LEARNING

ELECTRIC FIELD INTENSITY

ELECTRIC FIELD

This is a region around which electric force is experienced. It can be mapped out by electrostatic lines of force. That is, an imaginary lie representing a line of force such as electric or magnetic field, such that the tangent to any point is the direction of the field vector at that point. Arrows on the lines of force show the direction of the field and each direction is always radially outward for a positive charge and otherwise for a negative charge. The lines of force are called “**Electric flux**”.

The force exerted on a charged body in an electric field depends on the charge of the body and on the intensity or strength of the field.

PROPERTIES OF ELECTRIC LINES OF FORCE.

1. They do not intersect with each other

2. They are continuous lines and they start from +ve to -ve charges

3. The tangent to the lines of force at every point gives the direction of the point

4. The magnitude of electric field is %alpha ti the number of lines

DEFINITION

The intensity, E of an electrostatic field at any point can be defined as force (F) per unit charge, which it exerts at that point.

The direction of the field is that of a force exerted on a +ve charge.

Mathematically,

E = F/q

F = Eq

q is the test charge.

If a charge q, is placed at the distance r from the test charge, then the force between the charges using coulomb’s law is

F = kqq\_1/r^2

At point P, the electric field is

E = F/q = kqq\_1/qr^2 = kq/r^2

The direction of the field is radially outward if the charge is positive, otherwise, it is radially inward

FLUX FROM A POINT CHARGE

Direction of lines of force do not remain constant

The intensity, E at a point can be represented by the number of lines per unit area through a surface perpendicular to the line of force at the point considered. The force through an area perpendicular to the lines of force is equal to the product of electric field strength and cross-sectional area, A

Flux = EA

Flux through an arc A, F=EA

Flux from a point charge

Electric Flux

It is the number of electric lines that possess through a surface per unit area

d rsub E = E.A

d rsub E = |E||A|cos %theta

where %theta is the angle between the electric force and the normal to the surface

E => Electric force

A => Surface Area

d rsub E => Electric flux

GAUSS’ LAW

The outward flux of electric field through any close surface is equal to the net enclosed charged divided by permitivity of free space E rsub o

d rsub E = E . A

sigma = q/A

Q= sigma times A

int {d rsub E} = Q/E = int from {s} {d rsub E}. dA =sigma times A/ E

where s is a any close surface

Q is the net charge enclosed with surface area

dA (with arrow) is the direction of the outward normal

1. An electron of charge 1.6 times 10^-19C is placed in a uniform electric field of 12000 intensity (N/C). Find the force on it, its acceleration and the time it takes to travel 2cm from rest.

M rsub e = 9.11 times 10^-31kg

F = Eq

F = ma

S = ut + ½ at^2

2. What is the electric field through a sphere of radius 4m that contains

a. 50uC b. -50uC

E rsub o = 8.85 times 10^-12

Formula: flux = Q/E rsub o

Answers: a 5.65 times 10^6 b. -5.65 times 10^6

3. Given that E=100N/C alpha (angle made with the horizontal) = 30, A = pi r^2 r = 2cm, calculate the flux in the figure

flux = EA cos theta

For this question, theta is 60. Angle made with the normal

nswer 0.25 pi Nm^2/C

4. Given a cuboid and a point charge of 30uC, calculate the flux in each face

Solution

flux = q/E rsub o

For each face, since there are six sides of a cuboid, we divide the total flux by the number of sides

flux = q/ 6 times {E rsub o}

Answer: 5.65 times 10^5

5. An electron is fixed between the plates of a parallel capacitor. Between the plates, a uniform electric field of magnitude 1000N/C is applied at initial velocity, v\_o of 10^7 m/s. Calculate the vertical deflection of the electron after it has travelled 10cm horizontally between the plates

a\_x = 0, v\_x = constant

a\_y = F/m = qE/m = 1.76 times 10^14

using x = ut+1/2at^2

x = ut (since a = 0)

0.1 = 10^7 times t

t = 10^-8

v\_y = u\_y + at

u\_y = 0

v = at

v\_y = 1.76 times 10^14 times 10^-8

v\_y = 1.76 times 10^6

y – y\_o = u\_yt+1/2a\_yt^2

delta y = ½ times 1.76 times 10^14 times (10^-8)^2

delta y = 8.8 times 10^13m

With a velocity of 9.10^6m/s an electron enters the homogeneous electric field of a parallel plate capacitor are 65mm long at a distance of 50mm apart. The pd between the plates is 150v

a. What is the acceleration of the electron in the y-direction

b. What is the time taken by the electron to travel from one end of the plate to the other end

c. How far from x-axis is the electron when it leaves the plate of the capacitor

d. What is velocity of the electron in the y-axis direction when it leaves the electric field

e. Determine the angle that the velocity makes with the x-axis when it leaves the electric field

PERSONAL STUDY FROM ADEWALE

Electrostatics is the branch of science that deals with the electrical phenomena that arise from stationary electric charge. There are positive and negative charges. Benjamin Franklin (1706 – 1790) first referred to electric charges as positive and negative.

Rubbing plastic rubber with fur produces negative charge in the rubber

Rubbing ebonite rod with silk produces a positive charge in the ebonite rod

LAW OF CONSERVATION OF ELECTRIC CHARGE

This states that the net amount of electric charge is zero in any process.

COULOMB’S LAW

The french physicist Charles Coulomb (1736 – 1806) studied the magnitude of the force between two bodies/ charges using a torsion balance (a tool used for measuring small forces).

The experiment shows that the electrostatic force is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

Therefore, Coulomb’s law can be stated as “In free space, oppositely charged particles attract each other, while similarly charged bodies repel with a force that varies directly as the product of the magnitude of each charge and inversely as the square of the distance between them, the force being directed along the line joining the charges”.

If two particles carrying charges q1 and q2 are separated by a distance r in a vacuum, then the electrostatic force exerted by the particle with charge q1 on particle with charge q2 is given as

F rsub {21} proportional to q1q2/r^2

F rsub {21} = kq1q2/r^2

Here, k Is the constant of proportionality and F21 is the force exerted by q1 on q2. The electrostatic force will be the force between the charges when they are at rest

k = 1/4{%pi}E\_o = 9 times 10^9 Nm^2C^-2

Where E\_o = 8.85 times 10^-12C^2N^-1m^-2 and it is referred to as the permittivity of free space

In vector notation, the Coulomb’s law can be written as

F\_{12} = kq1q2/|r\_12|^2 dot ^r\_{12}

^r\_{12} is a unit vector. Unit vectors usually show the direction.

^r\_{12} = r\_{12}/|r\_{12}| = r1-r2/|r1-r2|.

R1 is the position vector of the charge q1 and r2 is the position vector his statement is known as the **principle of superposition**.

ELECTRIC FIELDS

An electric field can be defined as a region where a charged particle experiences an electric force. It can be mapped out by the lines of electric force.

A line of force is an imaginary line representing a field of force such as in an electric or magnetic field.

The tangent of the line of force at any point is the direction of the field vector at that point.

If you have a body of charge 2q and another of charge q, you’ll notice that the lines of the body of charge 2q will be twice as that of the one with charge of just q.

PROPERTIES OF THE ELECTRIC LINES OF FORCE

1. The electric lines of force are drawn such that the magnitude of the electric field is proportional to the number of lines crossing a unit area perpendicular to the lines.

As explained with the 2q and q charged body.

2. The tangent of the lines of force at every point gives the direction of the field at that point. This was also explained in the note earlier.

3. The lines of force are continuous and they start on positive charges and end only on negative charges

4. Lines of force do not touch or intersect one another

ELECTRIC FIELD STRENGTH

The **electric field strength** at any point is defined as the force per unit charge which it exerts at that point. Its unit is Newton per Coulomb (N/C)

E = F/q

Where q is the test charge placed at the point

If a point charge Q is located at a distance r away from a test charge q at a point P, then the force exerted on the test charge due to the charge Q, according to Coulomb’s law is:

F = kQq/r^2 dot ^r

E =F/q = kQ/r^2

ELECTRIC FIELD OF CONTINUOUS CHARGE DISTRIBUTION

To evaluate the electric field created by a continuous charge distribution, we first divide the charge distribution into small elements; each of which contains a small charge {%DELTA}q.

Therefore each will have a field intensity of

{%DELTA}E = k{%DELTA}q/r^2 dot ^r

The total electric field at the point P due to all the elements in the charge distribution is

int {{%DELTA}E} = k lim from{{%DELTA}q → 0} {sum from{i} {{{{{%DELTA} q} rsub i} over {r rsub i}^2}r^}} = k int {{dq} over {r rsub 2} dot r^}

Note the following:

Linear charge density. Charge per unit length

lambda = Q/l

Surface charge density: Charge per unit area

sigma = Q/A

Volume charge density. Charge per unit volume:

rho = Q/V

Taking a look at linear charge density.

Consider a segment of the rod of length dx. Which has a charge of dq.

From lambda = Q/l,

For that segment, lambda = dq/dx

dq = lambda dx

Assuming that the length of the rod is l and it is from a to l+a from the origin P. The segment with length dx has a distance x from the origin. The electric field intensity of the origin till this length dx of the rod

dE = k dq/x^2 = 1/4{pi}E\_o lambda dx/x^2 = lambda/4{pi}E\_o dx/x^2

E = int from{a} to{a+l} {dE} = {lambda over 4{pi}E\_o} int from{a} to{a+l} {dx/x^2} = lamda over {4{pi}E\_o} |-1/x| from{a} to{l+a}

E = 1/4{pi}E\_o Q/l (1/a – 1/l+a) = Q/4{pi}E\_oa{l+a}

For surface charge density/distribution

E = k int from{A} {{sigma dA/r^2}^r}

For volume charge density/distribution, dq is a volume charge distribution, we consider the element dq = rho dV that is small enough to be considered as a point charge.

E = k int from{V} {{rho dV/r^2}^r}

MOTION OF CHARGED PARTICLES IN A UNIFORM ELECTRIC FIELD

When a particle of charge q and mass m is placed in an electric field E, the charge experiences a force of magnitude Eq. This force can cause the body to accelerate according to newton’s second law of motion F = Eq = ma (provided the electric force is the only force on the particle)

The acceleration of the particle is therefore

a = Eq/m

If the field is uniform, acceleration is constant

If the particle is positive, acceleration is in the direction of the field

If the particle is negative, then its acceleration is in the direction opposite the electric field.

Consider an electron moving into an electric field with an initial speed v\_o (horizontal velocity, meaning that the vertical component is 0), it will be deflected towards the positive plate (unlike charges attract).

Since they are horizontal bars placed on top each other with some gap in between them, the electric field will be vertical which will mean that the electric field is also perpendicular to the velocity. Therefore, there will be no horizontal force acting on the electron as it enters the plates.

Therefore, the horizontal component of acceleration a\_x will be zero

Considering the motion along the vertical axis,

y = v\_{oy}t + ½ a\_y t^2

y = ½ a\_y t^2

y = ½ Eq/m t^2

Considering the motion along the horizontal axis,

x = v\_{ox}t + ½ a\_xt^2

x = v\_ot

Making t the subject of the formula,

t = x/v\_o

Applying it to the vertical equation

y = ½ Eq/m (x/v\_o)^2

From the above, it can be seen that the path of the moving electron will be a parabola (x^2) since the equation can be written in the form y=kx^2

ELECTRIC FLUX

Electric flux is defined as the product of electric field intensity E and the area A perpendicular to the field

Flux = EA cos theta

where E cos theta is the component of E along the perpendicular to the area

The SI unit of Flux is Newton-meters squared per coulomb Nm^2/C

The electric field may vary over a surface, Imagine the surface is divided up into a large number of small elements, each of area delta A is crossed by an electric field E in the direction which makes an angle theta with the normal to the area, then the electric flux delta F crossing the area delta A is given by

delta F = E delta A cos theta = E delta A

The net flux will be the total sum of all the flux

Flux = sum delta flux = int E. dA = int E cos theta dA

GAUSS’ LAW

Karl Friedrich Gauss (1777 – 1855) developed a relation between electric charge and electric field. It’s more general and elegant form of Coulomb’s law.

Flux = int E.dA Q\_in / E\_o

Q\_in is the charge inside the surface

E\_o permitivity of free space.

Any charge outside this surface must not be included in the calculation of electric field. Although a charge outside the chosen surface may affect the distribution of electric lines, but it will not affect the total number of electric lines entering or leaving the surface.

A gaussian surface is a closed surface in 3d space through which the flux of an electric field is calculated.

It is an arbitrary closed surface A = %delta V

Taking a single isolated charge Q, The gaussian surface for this point charge is an imaginary sphere of radius r centered on the charge.

Since the imaginary sphere is symmetrical about the charge at its center, we know that E must have the same magnitude at any point on the surface, and E points radially outward parallel to dA, an element on the surface area.

The surface area of a sphere of radius I 4{pi}r^2,

Therefore, int dA = 4{pi}r^2

The magnitude of E is the same at all points on the gaussian spherical surface.

Q/E\_o = int E.dA = E (4{pi}r^2).

Solving, we obtain

E = Q/4{pi}E\_or^2

Notice how we derived coulomb’s law from gauss’ law

Note the following

1. The net flux through any closed surface is independent of the shape of the surface

2. The net flux through any closed surface surrounding a point charge q is given by q/E\_o

3. The electric flux through a closed surface that surrounds the charge is zero

ELECTRIC POTENTIAL

Come back to this