BAL BHARATI PUBLIC SCHOOL PITAMPURA

SESSION 2020-21 CLASS 12 PHYSICS

Chapter–1 NCERT Electric Charges and Fields PART 3

INSTRUCTIONS

1 This is part 3 of the first chapters of class 12th physics which consists of the following topics as per CBSE syllabus

Electric Charges; Conservation of charge, Coulomb's law-force between two point charges, forces between multiple charges; superposition principle and continuous charge distribution. Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric fleld. Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

In this lecture we are going to study the following topics

Electric field, electric field due to a point charge, electric field lines

2 First 3 chapters of NCERT part 1 have a combined weightage of 16 marks in the CBSE examination.

3 To fully prepare this chapter , you can practice questions from previous year CBSE papers given along here.

4 Kindly do the assignment in your physics registers

Main points of the chapter

ELECTRIC FIELD

ELECTRIC FIELD refers to a region or volume of space around a charge where its effect can be experienced (by another charge)

ELECTRIC FIELD INTENSITY (OR STRENGTH)

Electric field strength or intensity at any point in an electric field is equal to the force exerted per unit charge (on a small test charge) placed at that point

$$\vec{E} = \frac{\vec{F}}{q_0}$$

Here q_0 is called test charge .(It is taken to be infinitely small (and also positive by convention) so that it does not cause a large force to act on the source charge Q and displace it.)

EFI is a vector quantity. SI unit of EFI (Electric Field intensity) is Newton/Coulomb or N/C.

Please note the value of EFI does not depend on the test charge, so EFI is a feature of the source charge mainly

Q←--------------------------r----------------→q_0

Substituting the value of F

$$E = \frac{kQq_0}{r^2 q_0}$$

$$E = \frac{kQ}{r^2}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

Direction of EFI (Electric Field intensity) is in direction of force for a positive charge .

Direction of EFI (Electric Field intensity) is in opposite direction of force for a negative charge

Electric field due to a point charge (in vector form)

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{\boldsymbol{Q}}{r^2}\hat{\boldsymbol{r}}$$

$\hat{r}$ is the unit vector in the direction of EFI

Electric field due to multiple point charges (in vector form)

Using the principle of superposition for EFI

The net EFI at any point in a system of n charges is the vector sum of individual EFI's exerted on that point by all the charges.

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{\boldsymbol{Q_1}}{r_1^2}\widehat{\boldsymbol{r_1}} + \frac{1}{4\pi\varepsilon_0}\frac{\boldsymbol{Q_2}}{r_2^2}\widehat{\boldsymbol{r_2}} + \frac{1}{4\pi\varepsilon_0}\frac{\boldsymbol{Q_3}}{r_3^2}\widehat{\boldsymbol{r_3}} + ---------$$

SOLVED NCERT PROBLEM

Example 1.9 Two point charges q_1 and q_2, of magnitude $+10^{-8}$ C and -10^{-8} C, respectively, are placed 0.1 m apart. Calculate the electric fields at points A, B and C shown in Fig. 1.14.

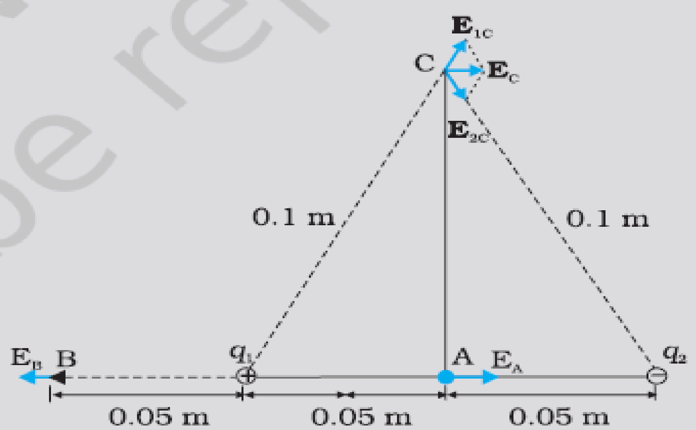


FIGURE 1.14

Solution The electric field vector $\mathbf{E}_{1A}$ at A due to the positive charge q_1 points towards the right and has a magnitude

$$E_{1A} = \frac{(9\times10^9\,\text{Nm}^2\text{C}^{-2})\times(10^{-8}\,\text{C})}{(0.05\,\text{m})^2} = 3.6\times10^4\ \text{N C}^{-1}$$

The electric field vector $\mathbf{E}_{2A}$ at A due to the negative charge q_2 points towards the right and has the same magnitude. Hence the magnitude of the total electric field E_A at A is

$E_A = E_{1A} + E_{2A} = 7.2\times10^4$ N C^{-1}

$\mathbf{E}_A$ is directed toward the right.

The electric field vector $\mathbf{E}_{1B}$ at B due to the positive charge q_1 points towards the left and has a magnitude

$$E_{1B} = \frac{(9\times10^9\,\text{Nm}^2\text{C}^{-2})\times(10^{-8}\text{C})}{(0.05\,\text{m})^2} = 3.6 \times 10^4 \text{ N C}^{-1}$$

The electric field vector $\mathbf{E}_{2B}$ at B due to the negative charge q_2 points towards the right and has a magnitude

$$E_{2B} = \frac{(9\times10^9\,\text{Nm}^2\text{C}^{-2})\times(10^{-8}\text{C})}{(0.15\,\text{m})^2} = 4 \times 10^3 \text{ N C}^{-1}$$

The magnitude of the total electric field at B is

$E_B = E_{1B} - E_{2B} = 3.2 \times 10^4 \text{ N C}^{-1}$

$\mathbf{E}_B$ is directed towards the left.

The magnitude of each electric field vector at point C, due to charge q_1 and q_2 is

$$E_{1C} = E_{2C} = \frac{(9\times10^9\,\text{Nm}^2\text{C}^{-2})\times(10^{-8}\text{C})}{(0.10\,\text{m})^2} = 9 \times 10^3 \text{ N C}^{-1}$$

The directions in which these two vectors point are indicated in Fig. 1.14. The resultant of these two vectors is

$$E_C = E_1 \cos\frac{\pi}{3} + E_2 \cos\frac{\pi}{3} = 9 \times 10^3 \text{ N C}^{-1}$$

$\mathbf{E}_C$ points towards the right.

Electric Field lines

Electric field lines are defined in 2 ways

They are lines or curves drawn in an electric field in such a way that a tangent drawn to them at any point gives the direction of EFI at that point.

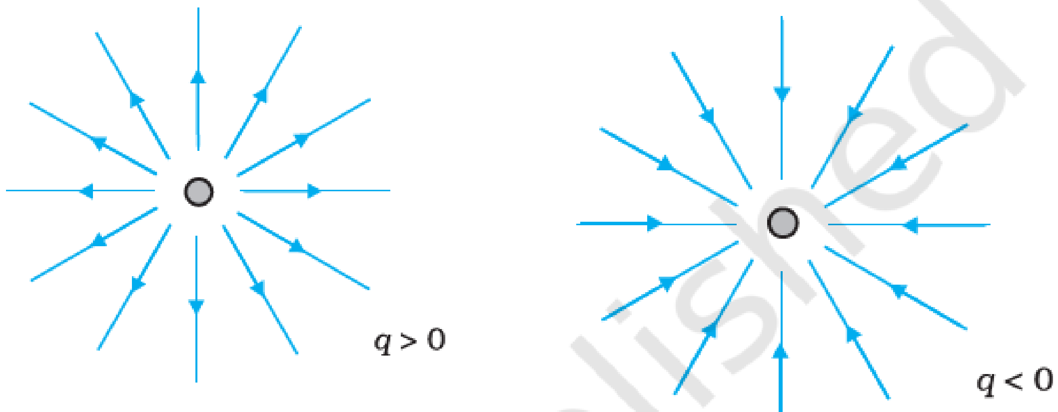
Or

They are paths drawn in an electric field along which a small positive test charge would travel if it were free to do so.

Pl note Electric field lines are imaginary but the electric field they represent is real.

Properties

In case of a single positive source charge, they start from positive charge and go till infinity.



(a)

(Diagram courtesy NCERT)

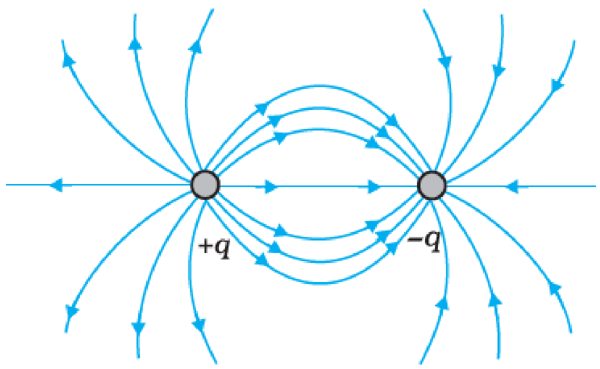
2.In case of a single negative source charge , they start from infinity and terminate at the negative charge**.**

3 A tangent drawn to them at any point gives the direction of EFI at that point.

4.Two field lines never cross each other, because if did so then at then at the point of intersection, EFI would have two directions which is impossible.

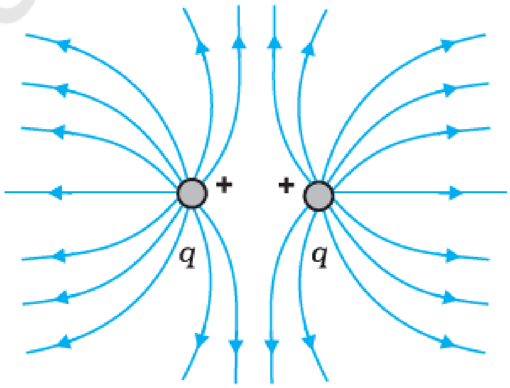
5. Electric field lines can never form closed loops since they do not start and end at the same point. The lines are discontinuous, start from + charge and terminate at – charge.

6. Electric field lines have tendency to contract longitudinally due to attraction between opposite charges .



(Diagram courtesy NCERT)

7 For a pair of similar charges the field lines look like this and exhibit lateral pressure.



(Diagram courtesy NCERT)

8 Electric field lines start and end normally to the surface of a conductor.

9. Crowded lines represent a strong electric field while distant lines represent a weak field.

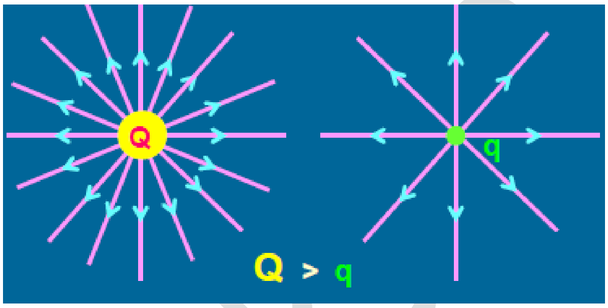


Image courtesy Prayash Mohapatra

10 A uniform Electric field (which has same magnitude and direction in a given region of space) is represented by a equidistant parallel lines.

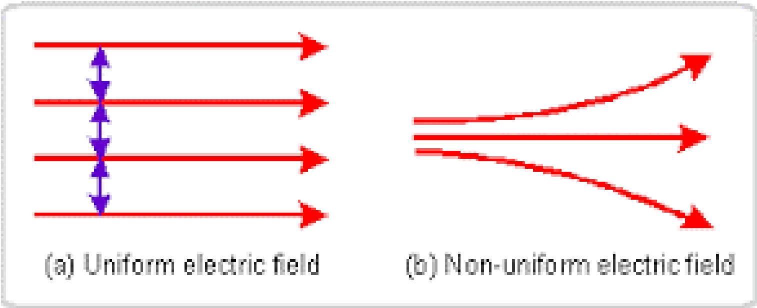


Image courtesy quora .com

Video links

Prof Walter Lewin's lecture

https://www.youtube.com/watch?v=Pd9HY8iLiCA&t=1163s

ASSIGNMENT

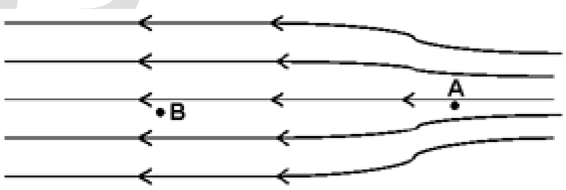
1 A positive point charge (+q) is kept in the vicinity of an uncharged conducting plate. Sketch electric field lines originating from the point on to the surface of the plate.

2A small test charge is released at rest at a point in an electrostatic field configuration. Will it travel along the line of force pointing through that point?

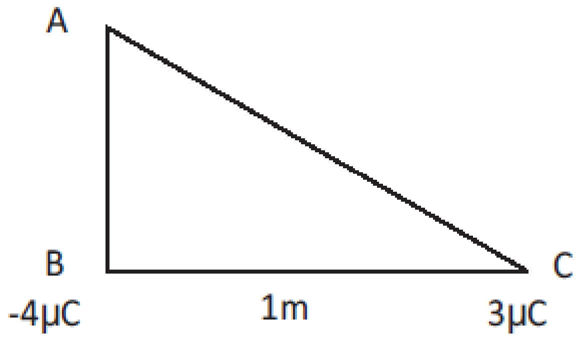
3 In which direction does an electron move in an electric field?

4. Charges of 16μC and -4 μC are placed on a line 10 cm apart. Find the point on this line where E net=0

5 In the electric field shown, the electric field lines on the left have twice the separation as that between those on the right. If the magnitude of the field at point A is 40N/C. Calculate the force experienced by a proton placed at point A. Also find the magnitude of electric filed at the point B.



6 Two electric charges 3μC, -4μC are placed at the two corners of an isosceles right angled triangle of side 1 m as shown in the figure. What is the direction and magnitude of electric field at A due to the two charges?



7 A pendulum bob of mass 80mg and carrying a charge of 2×10^{-8} C is at rest in a horizontal uniform electric field of 2×10^{4} V/m. Find the tension in the thread of the pendulum and the angle it makes with the vertical.

8 An electron falls through a distance of 4 cm in a uniform electric field of 3×10^{4} N/C. When the direction of the field is reversed a proton falls through the same distance. Calculate the time of fall in each case.

9 Two equal and opposite charges of magnitude 2×10^{-7} C are placed 15 cm apart. Find the magnitude of electrical intensity at a point mid way between the charges. What force would act on a proton (charge = 1.6×10^{-19} C) placed there?