Chapter .1
Electric Charges and Fields
Class – XII
Subject – Physics

1.1 What is the force between two small charged spheres having charges of 2x10-7 C and 3x10-7 C placed 30 cm apart in air?

Sol.

Given:

Q1 = 2x10-7 C

Q2 = 3x10-7 C

r = 30x10-2 m

We know,

F=(Q_1 Q_2)/(4πε_o r^2)

Substituting the given values, we get

F = 6x10-3 N

2.1 The electrostatic force on a small sphere of charge 0.4 micro coulomb due to another small sphere of charge -0.8 micro coulomb in air is 0.2 N.

a) What is the distance between the two spheres?

b) What is the force on the second sphere due to the first?

Sol.

a) From the formula

F=(Q_1 Q_2)/(4πε_o r^2)

Substituting the values, we get
r = 0.12 m = 12 cm

b) Force on second sphere due to first
F21 = (Q_1 Q_2)/(4πε_o r^2)
This comes to be -0.2 N, negative sign implying the attractive nature of force. This conforms to Newton's third law.

3.1 Check that the ratio ke2/Gmemp is dimensionless. Look up a table of Physical Constants and determine the value of this ratio. What does the ratio signify?

Sol.
We know very well
k = 9x109 Nm2/C2
e = 1.6x10-19 C
G = 6.6x10-11 Nm2/kg2
me = 9.11x10-31 kg
mp = 1.6x10-27 kg

Ratio = (Nm^2)/C^2 .C^2. 〖kg〗 ^2/ 〖Nm〗 ^2 .1/ 〖kg〗 ^2 = dimensionless

And value = 2.4x1039

The ratio signifies that electrical forces are immensely stronger than the gravitational forces.

4.1

a) **Explain the meaning of the statement 'electric charge of a body is quantized'.**
b) **Why can one ignore quantization of electric charge when dealing with macroscopic, i.e., large scale charges?**

Sol.

a) Quantization is one of the three basic properties of electric charge. It means that every charge is an integral multiple of e, i.e., ne, n = …-2, -1, 0, 1, 2…The addition of charges, subtraction of charges, being an integer always gives integer result. Thus a charge can always be incremented or decremented in terms of e.

b) Macroscopic charges have very large number of electrons. The quantization here can be taken as a continuous phenomenon, analogous to closely spaced dots resembling to line from a distance.

5.1 When a glass rod is rubbed with a silk cloth, charges appear on both. A similar phenomenon is observed with many other pairs of bodies. Explain how the observation is consistent with the law of conservation of charge.

Sol.

When two bodies are rubbed with each other transfer of charge takes place. One body receives charge and other loses, becoming negatively and positively charged respectively. In the whole process no new charge is created or destroyed. This implies that in an isolated system the total charge is always conserved.

6.1 Four point charges qA = 2 µC, qB = –5 µC, qC = 2 µC, and qD = –5 µC are located at the corners of a square ABCD of side 10 cm. What is the force on a charge of 1 µC placed at the centre of the square?

Sol.

The charges of equal magnitude and same sign are at the corners of same diagonal. So they will exhibit equal and opposite forces at the charge situated at center, cancelling out each other. So the force is zero Newton.

7.1

a) **An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why not?**

b) **Explain why two field lines never cross each other at any point?**

Sol.

a) The direction of electric field is given by tangent at each point on the curve. At sudden breaks, the field will have more than one direction which is not possible. That's why electrostatic field line is a continuous curve

b) At the crossing point there will be two directions of electric field at that point given by the two tangents. This cannot happen, and so two field lines never cross each other at any point.

8.1 Two point charges qA = 3 µC and qB = –3 µC are located 20 cm apart in vacuum.

a) **Two point charges qA = 3 µC and qB = –3 µC are located 20 cm apart in vacuum.**

b) **If a negative test charge of magnitude 1.5 × 10–9 C is placed at this point, what is the force experienced by the test charge?**

Sol.

a) Given:

qA = 3 microC

qB = -3 microC

r = 10 cm (point is in middle)

We know, electric field is given by formula
E=Q/(4πϵ_o r^2)

Electric field due to charge A (by use of above formula)
E1 = 2.7x106 N / C
Electric field due to charge B
E2 = -2.7x106 N/C
Since both the fields have the same direction, the electric field at O will be summation of above field
So E = 5.4x106 N/C

b) Given:
qA = 3 microC
qB = -3 microC
qO = -1.5 nanoC
r = 10 cm (point is in middle)
By the formula
F=(Q_1 Q_2)/(4πε_o r^2)
F1 = (3x10-6).(-1.5x10-9).(9x109) / (10x10-2)2
= -4.05x10-3 N (attractive)
F2 = +4.05x10-3 N (repulsive)
So the net force experienced by test charge
F = F1 – F2 = 8.1x10-3 N towards charge A.

9.1 A system has two charges qA = 2.5 × 10–7 C and qB = –2.5 × 10–7 C located at points A: (0, 0, –15 cm) and B: (0,0, +15 cm), respectively. What are the total charge and electric dipole moment of the system?

Sol.

Total charge of electric dipole = zero coulomb

Now, given

2a = 30 cm

q = 2.5x10-7 C

Dipole moment, p = q.2a

= (2.5x10-7).(30)

= 7.5x10-8 Cm

10.1 An electric dipole with dipole moment 4 × 10–9 C m is aligned at 30° with the direction of a uniform electric field of magnitude 5 × 104 NC–1. Calculate the magnitude of the torque acting on the dipole.

Given

Dipole moment, p = 4x10-9 Cm

ϴ = 30

E = 5x104 N/C

We know

Torque = p E sinϴ

= (4x10-9)(5x104)(sin30)

= 10-4 Nm

11.1 A polythene piece rubbed with wool is found to have a negative charge of 3 × 10–7 C.

a) **Estimate the number of electrons transferred (from which to which?)**
b) **Is there a transfer of mass from wool to polythene?**

Sol.

Given
q = -3x10-7 C on polythene

a) q = ne
Since e = 1.6x10-19C
Therefore, n = q/e = 1.875x1012 electrons.
Electrons are transferred from wool to polythene.

b) Mass transfer = number of electrons transferred x mass of an electron
= 1.7x10-18 kg
The transfer of mass is negligible.

12.1

a) **Two insulated charged copper spheres A and B have their centers separated by a distance of 50 cm. What is the mutual force of electrostatic repulsion if the charge on each is 6.5 × 10–7 C? Theradii of A and B are negligible compared to the distance of separation.**

b) **What is the force of repulsion if each sphere is charged double the above amount, and the distance between them is halved?**

Sol.

a) The force is given by

F= (Q_1 Q_2)/(4πε_o r^2)

Substituting the values

F = [(6.5x10-7)2.(9x109)] / [50x10-2]2 = 0.015 N

b) Now

q = 1.3x10-6 C

r = 25 cm

Using the above formula

F = 0.24 N

13.1 Suppose the spheres A and B in Exercise 1.12 have identical sizes. A third sphere of the same size but uncharged is brought in contact with the first, then brought in contact with the second, and finally removed from both. What is the new force of repulsion between A and B?

Sol.

When an uncharged sphere is brought in contact with sphere A, half of the charge will be shifted to third sphere. So the charge q1 on sphere A becomes 3.25x10-7 C. Again on contact of sphere C with sphere B, redistribution of charge will happen and charge q2 on sphere B gets 4.875x10-7 C. Then by the same formula for force, we get

F = (9x109).(q1.q2) / r2

= 5.7x10-3 N

14.1 **Figure 1.33 shows tracks of three charged particles in a uniform electrostatic field. Give the signs of the three charges. Which particle has the highest charge to mass ratio?**

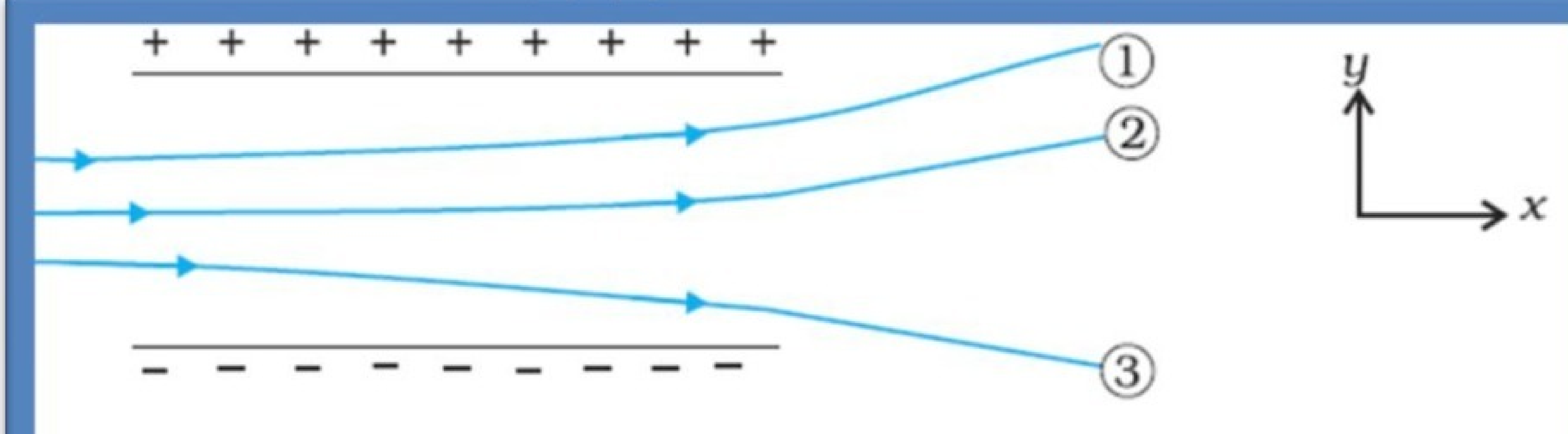

FIGURE 1.33

Sol.

Charge 1 = negative

Charge 2 = negative

Charge 3 = positive

Since mass of proton is more than mass of electron, charge 3 will have highest charge to mass ratio.

15.1 **Consider a uniform electric field E = 3 × 103î N/C.**

a) **What is the flux of this field through a square of 10 cm on a side whose plane is parallel to the yz plane?**
b) **What is the flux through the same square if the normal to its plane makes a 60° angle with the x-axis?**

Sol.

Given:
E = 3000 N/C
a = 10 cm

a) Flux = E.ΔS = 3000 x 100 x 1/10000 = 30 Nm2/C
b) Flux = E.ΔS.cos30 = 25.98 Nm2/C

16.1 **What is the net flux of the uniform electric field of Exercise 1.15 through a cube of side 20 cm oriented so that its faces are parallel to the coordinate lanes?**

Sol.

Zero. All the flux entering will leave the cube.

17.1 **Careful measurement of the electric field at the surface of a black box indicates that the net outward flux through the surface of the box is 8.0 × 103 Nm2/C.**

a) **What is the net charge inside the box?**
b) **If the net outward flux through the surface of the box were zero, could you conclude that there were no charges inside the box? Why or Why not?**

Sol.

Given:

Outward flux= 8x103 Nm2/C

a) We know, flux, Ø=q/ϵ_o

So, net charge q = (8x103).(8.85x10-12) = 7x10-8 C

b) No. The net charge is zero inside the box

18.1 **A point charge +10x10-6 C is a distance 5 cm directly above the centreof a square of side 10 cm, as shown in Fig. 1.34. What is the magnitude of the electric flux through the square? (Hint: Think of the square as one face of a cube with edge 10 cm.)**

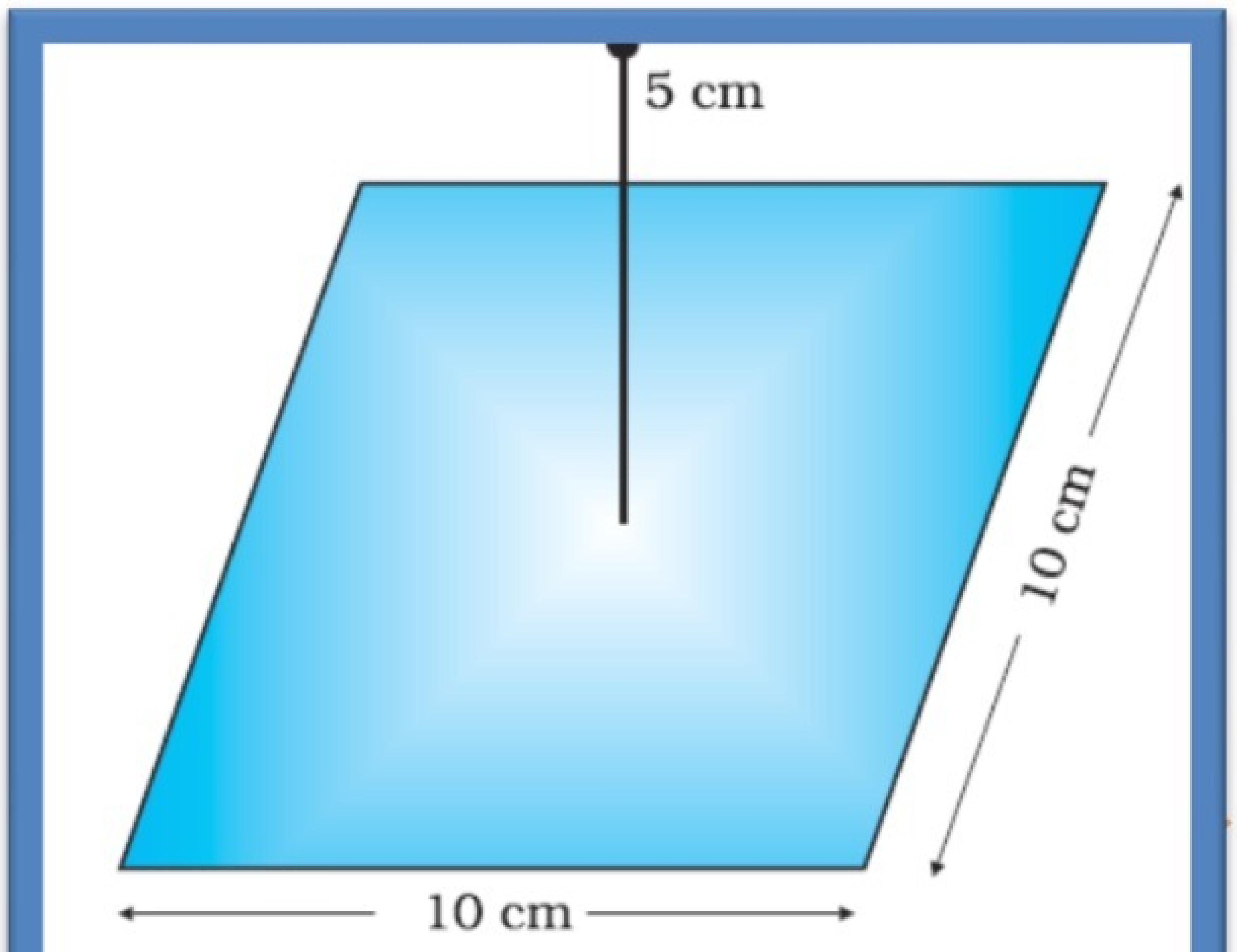

FIGURE 1.34

Sol.

Given in the question:

q = 10x10-6C
a = 10 cm
Considering the charge at the center of the imagined cube of dimension 10 cm, the flux can be calculated from the formula
ϕ=q/ϵ_o
= (10x10-6) / (8.85x10-12)
= 1.12x106 Nm2/C

19.1 A point charge of 2.0x10-6 C is at the centre of a cubic Gaussian surface 9.0 cm on edge. What is the net electric flux through the surface?

Sol.

Using the same formula used in previous question

flux = (2x10-6) / (8.85x10-12)

= 2.2x105 Nm^2/C

20.1 20A point charge causes an electric flux of –1.0 × 103 Nm2/C to pass through a spherical Gaussian surface of 10.0 cm radius centere on the charge.

a) If the radius of the Gaussian surface were doubled, how much flux would pass through the surface?

b) What is the value of the point charge?

Sol.

Given:

flux = 103 Nm2/C

a) Same flux will pass through the surface. It does not depend upon the dimension of Gaussian surface.

b) From the formula

ϕ=q/ϵ_o

Charge q = (-1000).(8.85x10-12) = -8.8x10-9 C

21.1 A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is 1.5 × 103 N/C and points radically inward, what is the net charge on the sphere?

Sol.

Given:
E = 1500 N/C
r = 20 cm
By the formula
E=Q/(4πϵ_o r^2)
Q = [(1500).(20x10-2)2] / [9x109]
= -6.67x10-19 C
Negative charge is due to the inward direction of electric field, implying the concerned charge is negative

22.1 A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of 80.0x10-6 C/m2

a) Find the charge on the sphere.
b) What is the total electric flux leaving the surface of the sphere?

Sol.
Given in the question:

Surface charge density σ = 80x10-6 C/m2
R = 1.2 m

a) Using the formula
$Q=4\pi R^2 \sigma$
Substituting the values
Q = 1.45x10-3 C

b) By the formula
$E=(\sigma R^2)/(\epsilon_o r^2)$
or E = (80x10-6) / (8.85x10-12) = 9x106 N/C

Total electric flux = E. $4\pi R^2$ = (9x106).(4).(3.14).(1.2x1.2)
= 1.6x108 Nm^2/C

23.1 **An infinite line charge produces a field of 9 × 104 N/C at a distance of 2 cm. Calculate the linear charge density.**

Sol.
Given:
E = 90000 N/C
r = 2 cm
Linear charge density = E.2πϵr
= (90000).(2x3.14).(8.85x10-12).(2x10-2)
= 10-7 C/m

24.1 **Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude 17.0 × 10–22 C/m2. What is E:**

a) in the outer region of the first plate
b) in the outer region of the second plate, and
c) Between the plates?

Sol.
Given:
Surface charge density = 17x10-22 C/m2

a) Zero, as the field due to both plates will cancel out each other.
b) Zero, with the above reason.
c) E due to plate 1
E1 = σ/2єo
= 17x10-22 / 2 x 8.85x10-12
= 9.6x10-11 N/C
Similarly E2 = 9.6x10-11 N/C
E1 will have outward direction towards plate 2, while E2 will have inward direction towards plate 2. So both the fields add up
Thus
E = E1 + E2

E = 1.9x10-10 N/C