10^9\ Nm^2C^{-2}$ and r is the distance between the two charges. Here r = $\sqrt{\left(\frac{d}{2}\right)^2 + x^2}$ Substituting we get, $F' = 2 \times k \times \left(\frac{qQ}{\left(\frac{d}{2}\right)^2 + x^2}\right) \times \frac{x}{\sqrt{\left(\frac{d}{2}\right)^2 + x^2}}$

$$\therefore F' = 2 \times k \times qQ \times \left(\frac{x}{\left(\left(\frac{d}{2}\right)^2 + x^2\right)^{\frac{3}{2}}}\right)$$

Using maxima ,

For maximum force $\frac{dF'}{dx} = 0$. Thus,

$$\frac{dF'}{dx} = 2kqQ \times \left[\left(\left(\frac{d}{2}\right)^2 + x^2\right)^{-\frac{3}{2}} - \left(\frac{3}{2}x\right)\left[\left(\left(\frac{d}{2}\right)^2 + x^2\right)^{\frac{-5}{2}} \times 2x\right]\right] = 0$$

$$\therefore \left(\left(\frac{d}{2}\right)^2 + x^2\right)^{-\frac{3}{2}} = (3x^2)\left[\left(\left(\frac{d}{2}\right)^2 + x^2\right)^{\frac{-5}{2}}\right] \therefore \frac{\left(\left(\frac{d}{2}\right)^2 + x^2\right)^{-\frac{3}{2}}}{\left(\left(\frac{d}{2}\right)^2 + x^2\right)^{\frac{-5}{2}}} = 3x^2$$

$$\therefore \left(\frac{d}{2}\right)^2 + x^2 = 3x^2 \therefore \left(\frac{d}{2}\right)^2 + x^2 - 3x^2 = 0 \therefore \left(\frac{d}{2}\right)^2 - 2x^2 = 0 \therefore \frac{d}{2} = \sqrt{2}\,x$$

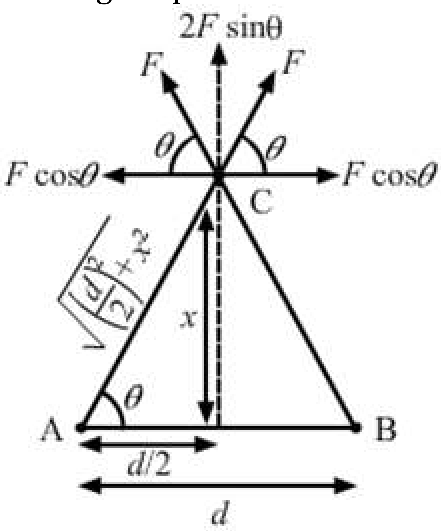
$\boldsymbol{\therefore x = \frac{d}{2\sqrt{2}}}$ The magnitude of maximum Force is:

$$F'_{Max} = 2kqQ\left(\frac{\frac{d}{2\sqrt{2}}}{\left(\left(\frac{d}{2}\right)^2+\left(\frac{d}{2\sqrt{2}}\right)^2\right)^{\frac{3}{2}}}\right)$$

Hence, the particle C must be placed at a distance of $\frac{d}{2\sqrt{2}}$ from the perpendicular bisector of AB so as to experience a maximum force of magnitude $F'_{Max} = 2kqQ\left(\frac{\frac{d}{2\sqrt{2}}}{\left(\left(\frac{d}{2}\right)^2+\left(\frac{d}{2\sqrt{2}}\right)^2\right)^{\frac{3}{2}}}\right)$

Answer.32

Given: Charge of particles A and B : q = QSeparation between A and B : d(a)



here 'x' is the distance at which particle C of mass m and charge 'q' is place on the perpendicular bisector of AB.**Formula used:**From the figure we can find sinθ : $sin\theta = \frac{x}{\sqrt{\left(\frac{d}{2}\right)^2 + x^2}}$ The horizontal components of force cancel each other.Total vertical component of force is: F'= 2FsinθWe use Coulomb's Law:$\boldsymbol{F = k \times \left(\frac{q_1 q_2}{r^2}\right)}$ Where F is the electrostatic force on b due to A, k is a constant .k = $\frac{1}{4\pi\epsilon_0}$ = 9× 10^9 Nm^2C^{-2} and r is the distance between the two charges.Here r = $\sqrt{\left(\frac{d}{2}\right)^2 + x^2}$Substituting we get,

$$F' = 2 \times k \times \left(\frac{qQ}{\left(\frac{d}{2}\right)^2 + x^2}\right) \times \frac{x}{\sqrt{\left(\frac{d}{2}\right)^2 + x^2}}$$

$$\therefore F' = 2 \times k \times qQ \times \left(\frac{x}{\left(\left(\frac{d}{2}\right)^2 + x^2\right)^{\frac{3}{2}}}\right)$$F' is the net electric force experience by particle C of charge q.(b)When x ≪ d,$\therefore x^2 \ll \left(\frac{d}{2}\right)^2$ Thus, x^2 can be neglected.Substituting we get,$\therefore F' = 2kqQ \times \left(\frac{x}{\left(\frac{d}{2}\right)^3}\right)$$\therefore F' = 16kqQ \times \left(\frac{x}{d^3}\right)$

$\therefore F' \alpha\ x$Thus, force is proportional to x.(c)The condition for Simple harmonic Motion of a particle is:$F' = m\omega^2 x$Here, m is the mass of the particle C, ω is the angular frequency.Thus comparing two equations of F', we get

$\therefore 16kqQ \times \left(\frac{x}{d^3}\right) = m\omega^2 x$ We know that $\omega = \frac{2\pi}{T}$. Where t is the Time Period.

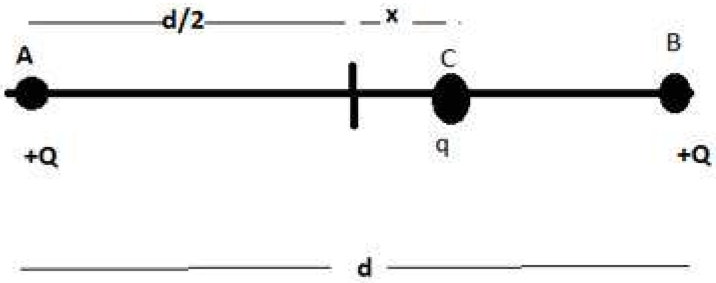
$$\therefore 16kqQ \times \left(\frac{x}{d^3}\right) = m \times \left(\frac{2\pi}{T}\right)^2 \times x \therefore T^2 = \frac{m \times 4\pi^2 \times x}{16kqQ \times \left(\frac{x}{d^3}\right)} \therefore T^2 = \frac{m\pi^2 d^3}{4kqQ}$$

$$\boldsymbol{\therefore T = \sqrt{\frac{m\pi^2 d^3}{4kqQ}}}$$

Hence time period when the particle is released after a small displacement under SHM is $\boldsymbol{T = \sqrt{\frac{m\pi^2 d^3}{4kqQ}}}$

Answer.33

Given: Charge of particles A and B : q = Q Separation between A and B : d



Here x is the displacement of particle C along AB. Distance between A and C is : $r_{AC} = \frac{d}{2} + x$

Distance between B and C is : $r_{BC} = \frac{d}{2} - x$ **Formula used:** For part (a), we will be using Coulomb's Law, $\boldsymbol{F = k \times \left(\frac{q_1 q_2}{r^2}\right)}$ Where F is the electrostatic force on B due to A, k is a constant .k = $\frac{1}{4\pi\epsilon_0}$ = 9× 10^9 Nm^2C^{-2} and r is the distance between the two charges. q_1=q_2=Q. now, the net force acting on C is: $F_{net} = F_{BC} - F_{AC}$

$$\therefore F_{net} = \frac{kqQ}{r_{BC}^2} - \frac{kqQ}{r_{AC}^2} \therefore F_{net} = kqQ\left[\left(\frac{1}{\left(\frac{d}{2} - x\right)^2}\right) - \left(\frac{1}{\left(\frac{d}{2} + x\right)^2}\right)\right]$$

$$\therefore F_{net} = kqQ\left[\frac{\left(\frac{d}{2} + x\right)^2 - \left(\frac{d}{2} - x\right)^2}{\left(\frac{d}{2} + x\right)^2 \times \left(\frac{d}{2} - x\right)^2}\right]$$

$$\therefore F_{net} = kqQ\left[\frac{\frac{d^2}{4} + dx + x^2 - \frac{d^2}{4} + dx - x^2}{\left(\left(\frac{d}{2}\right)^2 - x^2\right)^2}\right] \therefore \boldsymbol{F_{net} = kqQ \times \frac{2dx}{\left(\left(\frac{d}{2}\right)^2 - x^2\right)^2}}$$

F_{net} is the net electric force experience by particle C of charge q. (b) When x≪d, x^2≪$(d/2)^2$ Thus x^2 can be neglected. We get, $F_{net} = kqQ \times \frac{2dx}{\frac{d^4}{16}}$

$$\therefore \boldsymbol{F_{net} = \frac{32kqQx}{d^3}} \therefore F_{net} \propto x$$

Thus, when x≪d force is proportional to x (c) The condition for Simple harmonic Motion of a particle is: F'=$m\omega^2x$ Here, m is the mass of the particle C, ω is the angular frequency. Let F_{net} = F' Thus comparing two equations of F', we get $\frac{32kqQx}{d^3} = m\omega^2 x$ We know that $\omega = \frac{2\pi}{T}$. Where t is the Time Period.

$$\therefore \frac{32kqQx}{d^3} = m\left(\frac{2\pi}{T}\right)^2 x \therefore T^2 = \frac{m\pi^2 d^3}{8kqQ} \therefore \boldsymbol{T = \sqrt{\frac{m\pi^2 d^3}{8kqQ}}}$$

Hence time period when particle is displaced along AB is

$$T = \sqrt{\frac{m\pi^2 d^3}{8kqQ}}$$

Answer.34

Given: Electric Force exerted by a charge: F = 1.5 × 10^{-3} NCharge: q = 1.0 × 10^{-6} C**Formula used:**Here we use:$F = qE$Where, F is the electric force, q is the charge and E is the electric field at the position of the charge.Substituting we get,

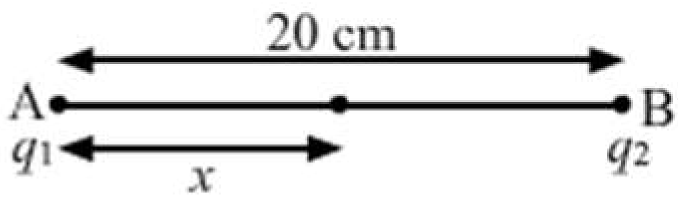
$1.5 \times 10^{-3}\,N = 1.0 \times 10^{-6}\,C \times E \therefore E = \frac{1.5 \times 10^{-3}\,N}{1.0 \times 10^{-6}\,C} \therefore E = 1500\,NC^{-1}$

$\therefore \boldsymbol{E = 1.5 \times 10^3\,NC^{-1}}$Hence, the magnitude electric field at the position of the charge is 1.5× 10^3 N/C

Answer.35

Given: Charge on particle A: q_A = +2× 10^{-6} CCharge on particle B : q_B = -4× 10^{-6} CSeparation between A and B : r = 20.0 cm=0.2m**Formula used:**Electric Field given as:$E = \frac{kq}{r^2}$Here, k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge and r is the distance between two charges.Also,Electric potential is given as:

$V = \frac{kq}{r}$Here, k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} .q is the point charge and r is the distance between two charges.Now,



Let there be a point at distance 'x' from A where net electric field is zero.Distance between A and the point be : r_A = x mDistance between B and the point be : r_B = (0.2-x) m

$E_{net} = \frac{kq_A}{x^2} + \frac{kq_B}{(0.2-x)^2} = 0 \therefore E_{net} = \frac{2 \times 10^{-6}}{x^2} - \frac{4 \times 10^{-6}}{(0.2-x)^2} = 0$

$\therefore \frac{2 \times 10^{-6}}{x^2} = \frac{4 \times 10^{-6}}{(0.2-x)^2} \therefore \frac{(2 \times 10^{-6})}{4 \times 10^{-6}} = \frac{x^2}{(0.2-x)^2} \therefore 0.5 = \frac{x^2}{(0.2-x)^2}$

$\therefore \sqrt{0.5} = \frac{x}{0.2-x} \therefore \sqrt{0.5} \times (0.2-x) = x \therefore 0.1414 - 0.707x = x$

$\therefore 0.1414 = x - 0.707x \therefore x = \frac{0.1414}{0.293} \therefore \mathbf{x = 0.4825\ m}$Hence, electric field is zero at a point 0.4825 m from A along AB.Now,Zero Net potential at the point is

$V_{net} = \frac{kq_A}{r_A} + \frac{kq_B}{r_B} = 0 \therefore \frac{2 \times 10^{-6}}{x} - \frac{4 \times 10^{-6}}{0.2 \pm x} = 0 \therefore \frac{2 \times 10^{-6}}{x} = \frac{4 \times 10^{-6}}{0.2 \pm x}$

$\therefore \frac{2\times10^{-6}}{4\times10^{-6}}=\frac{x}{0.2\pm x}\therefore 0.5=\frac{x}{0.2\pm x}\therefore 0.1\pm 0.5x=x\therefore 0.1=1.5x\therefore x=\frac{0.1}{1.5}$
$\therefore \boldsymbol{x=0.0666\ m}$ OR $\therefore 0.1=0.5x\therefore \boldsymbol{x=0.2\ m}$ Hence, potential can be zero at 0.0666 m from A along AB and at 0.2 m from B along AB.

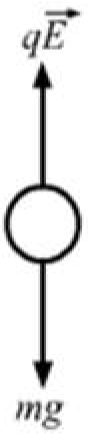
Answer.36

Given: Electric field due to a point charge: E = 5 N C^{-1} Distance between the point charge and the point at which electric field is produced : r = 40 cm = 0.4 m **Formula used:**

Electric field is given as: E=kq r^2 Here , k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ = 9× 10^9 Nm^2C^{-2} . q is the point charge .Substituting we get, $5=\frac{9\times10^9\times q}{0.4^2}\therefore q=\frac{5\times0.4^2}{9\times10^9}$
$\therefore \boldsymbol{q=8.89\times10^{-11}\ C}$ Hence, magnitude of the charge is 8.89× 10^{-11} C.

Answer.37

Given: Mass of the water particle : m= 10.0 mg = 10× 10^{-6} kg Charge of the particle: q = 1.5× 10^{-6} C



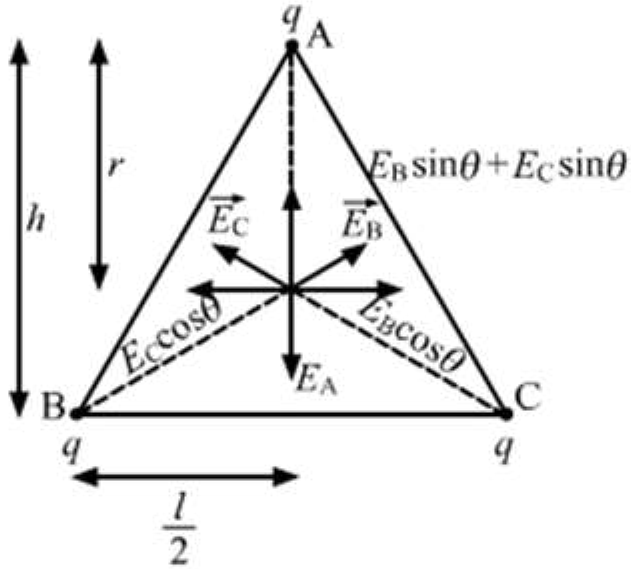
The suspended particle will be under the influence of gravity.Hence , gravity will act in downward direction as shown in the figure. **Formula used:** We know that, F_e = qE Where F is the electrostatic force, q is the charge and E is the electric field produced by the charge.But, Force due to gravity : is F_G= mg Here, m is the mass of the particle and g is the acceleration due to gravity.Now, for the particle to stay suspended in the room, the downward gravitational force must be equal and opposite to the electric force. $\therefore F_e=F_G$

$\therefore$ qE=mg $\therefore E=\frac{mg}{q}\therefore E=\frac{10\times10^{-6}\times9.8}{1.5\times10^{-6}}\therefore \boldsymbol{E=65.33\ NC^{-1}}$

Thus, the magnitude of electric field due to the charged water molecule suspended in the room is 65.33 NC and it is in upwards direction opposite to the gravitational force.

Answer.38

Given: Value of three identical charges: q = 1.0× 10^{-8} CSide of the equilateral triangle: l = 20cm = 0.2m



From the diagram,

A,B and C are the three vertices having equal charge q.E_A,E_B and E_c are the electric fields at the center of the triangle due to charges A,B and C respectively.h is the height of the equilateral triangleand r is the distance from the center of the triangle to it's all three vertices.

Formula used: Formula for potential at a point is:$V = \frac{kq}{r}$

Where k is a constant and k=$\frac{1}{4\pi\epsilon_0}$=9× 10^9 Nm^2C^{-2} .q is the point charge and r is the distance between the centre of the triangle and the vertex.

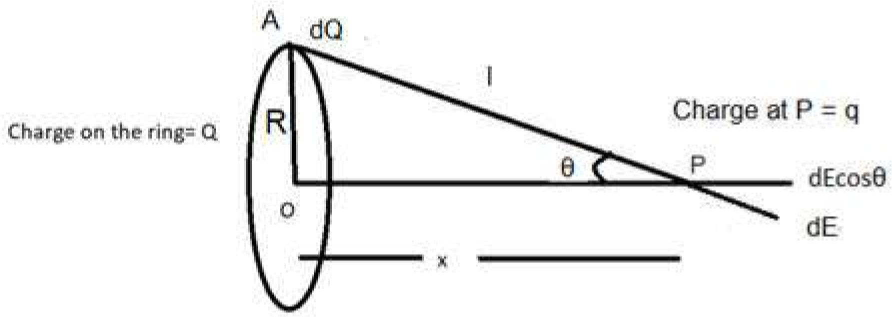
Since charges are equal at A,B and C:$E_A = E_B = E_C = E$The Field from B and C are resolved into horizontal and vertical components as seen from the figure.Here θ is 30° as every angle of an equilateral triangle is 60^o .The horizontal components balance each other.Therefore net electric field ,E_{net} = E_A -(E_B sinθ+$E_C$sinθ) ∴E_{net}= E-(Esinθ+Esinθ) ∴E_{net} = E(1-sin(30)-sin(30)) ∴E_{net} =E(1-0.5-0.5) ∴E_{net} =0Thus, the electric field at the center of the given equilateral triangle is zero.Now, using Pythagoras theorem to find value of h,$l^2 = \left(\frac{l}{2}\right)^2 + h^2 ∴ h^2 = 0.2^2 - 0.1^2$

$\therefore h = 0.173\ m$We know that, in an equilateral triangle$r = \frac{2}{3} \times h$Thus we get, $r = \frac{2}{3} \times 0.173 \therefore r = 0.1153\ m$

Since Electric field is same for all three points: $V_A = V_B = V_C$The potential at the center is :$V = V_A + V_B + V_C \therefore V = 3V_A \therefore V = 3 \times k \times \frac{q}{r}$

$\therefore V = 3 \times 9 \times 10^9 \times \frac{1.0 \times 10^{-8}}{0.1153} \therefore \boldsymbol{V = 2341\ V}$Hence , potential at the centre of the triangle is 2341 V and Electric field at the center is zero.

Answer.39

Given: 

Charge on the ring: QRadius of the ring : RCharge of the particle at point P : qMass of the particle : mDistance of P from the centre of the ring: xDistance of P from the element A : l**Formula used:**Electric force is given as:$F = qE \ldots.(1)$Where F is the electric force, q is the charge and E is the electric field.

Newton's Law gives : $F = ma \therefore a = \frac{F}{m} = \frac{kqQx}{mR^3} \ldots..(2)$Time period is given as: $T = 2\pi\sqrt{\frac{l}{a}} \ldots\ldots..(3)$Where, l is the length. In this case OP=x and a is the acceleration.

Where F is the electric force, q is the charge and E is the electric field.Consider an element of charge dQ on the ring at A.Electric field at P due to the element A is given as:$\boldsymbol{dE = \frac{kdQ}{l^2}}$Here, dE is the electric field due to element A. k=$\frac{1}{4\pi\epsilon_0}$=9× 10^9 Nm^2C^{-2}, dQ is the charge of the element A and l is the distance between A and P.Now, $l^2 = x^2 + R^2$ And $cos\theta = \frac{x}{\sqrt{x^2 + R^2}}$

As the ring is symmetric, the electric field at P will be along OP axis: Ecosθ

$\therefore dEcos\theta = \frac{kdQ}{l^2} \times \frac{x}{\sqrt{x^2+R^2}} \therefore dEcos\theta = \frac{kdQx}{(x^2+R^2)^{\frac{3}{2}}}$ Therefore, the net electric field at P due to the entire ring is: $E = \int dEcos\theta \therefore E = \int \frac{kdQx}{(x^2+R^2)^{\frac{3}{2}}}$

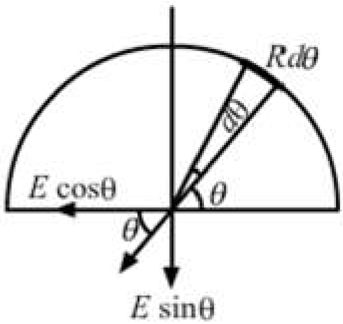
$\therefore E = \frac{kx}{(x^2+R^2)^{\frac{3}{2}}} \int dQ \therefore \boldsymbol{E} = \frac{\boldsymbol{kQx}}{(\boldsymbol{x^2}+\boldsymbol{R^2})^{\frac{3}{2}}}$ Therefore substituting in equation (1) we get, $\boldsymbol{F} = \frac{\boldsymbol{kqQx}}{(\boldsymbol{x^2}+\boldsymbol{R^2})^{\frac{3}{2}}}$ Here, F is the electric force on the particle due to entire charged ring. Now the condition given in the question is x≪R. Thus, x^2 can be neglected. $F = \frac{kqQx}{(R^2)^{\frac{3}{2}}} \therefore F = \frac{kqQx}{R^3}$ Hence using equation (2) and (3) we get,

$T = 2\pi\sqrt{\left(\frac{x}{\frac{kqQx}{mR^3}}\right)} \therefore \boldsymbol{T} = \boldsymbol{2\pi}\sqrt{\frac{\boldsymbol{mR^3}}{\boldsymbol{kqQ}}}$ Putting the value of k: $\boldsymbol{T} = \left(\frac{\boldsymbol{16\pi^3\epsilon_0 mR^3}}{\boldsymbol{Qq}}\right)^{\frac{1}{2}}$

Hence time period of oscillation of the particle is $\left(\frac{16\pi^3\epsilon_0 mR^3}{Qq}\right)^{\frac{1}{2}}$

Answer.40

Given: Length of the rod: L Uniformly distributed charge: Q When the rod is bent into a semicircle, let R be its radius.



Here, dθ is the width of the angular element on the circumference. The displacement of the element with width dθ is Rdθ. Let the displacement of the element be dl. The Electric field is divided in to horizontal and vertical components. Horizontal components are cancelled out. **Formula Used:** We know that: $\lambda = \frac{Q}{L}$ Here, λ is the linear charge density of the rod, Q is the charge of the rod and L is the length of the rod. for a charge dq of element dl we have $dq = \lambda \times dl$ We know what dl =rdθ

$\therefore dq = \frac{Q}{L} \times Rd\theta$ The formula for electric field is: $\boldsymbol{E} = \frac{\boldsymbol{kq}}{\boldsymbol{r^2}}$ Here, k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge and r is the distance between the charge and the point of influence. here r=R. The net electric field due to vertical component is:$E_{net} = \int dE sin\theta \ d\theta$Here, dE is the electric field due to element dl having charge dq and the limits of the integral would be from 0 to π as it is a semicircle.$\therefore E_{net} = \int_0^{\pi} \frac{kdq}{r^2}$$\therefore E_{net} = \frac{kQ}{L}\int_0^{\pi} \frac{Rd\theta}{R^2} \times sin\theta$$\therefore E_{net} = \frac{kQ}{LR}\int_0^{\pi} sin\theta d\theta$

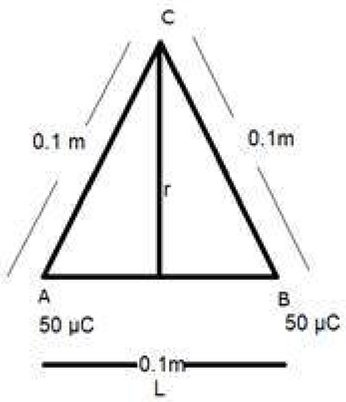
$\therefore E_{net} = \frac{kQ}{lR}[-cos\theta]_0^{\pi}$$\therefore E_{net} = \frac{kQ}{LR}[-(-1-1)]$$\therefore E_{net} = \frac{2kQ}{LR}$

If we substitute value of k we get,$\therefore E_{net} = \frac{2Q}{4\pi\epsilon_0 LR}$$\therefore \boldsymbol{E_{net} = \frac{Q}{2\epsilon_0 L^2}}$

As L=π R.Hence electric field at the centre of the curvature is $\frac{Q}{2\epsilon_0 L^2}$

Answer.41

Given: Length of the rod : L = 10cm = 0.1mCharge on the rod; q = +50 μC= 50× 10^{-6} C



Here, C is 10 cm = 0.1 m away from both ends of the rod AB.Distance between C and centre of AB : r**Formula used:**From Pythagoras Theorem,$r^2+(L/2)^2=(BC)^2$

$\therefore r^2= [0.1]^2- [0.05]^2$

$\therefore r^2= 7.5\times10^{-3}$

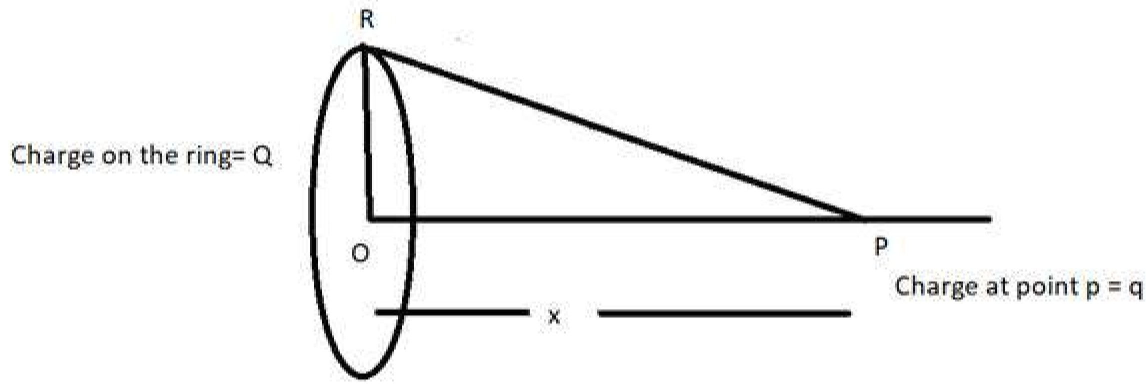
$\therefore r=\sqrt{(7.5\times10^{-3})}$

∴r=0.0866 mNow we know that, Electric field at a point on the perpendicular bisector of a uniformly charged rod is:$\boldsymbol{E = \frac{2kQ}{r(\sqrt{L^2+4r^2})}}$Here, k is a constant and $k=\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge, L is the length of the rod and Q is the magnitude of the charge.Substituting we get,

$E = \frac{2 \times 9 \times 10^9 \times 50 \times 10^{-6}}{0.0866\left(\sqrt{0.1^2 + 4(0.0866)^2}\right)}$ $\therefore$ $\boldsymbol{E = 5.2 \times 10^7\ NC^{-1}}$Hence, electric field at a point 10 cm away from the ends of the rod is $5.2 \times 10^7\ NC^{-1}$.

Answer.42

Given: Charge of the ring: QRadius of the ring :RLet P be the point where electric field is found.Distance between center of the ring and P is x.



Formula used: We know that electric field at any point on the axis at a distance x from the center is:$E = \frac{kQx}{(R^2 + x^2)^{\frac{3}{2}}}$Where k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2}. Q is the charge of the ring, x is the distance between center of the ring and point P and R is the radius of the ring.Now for the electric field to be maximum, we use the maxima property:$\frac{dE}{dx} = 0$Taking derivative of E w.r.t x,

$$\frac{dE}{dx} = kQ\left[(R^2 + x^2)^{-\frac{3}{2}} - \left(\frac{3}{2}x\right)(R^2 + x^2)^{-\frac{5}{2}} \times 2x\right] = 0$$

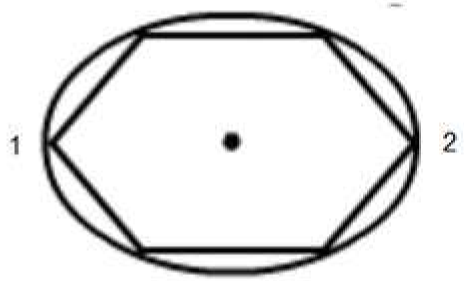
$$\therefore\ (R^2 + x^2)^{-\frac{3}{2}} - \left(\frac{3}{2}x\right)(R^2 + x^2)^{-\frac{5}{2}} \times 2x = 0$$

$$\therefore\ (R^2 + x^2)^{-\frac{3}{2}} = (3x^2)(R^2 + x^2)^{-\frac{5}{2}} \therefore\ (R^2 + x^2)^{-\frac{3}{2}} \times \frac{1}{(R^2 + x^2)^{-\frac{5}{2}}} = 3x^2$$

$\therefore R^2 + x^2 = 3x^2 \therefore R^2 = 2x^2 \therefore \boldsymbol{x = \frac{R}{\sqrt{2}}}$Hence Electric field is maximum at $x = \frac{R}{\sqrt{2}}$ on the axis.

Answer.43

Given: Uniformly distributed Charge on the regular hexagon : q



When a wire is bent in the form of a regular hexagon having charge q uniformly distributed, each point on the hexagon will contribute same magnitude of electric field.Say, 6 vertices of the hexagon have same charge q.Thus they will produce same electric field E at the center.This electric field gets nullified as same magnitude is acting from both sides.**Formula used:** Electric field at a point due to a point charge is given as: $E = \frac{kq}{r^2}$ Where k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2}. q is the charge and r is the distance between the point and the charge.Mathematically: $E_1=E_2$ From the figure E_1 is the electric field due to vertex 1 at the center and E_2 is the electric field due to vertex 2 at the center diametrically opposite to vertex 1.Thus net electric field at center due to 1 and 2 is $E_{net} = E_1-E_2$ ∴ $E_{net} = \frac{kq}{r^2} - \frac{kq}{r^2}$ ∴ $E_{net} = 0$ Eventually electric field due to all 6 vertices cancel out each other at the center.Hence, electric field at the center of the regular hexagon is zero.

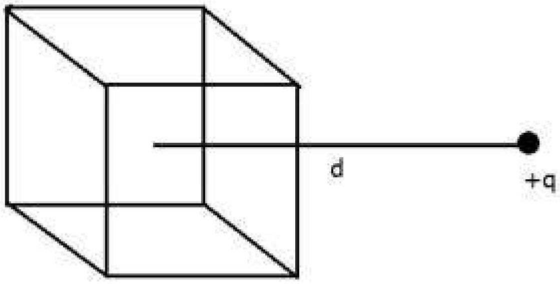
Answer.44

Given: Radius of the circular loop : a Total charge on the wire : Q Length of the cut off wire: dL **Formula used:** Electric field is given as: $E = \frac{kq}{r^2}$ Here, k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge and r is the distance between the charge and the point of influence.Here r=a=radius of the loop. We know that, electric field at the center of the uniformly charged circular wire $E_{cutoff} + E_{remaining} = 0$ Which means that sum of electric field due to cut off wire and remaining wire is zero.We know that, $\lambda = \frac{Q}{L}$ Where λ is the linear charge density. Q is the total charge and L is the length of the wire.Charge on the element dL be dq: $\lambda = \frac{dq}{dL}$ ∴ $dq = \lambda dL$ ∴ $dq = \frac{Q}{L} dL$ Here L = 2πa=circumference. Here, a is the radius of the loop and L is the Length of the loop.∴ $dq = \frac{Q}{2\pi a} dL$ Thus, electric field due to dL(cutoff wire) at the center is: $E_{cutoff} = \frac{kdq}{a^2}$ ∴ $E_{cutoff} = \frac{k\frac{Q}{2\pi a}dL}{a^2}$

$\therefore E_{cutoff} = \frac{kQdL}{2\pi a^3}$Since$E_{cutoff} + E_{remaining} = 0 \therefore \frac{kQdL}{2\pi a^3} + E_{remaining} = 0$
$\therefore E_{remaining} = -\left(\frac{kQdL}{2\pi a^3}\right)$ Thus, magnitude of electric field at the center of the circular wire due to remaining wire is E=$\frac{kQdL}{2\pi a^3}$ but in opposite direction to that of the field due to cut off wire.

Answer.45

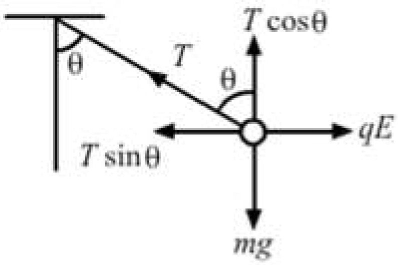
Given: Charge placed in front of a solid cube: +qDistance between the charge and the center of the cube: d



Formula used: Formula for electric field is:$E = \frac{kq}{r^2}$Here, k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge and r is the distance between the charge and the point of influence.Since we have to find electric field at the center of the cube$r = d$
$\therefore E = \frac{kq}{d^2} \therefore E = \frac{q}{4\pi\epsilon_0 d^2}$ Hence, electric field at the center of the cube due to a positive charge at a distance d from the center of cube is $E = \frac{q}{4\pi\epsilon_0 d^2}$.

Answer.46

Given: Mass of the bob: m = 80 mg= 80× 10^{-6} kgCharge on the bob: q = 2 × 10^{-8} CElectric field : E = 20 kVm^{-1} = 20× 10^3 Vm^{-1}.



Here the electric field is horizontal.The tension in the string is resolved into two components:Horizontal component : Tsinθ Vertical component : Tcosθ As shown in the figure.**Formula Used:**Since electric field acts on the bob having charge q, it experiences an electric field in horizontal direction.Electric force is given as:F=qEF is electric force, q is the charge on the bob and E is the horizontal electric field. This electric force is balanced by the horizontal component of the tension.Tsinθ = qENow the vertical component of tension is balanced by the weight of the bob.Tcosθ=mgDividing we get,$\frac{Tsin\theta}{Tcos\theta} = \frac{qE}{mg}$$\therefore tan\theta = \frac{2 \times 10^{-8} \times 20 \times 10^{3}}{80 \times 10^{-6} \times 9.8}$

$\therefore \tan\theta = 0.510 \therefore \theta = \tan^{-1}(0.510) \therefore \theta = 27.02°$ Substituting the value of θ , we can calculate tension in the string.$\therefore Tcos(27.02) = 80 \times 10^{-6} \times 9.8$

$\therefore T = \frac{7.84 \times 10^{-4}}{0.89}$$\therefore \boldsymbol{T = 8.8 \times 10^{-4} N}$ Hence the tension in the string is 8.8×10^{-4} N.

Answer.47

Given: Mass of the particle: mCharge of the particle: qinitial velocity of the particle when thrown : uUniform electric field : E**Formula used:**When a charge q moves in an uniform electric field E, it experiences an electric force F.F=qEBut this particle is thrown **against** the electric field, hence the force experience would be negative.F=-qEAccording to Newton's Second Law:F=maWhere a is the acceleration and m is the mass of the body.Thus,$a = \frac{F}{m} = -\left(\frac{qE}{m}\right)$We will be using one of the equations of motion.$\boldsymbol{v^2 = u^2 + 2as}$Here, v is the final velocity of the particle, u is the initial velocity, a is the acceleration and s is the displacement.Since particle comes to rest, final velocity: v=0Thus,

$0 = u^2 - \frac{2qE}{m} \times s \therefore \frac{2qE}{m} \times s = u^2 \therefore \boldsymbol{s = \frac{u^2 m}{2qE} units}$. Hence, the particle will travel $\frac{u^2 m}{2qE}$ units before coming to rest.

Answer.48

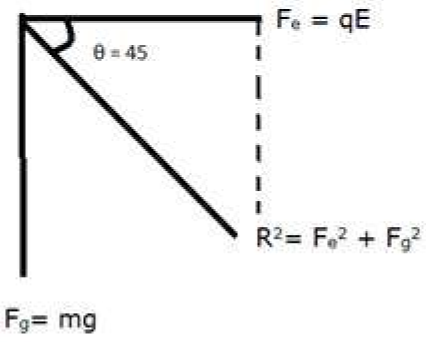
Given: Mass of the particle : m= 1g = 10^{-3} kgCharge of the particle: q = 2.5×10^{-4} CElectric Field: E = 1.2×10^{4} N C^{-1}Distance travelled : s = 40 cm = 0.4 mInitial velocity: u = 0**Formula used:**(a)When a charge q moves in an uniform electric field E, it experiences an electric force F_e.F_e = qEsubstituting the values we get,

$F_e = 2.5 \times 10^{-4} \times 1.2 \times 10^4$ ∴ F_e = 3NForce of gravity would be:$F_g = mg$ Where m is the mass of the particle and g is the acceleration due to gravity. $\therefore F_g = 10^{-3} \times 9.8 \therefore \boldsymbol{F_g = 9.8 \times 10^{-3} N}$Since the mass of the particle is very low, force due to gravity can be neglected.(b)From Newton's Second Law,F=mawhere a is the acceleration of the body and m is the mass.$\therefore a = \frac{F}{m}$acceleration of the particle is:$a = \frac{F_e}{m} = \frac{3}{10^{-3}} = 3 \times 10^3 \frac{m}{s^2}$Using one of the equations of motion: $\boldsymbol{s = ut + \frac{1}{2}at^2}$Here, s is the distance travelled, u is the initial velocity, t is the time required to travel s, and a is the acceleration of the particle.Substituting we get,$0.4 = 0 + 0.5 \times 3 \times 10^3 \times t^2 \therefore t^2 = \frac{0.4}{1500} \therefore t = (2.67 \times 10^{-4})^{\frac{1}{2}}$ $\therefore \boldsymbol{t = 0.0163\ seconds}$ It will take 0.0163 seconds for the particle to travel a distance of 40 cm.(c)Using another equation of motion$\boldsymbol{v^2 = u^2 + 2as}$Here v is the final velocity of the particle,u is the initial velocity of the particle, a is the acceleration and s is the distance travelled by the particle.Substituting we get, $v^2 = 0 + 2 \times 3 \times 10^3 \times 0.4 \therefore v^2 = 2400 \therefore \boldsymbol{v = \sqrt{2400} = 48.9 \frac{m}{s}}$After travelling 40cm the speed of the particle will be 48.9 m/s.(d)We know that,Work=Force×DisplacementThus work done by the electric force:W = F × s ∴ W = 3× 0.4 ∴ W = 1.2 J

Hence , work of 1.2 J is being done by the electric force on the particle.

Answer.49

Given: Mass of the ball : m = 100 g = 100× 10^{-3} kg =0.1 kgCharge on the ball : q = 4.9 × 10^{-5} CHorizontal electric field : E= 2.0 × 10^4 C NC^{-1}Initial Velocity of the ball: u

= 0 

Here, R is the resultant Force due to

gravitational force F_g and electric force F_e.**Formula used:**(a)Electric force F_e due to charge q and electric field E isF_e = qE.$\therefore F_e = 4.9 \times 10^{-5} \times 2.0 \times 10^4$

$\therefore \mathbf{F_e = 0.98\ N}$ Gravitational force F_g experience due to mass of the ball m and acceleration due to gravity g is:F_g=mg.$\therefore F_g = 0.1 \times 9.8 \therefore \boldsymbol{F_g = 0.98\ N}$Thus we see that $F_e = F_g$The Resultant force R can be calculated by:$R^2=F_e^2+F_g^2$

$\therefore R^2= (0.98)^2+(0.98)^2$

$\therefore R=\sqrt{1.9208}$

$\therefore$R=1.3859 N Hence the resultant force of 1.3859 N is acting on the ball.(b)We take tangent of the angle θ $tan\theta = \frac{Opposite\ side}{Adjacent\ side}$$tan\theta = \frac{F_g}{F_e}$But $F_g= F_e$,$\therefore tan\theta = 1$

$\therefore \theta = 45°$ Hence, the path of the ball is along a straight line and inclined at an angle of 45° with the horizontal electric field.(c)Here, we will be using one of the equations of motion.$\boldsymbol{s = ut + \frac{1}{2}at^2}$Here s is the distance covered by the ball, u is the initial velocity of the ball, a is the acceleration of the ball and t is the time required to cover s.We need to find s at t=2sFirstly ,vertical displacement due to gravitational force is:a=g.$\therefore s = 0 + 0.5 \times 9.8 \times 2^2 \therefore s_v = 19.6\ m.$ Secondly, $a = \frac{F}{m}$Horizontal displacement due to electric force is:$s_h = 0 + \frac{1}{2} \times \frac{F_e}{m} \times 2^2$

$\therefore s = 0.5 \times \frac{0.98}{0.1} \times 4 \therefore s = 19.6\ m$Thus net displacement = $(s_v^2+ s_h^2)^{1/2}$$\therefore$ Net displacement = $((19.6)^2+(19.6^2))^{1/2}$$\therefore$ Net displacement = 27.71 m

Thus, the ball will be at a distance of 27.71m after 2s

Answer.50

Mass of the bob: m = 40 g = 0.04 kgCharge of the bob: q = 4.0 × 10^{-6} COscillations in t=45s : 20Vertical electric field: E = 2.5 × 10^4 N C^{-1}.**Formula used:**Time period of a simple pendulum is:$T = 2\pi\sqrt{\frac{l}{g}}$here l is the length of the string .Thus, when there is no electric field, the time period is:$T_1 = 2\pi\sqrt{\frac{l}{g}}$When a vertical electric field is applied, the positively charged bob will experience a vertical acceleration due to electric force. Thus net acceleration of the bob = g-aTime period of the simple pendulum when vertical electric field applied is:$T_2 = 2\pi\sqrt{\frac{l}{g-a}}$Now,Since a is due to electric force, by Newton's Second Law and Formula for electric force, we get $a = \frac{F}{m} = \frac{qE}{m}$$\therefore a = \frac{4.0 \times 10^{-6} \times 2.5 \times 10^{4}}{0.04}$$\therefore a = 2.5\frac{\text{m}}{\text{s}^2}$Thus g-a = 9.8-2.5 = 7.3 m/s^{2}Taking ratio we get:$\frac{T_1}{T_2} = \frac{2\pi\sqrt{\frac{l}{g}}}{2\pi\sqrt{\frac{l}{g-a}}}$$\therefore \frac{T_1}{T_2} = \sqrt{\frac{g-a}{g}}$$\therefore \frac{T_1}{T_2} = \sqrt{\frac{7.3}{9.8}}$ $\therefore \frac{T_1}{T_2} = 0.863$$\therefore T_2 = \frac{45}{0.863}$$\therefore T_2 = 52\ seconds.$Hence time required by the bob to complete 20 oscillations in presence of a vertical electric field is 52 seconds.

Answer.51

Given: Mass of the block: mCharge of the block: q**Formula used:**When a charged body of charge q and mass m is brought under an horizontal electric field E, it will experience electric force F_e in the direction of the field.F_e=qEWhen the block is accelerated due to the electric force, the spring will cause a restoring spring force in the opposite direction.Spring force is:F_s = -kxWhere, k is the spring constant and x is the distance the spring is stretched or compressed.Here x is the amplitude.Thus,F_e = F_s ∴ qE = -kx.$\therefore x = \left|-\frac{qE}{k}\right|$$\therefore \boldsymbol{x} = \frac{\boldsymbol{qE}}{\boldsymbol{k}}$We used modulus as the amplitude cannot be negative.Hence, $\frac{qE}{k}$ is the amplitude of the resulting SHM of the block.

Answer.52

Given: Mass of the block : mCharge on the block: qDistance between block and the wall : dHorizontal electric field: EInitial velocity: u=0

Formula used: It is not Simple Harmonic Motion. In SHM the acceleration is directly proportional to the displacement of the body and in opposite direction of the displacement. In this case, acceleration is proportional to the displacement **but** not in the opposite direction.We know that,$F = qE \ and \ F = ma \therefore a = \frac{qE}{m}$Here, F is the horizontal Electric force , q is the charge of the body and E is the electric force (horizontal), a is the acceleration and m is the mass of the bodyTo find time required by the block to collide into the wall can be calculated by laws of motion. $s = ut + \left(\frac{1}{2}\right) at^2$Here s is the displacement; s=d. u is the initial velocity , a is the acceleration of the block and t is the time required to travel the displacement. $\therefore d = 0 + \frac{1}{2} \times \frac{qE}{m} \times t^2 \therefore t = \sqrt{\frac{2dm}{qE}}$This is the time required by the block to travel d and hit the wall.Since it is assumed to be elastic collision , after collision with the wall the block will take same time ‘t’ to come back till it’s velocity is zero.Thus Total time take:T$T = 2t \therefore \boldsymbol{T = 2\sqrt{\frac{2dm}{qE}}}$Time period of the resulting oscillatory motion is $T = 2\sqrt{\frac{2dm}{qE}}$

Answer.53

Given: Electric field: E= 10 N C^{-1}Change in Height : dh = 50 cm= 0.5 m**Formula used:**Since the electric field exists in vertically downward direction, E becomes negative as one goes up. E= -10 N C^{-1}Change in potential is :dV = -E.drHere, dV is change in potential, dr is the distance moved and E is the electric field.In this case dr=dh∴ dV = -(-10)× 0.5 ∴ dV = 5 VHence, Increase in potential as one goes up by 50cm is 5V.

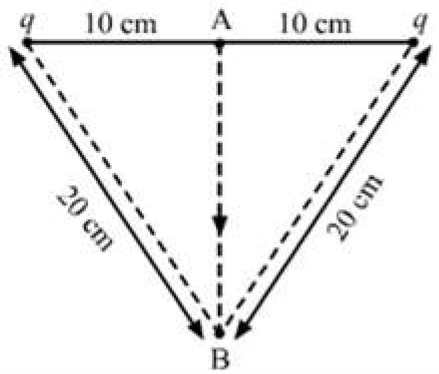
Answer.54

Given: Work done against electric field: W= 12 JCharge : q= 0.01 C**Formula used:**Work done is given by:W=Potential difference×charge

∴W=(V_B-V_A)×qHere, V_B-V_A is the potential difference and q is the charge. $\therefore\ V_B - V_A = \frac{W}{q}\therefore\ V_B - V_A = \frac{12}{0.01}\therefore\ \boldsymbol{V_B - V_A = 1200\ V}$Hence, potential difference is 1200 V

Answer.55

Given: Magnitude of all three charges: q_1=q_2=q_3= q= 2.0 × 10^{-7} CSeparation between first two charges: d = 20 cm = 0.2m



From the figure,Distance between charge at A and both the charges:r =10cm= 0.1 mDistance between charge at b and both the charges:r'= 20 cm= 0.2 m**Formula used:**Potential is given as$\boldsymbol{V = \frac{Kq}{r}}$Here, Here, k is a constant and k=$\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge and r is the distance between the charge and the point of influence.Since A is midway between two point charges, potential at A will be due to both the charges:$V_A = 2 \times \frac{kq}{r}\therefore\ V_A = \frac{2 \times 9 \times 10^9 \times\ 2.0\ \times\ 10^{-7}}{0.1}$

$\therefore\ V_A = 36000\ V$ Now, when charge at A is displaced to B, potential difference is created. Potential at B is due to both the charges at 0.2 m equally from B.Potential at B:$V_B = 2 \times \frac{kq}{r'}\therefore\ V_B = \frac{2 \times 9 \times 10^9 \times\ 2.0\ \times\ 10^{-7}}{0.2}\therefore\ V_B = 18000\ V$Thus, Potential difference is:V_A-V_B =36000-18000 ∴ V_A-V_B = 18000Work done is:W= (V_A-V_B) × q ∴ W = 18000 × 2.0 × 10^{-7} ∴ W = 3.6 × 10^{-3} JHence, 3.6× 10^{-3} J of work is being done by the electric field during whole process.

Answer.56

Given: Magnitude of Electric field: $E = 20\ N\ C^{-1}$ E is along x-axis **Formula used:** As Electric field is along x-axis, potential difference will be along x-direction. Which means only x co-ordinates will be considered. We know that, $dV = -E.ds$ Here dV is the change in potential : dV= V_B-V_A E is the electric field along positive x axis and ds is the change in displacement. (a) A = (0, 0); B = (4m, 2m) ∴ V_B-V_A= -20×(4-0) = -80 V (b) A = (4m, 2m); B = (6m, 5m) ∴ V_B-V_A= -20×(6-4) = -40 V (c) A = (0, 0); B = (6m, 5m) ∴ V_B-V_A= -20×(6-0) = -120 V (d) From (a),(b) and (c), we conclude that: Potential difference of at points A = (0, 0), B = (6m, 5m)= Potential difference at points A = (0, 0), B = (4m, 2m)+ Potential difference at points A = (4m, 2m), B = (6m, 5m)

Answer.57

Given: Magnitude of Electric field: $E = 20\ N\ C^{-1}$ Magnitude of charge moved from A to B = -2.0×10^{-4} C **Formula used:** Change in Electrical potential energy is $\boldsymbol{\Delta U = \Delta V \times q}$ Here, ΔU is change in Electrical potential energy, Δ V is change in potential and q is the charge displaced. ΔU = U_B-U_A where U_B is electric potential energy at B and U_A is electric potential energy at A (a) A = (0, 0); B = (4m, 2m) ∴ V_B-V_A= -20×(4-0) = -80 V Thus Change in Electrical potential energy is U_B-U_A = (V_B – V_A)× q ∴ Δ U = -80 × -2.0× 10^{-4} ∴ Δ U = 0.016 J (b) A = (4m, 2m); B = (6m, 5m) ∴ V_B-V_A= -20×(6-4) = -40 V Thus Change in Electrical potential energy is U_B-U_A = (V_B – V_A)× q ∴ Δ U = -40 × -2.0× 10^{-4} ∴ Δ U = 0.008 J (c) A = (0, 0); B = (6m, 5m) ∴ V_B-V_A= -20×(6-0) = -120 V Thus Change in Electrical potential energy is U_B-U_A = (V_B – V_A)× q ∴ Δ U = -120 × -2.0× 10^{-4} ∴ Δ U = 0.024 Hence, for the cases (a),(b) and (c) the change in electric potential energy when the charge is moved from A to B is 0.016 J, 0.008 J , 0.024 J respectively.

Answer.58

Given: Electric field: $\vec{E}$ = 20$\vec{i}$+ 30$\vec{j}$ NC^{-1}V(0,0) = 0Final position: $\vec{r} = (2\vec{i} + 2\vec{j})$
Formula used: We know that Electric potential is given as:$V = -E.ds$Where ds is the change in displacement.In vector form$\vec{V} = -\vec{E}.\vec{r}$Here, r̄ is the changed position from origin.∴ $\vec{V} = -(20\vec{i} + 30\vec{j}).(2\vec{i} + 2\vec{j})$
∴ $\vec{V} = -(20 \times 2 + 30 \times 2)$∴ $\vec{\boldsymbol{V}} = -\mathbf{100}\ \boldsymbol{V}$

Hence potential at (2m,2m) is -100 V.

Answer.59

Given: Electric Field : $\vec{E} = Ax\vec{i}$A = 10 Vm^{-2}V(10m,20m) = 0**Formula used:**Change in potential is:$dV = -E.dx$Where dV is change in potential, E is the electric field and dx is the change in displacement.$\vec{E} = 10x\vec{i}$In vector form:$dV = -\vec{E}.\vec{dx}$
∴ $dV = -10xdx$Integrating we get:$V = -10\int_{10}^{0} xdx$∴ $V = -10\left[\frac{x^2}{2}\right]_{10}^{0}$
∴ $\boldsymbol{V} = \mathbf{10} \times \frac{\mathbf{100}}{\mathbf{2}} = \mathbf{500}\ \boldsymbol{V}$Here limits 10 to 0 is taken as 10 m is the x co-ordinate and origin has (0,0)Hence. potential of 500 V exists at the origin.

Answer.60

Given: Electric Potential :V(x,y,z) = A (xy + yz + zx).A = 10 SI units.**Formula used:**
(a)From the given data V(x,y,z) = A (xy + yz + zx), we can say that Voltage is the product of A and length^2(xy+yz+zx)Volt = A× m^2∴ $A = \frac{Volt}{m^2}$We know that Volt = $\left[\frac{ML^2}{QT^2}\right]$, where Q= $[IT^{-1}]$∴ $A = \frac{[ML^2I^{-1}T^{-3}]}{[L^2]}$ ∴ $\boldsymbol{A} = [\boldsymbol{MI^{-1}T^{-3}}]$Thus, dimensions of A are $[\boldsymbol{MI^{-1}T^{-3}}]$(b)Formula for electric field is:$\vec{\boldsymbol{E}} = -\boldsymbol{\nabla}.\boldsymbol{V}$Where
∇= $\frac{\partial}{\partial x}\vec{i} + \frac{\partial}{\partial y}\vec{j} + \frac{\partial}{\partial z}\vec{k}$∴ $\vec{\boldsymbol{E}} = -\left(\left(\frac{\partial}{\partial x}\vec{i} + \frac{\partial}{\partial y}\vec{j} + \frac{\partial}{\partial z}\vec{k}\right).A\,(xy + yz + zx)\right)$

$$\therefore \vec{E} = -\left(A\left(\frac{\partial(xy + yz + zx)}{\partial x}\right)\vec{\imath} + A\left(\frac{\partial(xy + yz + zx)}{\partial y}\right)\vec{\jmath} + A\left(\frac{\partial(xy + yz + zx)}{\partial z}\right)\vec{k}\right)$$

$\therefore \boldsymbol{\vec{E} = -A(y+z)\vec{\imath} - A(x+z)\vec{\jmath} - A(x+y)\vec{k}}$Hence , expression of electric field is $\vec{E} = -A(y+z)\vec{\imath} - A(x+z)\vec{\jmath} - A(x+y)\vec{k}$(c)A = 10 SI units(x,y,z) = (1m,1m,1m)Substituting in the expression of E we get:
$\vec{E} = -10(1+1)\vec{\imath} - 10(1+1)\vec{\jmath} - 10(1+1)\vec{k} \therefore \vec{E} = -20\vec{\imath} - 20\vec{\jmath} - 20\vec{k}$
Magnitude of Electric field is$E = \sqrt{(-20)^2 + (-20)^2 + (-20)^2} \therefore E = \sqrt{1200}$
$\therefore \boldsymbol{E = 34.64\ NC^{-1}}$

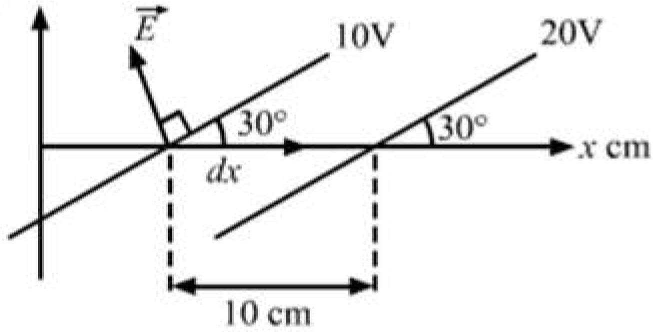
Hence, magnitude of Electric field at (1m,1m,1m0 is 34.64 NC^{-1}.

Answer.61

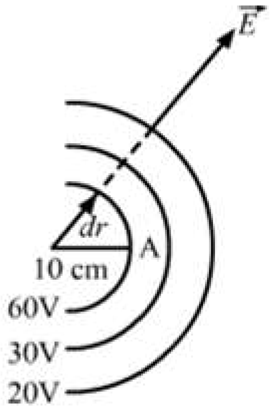
Given: Charge of two particles: $q_1=q_2= 2.0 \times 10^{-5}$ CSeparation between two charges: r = 10 cm = 0.1 m**Formula used:**Electric potential energy is given as: $U = \frac{kq_1q_2}{r}$Where,k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge and r is the separation between two charges.When two charges were at infinity, the separation between them was infiniteThus,$U_\infty = \frac{kq_1q_2}{\infty} \therefore U_\infty = 0$Now, when the separation between them was 10 cm;$U_f = \frac{kq_1q_2}{r}$Where U_f is the final electric potential energy.Substituting the values we get,
$U_f = \frac{9 \times 10^9 \times 2.0 \times 10^{-5} \times 2.0 \times 10^{-5}}{0.1} \therefore \mathbf{U_f = 36\ J}$ Now, increase in electric potential energy: Δ U$\Delta U = U_f - U_\infty \therefore \Delta U = 36 - 0 \therefore \boldsymbol{\Delta U = 36\ J}$Hence, Electric potential energy increased by 36 J during the process.

Answer.62

Given: From figure (a)Angle between equipotential surfaces and the displacement x:θ = 30°Change in potential : dV = 10 VChange in displacement between two consecutive equipotential surfaces: dx = 10 cm = 0.1 mFrom figure (b)Increase in radius from center: dr= 10cm=0.1m**Formula used:**(a)As we know that the electric field $\vec{E}$ is always perpendicular to the equipotential surface



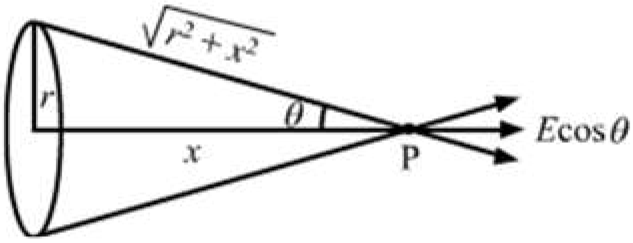
From the above diagram, the angle between Electric field $\vec{E}$ and dx ; θ' = 90° +30° =120°Change in electric potential is given as:$dV = -\vec{E}.dx \therefore 10 = -Edx\cos(\theta')$ $\therefore 10 = -E \times 0.1 \times \cos(120°) \therefore E = \frac{10}{0.1 \times 0.5} \therefore \boldsymbol{E = 200\frac{V}{m}}$ Hence the magnitude of electric field is 200 V/m making an angle of 120° with the x axis.(b)As we know that the electric field $\vec{E}$ is always perpendicular to the equipotential surface



Radius increases by: dr= 10 cm = 0.1 mAs $\vec{E}$ is perpendicular to the equipotential surface, $\vec{E}$ and dr would be along same line as shown in the figure above.Thus angle between $\vec{E}$ and dr : θ = 0We know that potential at a point due to a charge q is given as:$V = \frac{kq}{r}$Where, k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge and r is radius of that surface.Consider potential at point A where r=0.1 m$V_A = 60V \therefore 60 = \frac{kq}{0.1}$ $\therefore kq = 60 \times 0.1 = 6$Electric field is given as:$E = \frac{kq}{r^2}$Substituting value of kq we get,$\boldsymbol{E = \frac{6}{r^2}}$Hence, the magnitude of the electric field is $\frac{6}{r^2}$ and it's direction is radially outward with decreasing with increasing radii.

Answer.63

Given: Radius of the circular ring: rLinear charge density : λDistance of a point from the center of the ring : x



From the diagram we can see that,Point P is at a distance x from the center of the ring.Point P is at a distance of $\sqrt{r^2+x^2}$ from the surface of the ring: r’ = $\sqrt{r^2+x^2}$ Circumference of the ring is : L = 2π r**Formula used:**We can see that, Electric field as p is resolved into vertical and horizontal components. As the ring is symmetric, vertical components are cancelled out and horizontal components add.Thus E_{net} =Ecosθ , where θ is the angle between x and $\sqrt{r^2+x^2}$.We know that,$\boldsymbol{\lambda} = \frac{\boldsymbol{Q}}{\boldsymbol{L}}$Where, λ is the linear charge density, Q is the Total charge due to whole ring and L is the circumference of the ring.$\therefore\ Q = 2\pi r\lambda$Potential at a point due to charge Q is: $\boldsymbol{V} = \frac{\boldsymbol{kQ}}{\boldsymbol{r'}}$Here, k is a constant and k=$\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge.

$\therefore V = \frac{k2\pi r\lambda}{\sqrt{r^2+x^2}}$If we substitute value of k then:$V = \frac{1}{2\epsilon_0}\frac{r\lambda}{\sqrt{r^2+x^2}}$

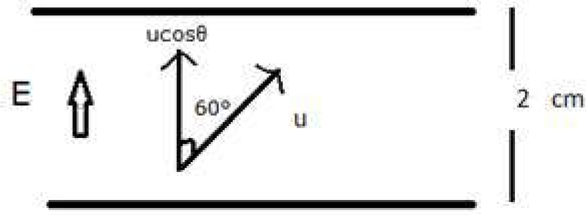
Hence, Electric potential at a point x from the center of the ring is $V = \frac{k2\pi r\lambda}{\sqrt{r^2+x^2}}$.Net electric field at P is Ecosθ and $E = \frac{V}{r'}$From the figure:$cos\theta = \frac{x}{\sqrt{r^2+x^2}}$

$\therefore E_{net} = \frac{V}{r'}cos\theta \therefore E_{net} = \frac{1}{2\epsilon_0}\frac{r\lambda}{\sqrt{r^2+x^2}} \times \frac{1}{\sqrt{r^2+x^2}} \times \frac{x}{\sqrt{r^2+x^2}}$

$\therefore \boldsymbol{E_{net}} = \frac{\mathbf{1}}{\mathbf{2\epsilon_0}}\frac{\boldsymbol{r\lambda}}{(\boldsymbol{r^2+x^2})^{\frac{3}{2}}}$Hence, Electric field at P is $\frac{\mathbf{1}}{\mathbf{2\epsilon_0}}\frac{\boldsymbol{r\lambda}}{(\boldsymbol{r^2+x^2})^{\frac{3}{2}}}$

Answer.64

Given: Magnitude of the electric field : E = 1000 NC^{-1}Separation between the plates: r = 2 cm = 0.02 mAngle made by the projection with the field : θ = 60°



Formula used:(a)The Potential difference is:V = -E.rHere, E is the electric field and r is the separation between the plates.V = -1000 × 0.2 ∴ V = -200 = |-200| = 200 V

Hence, the potential difference between the plates is of 200 V(b)Charge on an electron: e = -1.6× 10^{-19} CWe know thatF=qE=maWhere F is the electric force, E is the electric field, m is the mass of the body and a is the acceleration of the body.Here, q=e of electron. And m = 9.7× 10^{-31} kg mass of the electron.

$\therefore a = \frac{eE}{m} = \frac{-1.6 \times 10^{-19} \times 1000}{9.7 \times 10^{-31}} \therefore \mathrm{a} = -1.75 \times 10^{14} \frac{m}{s^2}$Using one of the equations of motion we get,$v^2=u^2+2as$Here, v is the final velocity of the electron= 0Here v is zero as it we have to calculate u when it just reaches the upper plate, u is the initial velocity of the electron, s is the distance between the plates: s=r and a is the acceleration of the electrons$\therefore 0 = u^2 - 2 \times 1.75 \times 10^{14} \times 0.02$

$\therefore u^2 = 7 \times 10^{12} \therefore u = \sqrt{7 \times 10^{12}} \therefore \boldsymbol{u = 2.64 \times 10^6 \frac{m}{s}}$Hence, with a minimum speed of 2.64× 10^6 m/s^2 should the electron be projected from the lower plate in the direction of the field for it to reach the upper plate.(c)As direction of projection makes an angle 60° with the electric field.Initial velocity is resolved into its cos component which is along the direction of the electric field as shown in the figure above.Hence, u'=ucos(60°), u' is the resolved initial velocity.Using the same equation of motion used in (b) we get,$\therefore v^2 = u'^2 - 2 \times a \times h$Where h is the maximum height reached by the electron.

$\therefore 0 = (2.64 \times 10^6 \times 0.5)^2 - 2 \times 1.75 \times 10^{14} \times h \therefore h = \frac{1.74 \times 10^{12}}{3.5 \times 10^{14}}$

$\therefore \mathbf{h = 4.97 \times 10^{-3}\ m}$ Hence, the maximum height reached by the electron is 4.7× 10^{-3} m.

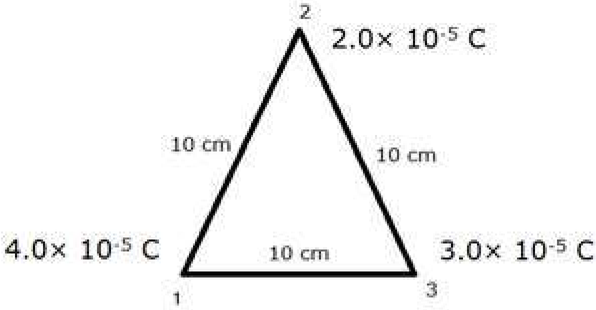
Answer.65

Given:(a)Magnitude of Electric field: E = 2.0 NC^{-1}V(0,0,0) = 0 V(b) V= 25 V(c) V(0,0,0) = 100 V**Formula used:**(a) Electric field exists in x-direction.We know that, Potential difference is :

V=V_B-V_A=V_B-0=V_BHere V_B is the potential at general point (x,y,z) and V_A is the potential at origin = 0.Potential is given aV = -E.rWhere E is the electric field and r is the position of the point in space.In vector form: $\boldsymbol{E = E_x\hat{\imath} + E_y\hat{\jmath} + E_z\hat{k}}$ $\boldsymbol{r = x\hat{\imath} + y\hat{\jmath} + z\hat{k}}$ Substituting ,$\therefore V = -(E_x\hat{\imath} + E_y\hat{\jmath} + E_z\hat{k}).(x\hat{\imath} + y\hat{\jmath} + z\hat{k})$ $\therefore \mathrm{V} = -E_x x$Here, y and z components are not considered as electric field is along x direction.$\therefore$ $\boldsymbol{V = -2x\,V}$Hence expression of potential at a general point (x,y,z) in space is -2x V.(b)Here, V_B is 25 V.$V_B - V_A = -2x \therefore 25 - 0 = -2x$ $\therefore \boldsymbol{x = \frac{25}{-2} = -12.5\,m}$Hence at x= -12.5 m, potential is 25 V.(c)Now similar to part (a), here potential at origin is given and we need to find potential at general point.V(0,0,0) = 100 VUsing formula for potential derived in (a) we get, $V_B - V_A = -2x \therefore V_B - 100 = -2x \therefore V_B = 100 - 2x \therefore \boldsymbol{V(x,y,z) = 100 - 2x\,V}$ Hence, potential at general point is 100 − 2x V(d)Let potential at infinity be : V_∞ = 0 and x=∞Potential at origin is : V_0Using the formula for potential and result of (a):$V_\infty - V_0 = -2xV_0 = V_\infty + 2x \therefore V_0 = 0 + 2 \times \infty \therefore \boldsymbol{V_0} = \infty$Hence, potential at origin is infinite.It is not practical to choose potential at infinity to be zero as it will make potential at origin to be infinite as we derived which will make the calculations impossible.

Answer.66

Given:



Charge at 1 : $q_1 = 4.0 \times 10^{-5}$ CCharge at 2 : $q_2 = 2.0 \times 10^{-5}$ CCharge at 3 : $q_3 = 3.0 \times 10^{-5}$ CLet side of the equilateral triangle be L = 10 cm = 0.1 m**Formula used:**To assemble the charges at three vertices electric potential energy is required.Thus, the work done in assembling these charges is equal to the total electric potential energy used.$W = U_{12} + U_{23} + U_{31}$Here, W is the work done.U_{12}: Electric Potential energy due to charges at 1 and 2 having separation 0.1 m.U_{23} : Electric Potential energy due to charges at 2 and 3 having separation 0.1 m.U_{31}: Electric Potential energy due to charges at 3 and 1 having separation 0.1 m.Formula for Electric potential energy is: $\boldsymbol{U = \frac{kq_1q_2}{r}}$Here, k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} , q_1 and q_2 are point charges and r is the separation between them and U is the electric potential energy required to moves charges q_1 and q_2 apart.Substituting,

$W = \frac{kq_1q_2}{L} + \frac{kq_2q_3}{L} + \frac{kq_3q_1}{L} \therefore W = \frac{k}{L} \times 10^{-10}(4 \times 2 + 2 \times 3 + 3 \times 4)$

$\therefore W = \frac{9 \times 10^9 \times 10^{-10} \times 26}{0.1} \therefore \boldsymbol{W = 234\ J}$Hence, 234 J of work is required for assembling the charges at the vertices of the equilateral triangle.

Answer.67

Given: Change in Kinetic Energy of a charged particle: ΔE = 10 JPotential difference : dV = 200-100 =100 VWe know that, when energy of a body is changed, work is being done.Change in kinetic energy = Work DoneThus, Work done : W = 10 JAlso Work is given as:W = dV× qHere dV is the potential difference and q is the charge of the particle.Substituting the values:$10 = 100 \times q \therefore \boldsymbol{q = \frac{10}{100} = 0.1\ C}$Hence the charge on the particle is 0.1 C

Answer.68

Given: Charge on two identical particles: $q_1=q_2= 2.0 \times 10^{-4}$ CMass of the two particles : $m_1=m_2= m$ = 10 g = 0.01 kgSeparation between the charges : r = 10 cm =

0.1 m**Formula used:**When they are released, the force of repulsion will be acting on both the particles making them drift apart thereby increasing distance between them.Potential Energy at the start will be$\boldsymbol{U_{initial} = \frac{kq_1q_2}{r}}$where $U_{initial}$ is the initial potential energy between the charges ,k is a constant and k=$\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} , q_1 and q_2 are point charges and r is the separation between them.Final Potential energy would be zero as the particles will gain Kinetic energy and the separation between the charges would approach infinity : U_{final} = 0Now by conservation of energy:$\boldsymbol{Total\ Potential\ energy = Total\ Kinetic\ energy}$

Total kinetic energy is : $\boldsymbol{KE = \frac{1}{2}m_1V^2 + \frac{1}{2}m_2V^2 = 2 \times \frac{1}{2}mV^2}$Where , m is the mass of the particles and V is the velocity gained by the particles.

$\therefore\ U_{initial} - U_{final} = K.E \therefore \frac{kq_1q_2}{r} = 2 \times \frac{1}{2}mV^2 \therefore V^2 = \frac{kq_1q_2}{mr}$

$\therefore V^2 = \frac{9 \times 10^9 \times 2.0 \times 10^{-4} \times 2.0 \times 10^{-4}}{0.01 \times 0.1} \therefore V = \sqrt{360000} \therefore \boldsymbol{V = 600\ m/s}$

Hence, when the separation becomes large the speed of the particles should be 600 m/s.

Answer.69

Given: Mass of the two particles : m_1=m_2= m = 5.0 g = 0.005 kgCharge on particle 1 : q_1 = +4.0 × 10^{-5} CCharge on particle 2 : q_2 = -4.0 × 10^{-5} CSeparation between the charges : r = 1 mInitial velocity: v = 0**Formula used:**Conservation of Energy is:$U_{initial}$ + $K.E_{initial}$ = U_{final} + $K.E_{final}$where, $U_{initial}$ and $K.E_{initial}$ are the Initial potential energy and initial kinetic energy respectively .U_{final} and $K.E_{final}$ are the final potential energy and final kinetic energy respectively.Now, as initial velocity is zero : $K.E_{initial}$ = 0Final Kinetic Energy of both the particles is:

$K.E_{final} = \frac{1}{2}m_1V^2 + \frac{1}{2}m_2V^2 = 2 \times \frac{1}{2}mV^2$Also, Electric potential energy is given as;$\boldsymbol{U = \frac{kq_1q_2}{r}}$Where k is a constant and k=$\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} , q_1 and q_2 are point charges and r is the separation between them.For initial situation : r = 1 mFor final situation : r = 50 cm = 0.5 m = r/2Substituting in the conservation formula we get,$\therefore \frac{kq_1q_2}{r} + 0 = \frac{kq_1q_2}{\frac{r}{2}} + 2 \times \frac{1}{2}mV^2 \therefore \frac{kq_1q_2}{r} - \frac{2kq_1q_2}{r} = mV^2$

$\therefore \frac{kq_1q_2}{r}(1-2) = mV^2$

$-\frac{9 \times 10^9 \times 4.0 \times 10^{-5} \times 4.0 \times 10^{-5}}{1} \times (-1) = 0.005 \times V^2 \therefore V^2 = \frac{14.4}{0.005}$

$\therefore V = \sqrt{2880} \therefore \boldsymbol{V = 53.66\ m/s}$ Hence the velocity of the particles when separation is reduced to 50 cm is 53.66 m/s

Answer.70

Given: Electric field : E = 2.5 × 10^4 N C^{-1}Dipole moment of each HCl molecule :P = 3.4 × 10^{-30} cm = 3.4 × 10^{-30} Cm .**Formula used:** Torque acting on a dipole is given as$\boldsymbol{\tau} = \vec{\boldsymbol{P}} \times \vec{\boldsymbol{E}}$Where, τ is the torque acting on the dipole, P is the dipole moment of the HCl molecules and E is the electric field.τ = PEsinθFor maximum torque θ = 90°Thus sin(90) = 1$\therefore \tau = PE \therefore \tau = 3.4 \times 10^{-30} \times 2.5 \times 10^4$

$\therefore \boldsymbol{\tau} = \mathbf{8.5 \times 10^{-26}}\ \boldsymbol{Nm}$ Hence a maximum of 8.5× 10^{-26} Nm of torque can act on a HCl molecule.

Answer.71

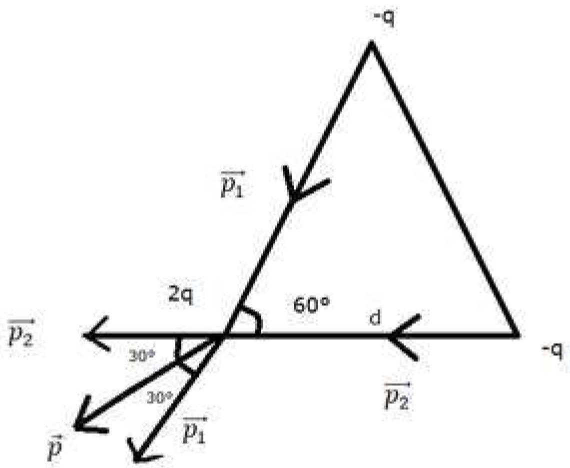
Given:(a)Charge on particle A : q_1 = 2.0 × 10^{-6} CCharge on particle B : q_2 = -2.0 × 10^{-6} CMagnitude of both the charges : q = 2.0 × 10^{-6} CSeparation between A and B : d = 1.0 cm = 0.01 m(b)Distance between center and the point on the axis of dipole: r= 1 cm= 0.01 m(c)Distance between center and the point on the perpendicular bisector of the dipole:r'= 1 m**Formula used:**(a)Electric dipole moment is given as: $\vec{\boldsymbol{p}} = \boldsymbol{q}\vec{\boldsymbol{d}}$Where, $\vec{p}$ is the electric dipole moment, q is the magnitude of the charges at the end of the dipole and $\vec{d}$ is the vector joining the two charges.$\therefore p = qd$

$\therefore p = 2.0 \times 10^{-6} \times 0.01 \therefore \mathbf{p = 2 \times 10^{-8}\ Cm}$ Hence, electric dipole moment between A and B is 2× 10^{-8}Cm(b)Electric field at a point on the axis of the dipole is: $\boldsymbol{E} = \frac{\boldsymbol{k2p}}{\boldsymbol{r^3}}$Here k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2}, p is the Electric dipole moment and r is the distance between the point on the axis and it's center.Substituting we get,$E = \frac{9 \times 10^9 \times 2 \times 2 \times 10^{-8}}{(0.01)^3} \therefore \boldsymbol{E} = \mathbf{3.6 \times 10^8}\ \boldsymbol{NC^{-1}}$

Hence, electric field at a distance 1 cm away from the center of the dipole to the point on it's axis is 3.6× 10^8 NC^{-1}.(c)Electric field at a point on the perpendicular bisector of the dipole is given as:$\boldsymbol{E} = \frac{\boldsymbol{kp}}{\boldsymbol{r'^3}}$Here, k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2}, p is the Electric dipole moment and r' is the distance between the point on the perpendicular bisector of the dipole and it's centerSubstituting we get: $E = \frac{9 \times 10^9 \times 2 \times 10^{-8}}{1^3}$ $\therefore \boldsymbol{E = 180\ NC^{-1}}$Hence, electric field at a point on the perpendicular bisector of the dipole 1 m away from it's center is 180 NC^{-1}.

Answer.72

Given: Distance between two charges :d

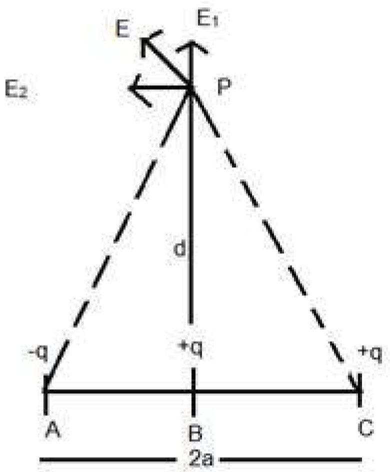


In the diagram, the dipole moments $\vec{p_1}\ and\ \vec{p_2}$ are extended and resolved into the resultant component $\vec{p}$.**Formula used:**The resultant $\vec{p}$ is given as vector sum of $\vec{p_1}\ and\ \vec{p_2}\therefore\ \vec{p} = \vec{p_1} + \vec{p_2}$ As angle between $\vec{p}$ and $\vec{p}_1$ is 30° , the value of the resultant:$p = 2p_1 cos30$ As $p_1=p_2$, the resultant due to $\vec{p}_1\ and\ \vec{p_2}$ is : $p = 2p_1 cos(30)$We know that:p=qdWhere p is the dipole moment, q is the magnitude of charges and d is the distance between the charges forming the dipole.Substituting, the resultant dipole moment is:$p = \frac{2qd\sqrt{3}}{2}$ $\therefore \boldsymbol{p = qd\sqrt{3}}$

Hence, dipole moment of the combination is qd√3

Answer.73

Given:(a)Distance between charge and P : d(b)Distance between two charges +q and -q = 2aDipole moment : p =2qa**Formula used:**(a)It's a direct formula of the electric field due to a point charge:$\boldsymbol{E_1 = \frac{kq}{d^2}}$Here, k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} . q is the point charge and d is the distance between the charge and the point P(b)For the second configuration too we have a direct formula.Opposite charges at both ends separated by a distance forms a dipole and electric field at a point on the perpendicular bisector of the dipole is given as:$\boldsymbol{E_2 = \frac{kp}{d^3}}$Here, p is the dipole moment and is : p= 2qa and k is a constant and k= $\frac{1}{4\pi\epsilon_0}$ =9× 10^9 Nm^2C^{-2} , d is the distance between Point P and the center of the dipole.(c)Figure (c) is made up of combination of system in (a) and (b)



Point P is influenced by two dipoles.1.-q and +q (A and B)2. +q and +q (B and C)1. Is the result of (b) = $E_2$2. Is the result of (a) = E_1Hence net electric field at P in the configuration (c) would be resultant of E_1 and E_2∴ $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2$∴ $E_{net} = \sqrt{E_1^2 + E_2^2}$

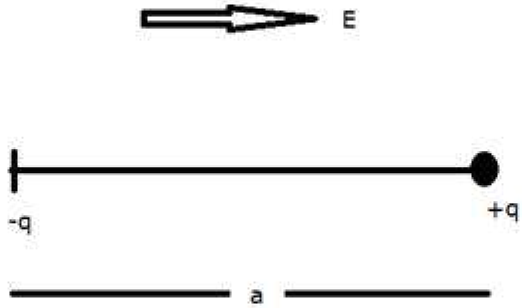
$\therefore E_{net} = \sqrt{\left(\frac{kq}{d^2}\right)^2 + \left(\frac{kp}{d^3}\right)^2}$ ∴ $E_{net} = k\sqrt{\frac{q^2}{d^4} + \frac{p^2}{d^6}}$∴ $E_{net} = k\sqrt{\frac{1}{d^6}(q^2d^2 + p^2)}$

$\boldsymbol{\therefore E_{net} = \frac{k}{d^3}\sqrt{(q^2d^2 + p^2)}}$

Hence, results for (a), (b) and (c) are $\boldsymbol{\frac{kq}{d^2}}$, $\boldsymbol{\frac{kp}{d^3}}$, and $\boldsymbol{\frac{k}{d^3}\sqrt{(q^2d^2 + p^2)}}$ respectively.

Answer.74

Given: Magnitude of charge on both the particles: qMass of both the particles: mElectric field : EThe axis of the dipole is along the electric field.Length of the dipole: l=a



Formula used: We know that, a charge placed in an electric field E will experience electric force.When a dipole with charge of magnitude q at its ends is suspended under a magnetic field and having one end clamped (-q), the free end (+q) will experience an electric force and it will start oscillating.Electric force is given as:F=qEandF = ma ∴ qE = ma $\therefore a = \frac{qE}{m}$Where a is the acceleration of the particle, q is the charge on the particle, m is the mass of the particle and E is the electric field.Also, time period for Simple pendulum is:$T = 2\pi\sqrt{\frac{l}{g}}$Here, g=a(acceleration) as we are neglecting gravity.Substituting we get,$T = 2\pi\sqrt{\frac{a}{\frac{qE}{m}}}$$\therefore \boldsymbol{T = 2\pi\sqrt{\frac{am}{qE}}}$Hence, time period of the small oscillations is $2\pi\sqrt{\frac{am}{qE}}$.

Answer.75

Given: Atomic weight of copper = 64 g mol^{-1}Mass of copper wire : m = 6.4 g**Formula used:**We know that,Number of moles in 64 g of copper = 1Thus, number of moles in 6.4 g of copper = 0.1Also,Number of atoms in one mole=N_AHere, N_A is the Avogadro Number : N_A = 6.023× 10^{23} atoms∴No.of atoms in 0.1 mole of copper=0.1× 6.023× 10^{23}∴No.of atoms in 0.1 mole of copper=0.1× 6.023× 10^{22}It is given that each atom contributes one free electron,Therefore in 0.1 mole of copper 6.023×10^{22} atoms will contribute 6.023×10^{22} free electrons.Hence, there will be 6.023×10^{22} free electron in 6.4 g of copper.