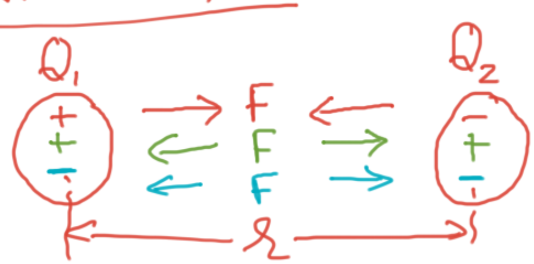
July 02, 20

ELECTRIC FIELDS

Coulomb's law:-

Statement: The force of attraction or repulsion b/w two point charges is directly proportional to product of their charges and inversely proportional to the square of separation b/w their centres.

Mathematical form



$F \propto Q_1 Q_2$ ---(1)

$F \propto \frac{1}{r^2}$ ---(2)

Combining (1) and (2)

$$F \propto \frac{Q_1 Q_2}{r^2}$$

$$F = K \frac{Q_1 Q_2}{r^2}, \quad K = \frac{1}{4\pi\varepsilon_0} = \frac{1}{4(3.14)(8.85\times10^{-12})}$$

$$K = 8.99 \times 10^{9}\ Nm^2C^{-2}$$

Here $\varepsilon_0 = 8.85\times10^{-12}\ Fm^{-1}$ and is called Permittivity of free space.

$$\boxed{F = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1 Q_2}{r^2}\right)}$$

$$F = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1 Q_2}{r^2}\right)$$

Note:

(1) If Q_1 and Q_2 are like charges.

$F = +ve$ (Repulsive force)

(2) If Q_1 and Q_2 are opposite charge

$F = -ve$ (attractive force)

Q) Calculate the ratio of Electric force to Gravitational force between protons in a Helium nucleus (^4_2He).

* Mass of a proton: $m_p = 1.67 \times 10^{-27}$ kg
* Charge on an elementary particle $= e = 1.60 \times 10^{-19}$ C
* $G = 6.67 \times 10^{-11}\ Nm^2kg^{-2}$
* $K = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9\ Nm^2C^{-2}$

$$\frac{F_E}{F_G} = \frac{K\frac{Q_1 Q_2}{r^2}}{G\frac{m_1 m_2}{r^2}} \Rightarrow \frac{F_E}{F_G} = \frac{KQ_1Q_2}{Gm_1m_2}$$

$$\frac{F_E}{F_G} = \frac{(8.99\times10^{9})(1.60\times10^{-19})^2}{(6.67\times10^{-11})(1.67\times10^{-27})^2}$$

$$= 1.24 \times 10^{36}$$

(b) Compare both forces and specify which force is responsible to provide centripetal force to electrons

$F_E = 1.24 \times 10^{36}\ F_G$

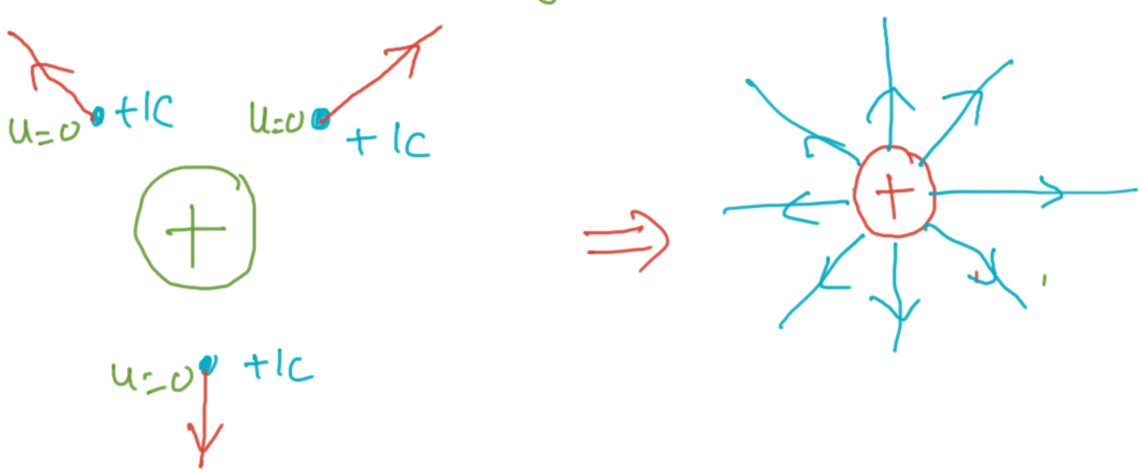
$F_E \ggg F_G$, So Gravitational effects are neglected in comparison to Electr force in case of an atom.

Electric pull of +ve nucleus provides Centripetal force to electrons.

Electric field:-

Concept:
* Field → 3D region of space
* Source → Static charged particle
* test/detect/identify → Another charged particle experience an electric force.

Representation: By field lines i.e. towards the motion of unit +ve charge placed in the field of another charge.

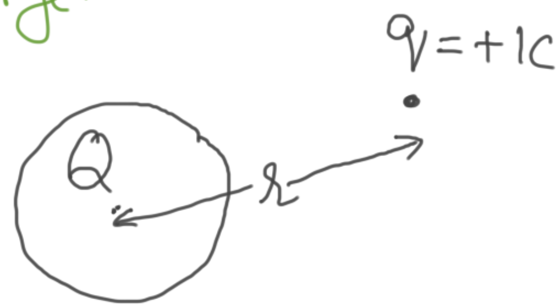


non-uniform field because separation b/w adjacent field lines vary.

Electric field strength: (E)

Def Electric force per unit +ve charge.

Formula



$$E = \frac{F}{q}$$

But $F = \frac{1}{4\pi\varepsilon_0}\left(\frac{Qq}{r^2}\right)$

$$E = \frac{\frac{1}{4\pi\varepsilon_0}\left(\frac{Qq}{r^2}\right)}{q}$$

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{r^2}\right)}$$

Note:

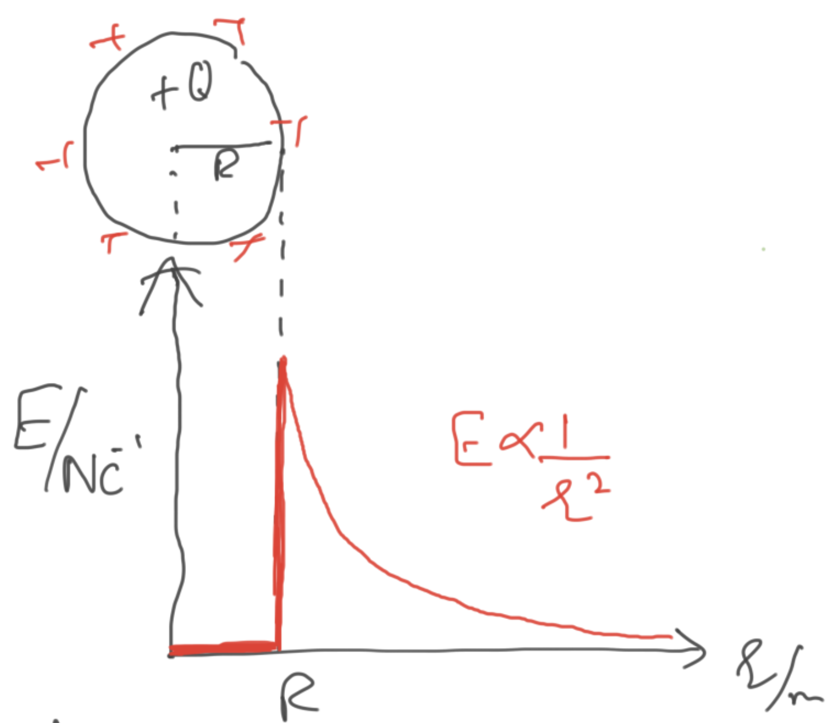
(i) If $Q = +ve$, $E = +ve$

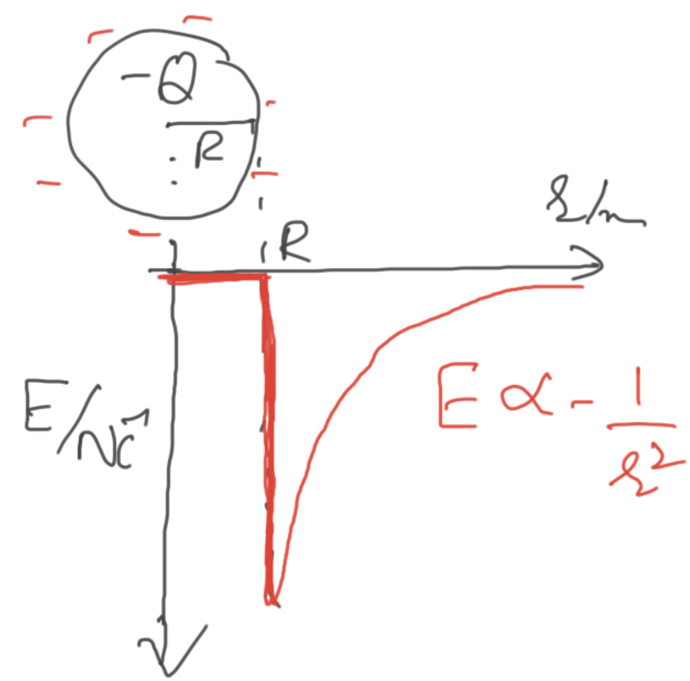
(ii) If $Q = -ve$, $E = -ve$

(iii) $E \downarrow$ if $r \uparrow$ by $E \propto \frac{1}{r^2}$ (follows the inverse square relationship)

(iv) Since there is no charge inside the charged sphere, so Electric field strength inside the sphere is zero and is maximum at its surface. It decreases by following inverse square law when moved away from charged sphere.

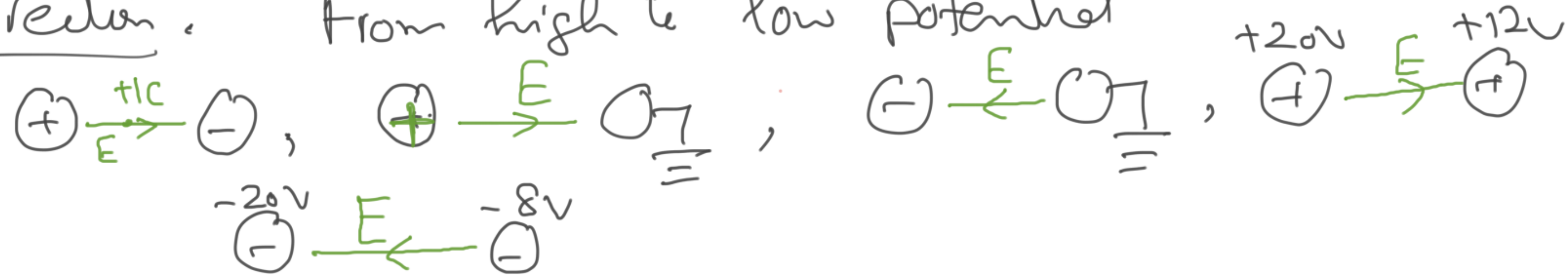
Graph



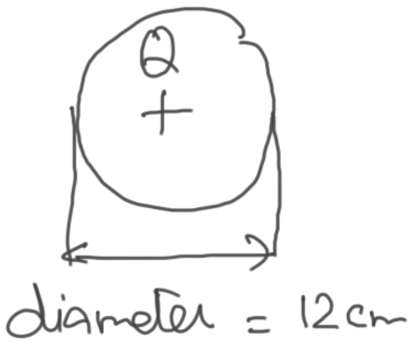


P.S Vector

Direction: From high to low potential



Q7



Electric field strength at the surface of the charged sphere of diameter 12cm is $4.0 \times 10^5 \ NC^{-1}$

Calculate

(a) Charge at the surface of sphere

(b) Calculate the electric field strength at a distance of 24 cm from the centre of sphere.