-:(Applied Physics):-

Semester 01:-

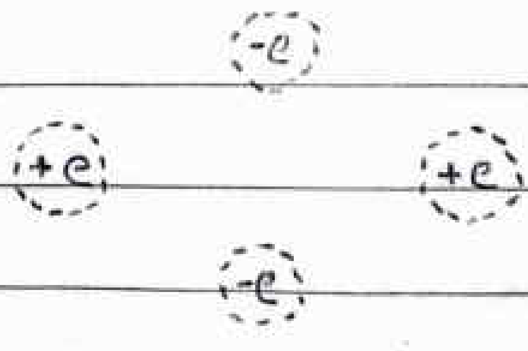
QNo18:-

Calculate Electric Potential due to quadrupole?

Answer:-

The two electric dipoles arranged in such a way that they almost cancel electric effects of each other at distant points is called Quadrupole.

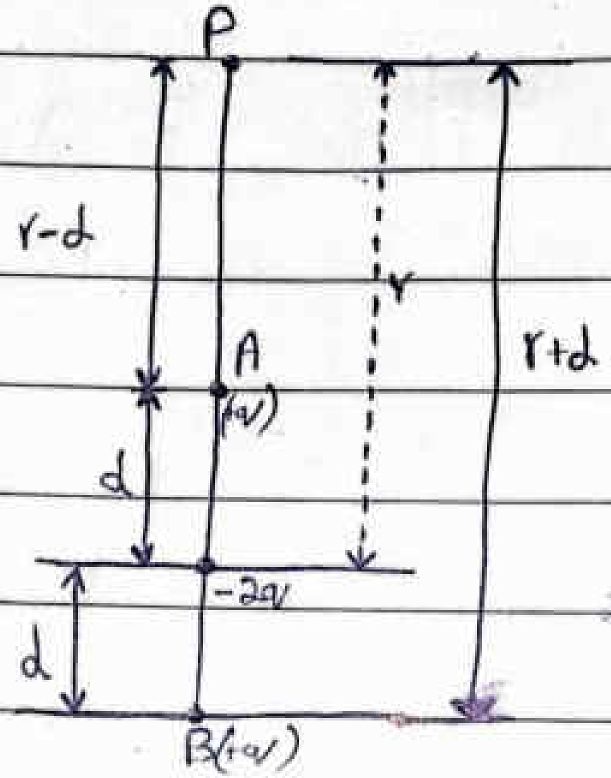
Diagram:-



An elementary quadrupole can be represented as two dipoles oriented antiparallel. The most important uses of quadrupole is the characterization of nuclei.

Electric Potential due to Quadrupole:-

Diagram:-



Explanation:-

Consider two charges each of value -q are placed at origin on x-axis.

Now place +q charge at point A having distance 'd' from '-2q'.

Similarly place an other charge (+q) at point B having distance 'd' from '-2q'.

Now take a point P on z-axis having distance 'r' from -2q and [diameter]* distance (r+d) from +q charges at B.

The electric potential at P due to +q at A is:

$$V_1 = \frac{Kq}{r-d}$$

Similarly due to +q at B.

$$V_2 = \frac{Kq}{r+d}$$

due to -2q charge.

$$V_3 = \frac{K(-2q)}{r}$$

The total electric potential is:

$$V = V_1 + V_2 + V_3$$

$$V = \frac{Kq}{r-d} + \frac{Kq}{r+d} - \frac{2Kq}{r}$$

$$V = Kq\left(\frac{1}{r-d} + \frac{1}{r+d} - \frac{2}{r}\right)$$

$$V = Kq\left(\frac{r^2 + dr + r^2 - dr - 2(r^2 - d^2)}{r(r-d)(r+d)}\right)$$

$$V = Kq\left(\frac{\cancel{2r^2} - \cancel{2r^2} + 2d^2}{r(r^2 - d^2)}\right)$$

$$V = \frac{Kq(2d^2)}{r(r^2 - d^2)}$$

$$V = \frac{K(2qd^2)}{r^3\left(1 - \frac{d^2}{r^2}\right)}$$

$$\left\{\because \begin{array}{l} P = qd \\ Q = 2qd^2 \end{array}\right\}$$

$$V = \frac{KQ}{r^3}\left(1 - \frac{d^2}{r^2}\right)^{-1}$$

By Binomial :-

$$V = \frac{KQ}{r^3}\left(1 + (-1)\left(\frac{-d^2}{r^2}\right) + \dots\dots\right)$$

The term $\left(\frac{-d^2}{r^2}\right) = 0$ because $r >>> d$

$$\boxed{V = \frac{KQ}{r^3}}$$

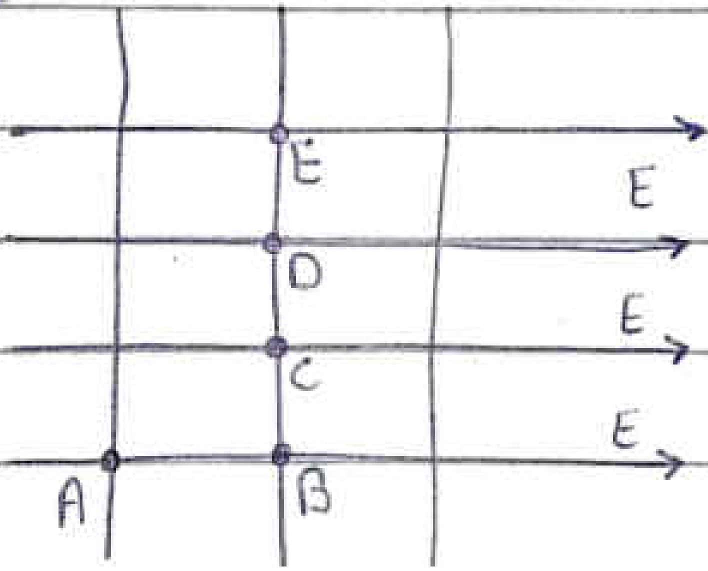
Topic:-

Equipotential Surfaces :-

The family of surfaces that connect points having same value of the electric potential are called equipotential surfaces.

Due to Uniform field:-

Diagram:-



DAY:

Explanation:-

Consider uniform electric field indicated by horizontal electric lines of force. The perpendicular dashed lines are cross-section of equipotential surface.

Take two points having distance l.

$$\Delta V = -\int_A^B E \cdot ds$$

$$\Delta V = -El$$

Potential difference b/w B and C:

Electric potential at B is $V_B = \frac{Kq}{r_B}$

Electric potential at C is $V_C = \frac{Kq}{r_C}$

$$\Delta V = V_B - V_C$$

$$V_B - V_C = \frac{Kq}{r_B} - \frac{Kq}{r_C} \qquad \{\because r_B = r_C\}$$

$$V_B - V_C = \frac{\cancel{Kq}}{\cancel{r_B}} - \frac{\cancel{Kq}}{\cancel{r_B}}$$

$$V_B - V_C = 0$$

$$\boxed{V_B = V_C}$$

Since $\Delta V = \frac{-W_{BC}}{q_o} = 0$, So $W_{BC} = 0$

Hence no work is done by electric field when q_o is moved from B to C.

(ii) **Due to positive point charge:-**

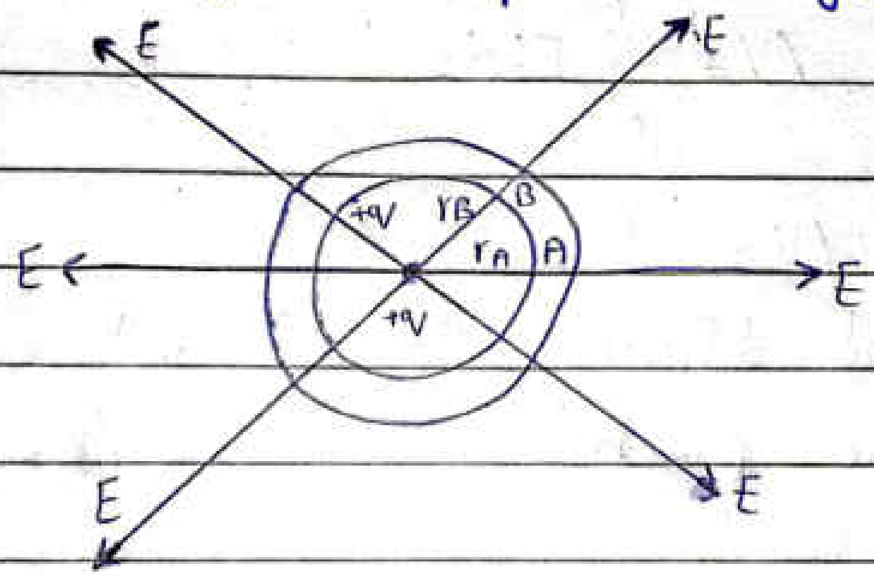


Diagram:-

In this way all the points on the line containing points A, B, C etc have same potential. The surface passing through these points are called equipotential surface.

Consider a +q charge is placed at the center of sphere. The electric field is along ~~radius~~ direction.

Potential difference b/w A and B.

$$V_A - V_B = Kq\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$$

when points A and B lies on the surface of same sphere $r_A = r_B$

In this case:-

$$V_A - V_B = Kq\left(\cancel{\frac{1}{r_A}} - \cancel{\frac{1}{r_A}}\right)$$

$$V_A - V_B = 0$$

$$\boxed{V_A = V_B}$$

It means all points at a given radius have the same potential. Therefore, the equipotential surface of a given charge from a family of concentric sphere.

For a dipole, the equipotential surfaces are more complicated.