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Physics XII

Intermediate Part II

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ZN

Zartash Notes Series

COMPLETE CHAPTER-WISE SOLUTION

BY

Asim Ghafoor Zartash

M.Phil. Physics

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SECOND YEAR PAPER PATTERN

TOTAL TIME: 03:00 HRS TOTAL MARKS: 85

OBJECTIVE PART

Q NO 1: **MCQS**

TOTAL MCQS=17 TIME=20 MINTS

SUBJECTIVE PART

TIME=2:40 HRS

MARKS=44

SECTION A

SHORT QUESTIONS

Q NO 2: **MARKS (8×2=16)**

TWELVE SHORT QUESTIONS WILL BE GIVEN. ATTEMPT ANY 08 SHORT QUESTIONS

CH 12= 4 Short Questions

CH 14=4 Short Questions

CH 15=4 Short Questions

Q NO 3: **MARKS (8×2=16)**

TWELVE SHORT QUESTIONS WILL BE GIVEN. ATTEMPT ANY 08 SHORT QUESTIONS

CH 13= 3 Short Questions

CH 16=3 Short Questions

CH 17=3 Short Questions

CH 18=3 Short Questions

Q NO 4: **MARKS (6×2=12)**

NINE SHORT QUESTIONS WILL BE GIVEN. ATTEMPT ANY 06 SHORT QUESTIONS

CH 19 =3 Short Questions

CH 20=3 Short Questions

CH 21=3 Short Questions

SECTION B

MARKS (8×3=24)

LONG QUESTIONS

FIVE LONG QUESTIONS WILL BE GIVEN. ATTEMPT ANY 03 LONG QUESTIONS

Q NO : 5 From CH 12 & CH 13

(a) LONG QUESTION (MAY FROM CHAPTER 12 OR 13) MARKS=05

(b) NUMERICAL QUESTION (MAY FROM CHAPTER 12 OR 13) MARKS=03

Q NO : 6 From CH 14 & CH 15

(a) LONG QUESTION (MAY FROM CHAPTER 14 OR 15) MARKS=05

(b) NUMERICAL QUESTION (MAY FROM CHAPTER 14 OR 15) MARKS=03

Q NO : 7 From CH 16 & CH 18

(a) LONG QUESTION (MAY FROM CHAPTER 16 OR 18) MARKS=05

(b) NUMERICAL QUESTION (MAY FROM CHAPTER 16 OR 18) MARKS=03

Q NO : 8 From CH 17 & CH 19

(a) LONG QUESTION (MAY FROM CHAPTER 17 OR 19) MARKS=05

(b) NUMERICAL QUESTION (MAY FROM CHAPTER 17 OR 19) MARKS=03

Q NO : 9 From CH 20 & CH 21

(a) LONG QUESTION (MAY FROM CHAPTER 20 OR 21) MARKS=05

(b) NUMERICAL QUESTION (MAY FROM CHAPTER 20 OR 21) MARKS=03

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ELECTROSTATICS

Questions from Chapter

Q.No.1: Define electrostatics? Give its important applications

Ans:

Definition: The branch of physics which deals with the study of charges at rest under the action of electric forces is called electrostatics.

Applications: There are two main applications of electrostatics.

(i) Photocopier (ii) Ink jet printer

Q.No.2: State Coulomb's law? Also give its mathematical expression

Ans:

Statement: This law states that "The force between two point charges is directly proportional to the product of magnitude of charges and inversely proportional to the square of distance between them"

Mathematical expression: It is mathematically expressed as

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

Q.No.3: Define charge. Also give its types

Ans:

Definition: Electric charge is physical property of matter that causes it to experience a force when placed in electromagnetic force.

Types of Charges:

Charges are of two types

(i) Positive charges (ii) Negative charges

Q.No.4: Mention the properties of charges?

Ans: There are two properties of charges

(i) Attraction (ii) Repulsion

Q.No.5: What is dielectric?

Ans: An insulating medium present between two charges which always reduces the electrostatic force is called dielectric.

Q.No.6: What is relative permittivity?

Ans: The presence of a dielectric always reduces the electrostatic force as compared to free space by a certain factor which is constant for the given dielectric. This constant is called relative permittivity and is represented by ε_r

Q.No.7: Which laws enable us to calculate the magnitude and directions of gravitational and electric forces?

Ans: Newton's universal gravitational law and Coulomb's law enable us to calculate the magnitude and directions of gravitational and electric forces?

Q.No.8: What is origin of electrical and magnetic force? Or Why electrical and magnetic forces are considered as basic forces of nature?

Ans: The origin of these forces is still unknown. The existence of these forces is accepted as it is. That is why these are called basic forces of nature.

Q.No.9: What is electric field?

Ans: The space around the electric charge at which it exerts a force on other charges is called electric field.

It has no units and formula

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Q.No.10: Define electric field intensity? Mention its SI units also.

Ans:

Definition: The electric force per unit positive test charge is called electric field intensity. It's a vector quantity. Its direction is in the direction of electric force.

Formula: It is denoted as $$\boldsymbol{E} = \frac{\boldsymbol{F}}{q_o}$$

Units: Its units are N/C.

Q.No.11: Define line of forces?

Ans: The electric field lines provide the information about the direction and strength of the electric field at various places are called lines of forces. These lines originate from positive charges and end on negative charges.

Q.No.12: What is neutral zone or zero field spot?

Ans: The middle region between identical positive charges or identical negative charges shows no electric field is called neutral zone

Q.No.13: Summarize the properties of electric field lines?

Ans: Following are the properties of electric filed lines.

(i) Electric field lines originate from positive charges and end on negative charges

(ii) Tangent to field line at any point gives the direction of the electric field at that point

(iii) Where lines are closer the field is strong and where lines are apart the field is weak.

(iv) No two lines cross each other. This is because **E** has only one direction at any given point.

Q.No.14: Which device produced coloured copies?

Ans: Inject printers produced coloured copies.

Q.No.15: How many applications of electro statistics?

Ans: There are basic two applications of electrostatics. (i) Photocopier (ii) Inkjet printers

Q.No.16: Define electric flux? Calculate maximum and minimum values of flux

Ans:

Definition: Number of electric field lines passing through certain area is called electric flux. It is scalar quantity

Formula: It is denoted as $\Phi = \mathbf{E}.\mathbf{A}$

Units: Its units are Nm^2C^{-1}

Maximum Flux:

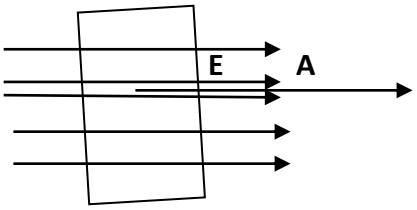
When the plane of the coil is perpendicular to the electric field then angle between **E** and **A** becomes zero ($\theta = 0^o$). Then value of flux will be maximum.

Mathematically

The magnetic flux is given as

$\Phi = \mathbf{E}.\mathbf{A} = EA\cos\theta$

$\Phi = EA\cos 0^o = EA$



Minimum Flux:

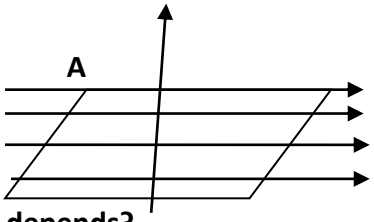
When the plane of the coil is parallel to the electric field then angle between **E** and **A** becomes 90^o. Then value of flux will be minimum.

Mathematically

The magnetic flux is given as

$\Phi = \mathbf{E}.\mathbf{A} = EA\cos\theta$

$\Phi = EA\cos 90^o = 0$



Q.No.17: Upon what factors total flux through closed surface depends?

Ans: Total flux through closed surface is represented as

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$$\phi_e = \frac{q}{\epsilon_o}$$

So we can conclude that total flux through a closed surface does not depend upon the shape or geometry of the closed surface. It depends upon the medium and charge enclosed

Q.No.18: State Gauss's law?

Ans:

Statement: It states that flux through any closed surface is equal to $1/\varepsilon_o$ times the total charge enclosed by that surface.

Formula: Mathematically it is denoted as $\phi = \frac{1}{\epsilon_o} \times Q$

Q.No.19: Define Gaussian surface?

Ans: An imaginary closed surface at which electric intensity is to be calculated is called Gaussian surface.

Q.No.20: Define electric potential? Write down its expression and also units

Ans:

Definition: Work done in bringing a unit positive charge from infinity to a particular point in an electric field keeping the charge in equilibrium is called electric potential at that point.

Formula: It is mathematically represented as

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

Units: Units of electric potential are volts or J/C

Q.No.21: Define potential difference? Write down its expression as well

Ans:

Definition: Work done in bringing a unit positive charge from point A to point B in an electric field keeping the charge in equilibrium is called potential difference between these points A and B.

Formula: It is mathematically represented as

$$\Delta V = \frac{W_{AB}}{q}$$

Q.No.22: Define the term volt?

Ans:

Definition: Potential difference will be 1 volt between two points if 1 joule work is done in moving a unit positive charge of 1 C from one point to other, keeping the charge in equilibrium.

Formula: It is mathematically represented as

$$1\ V = \frac{1\ J}{1\ C}$$

Q.No.23: Prove that E=–ΔV/Δr?

Ans: Change in electrical potential is given as

$$\Delta V = \frac{W_{AB}}{q_o}$$

Where

$$w_{AB} = Fd = -q_o Ed$$

By putting this value in above equation , we get

$$\Delta V = \frac{-q_o Ed}{q_o}$$

Thus

$$E = -\frac{\Delta V}{d}$$

If distance between charges is Δr then

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$$E = -\frac{\Delta V}{\Delta r}$$

Q.No.24: Prove that 1volt/meter=1 Newton/Coulomb?

Ans: $\frac{1Volt}{meter} = 1\frac{^{joule}/_{coulomb}}{meter} = 1\frac{newton \times meter}{meter \times coulomb} = 1\frac{newton}{coulomb}$

Q.No.25: Define 1 eV. Prove that 1eV=1.6×10^{-19}J

Ans:

Definition of 1 eV:

The amount of energy acquired or lost by an electron as it traverses a potential difference of one volt.

Prove of 1eV=1.6×10^{-19}J:

Change in potential energy of a charge is given as

$$\Delta U = q\Delta V$$

If no external force acts on the charge then change in P.E. appears in the form of change in K.E.

$$K.E = q\Delta V$$

If the charge carried by the particle is $q = e = 1.6 \times 10^{-19} C$ and $\Delta V = 1\ volt$

then we have $K.E = q\Delta V = e\Delta V$

$$K.E = 1.6 \times 10^{-19} C \times 1\ V$$

Mathematically $K.E = 1\ eV$

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

Q.No.26: Make the comparison between electric force and gravitational force?

Ans:

DIFFERENCES:

Electric force	Gravitation force
Coulomb's electrostatic force is always between two charges given by the formula $F=Kq_1q_2/r^2$	Gravitational force is always between two point masses given by the formula $F=Gm_1m_2/r^2$
Electrostatic force can be both repulsive and attractive	Gravitational force is only attractive
It is a strong force	It is a weak force
It is medium dependent	It lacks the property of medium

SIMILARITIES:

1- Bothe forces are conservative forces
2- Both follow inverse square law. Because both forces are inversely proportional to the square of distance b/w two charges or two masses

Q.No.27: Under what conditions a given droplet between two plates could be suspended?

Ans: A given droplet between two plates could be suspended in air if the gravitational force F_g acting on the drop equal to the electrical force F_e. It can be done by adjusting the value of potential of external battery.

So mathematically it can be written as $F_e = F_g$

This implies that $qE = mg$

Q.No.28: What is capacitor? Define capacitance and write down its units

Ans:

Capacitor: A capacitor is a device that can store charge. It consists of two plates. One is positively charged and other is negatively charged.

Formula : As $Q \propto V$

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This implies that $Q = CV$

where C is proportionality constant called the capacitance of the capacitor.

Capacitance: The ability of capacitor to store charge is called capacitance. In other words the capacitance of a capacitor is the ratio of charge with the potential difference.

Formula: It is denoted as $C = \frac{Q}{V}$

Q.No.29: Upon what factors the capacitance of capacitor depends?

Ans: The capacitance of capacitor depends upon the geometry of plates and medium between them. Its formula is given as $C = \frac{A\varepsilon_o\varepsilon_r}{d}$

Q.No.30: Define the term farad?

Ans: The capacitance of capacitor will be one farad if a charge of 1 coulomb which is given to the one of the plates of capacitor, produces a potential difference of one volt between them.

Formula: Farad can be represented as $1\ F = \frac{1\ C}{1\ V}$

Q.No.31: Define dielectric co-efficient/constant? Also write down its expression?

Ans:

Definition: The ratio of the capacitance of a parallel plate capacitor in an insulating medium to the capacitance of that capacitor in vacuum.

Formula: It is denoted as $\varepsilon_r = \frac{C_{med}}{C_{vac}}$

Q.No.32: Define the term dipole?

Ans: Two equal and opposite charges separated by a small distance are said to be dipole.

Q.No.33: Explain polarization of dielectrics?

Ans: The dielectrics contain equal number of positive and negative charges such that their centers coincide. When an electric field is applied between the plates of a capacitor, the negative charges (electrons) are attracted towards the positive plate of the capacitor and the positive charges towards the negative plate. As a result of one end of molecules shows a negative charge and the other positive charge but the molecules as a whole is still neutral. Two equal and opposite charges separated by a small distance are said to constitute a dipole. This effect is called polarization

Q.No.34: Calculate the value of energy stored in a capacitor?

Ans:

When a capacitor is uncharged then potential difference is zero and when charged its value becomes V.

$$\text{So its average value is } \frac{0+\mathrm{V}}{2} = \frac{\mathrm{V}}{2}$$

Therefore

$$\text{P. E.} = \text{ Energy} = \frac{1}{2}\,\mathrm{qV}$$

Using the relation

$$\mathrm{q} = \mathrm{CV}$$

For capacitor, we get

$$\text{Energy} = \frac{1}{2}\mathrm{CV}^2$$

By putting these values we get $\mathrm{V} = \mathrm{Ed}$ and $\mathrm{C} = \frac{\mathrm{A}\varepsilon_o\varepsilon_r}{\mathrm{d}}$,

$$\text{Energy} = \frac{1}{2}\frac{\mathrm{A}\varepsilon_o\varepsilon_r}{\mathrm{d}}(\mathrm{Ed})^2 = \frac{1}{2}\varepsilon_o\varepsilon_r\mathrm{E}^2(\mathrm{Ad})$$

Q.No.35: Define Energy density?

Ans:

Definition: Energy stored in a capacitor per unit volume is called energy density.

Formula: Energy density is described as

$$\text{Energy density} = \frac{\text{Energy}}{Volume} = \frac{1}{2}\varepsilon_r\varepsilon_o E^2$$

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Q.No.36: Define the term time constant?

Ans: The time required by the capacitor to deposit 0.63 times the equilibrium charge q_o is called time constant of capacitor

Q.No.37: Verify that Ohm times farad is equivalent to second

Ans: $Ohm's law\ is\ given\ as$ $V = IR$

$where$ $I = \frac{q}{t}$

$V = \frac{q}{t}R$

and $q = CV$

$V = \frac{CV}{t}R$

$1 = \frac{C}{t}R$

$RC = t$

$ohm \times farad = second$

Exercise Questions

Q.No.12.1: The potential is constant throughout a given region of space. Is the electrical field zero or non-zero in the region? Explain

Ans: The formula of electric intensity is given as $E = -\frac{\Delta V}{\Delta r}$

If potential is constant V=Constant so that ΔV=0. So electric field will zero in that region

As electric potential is given as

$$E = -\frac{\Delta V}{\Delta r}$$

So

$$E = -\frac{(0)}{\Delta r} = 0$$

Q.No.12.2: Suppose that you follow an electric field line due to a positive charge. Do electric field and the potential increases or decreases?

Ans: If we follow an electric field line due to a positive point charge, then it means that we are moving away from it. Thus the distance from charge increases. Due to this electric potential and intensity will decrease according to given relations.

$$E \propto \frac{1}{r^2} \quad \text{and} \quad V \propto \frac{1}{r}$$

Q.No.12.3: How you can identify that which plate of capacitor is positively charged?

Ans: For the identification of charge on capacitor, a device is used called gold leaf electroscope. The divergence of the leaves of electroscope increases due to negative plate of capacitor. The divergence of the leaves of electroscope decreases due to positive plate of capacitor. Due to that method positively charged plate can be identified.

Q.No.12.4: Describe the force or forces on a positive point charge when placed between parallel plates

(a) will similar and equal charges (b) with opposite and equal charges

Ans:

(a) When a positive charge is placed between parallel plates with similar and equal charges then the net force on charge will be zero. So that's why electric intensity will also be zero

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(b) When a positive charge is placed between parallel plates with opposite and equal charges then the net force on charge will be towards negative charges. So that's why electric intensity will also be toward negative charges.
(Diagrams are necessary for both cases)

Q.No.12.5: Electric lines of force never cross each other. Why?

Ans: Electric lines of forces never cross each other because **E** has only one direction at a given point. If lines of forces cross each other then it means **E** has more than one direction which is physically not possible.

Q.No.12.6: If a point charge q of mass m is released in a non-uniform electric field with field lines pointing in the same direction, will it make a rectilinear motion?

Ans: If a point charge q of mass m is released in a non-uniform electric field with field lines pointing in the same direction, then will make a rectilinear motion due to repulsive forces.

Q.No.12.7: If E necessarily zero inside a charged rubber balloon if balloon is spherical? Assume that charge is distributed uniformly over the surface.

Ans: Yes **E** is necessarily zero inside a charged rubber balloon if balloon is spherical. In this situation, there is no charge inside the balloon. So electric field will necessarily zero inside it.

Mathematical proof: Mathematically it is proved as:

Flux is given as $\phi = \frac{q}{\epsilon_o}$

As $q = 0$

Then $\phi = \frac{0}{\epsilon_o} = 0$

Since $\phi = \boldsymbol{E}.\boldsymbol{A} = 0$

As $\boldsymbol{A} \neq 0$ So $\boldsymbol{E} = 0$

Q.No.12.8: Is it true that Gauss's law states that the total number of lines of forces crossing any closed surface in the outward direction is proportional to the net positive charge enclosed within surface?

Ans: Yes above statement is true. Electric flux is defined as the number of electric field lines passing though a certain area. According to Gauss's law, the flux through any closed surface is $1/\varepsilon_o$ times the total charge enclosed by that surface. Hence this statement follows Gauss's law so that the total number of lines of forces crossing any closed surface in the outward direction is proportional to the net positive charge enclosed within surface

Q.No.12.9: Do electrons tend to go to region of high potential or of low potential?

Ans: Electrons tend to go towards the region of high potential from low potential. As the electrons are negatively charged particles so they tend to move from negative terminal of the battery (low potential) toward positive terminal of the battery (high potential)

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Long Questions

12.1 COULOMB'S LAW:

SATEMEMNT:

This law states that "The force between two point charges is directly proportional to the product of magnitude of charges and inversely proportional to the square of the distance between them"

FORMULA:

It is mathematically expressed as

$$F \propto \frac{q_1 q_2}{r^2}$$

or

$$F = K\frac{q_1 q_2}{r^2}$$

EXPLANANTION:

Actually there are two kinds of charges. These are named as positive and negative charges. The charge on electron is assumed to be negative and on proton is positive. There are two properties of charges. (i) Like charges repel each other (ii) Unlike charges attract each other. These properties clearly described that there are forces of repulsion and attraction present between charges. The first measurement of the force between charges was made by Charles Coulomb in 1784. He was a French military engineer.

In the above mentioned formula, F is the magnitude of the mutual force that acts between charges q_1 and q_2 and r is the distance between charges. The force always acts along the line joining the two point charges.

Proportionality constant: Where k is the constant of proportionality.

Value of k depends upon the

(i) Nature of the medium between charges

(ii) System of units in which F, r, q are measured

If the medium between two charges is free space, and system of units is SI then K is represented as

$$K = \frac{1}{4\pi\varepsilon_o}$$

Where ε_o is the an electrical constant known as permittivity of free space. In SI units its value is $8.85\times10^{-12}\ C^2N^{-1}m^{-2}$

By substituting the value of ε_o the value of proportional constant is given below

$$K = 9\times10^9 Nm^2C^{-2}$$

Coulomb's force: So the Coulomb's force in free space is given as

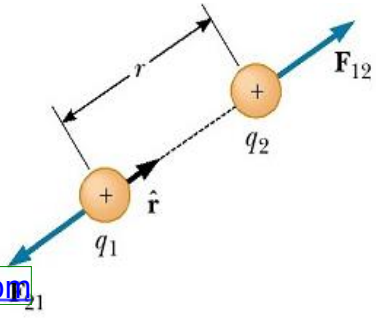
$$F = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}$$

Mutual force: Coulomb's force is mutual force. It means that q_1 exerts a force on q_2 then q_2 also exerts an equal and opposite force on q_1. If we denote F_{21} is force exerted by q_2 on q_1 and F_{12} is force exerted by q_1 on q_2 then can be written as

$$\boldsymbol{F_{12} = -F_{21}}$$

Direction of these two forces: To represent the direction of these two forces, we introduce unit vectors. The two forces can be represented in the form of unit vectors as follows

$$\boldsymbol{F}_{21} = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}\hat{\boldsymbol{r}}_{21}$$



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$$\boldsymbol{F}_{12} = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}\hat{\boldsymbol{r}}_{12}$$

The sign of charges in above mentioned equations determine whether the forces are attractive or repulsive.

Effect of medium: Effect of medium between two charges upon force is also observed. If the medium is insulator which is usually called dielectric then due to presence of dielectric always reduces the electrostatic force as compared to the free space of air by a factor. This factor is a constant which is known as relative permittivity and represented by ε_r.

So the Coulomb's force in a medium of relative permittivity ε_r is given as

$$F = \frac{1}{4\pi\varepsilon_o\varepsilon_r}\frac{q_1 q_2}{r^2}$$

CONCLUSION: It is concluded that

- Force between two charges directly depends upon the magnitude of charges and inversely linked with distance between charges.
- Coulomb's force is mutual force.
- It can be attractive or repulsive.
- It is medium dependent force.
- Coulomb's force for air and vacuum are nearly equal because value of relative permittivity for vacuum is one and for air is 1.0006 which is also nearly equal to one.

12.6 ELECTRIC FLUX THOUGH A SURFACE ENCLOSING A CHARGE:

ELECTRIC FLUX:

The number of filed lines passing through a certain area is known as electric flux through that area.

FORMULA:

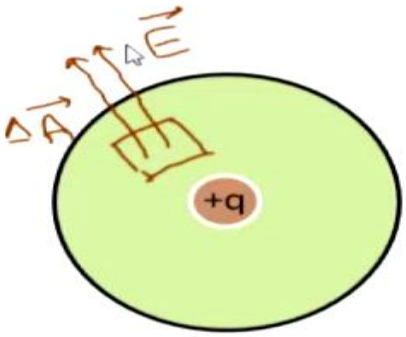
General formula of electric flux is given as:

$$\phi = \boldsymbol{E}.\boldsymbol{A} = EA\cos\theta$$

Electric flux trough a closed surface is:

$$\phi = \frac{q}{\varepsilon_o}$$

DERIVATION: Let us calculate the electric flux through a closed surface in the shape of sphere of radius r due to charge q as shown in figure.



To apply the formula $\phi = \boldsymbol{E}.\boldsymbol{A}$ the surface should be flat. Due to this total surface of sphere is divided into small patches with areas of magnitudes ΔA_1, ΔA_2, ΔA_3…… ΔA_n. And there corresponding areas are **ΔA_1, ΔA_2, ΔA_3…… ΔA_n**. The direction of each vector area is along perpendicular to the surface of patch. The electric intensities for areas **ΔA_1, ΔA_2, ΔA_3…… ΔA_n** are **E_1, E_2, E_3…… E_n.**

The flux through first patch is given as

$$\phi_1 = \boldsymbol{E_1}.\Delta\boldsymbol{A_1}$$

Similarly flux through second patch is

$$\phi_2 = \boldsymbol{E_2}.\Delta\boldsymbol{A_2}$$

And flux for nth patch is

$$\phi_n = \boldsymbol{E_n}.\Delta\boldsymbol{A_n}$$

Hence the total flux can be obtained by adding flux of all segments as given below

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$$\phi = \boldsymbol{E_1}.\Delta\boldsymbol{A_1} + \boldsymbol{E_2}.\Delta\boldsymbol{A_2} + \boldsymbol{E_3}.\Delta\boldsymbol{A_3} - - - - - -\boldsymbol{E_n}.\Delta\boldsymbol{A_n}$$----------(i)

The direction of electric intensity and vector area is same at each patch because of spherical symmetry.

So

$$E_1 = E_2 = E_3 = - - - - - - - - - - = E_n = E$$

And value of electric field intensity is given as

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$$----------(ii)

By solving the equation (i)

$$\phi = E_1\Delta A_1 cos0^0 + E_2\Delta A_2 cos0^0 + E_3\Delta A_3 cos0^0 - - - - - -E_n\Delta A_n cos0^0$$

$$\phi = E_1\Delta A_1 + E_2\Delta A_2 + E_3\Delta A_3 - - - - - -E_n\Delta A_n$$

As

$$E_1 = E_2 = E_3 = - - - - - - - - - - = E_n = E$$

So

$$\phi = E\Delta A_1 + E\Delta A_2 + E\Delta A_3 - - - - - -E\Delta A_n$$

$$\phi = E(\Delta A_1 + \Delta A_2 + \Delta A_3 - - - - - -\Delta A_n)$$

By modifying the equation we get

$$\phi = E \times (Total\ area\ of\ sphere)$$

By putting the value of area and electric field intensity in above mentioned equation we get

$$\phi = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2} \times (4\pi r^2)$$

By solving we get

$$\phi = \frac{q}{\varepsilon_o}$$

CONCLUSION:

Hence it is concluded that total flux through a closed surface does not depend upon

(i) the shape of the closed surface
(ii) geometry of the closed surface

It depends upon the

(i) medium
(ii) charge enclosed

12.8 ELECTRIC FIELD INTENSITY DUE TO INFINITE SHEET OF CHARGE

GAUSS'S LAW:

Gauss's law is stated as " The flux through any closed surface is $1/\varepsilon_o$ times the total charge enclosed in it"

FORMULA:

Formula for Gauss's law is given as

$$\phi_e = \frac{1}{\varepsilon_o} \times Q$$

ELECTRIC FIELD INTENSITY DUE TO INFINITE SHEET OF CHARGE:

Consider we have a plane infinite metallic sheet and positive charges are uniformly distributed on it. Where σ is the uniform surface charge density. An finite part of sheet is shown in the figure.

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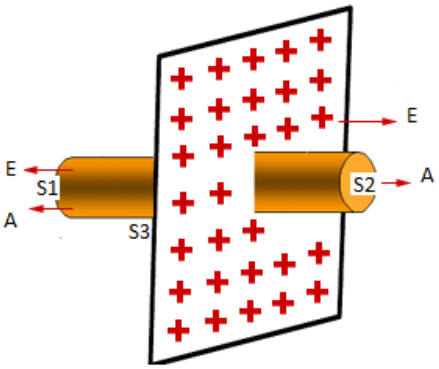
To calculate the electric field intensity E, consider a closed Gaussian surface in the form of cylinder passing through a sheet whose one flat face contains point as showing fig.

Surfaces of Cylinder:

Cylinder has three surfaces

1. One flat surface S_1
2. Second flat surface S_2
3. Third curved surface S_3



Suppose surface S_1 and S_2 are at equal distance from the sheet. **A** is the surface area of the flat faces S_1 and S_2.

Electric flux at Surface S_1:

Since **E** is perpendicular to the surface S_1 and direction of its area **A** is perpendicular to the surface S_1. So angle between **E** and area of surface S_1 will be 0^o. Hence flux through surface S_1 can be calculated as

$$\Phi_1 = EA\ cos0^o = EA$$

Electric flux at Surface S_2:

Value of flux will be same at surface S_2 as at surface S_1. Since **E** is perpendicular to the surface S_2 and direction of its area **A** is perpendicular to the surface S_2. So angle between **E** and area of surface S_2 will be 0^o. Hence flux through surface S_1 can be calculated as

$$\Phi_2 = EA\ cos0^o = EA$$

Electric flux at Surface S_3:

Since **E** is parallel to the curved surface of the cylinder, so there will no contribution to the flux from the curved wall of the cylinder. Because angle will be 90^o in this case. Hence flux through surface S_3 can be calculated as:

$$\Phi_3 = EA\ cos90^o = 0$$

Total electric flux:

Hence the total flux at all three surfaces can be calculated as:

$$\Phi_e = EA + EA + 0 = 2EA \quad \text{----------(i)}$$

Electric field intensity:

According to Gauss's law $\phi_e = \frac{1}{\varepsilon_o} \times Q$ ----------(ii)

As the charge density is given as

$$\sigma = \frac{Q}{A}$$

Hence charge can be determined as

$$Q = \sigma A$$

By putting the value of charge in above mentioned equation, we get

$$\phi_e = \frac{1}{\varepsilon_o} \times \sigma A \text{ ----------(iii)}$$

By comparing the equations (i) and (iii) we get

$$2EA = \frac{1}{\varepsilon_o} \times \sigma A$$

Or

$$2E = \frac{1}{\varepsilon_o} \times \sigma$$

Hence

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$$E = \frac{\sigma}{2\varepsilon_o}$$

In vector form

$$\vec{E} = \frac{\sigma}{2\varepsilon_o}\,\hat{r}$$

ELECTRIC FIELD INTENSITY BETWEEN TWO OPPOSITELY CHARGED PARALLEL PLATES:

GAUSS'S LAW:

Gauss's law is stated as " The flux through any closed surface is $^1/_{\varepsilon_o}$ times the total charge enclosed in it"

FORMULA:

Formula for Gauss's law is given as

$$\phi_e = \frac{1}{\varepsilon_o} \times Q$$

ELECTRIC FIELD INTENSITY BETWEEN TWO OPPOSITELY CHARGED PARALLEL PLATES:

Suppose that two parallel plates which are closely spaced metal plates. They are separated by vacuum. One plate contains positive charges and other plate contains negative charges. The field lines start from inner side of positive charges and end on the negative charges on inner side as shown in the figure.

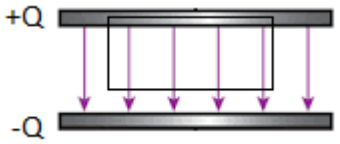
Thus the charges are uniformly distributed on the inner surface of the plate in a form sheet of charges.

Imagine now, a Gaussian surface in the form of hollow box with its top inside the upper metal plate and its bottom in the space between the plates as shown in figure

Ends of Hollow box:

Hollow box has four ends.

1. Two sides
2. Upper end
3. Lower end



Electric flux at both sides:

As the field lines are parallel to the both sides. So flux will be zero on both sides. Since **E** is perpendicular to area **A** of these sides. So angle between them will be 90°. Hence flux on both sides can be calculated as

$$\Phi_1 = EA\ cos90^o = 0$$

Electric flux at upper end:

Value of flux at upper end will be zero because there is no field inside the metal plate.

$$\Phi_2 = EA\ cos\theta = (0)A\ cos\theta = 0$$

Electric flux at lower end:

The field lines are uniformly distributed on the lower bottom face and directed normally to it. And angle will be 0° in this case. Hence flux through bottom end can be calculated as:

$$\Phi_3 = EA\ cos0^o = EA$$

Total electric flux:

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Hence the total flux at all ends can be calculated as:

$$\phi_e = 0 + 0 + EA = EA \quad \text{----------(i)}$$

Electric field intensity:

According to Gauss's law $\phi_e = \frac{1}{\varepsilon_o} \times Q$ ----------(ii)

As the charge density is given as

$$\sigma = \frac{Q}{A}$$

Hence charge can be determined as

$$Q = \sigma A$$

By putting the value of charge in above mentioned equation, we get

$$\phi_e = \frac{1}{\varepsilon_o} \times \sigma A \quad \text{----------(iii)}$$

By comparing the equations (i) and (iii) we get

$$EA = \frac{1}{\varepsilon_o} \times \sigma A$$

Or

$$E = \frac{1}{\varepsilon_o} \times \sigma$$

Hence

$$E = \frac{\sigma}{\varepsilon_o}$$

The field intensity is same at all points between the plates. The direction of each electric field line is from positive to negative. Because a unit positive charge between the plates always repelled by positive plate and attracted by negative plate.

In vector form

$$\vec{E} = \frac{\sigma}{\varepsilon_o} \hat{r}$$

Where $\hat{r}$ is the unit vector directed from positive to negative plate

ELECTRIC POTENTIAL AT A POINT DUE TO POINT CHARGE:

ELECTRIC POTENTIAL:

Electric potential is defined as work done in bringing a unit positive charge from infinity to that point keeping the charge in equilibrium. In other word work done per unit positive charge is called electric potential.

FORMULA:

Formula for electric potential is given as

$$V = \frac{W}{q_o}$$

ELECTRIC POTENTIAL AT A POINT DUE TO POINT CHARGE:

Let us drive an expression for the potential at a certain point in the field of positive point charge q. This can be done by bringing a unit positive charge from infinity to that point keeping the charge in equilibrium.

Let us take two points A and B very close to each other so that electric field remains constant between them. The distance of points A and B from q are r_A and r_B respectively.

And r is the distance between midpoint of A and B from q.

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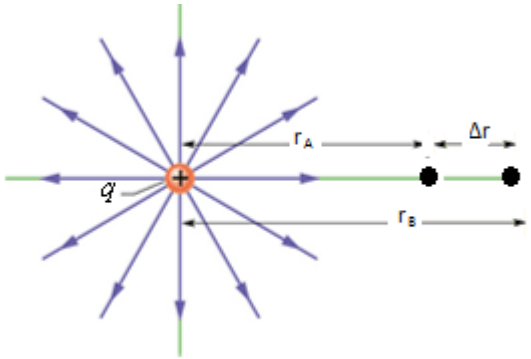
Potential difference:

For calculating the electric potential at a point, at first we have to calculate the potential difference by using the given formula



$$E = \frac{\Delta V}{\Delta r}$$

$$\Delta V = E\Delta r \text{----------(i)}$$

Electric field intensity:

For calculating electric potential, electric field intensity should be calculated at first. The electric field intensity is given as

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2} \text{----------(ii)}$$

First of all we have to calculate the r^2. So according to figure we get

$$r_B = r_A + \Delta r$$

Hence Δr can be calculated as

$$\Delta r = r_B - r_A \text{---------(iii)}$$

As r represent the midpoint of interval between A and B so

$$r = \frac{r_A + r_B}{2}$$

And value of r^2 can be calculated by taking the arithmetic mean equal to geometric mean which gives

$$\frac{r}{r_A} = \frac{r_B}{r}$$

Therefore

$$r^2 = r_A r_B$$

By putting the value of r^2 in equation number (ii) we get

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r_A r_B} \text{--------(iv)}$$

Electric potential and potential difference:

By rewriting the equation number (i) we have

$$V_A - V_B = E(r_B - r_A)$$

By putting the value of E from equation (iv) we get

$$V_A - V_B = \frac{1}{4\pi\varepsilon_o}\frac{q}{r_A r_B}(r_B - r_A)$$

$$V_A - V_B = \frac{q}{4\pi\varepsilon_o}\left(\frac{r_B - r_A}{r_A r_B}\right)$$

By solving

$$V_A - V_B = \frac{q}{4\pi\varepsilon_o}\left(\frac{r_B}{r_A r_B} - \frac{r_A}{r_A r_B}\right)$$

Hence

$$V_A - V_B = \frac{q}{4\pi\varepsilon_o}\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$$

To calculate the absolute potential or potential at A , point B is assumed to be infinity point so that $V_B = 0$

Hence

$$\frac{1}{r_B} = \frac{1}{\infty} = 0$$

So

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$$V_A - 0 = \frac{q}{4\pi\varepsilon_o}(\frac{1}{r_A} - 0)$$

This gives

$$V_A = \frac{q}{4\pi\varepsilon_o}\frac{1}{r_A}$$

The general expression for electric potential V at a distance r from q is

$$V = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$$

CONCLUSION:

Hence it is concluded that electric potential depends upon charge and distance. Electric potential varies inversely to the distance from the charge. As we move away from the charge, electric potential will decrease and vice versa.

12.12 CALCULATE THE CHARGE ON AN ELECTRON BY MILLIKAN'S METHOD

INTRODUCTION:

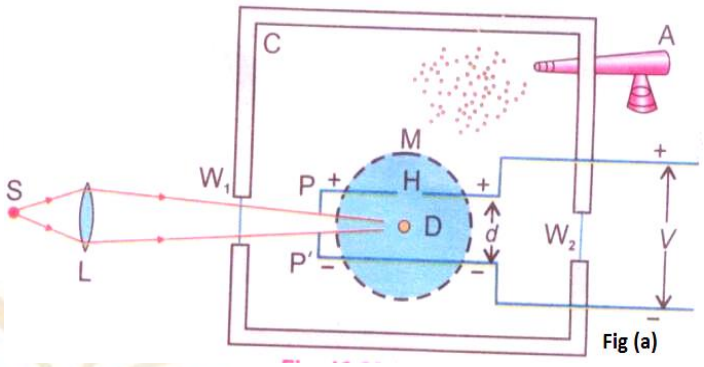
In 1909, R.A Millikan found the charge on an electron. Millikan measured the charge on many drops and found that each charge was an integral multiple of minimum value of charge equal to $1.6 \times 10^{-19}\ C$. So he found that minimum value of charge is the charge of electron. His experimental measurement is given below.

EXPERIMENTAL ARRANGEMENT:

An experimental arrangement of Millikan oil drop experiment is shown in fig (a)

List of Apparatus:

- Two parallel plates
- Container
- Battery
- Atomizer
- Source of light
- Lens
- Microscope



EXPLANATION:

Two parallel plates PP/ are placed inside a container C, to avoid the air friction. The separation between the plates is d. The upper plate p has a small hole H. A voltage V is applied to the plates and so an electric field $\vec{E}$ between the plates is setup.

The magnitude of $\vec{E}$ is given by $E = \frac{V}{d}$ _____ (i)

An atomizer A is used for spraying oil drop into the container through a nozzle. The oil drop gets charged due to friction between walls of atomizer and oil drops. Some of these drops will pass through the hole in the upper plate P. Millikan observed the path of motion of one of these charged droplets by means of a microscope M. For this, light is made to fall on the droplet by light source S and focused by a lens L.

Adjustment of voltage:

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The voltage of the plates was so adjusted that the droplet remained suspended and stationary between the plates. Thus the gravitational force $F_g = mg$ acting on the droplet is equal to the electrical force $F_e = qE$ as shown in fig (b).

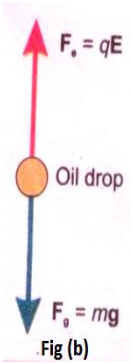

Fig (b)

In this case, we can write as

$$F_g = F_e$$

$$mg = qE \quad \text{(ii)}$$

We know that $E = \frac{V}{d}$

By putting the above value in equation (ii) we get

$$q.\frac{V}{d} = mg$$

Or $$q = \frac{mgd}{V} \quad \text{(iii)}$$

Determination of mass:

To find the mass m of the droplet, the electric field between the plates is switched off. The droplet falls under the action of gravity through air. It attains terminal speed v_t. Millikan calculated the speed v_t by observing the time which the droplet took to fall through a known distance. Since the drag force F due to air acting upon the drop when it is falling with constant terminal speed is equal to its weight.

Hence by using Stokes's law we get

$$F = 6\pi\eta r v_t \quad \text{(iv)}$$

Where r is the radius of the droplet and η (eta) is the coefficient of viscosity of air. If ρ is the density of the droplet, then

$$density = \frac{mass}{Volume}$$

$$\rho = \frac{m}{V}$$

Hence $$m = \rho V$$

Or $$m = \rho \frac{4}{3}\pi r^3$$

$$F_g = mg = \rho \frac{4}{3}\pi r^3 g \quad \text{(v)}$$

By comparing equations (iv) and (v) we get

$$6\pi\eta r v_t = \rho \frac{4}{3}\pi r^3 g$$

Or $$r^2 = \frac{9\eta v_t}{2\rho g}$$

Knowing the value of "r" mass can be calculated by using equation (v). And then this value of mass is substituted in equation (iii) to get the value of charge on the droplet.

CONCLUSION:

Millikan measured the charge on many drops and found that each charge was an integral multiple of minimum value of charge equal to $1.6 \times 10^{-19}\ C$. He, therefore, concluded that minimum value of charge is the charge of electron.

12.12 CAPACITANCE OF A PARALLEL PLATE CAPACITOR

CAPACITOR:

A device which is used to store the charge and energy is called capacitor. It consists of two parallel plates. These plates are separated by air, vacuum or other insulator known as dielectric.

CAPACITANCE:

Ability of a capacitor to store charge is called capacitance. Its units are farad.

FORMULA:

General formula for capacitance is given as

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$$C = \frac{Q}{V}$$

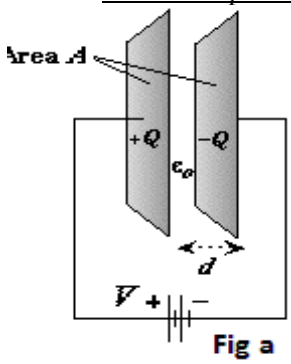

Fig a

CAPACITANCE OF A PARALLEL PLATE CAPACITOR:

Consider a parallel plate capacitor consisting of two plane metal plates. Each plate has area A and these plates are separated by distance d as shown in fig a. The distance d is small so that the electric field E between the plates is uniform and confined.

CALCULATION:

For vacuum:

Let the medium between plates is initially air or vacuum so capacitance can be written as

$$C_{vac} = \frac{Q}{V} \text{----------(i)}$$

Where Q is the charge on capacitor and V is the potential difference between plates.

So the magnitude of electric field intensity E is given as

$$E = \frac{V}{d} \text{----------(ii)}$$

As Q is the charge on either of the plates of area A, the surface charge density on the plates is given as

$$\sigma = \frac{Q}{A} \text{----------(iii)}$$

As we already know that, according to Gauss's law, the electric field intensity between oppositely charged plates is given by

$$E = \frac{\sigma}{\varepsilon_o} \text{----------(iv)}$$

By comparing equation (ii) and (iii) we get

$$\frac{V}{d} = \frac{\sigma}{\varepsilon_o}$$

By putting the value of charge density in above mentioned equation

$$\frac{V}{d} = \frac{Q}{A\varepsilon_o}$$

By re-arranging we get

$$\frac{Q}{V} = \frac{A\varepsilon_o}{d}$$

By comparing the above equation with equation (i) we get

$$C_{vac} = \frac{A\varepsilon_o}{d} \text{----------(v)}$$

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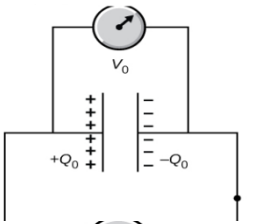
For dielectric:

If an insulating medium, called dielectric, of relative permittivity ε_r is introduced between the plates, the capacitance of capacitor is increased by the factor ε_r.



Following experiment gives the effect of insertion of dielectric between the plates of a capacitor. Consider the charged capacitor whose plates are connected to a voltmeter as shown in fig b. The voltmeter is used to measure the potential difference between plates. When a dielectric material is inserted between the plates, potential difference between the plates decreases as shown in fig c.

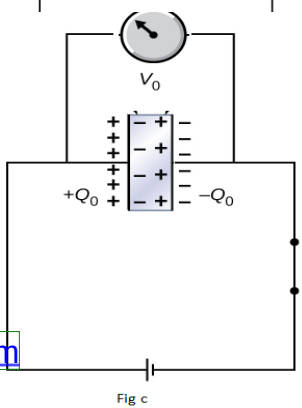


Fig c

Hence the value of capacitance C increases. Then equation (v) becomes

$$C_{med} = \frac{A\varepsilon_o\varepsilon_r}{d} \text{----------(vi)}$$

Dependence of capacitance:

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Capacitance of capacitor depends upon area of plates, the separation between the plates and medium between them.

Definition of dielectric constant:

The ratio of the capacitance of a parallel plate capacitor with the insulating medium between plates of capacitor with vacuum between them

Formula:

Its formula is given as

$$\varepsilon_r = \frac{C_{med}}{C_{vac}}$$

CONCLUSION:

Hence it is concluded that capacitance of capacitor increases by inserting dielectric upon between the plates. And capacitance increases due to polarization. Capacitance depends upon the area of plates, separation between plates and medium between plates.

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Numerical

Numerical 12.1: Compare magnitudes of electrical and gravitational forces exerted on an object (mass=10.0 g, charge=20.0 μC) by an identical object that is placed at 10.0 cm from the first. ($G=6.67\times10^{-11}\ Nm^2kg^{-2}$)

Solution:

$m_1 = m_2 = m = 10.0\ g$

$m_1 = m_2 = m = \frac{10.0}{1000}\ kg$

$m_1 = m_2 = m = 0.01\ kg$

$q_1 = q_2 = q = 20.0\ \mu C$

$q_1 = q_2 = q = 20.0\ \times 10^{-6} C$

$r = 10.0\ cm \qquad r = \frac{10.0}{100}\ m = 0.1\ m$

$G = 6.67 \times 10^{-11} Nm^2kg^{-2}$

$K = 9 \times 10^9 Nm^2C^{-2}$

$\frac{F_e}{F_g} = ?$ $\qquad F_e = K\frac{q_1q_2}{r^2}$

$$F_g = G\frac{m_1m_2}{r^2}$$

By dividing these two equation, we get

$$\frac{F_e}{F_g} = \frac{K\frac{q_1q_2}{r^2}}{G\frac{m_1m_2}{r^2}}$$

$$\frac{F_e}{F_g} = \frac{Kq_1q_2}{Gm_1m_2}$$

$$\frac{F_e}{F_g} = \frac{(9\times10^9)(20.0\ \times10^{-6})(20.0\ \times10^{-6})}{(6.67\times10^{-11})(0.01)(0.01)}$$

$$\frac{F_e}{F_g} = \frac{3.6}{(6.67\times10^{-15})}$$

$$\boxed{\frac{F_e}{F_g} = 5.4\times10^{14}}$$

Numerical 12.3: A point charge q=-8.0×10^{-8} C is placed at the origin. Calculate electric field at a point 2.0 m from the origin on the z-axis

Solution:

$q = -8.0\times10^{-8}\ C \qquad r = 2.0\ m$

$E = ?$

$$E = K\frac{q}{r^2}$$

$$E = \frac{(9\times10^9)(-8.0\ \times10^{-8})}{(2.0)^2}\frac{N}{C}$$

$$\boxed{E = (-1.8\times10^2\hat{k})\frac{N}{C}}$$

Numerical 12.4: Determine the electric field at the position $\boldsymbol{r} = (4\hat{\imath} + 3\hat{\jmath})m$ caused by a point charge q=5.0×10^{-6} C placed at origin.

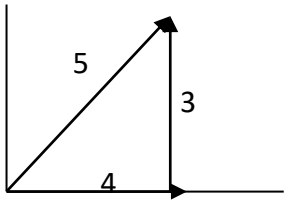
Solution:

$\boldsymbol{E} = ?$

$\boldsymbol{r} = (4\hat{\imath} + 3\hat{\jmath})m \qquad q = 5.0\ \times10^{-6}C$

$r = \sqrt{4^2+3^2} = \sqrt{25} \qquad r = 5\ m$

$\boldsymbol{E} = E_x\hat{\imath} + E_y\hat{\jmath} --(i)$



$E_x = E\cos\theta$

$E_y = E\ \sin\theta$

$cos\theta = \frac{4}{5} \qquad sin\theta = \frac{3}{5}$

$$E = K\frac{q}{r^2}$$

$$E = \frac{(9\times10^9)(5.0\ \times10^{-6})}{(5)^2}\frac{N}{C}$$

$$E = 1800\frac{N}{C}$$

$$E_x = E\ cos\theta = (1800\left(\frac{4}{5}\right)\frac{N}{C} = 1440\frac{N}{C}$$

$$E_y = E\ sin\theta = (1800\left(\frac{3}{5}\right)\frac{N}{C} = 1080\frac{N}{C}$$

$$\boldsymbol{E} = (1440\hat{\imath} + 1080\hat{\jmath})\frac{N}{C}$$

By putting these above values in eq. (i), we get

$$\boxed{\boldsymbol{E} = (1440\hat{\imath} + 1080\hat{\jmath})\frac{N}{C}}$$

Numerical 12.5: Two point charges, q_1=-1.0×10^{-6} C and q_2=+4.0×10^{-6} C are separated by a distance of 3.0 m. Find and justify the zero field location

Solution:

$$q_1 = -1.0\times10^{-6}C$$

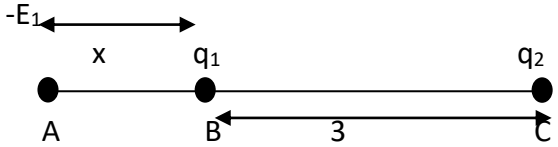
$$q_2 = 4.0\times10^{-6}C$$

$$r = 3.0\ m$$

$$x = ?$$

$$E_1 = \frac{Kq_1}{{r_1}^2}$$

$$E_1 = \frac{(9\times10^9)(-1.0\times10^{-6})}{x^2}$$



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$$E_2 = \frac{Kq_2}{r_2{}^2}$$

$$E_2 = \frac{(9\times10^9)(4.0\times10^{-6})}{(x+3)^2}$$

According to the condition of question

$$-E_1 = E_2$$

$$-\frac{(9\times10^9)(-1.0\times10^{-6})}{x^2} = \frac{(9\times10^9)(4.0\times10^{-6})}{(x+3)^2}$$

$$\frac{1}{x^2} = \frac{4}{(x+3)^2}$$

$$(x+3)^2 = 4x^2$$

$$x^2 + 6x + 9 = 4x^2$$

$$3x^2 - 6x - 9 = 0$$

$$3(x^2 - 2x - 3) = 0$$

$$x^2 - 2x - 3 = 0$$

$$x^2 - 3x + x - 3 = 0$$

$$x(x-3) + 1(x-3) = 0$$

$$(x+1)(x-3) = 0$$

$$x + 1 = 0 \qquad x - 3 = 0$$

$$x = -1$$

So

$$\boxed{x = 3\ m}$$

Numerical 12.6: Find the electric field strength required to hold suspended a particle of mass 1.0×10^6 kg and charge 1.0 µC between two plates 10.0 cm apart.

Solution:

$$\text{E} = ? \qquad m = 1.0\times10^{-6}kg$$

$$r = 10.0cm = \frac{10}{100}m = 0.1m$$

$$q = 1.0\mu C = 1.0\times10^{-6}C$$

For suspension of particle,

$$F_e = F_g$$

$$qE = mg$$

$$E = \frac{mg}{q} = \frac{(1.0\times10^{-6})(9.8)}{(1.0\times10^{-6})}Vm^{-1}$$

$$\boxed{E = 9.8\,Vm^{-1}}$$

Numerical 12.7: A particle having a charge of 20 electrons on it falls through a potential difference of 100 volts. Calculate the energy acquired by it in electron volt(eV)

Solution:

$n = 20 \qquad V = 100\ volts$

$K.E = ?$

$q = ne = (20)(1.6\times10^{-19})C$

$K.E = qV = (20)(1.6\times10^{-19})(100)J$

E₂ x+3

$$K.E = \frac{(20)(1.6\times10^{-19})(100)}{1.6\times10^{-19}}eV$$

$$\boxed{K.E = 2\times10^3 eV}$$

Numerical 12.10: Using zero reference point at infinity, determine the amount by which point charge of 4.0×10^{-8} C alters the electrical potential at a point 1.2 m away, when

(a) Charge is positive (b) Charge is negative

Solution:

$q = 4.0\times10^{-8}C \qquad r = 1.2\ m$

(a) $V = ?$ when charge is positive

$$V = K\frac{q}{r}$$

$$V = \frac{(9\times10^9)(4.0\times10^{-8})}{1.2}\ V$$

$$\boxed{V = 3.0\times10^2\ V}$$

(b) $V = ?$ when charge is negative

$$V = K\frac{q}{r}$$

$$V = \frac{(9\times10^9)(-4.0\times10^{-8})}{1.2}\ V$$

$$\boxed{V = -3.0\times10^2\ V}$$

Numerical 12.12: The electronic flash attachment for a camera contains a capacitor for storing the energy used to produce the flash. In one such unit, the potential difference between the plates of a 750 µF capacitor is 330V. Determine the energy that is used to produce the flash.

Solution:

$V = 330\ V \qquad C = 750\mu\text{F} = 750\times10^{-6}F$

$E = ?$

$$E = \frac{1}{2}CV^2 = \frac{1}{2}(750\times10^{-6})(330)^2J$$

$$\boxed{E = 40.8\,J}$$

Numerical 12.13: A capacitor has a capacitance of 2.5×10^{-8} F. In the charging process, the electrons are removed from one plate and placed on the other one. When the potential difference between the plates is 450 V, how may electrons have been transferred? ($e=1.60\times10^{-19}$C)

Solution :

$C = 2.5\times10^{-8}\ F \qquad V = 450\ V$

$e = 1.60\times10^{-19}\ C \qquad n = ?$

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We know that

$Q = ne \qquad Q = CV$

By comparing these two above equations, we get

$$ne = CV$$
$$n = \frac{CV}{e}$$
$$n = \frac{(2.5 \times 10^{-8})(450)}{(1.60 \times 10^{-19})}$$
$$\boxed{n = 4.0 \times 10^{13} \text{ electrons}}$$

Numerical 12.9: A proton placed in a uniform electric field of 5000 N/C directed to right is allowed to go a distance of 10.0 cm from A to B. calculate

(a) Potential difference between two points
(b) Work done by the field
(c) The change in potential energy
(d) The change in kinetic energy
(e) Its velocity (mass of proton is 1.67×10^{-27} kg)

Solution:

$E = 5000\ NC^{-1} \qquad d = 10\ cm = 0.1\ m$
$m = 1.67 \times 10^{-27} kg \qquad q = 1.6 \times 10^{-19}\ C$

(a) V =?

$$V = -Ed$$
$$\boxed{V = -(5000)(0.1) V = -500V}$$

(b) W =?

$$W = qV$$
$$W = (1.6 \times 10^{-19})500J$$
$$W = \frac{(1.6 \times 10^{-19})500}{1.6 \times 10^{-19}} eV$$
$$\boxed{W = 500\ eV}$$

(c) ΔU =?

$$As\ \Delta U = W$$

So

$$\boxed{\Delta U = 500\ eV}$$

(d) ΔK =? $\qquad \Delta K = qV$

$$\Delta K = (1.6 \times 10^{-19})500J$$
$$\Delta K = \frac{(1.6 \times 10^{-19})500}{1.6 \times 10^{-19}} eV$$
$$\boxed{\Delta K = 500eV}$$

(e) v =?

$$\Delta K = \frac{1}{2}mv^2$$
$$(1.6 \times 10^{-19})500 = \frac{1}{2}(1.67 \times 10^{-27})v^2$$
$$\sqrt{\frac{(1.6 \times 10^{-19})1000}{1.67 \times 10^{-27}}} ms^{-1} = v$$
$$\boxed{v = 3.095 \times 10^5\ ms^{-1}}$$

Numerical 12.11: In Bohr's atomic model of hydrogen atom, the electron is in an orbit around the nuclear proton at a distance of 5.29×10^{-11} m with a speed 2.18×10^{6} m s^{-1}. (e=1.60×10^{-19} C, mass of electron= 9.10×10^{-31} kg). Find

(a) The electrical potential that a proton exerts at this distance
(b) Total energy of the atom in eV
(c) The ionization energy for the atom in eV

Solution:

$r = 5.29 \times 10^{-11}\ m$
$v = 2.18 \times 10^{6}\ m/s$
$q = e = 1.60 \times 10^{-19}\ C$
$m = 9.10 \times 10^{-31}\ kg$

(a) V =?

$$V = \frac{Kq}{r}$$
$$V = \frac{(9 \times 10^{9})(1.60 \times 10^{-19})}{5.29 \times 10^{-11}}\ V$$
$$\boxed{V = 27.22\ V}$$

(b) $T.E$ =? $\qquad T.E = -U + K.E$

$$K.E = \frac{1}{2}mv^2$$
$$K.E = \frac{1}{2}(9.10 \times 10^{-31})(2.18 \times 10^{6})^2\ J$$
$$K.E = 2.16 \times 10^{-18} J$$
$$K.E = \frac{2.16 \times 10^{-18}}{1.60 \times 10^{-19}} eV = 13.5\ eV$$
$$U = qV$$
$$U = (1.60 \times 10^{-19})(27.22)J$$
$$U = \frac{(1.60 \times 10^{-19})(27.22)}{1.60 \times 10^{-19}} eV = 27.22\ eV$$
$$T.E = -27.22 + 13.5\ eV = -13.6eV$$

$I.E$ =? (Ionization energy)

As the electron has total energy in the ground state of hydrogen atom equal to -13.6eV

So

$$\boxed{E_{ion} = 13.6\ eV}$$

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