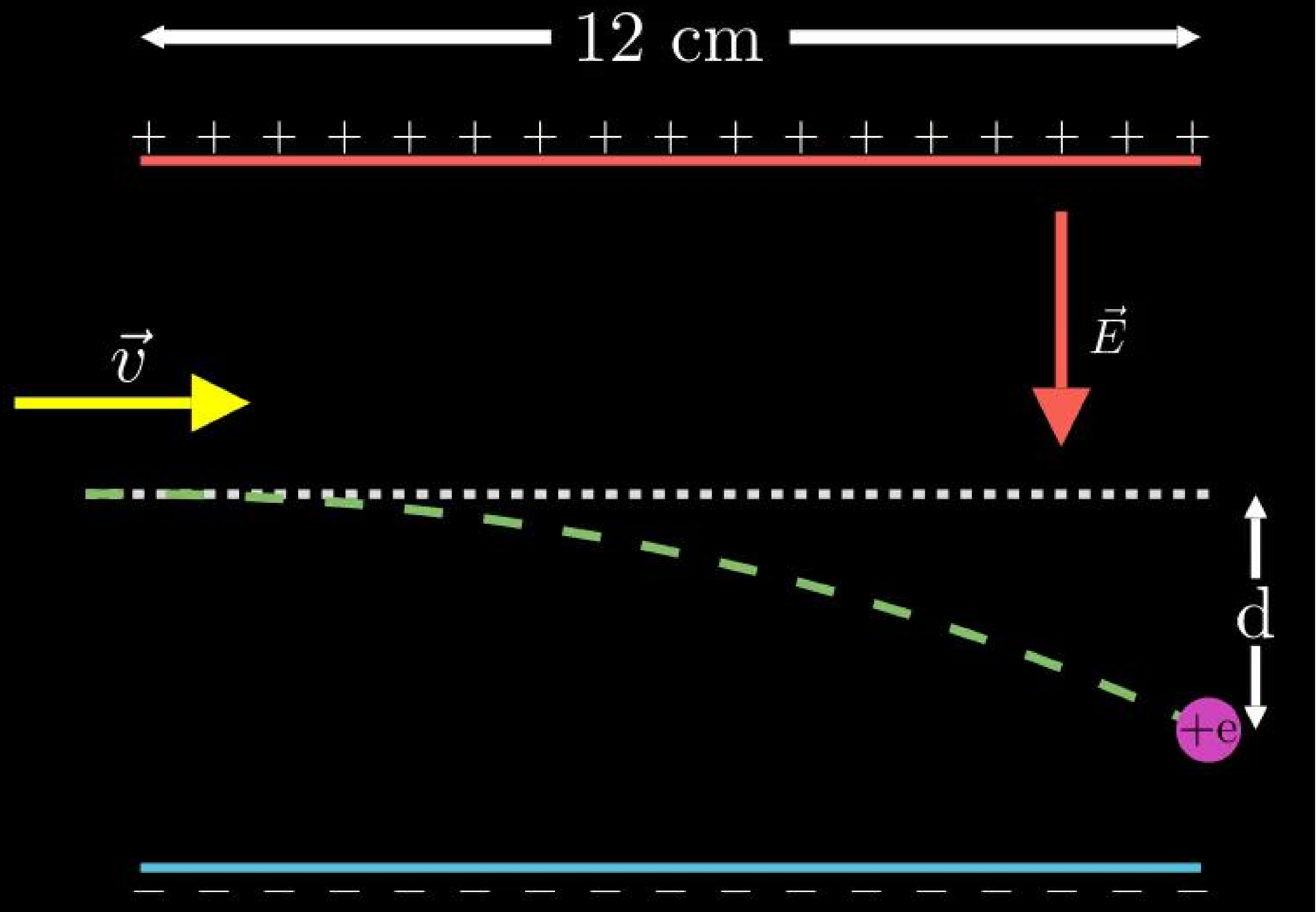
Example 28 :A proton enters the uniform electric field produced by the two charged plates shown below. The magnitude of the electric field is 4.0×10^5 N/C, and the speed of the proton when it enters is 1.5×10^7 m/s. What distance d has the proton been deflected downward when it leaves the plates?



Solution :

Solution :

- Given: $E = 4.0 \times 10^5$ N/C, $v = 1.5 \times 10^7$ m/s, and Plate Length $l = 12$ cm $= 12 \times 10^{-2}$ m
- Find: Downward deflection $d = ?$
- Motion along x-axis:

$$x_0 = 0,\ u_x = v,,\ a_x = 0 (\because F_x = 0)$$

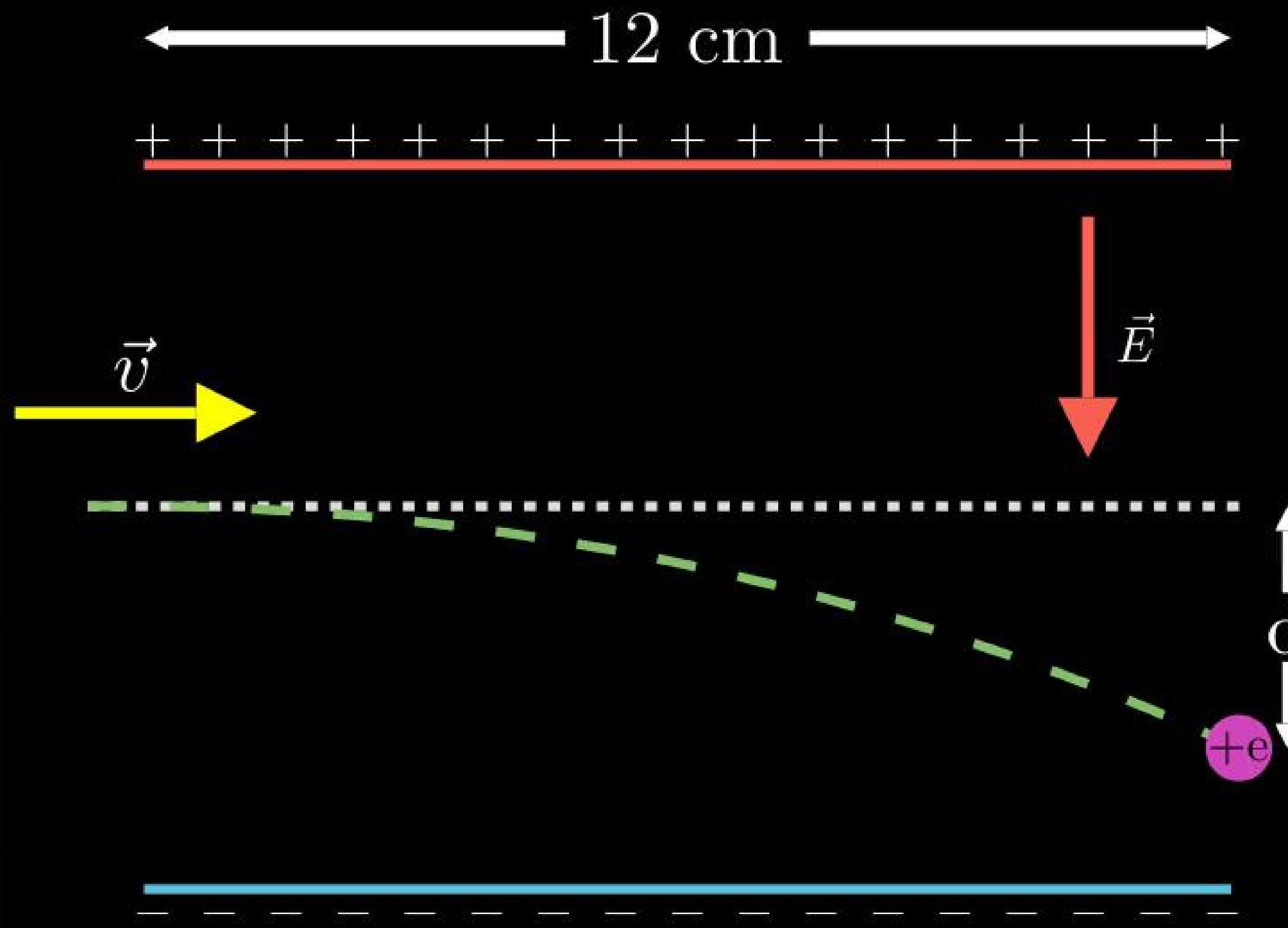
$$x - x_0 = u_x \times t + \frac{1}{2} a_x t^2 \text{ (Using 2nd eq. of Motion)}$$

$$x = v \times t \text{ Or } t = \frac{x}{v} \text{ ....(1)}$$

- Motion along y-axis:

$$y_0 = 0,\ u_y = 0,\ a_y = \frac{eE}{m} (\because F_y = eE)$$

$$y - y_0 = u_y \times t + \frac{1}{2} a_y t^2 \text{ (Using 2nd eq. of Motion)}$$



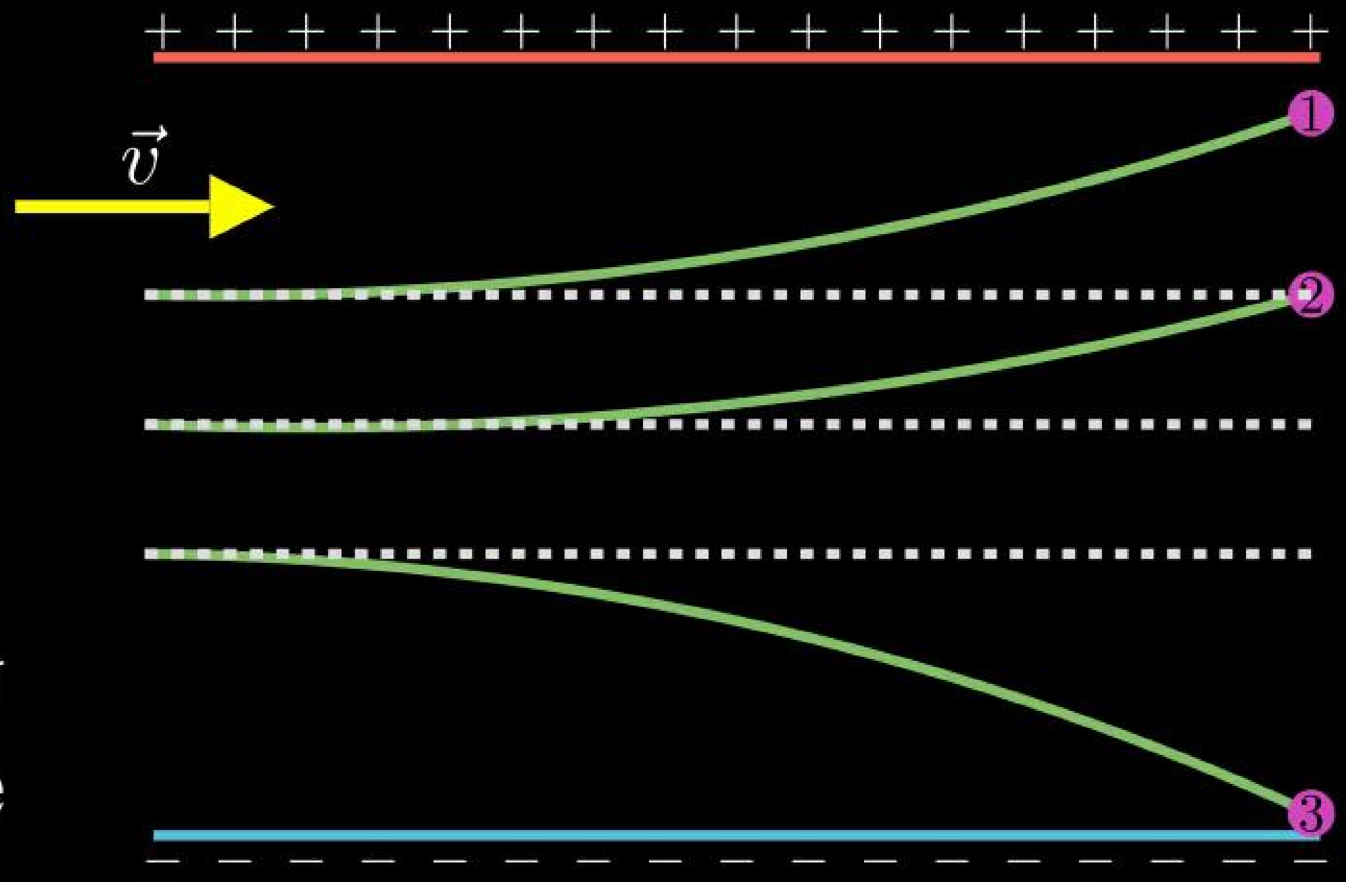
$$y = \frac{1}{2} \frac{eE}{m} t^2 \text{ ....(2)}$$

- Put Value of t from eq(1) to eq(2

$$y = \frac{1}{2} \frac{eE}{m} \frac{x^2}{v^2} \text{ (eqn of Parabola)}$$

$$d = \frac{1}{2} \frac{eE}{m} \frac{l^2}{v^2}$$

Exercise 1.14 :Figure 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?



Solution :

- Particles 1 and 2 have negative charges because they are being deflected towards the positive plate of the electrostatic field.
- Particle 3 has positive charge because it is being deflected towards the negative plate.
- Deflection(d) of charged particle in y-direction is

$$d = \frac{1}{2}\frac{qE}{m}\frac{l^2}{v^2} \text{ OR } d \propto \frac{q}{m}$$

- As the particle 3 suffers maximum deflection in y-direction, so it has highest charge to mass $\dfrac{q}{m}$ ratio.

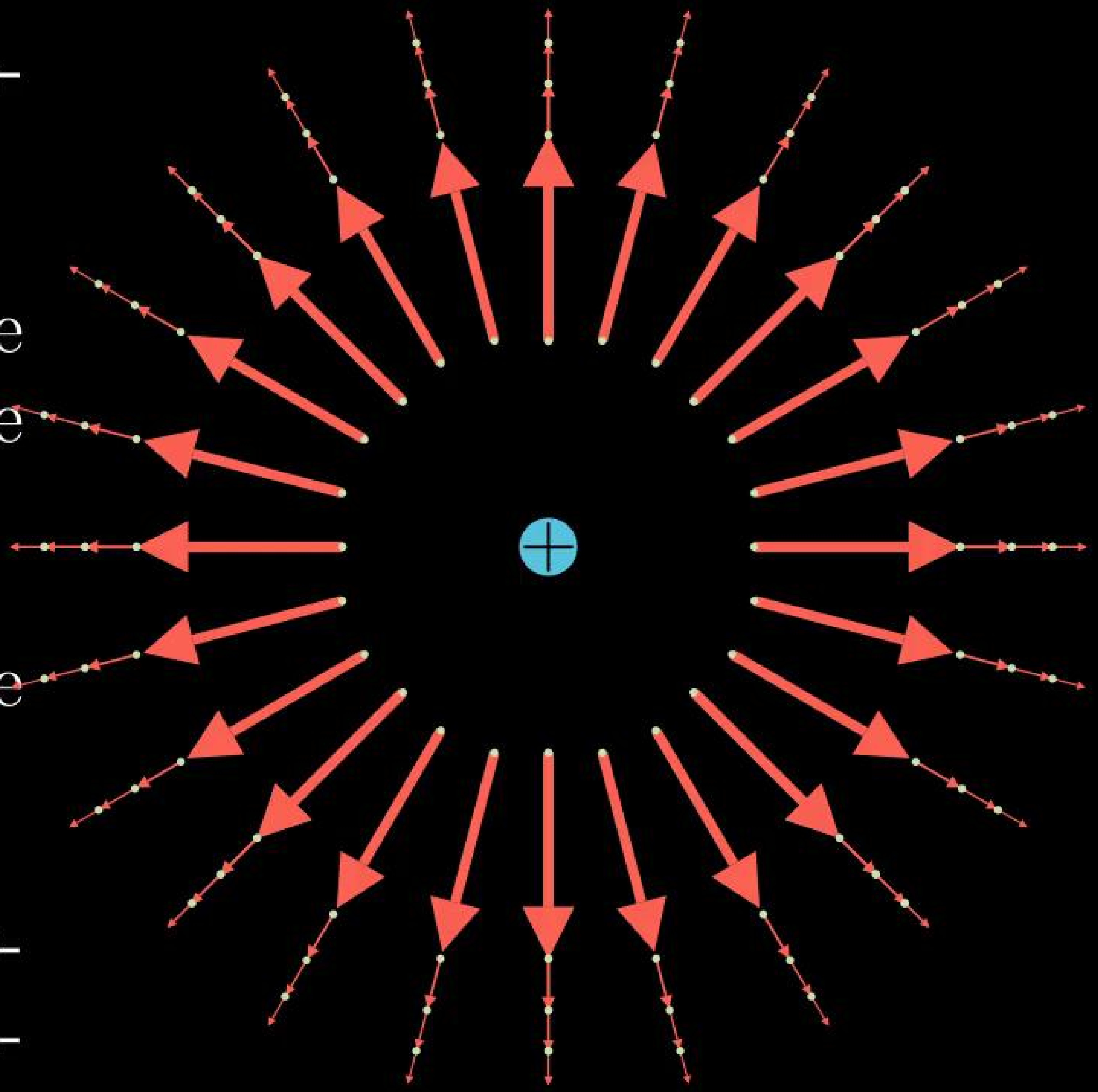
Electric Field Lines

- Let us try to represent $\vec{E}$ due to a point charge pictorially.

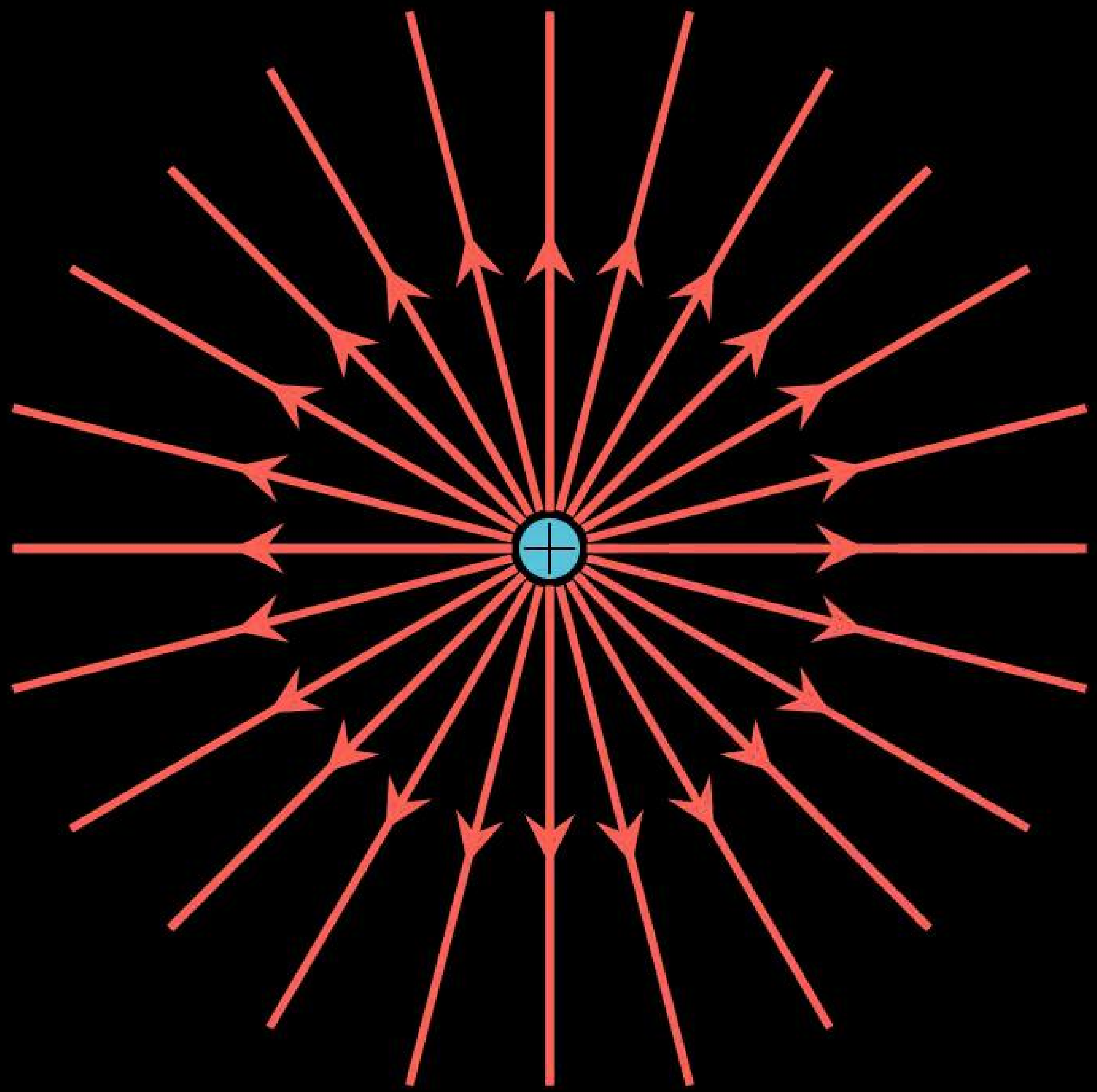
- Draw vectors pointing along the direction of the electric field with their lengths proportional to the strength (magnitude) of the field at each point.

- The vector gets shorter as one goes away from the origin, always pointing radially outward

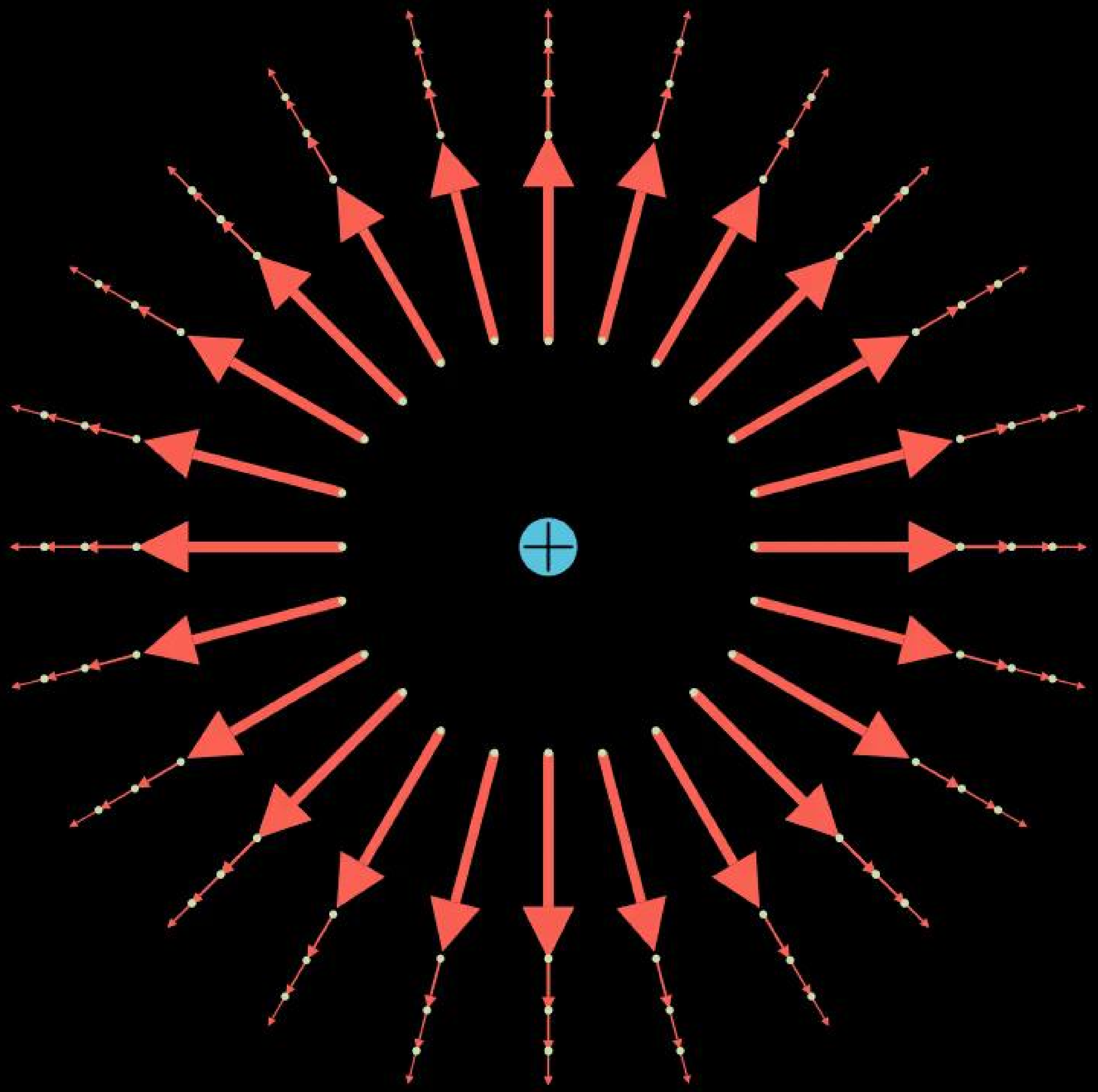
- There is a more useful way to present the same information. Rather than drawing a large number of increasingly smaller vector arrows,we instead connect all of them together, forming continuous lines and curves



Electric Field Lines



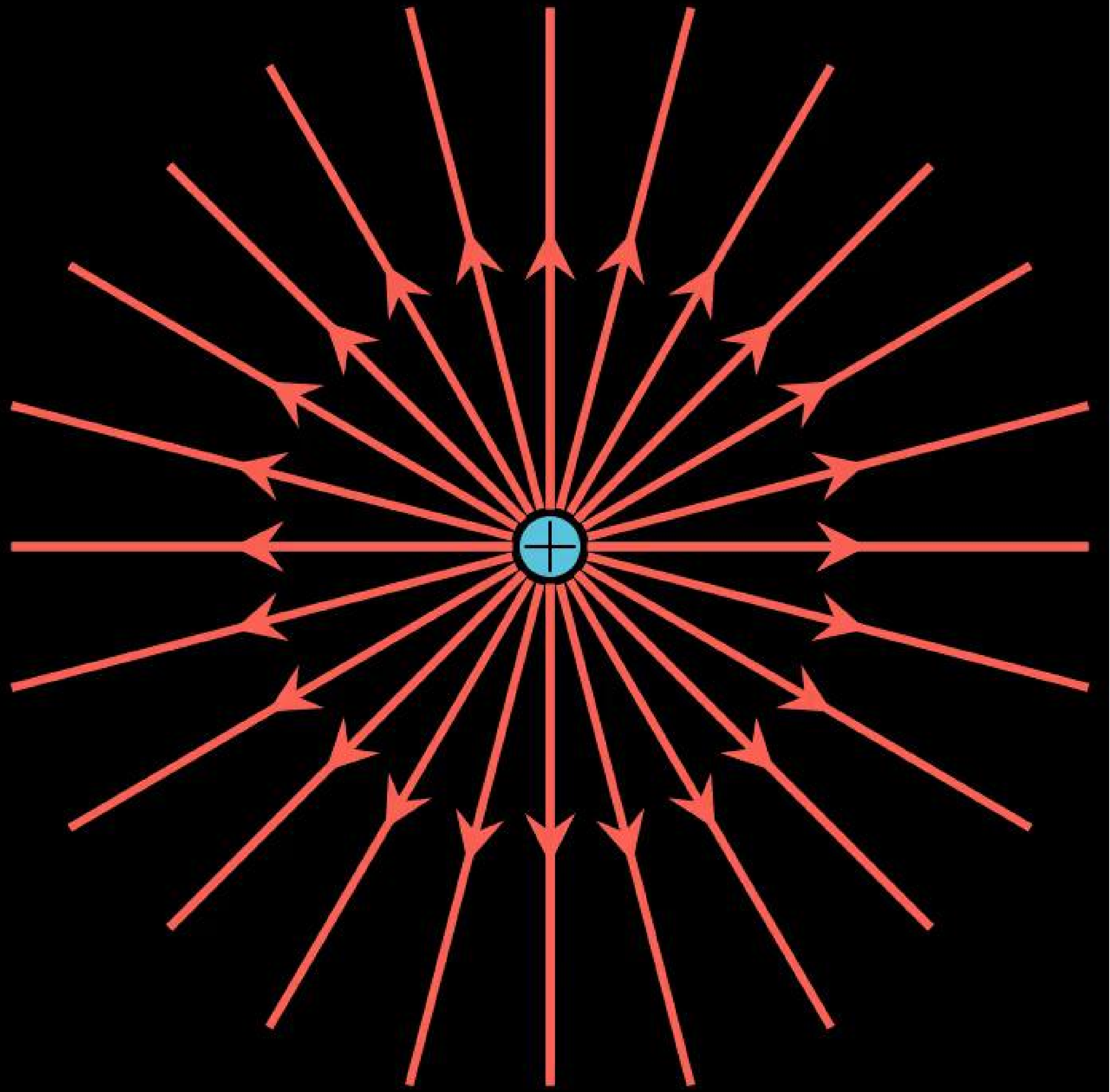
The electric field line diagram of a positive point charge



The vector field of a Positive point charge

Electric Field Lines

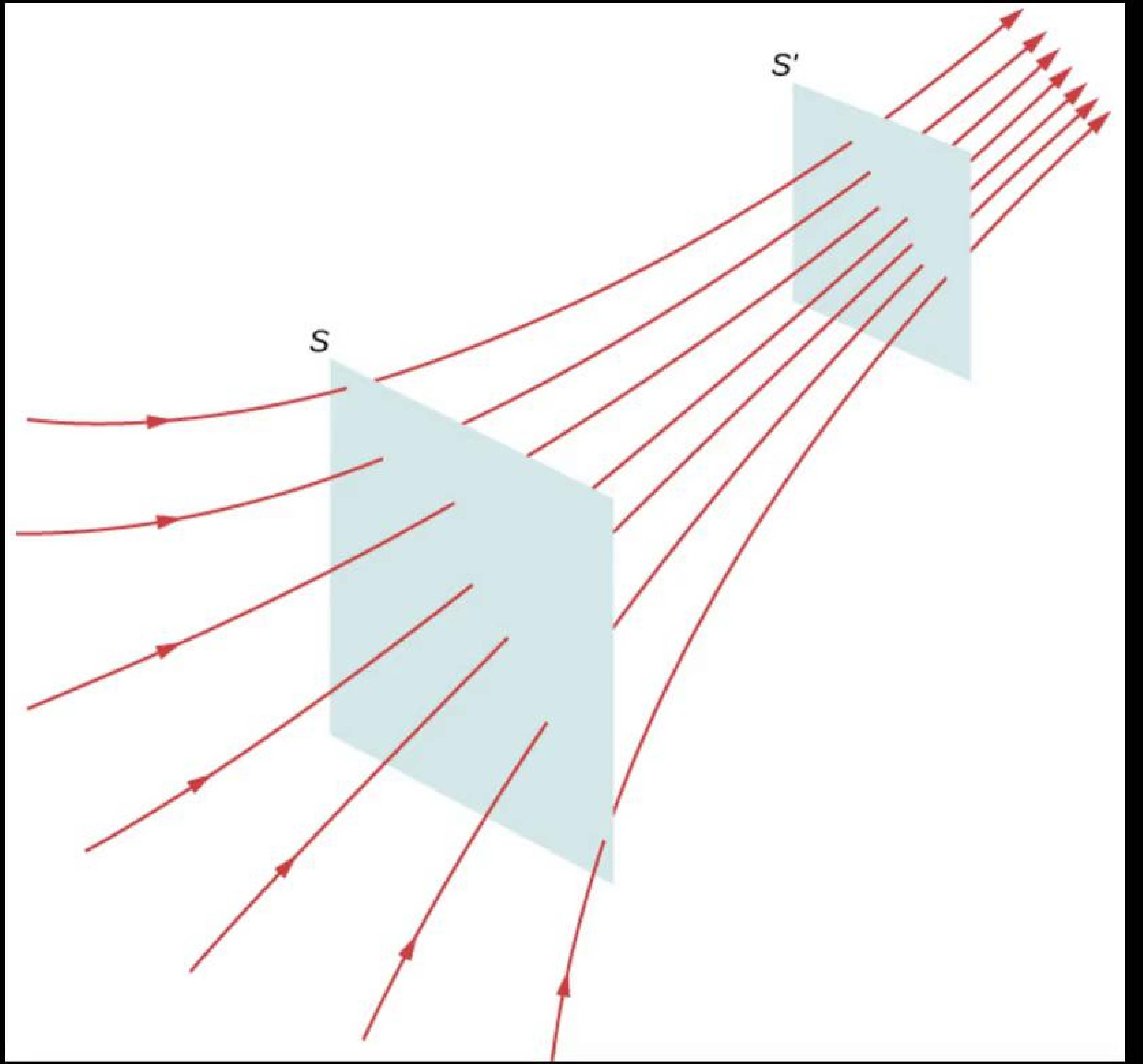
- Have we lost the information about the strength or magnitude of the field now, because it was contained in the length of the arrow?
- No. Now the magnitude of the field is represented by the density of field lines.
- E is strong near the charge, so the density of field lines is more near the charge and the lines are closer.
- Away from the charge, field gets weaker and the density of field lines is less, resulting in well-separated lines.



The electric field line diagram of a positive point charge

Electric Field Lines

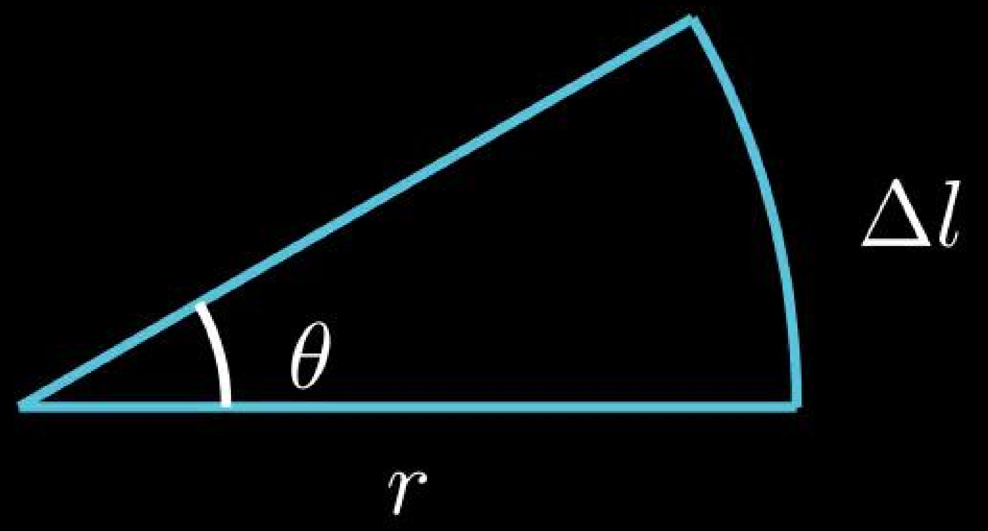
- In Figure., the same number of field lines passes through both surfaces (S and S'),
- but the surface S is larger than surface S'
- Therefore, the density of field lines (number of lines per unit area) is larger at the location of S', indicating that the electric field is stronger at the location of S' than at S.

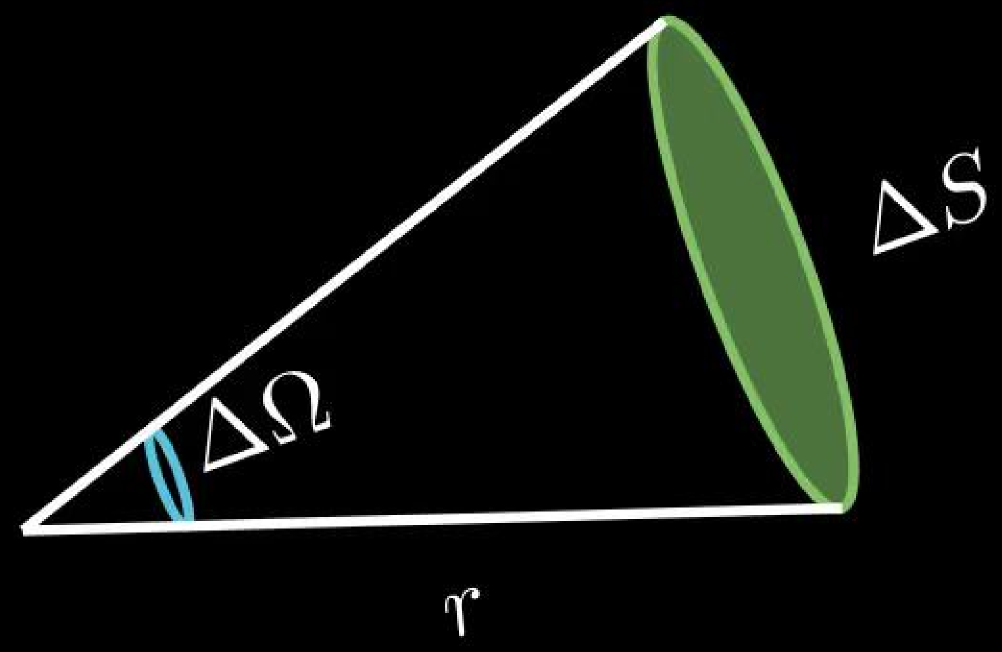


Electric Field Lines

- Plane Angle $\theta = \dfrac{\text{arc}}{\text{radius}} = \dfrac{\Delta l}{r}$

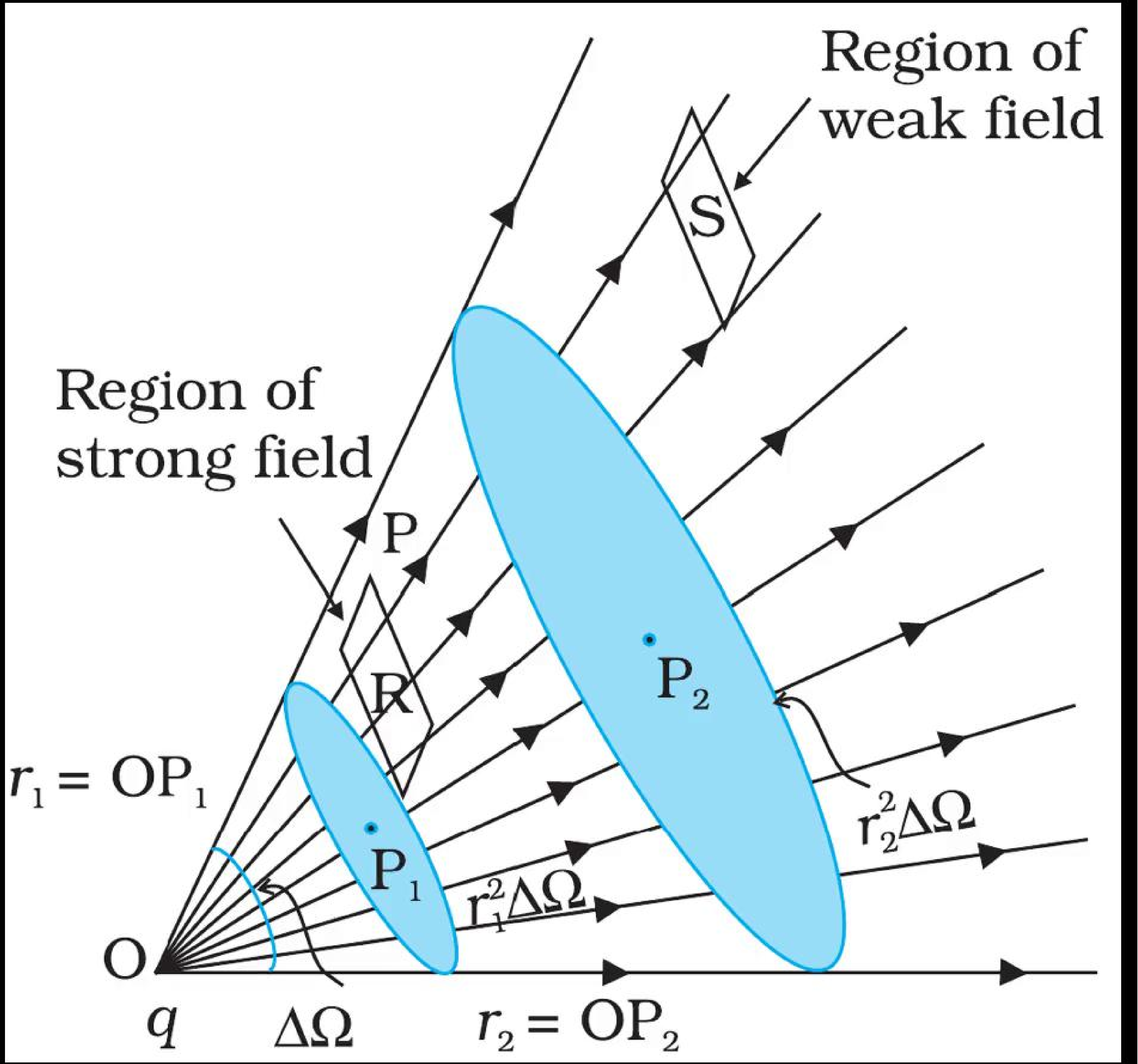
- Solid Angle $\Delta\Omega = \dfrac{\text{Plane area}}{\text{radius}^2} = \dfrac{\Delta S}{r^2}$





Electric Field Lines

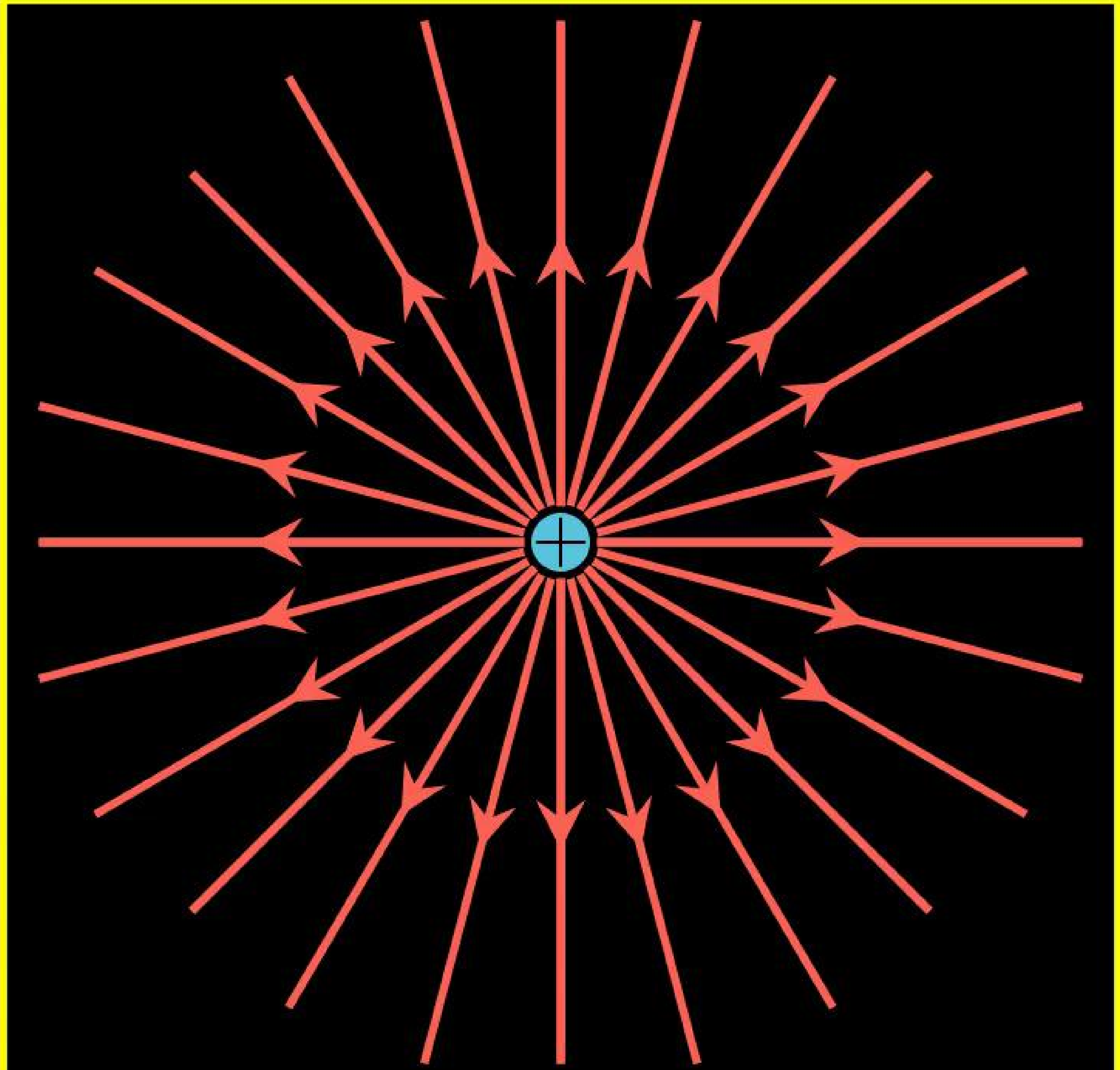
- Plane Angle $\theta = \dfrac{\text{arc}}{\text{radius}} = \dfrac{\Delta l}{r}$
- Solid Angle $\Delta\Omega = \dfrac{\text{Plane area}}{\text{radius}^2} = \dfrac{\Delta S}{r^2}$
- Electric Filed at P_1: $E_{P_1} \propto \dfrac{n}{\Delta S_1} \propto \dfrac{n}{\Delta\Omega\ r_1^2}$
- Electric Filed at P_2: $E_{P_2} \propto \dfrac{n}{\Delta S_2} \propto \dfrac{n}{\Delta\Omega\ r_2^2}$
- Since n and $\Delta\Omega$ are common, the strength of the field clearly has a $\dfrac{1}{r^2}$ dependence.



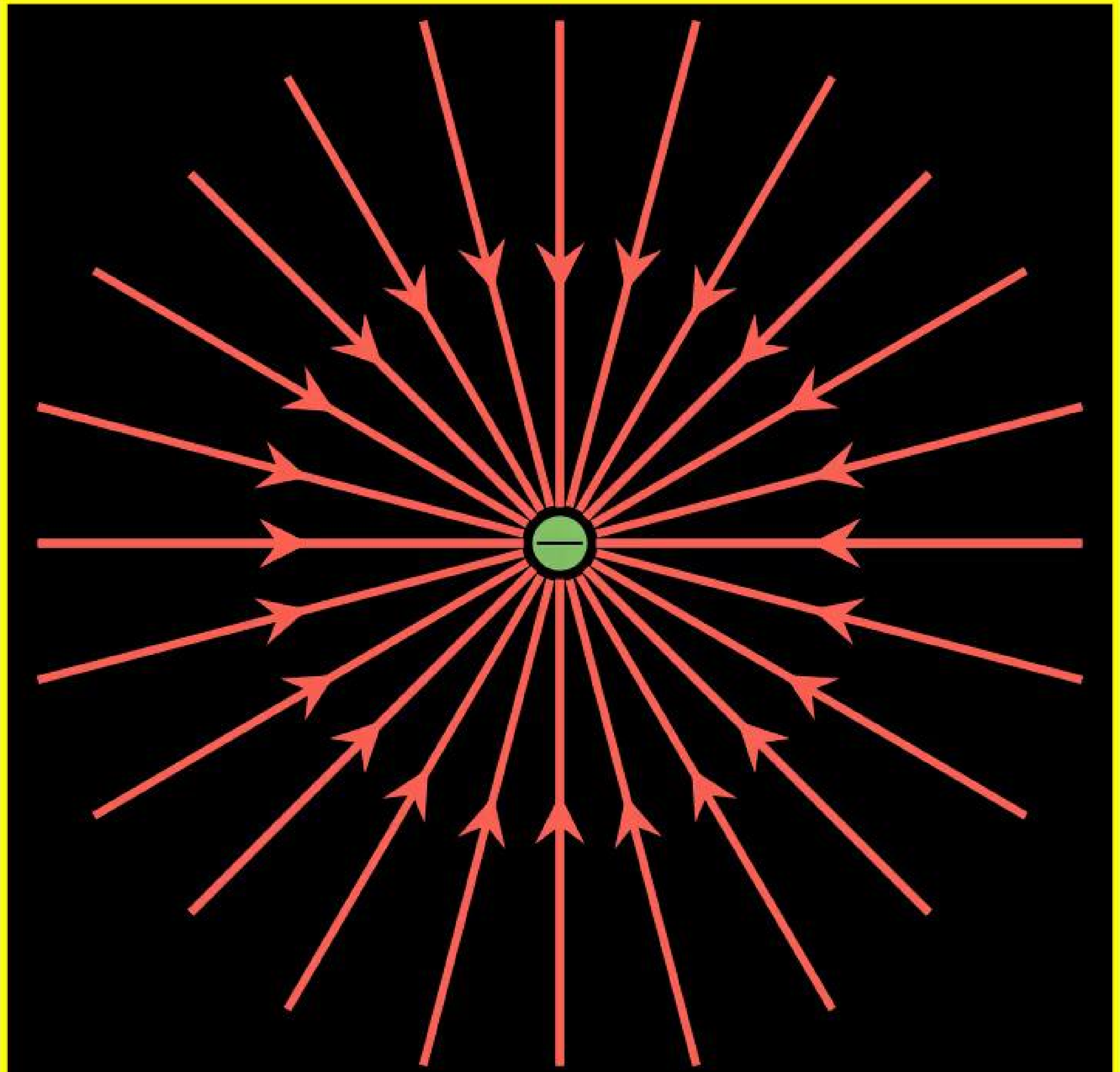
Electric Field Lines

- The picture of field lines was invented by Faraday to develop an intuitive non-mathematical way of visualising electric fields around charged configurations. Faraday called them lines of force
- Electric field lines are thus a way of pictorially mapping (visualising) the electric field around a configuration of charges.
- An electric field line is, in general a curve drawn in such a way that the tangent to it at each point is in the direction of the net field at that point.
- The arrow specify the direction of electric field from the two possible directions indicated by a tangent
- The denser the electric field line, the stronger the electric field.

Electric Field Lines

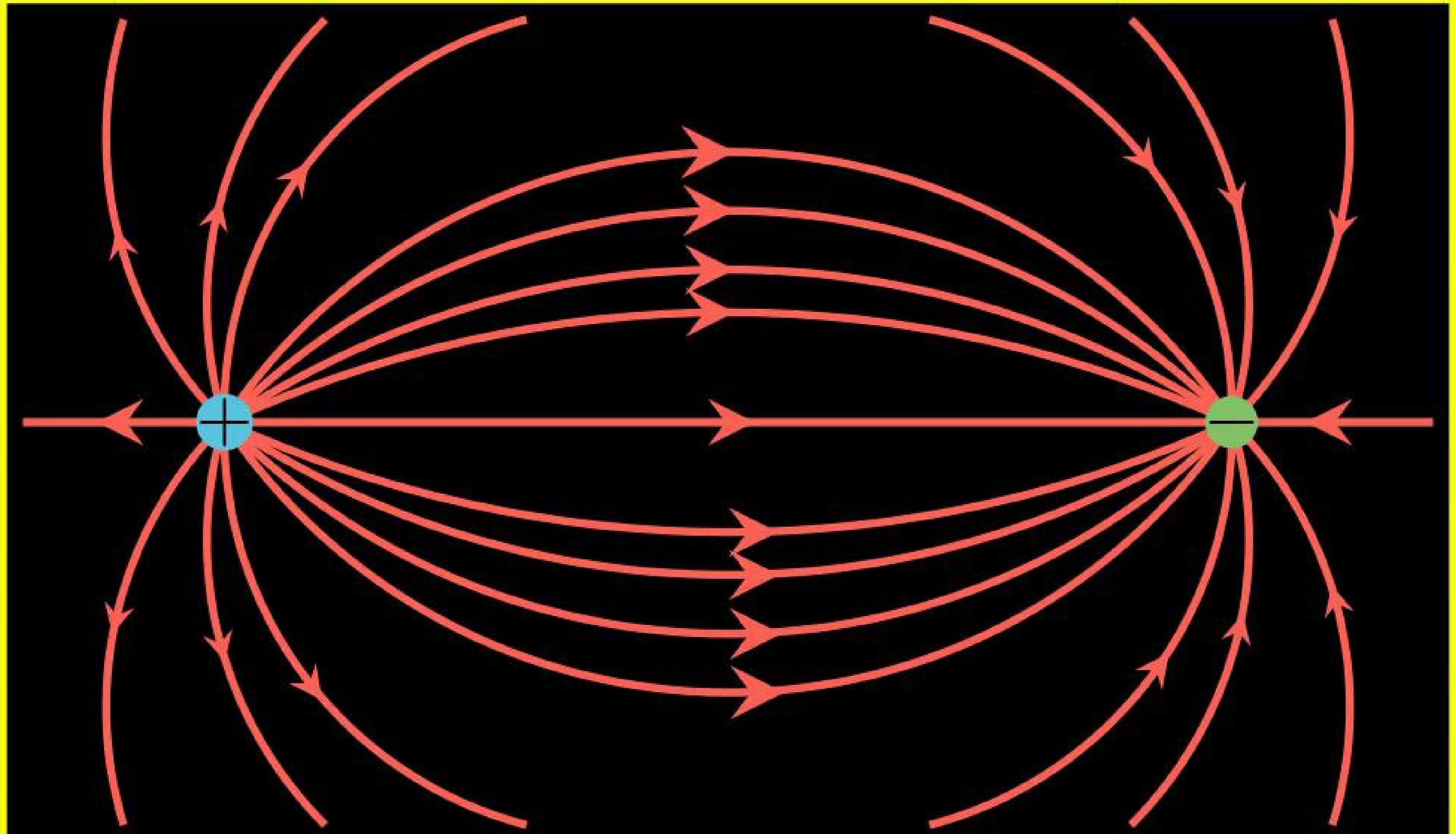


(1) The field lines of a single positive charge are radially outward

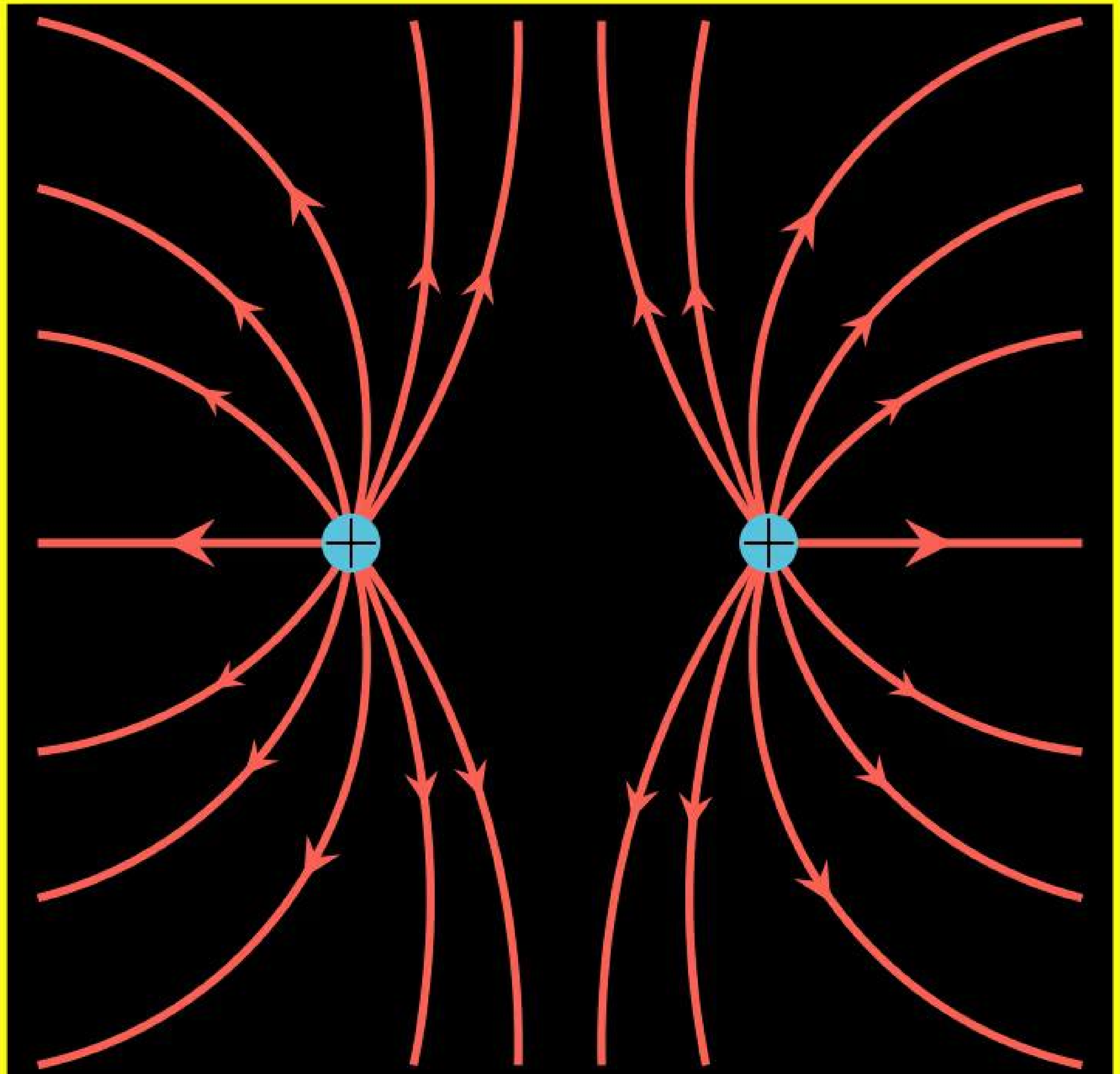


(2) The field lines of a single negative charge are radially inward

Electric Field Lines



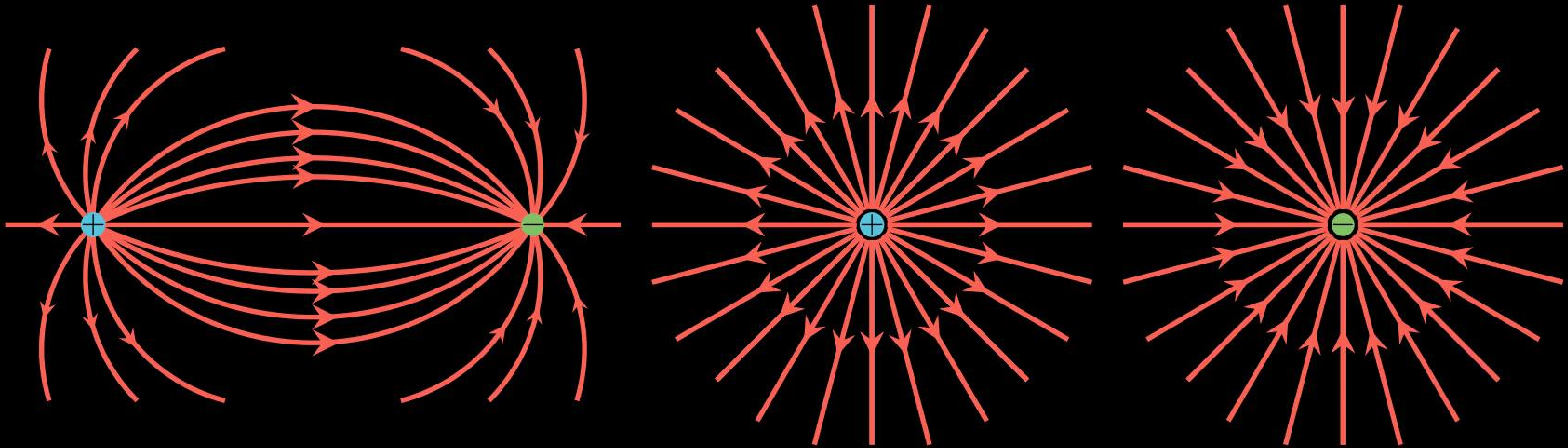
(3) The field lines of a A dipole
(Two equal an opposite charges)



(4) The field lines of Two identical charges

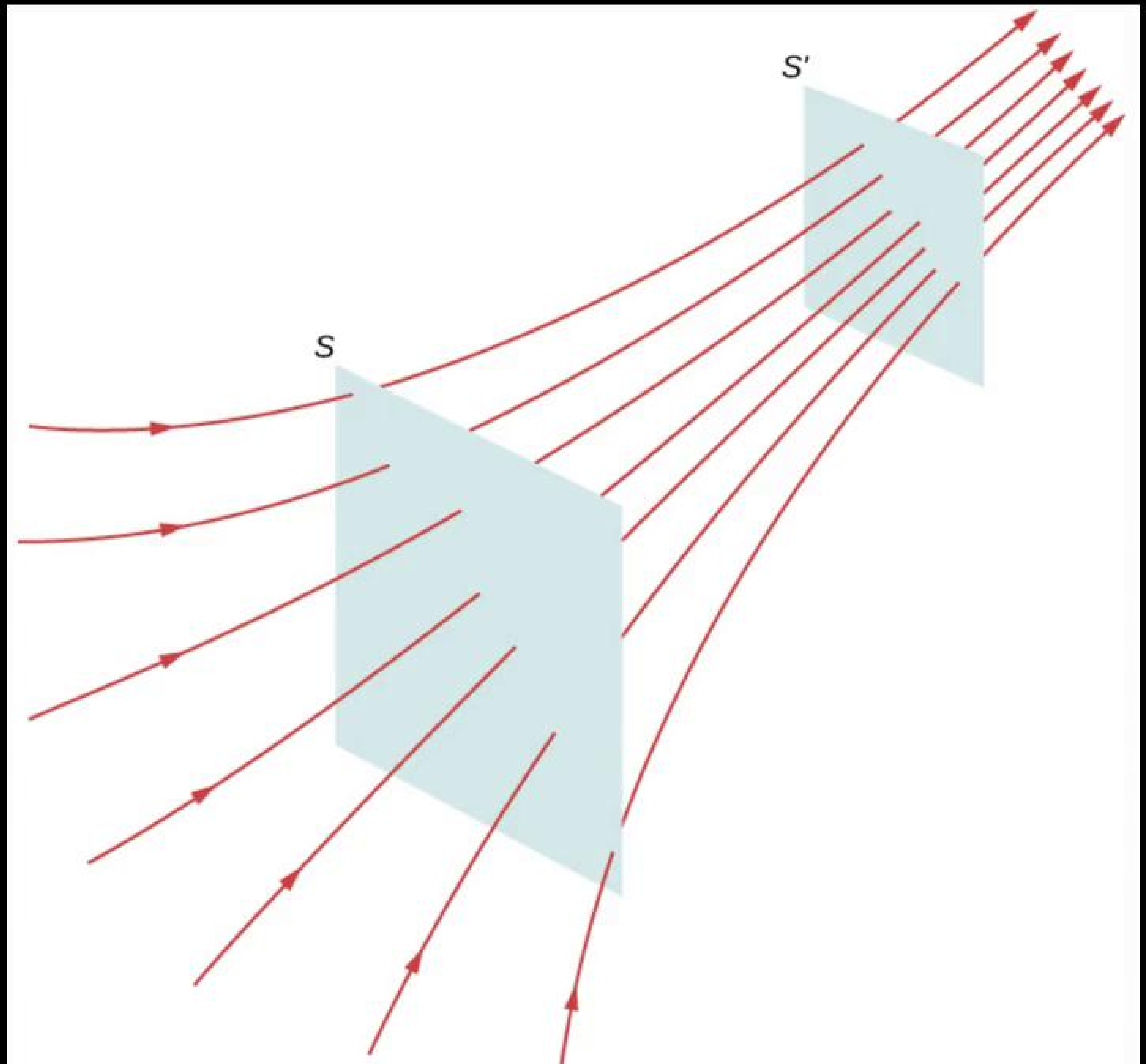
Properties of Electric Field Lines

- (1) Field lines starts from positive charge and end at negative charge. If there is a single charge, they may start or end at infinity.



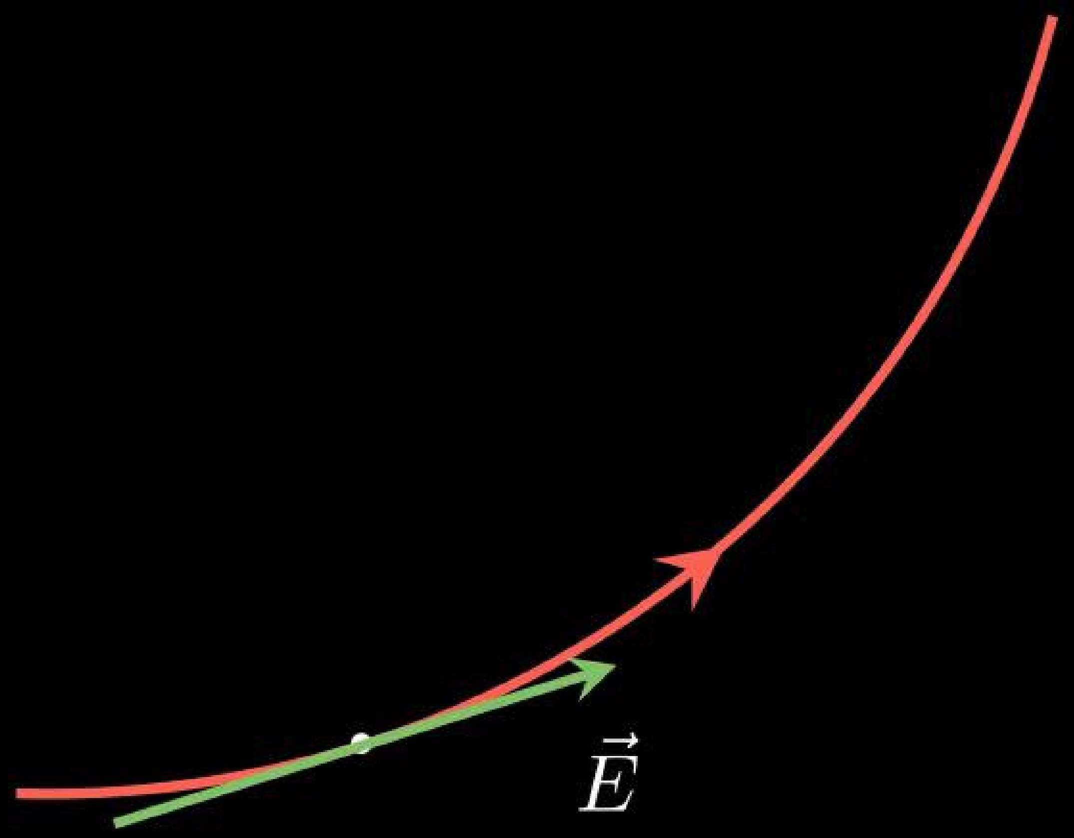
Properties of Electric Field Lines

- (2) Magnitude of electric field is repersented by the density of Filed lines. The denser the electric field line, the stronger the electric field.



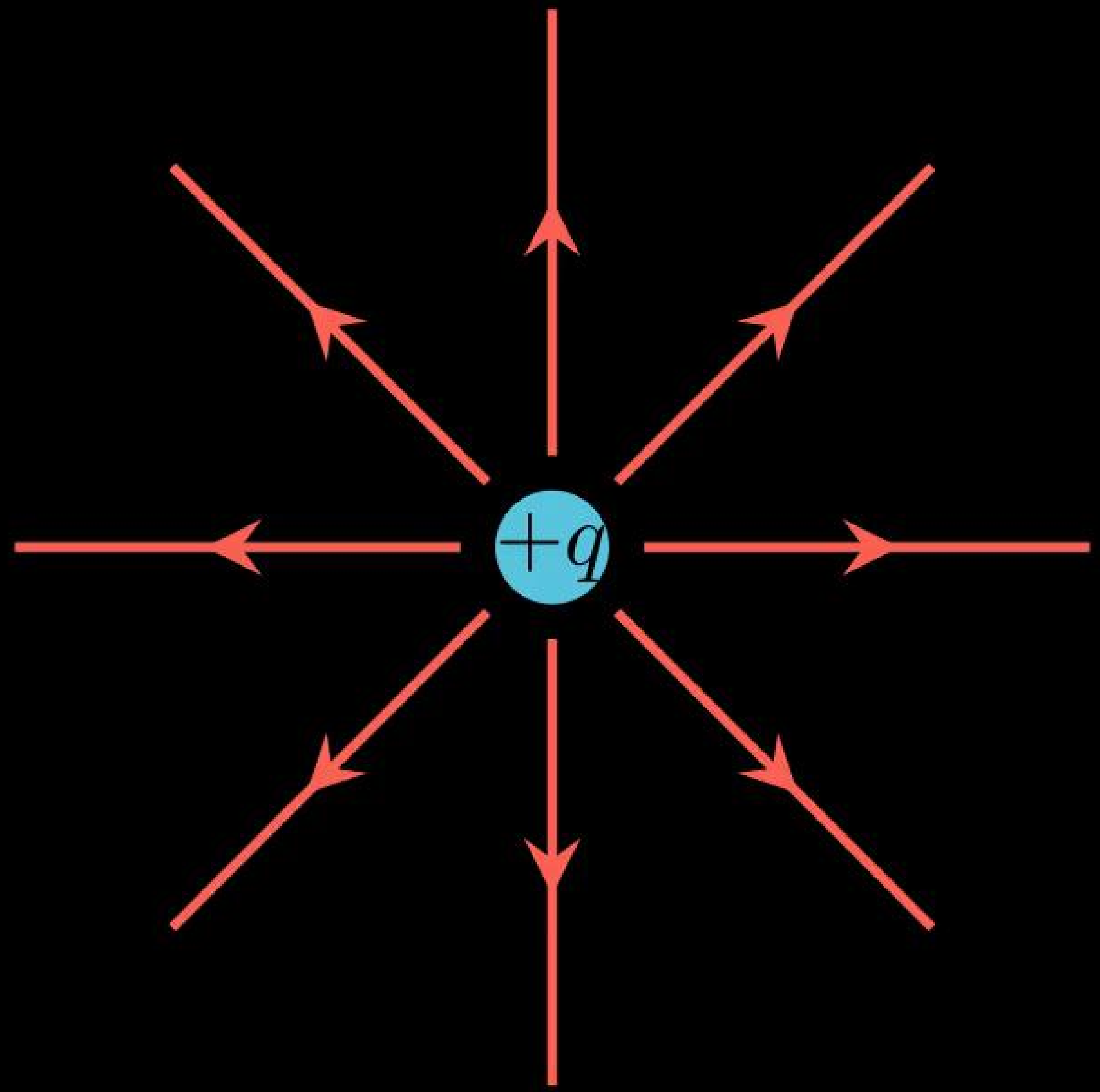
Properties of Electric Field Lines

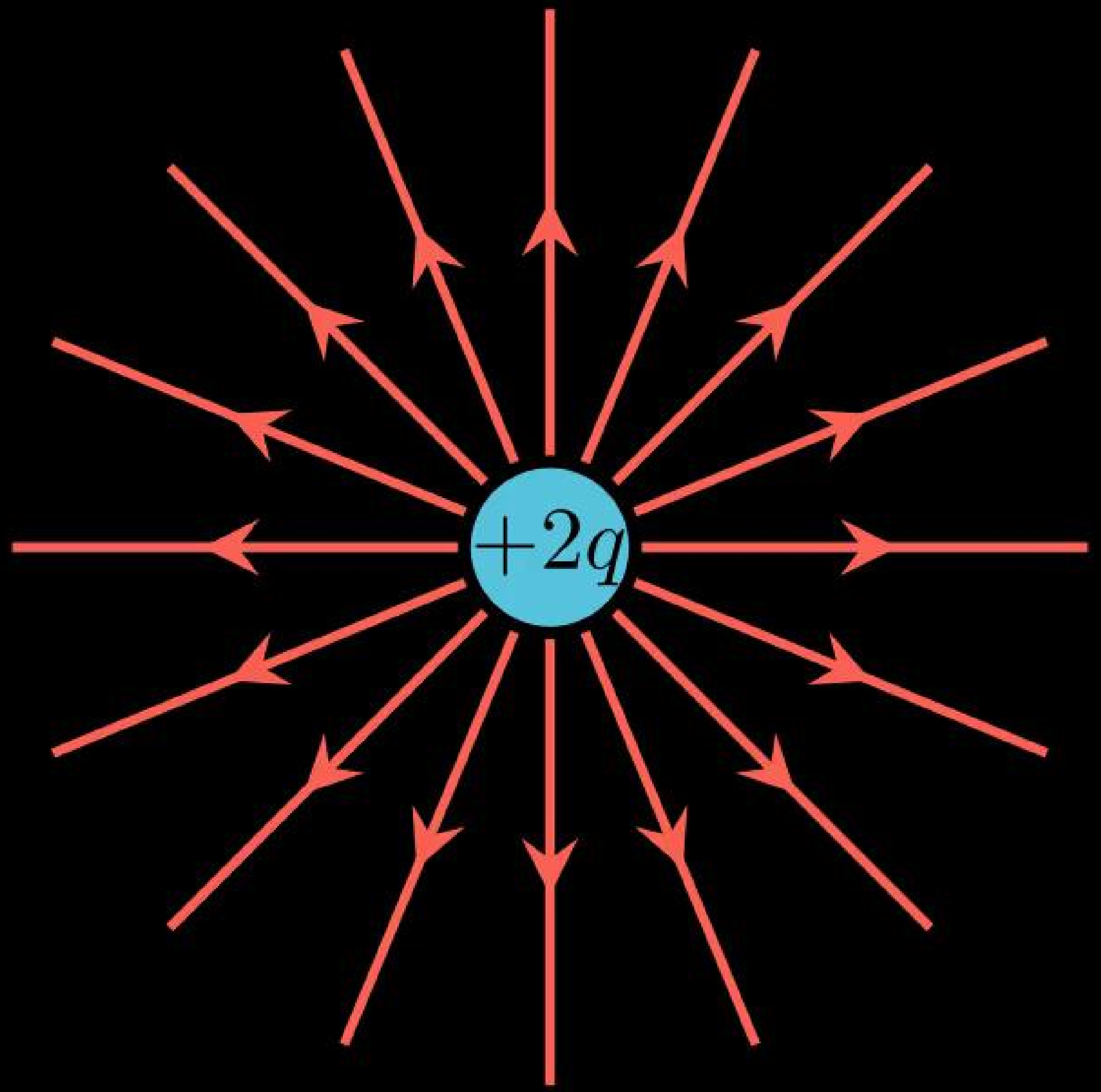
- (3) The tangent at any point of a field line gives the direction of net field at that point.



Properties of Electric Field Lines

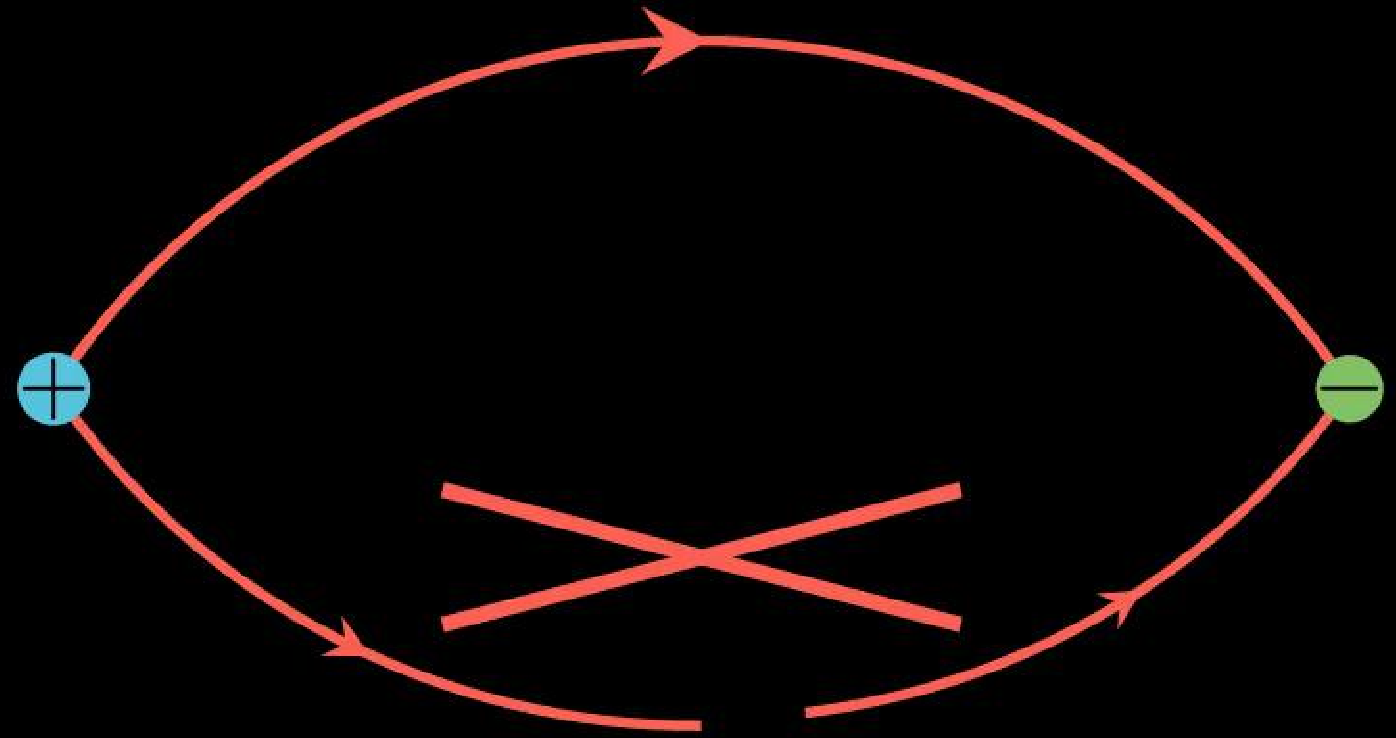
- (4) When drawing lines, the number of lines is proportional to the amount of electric charge.





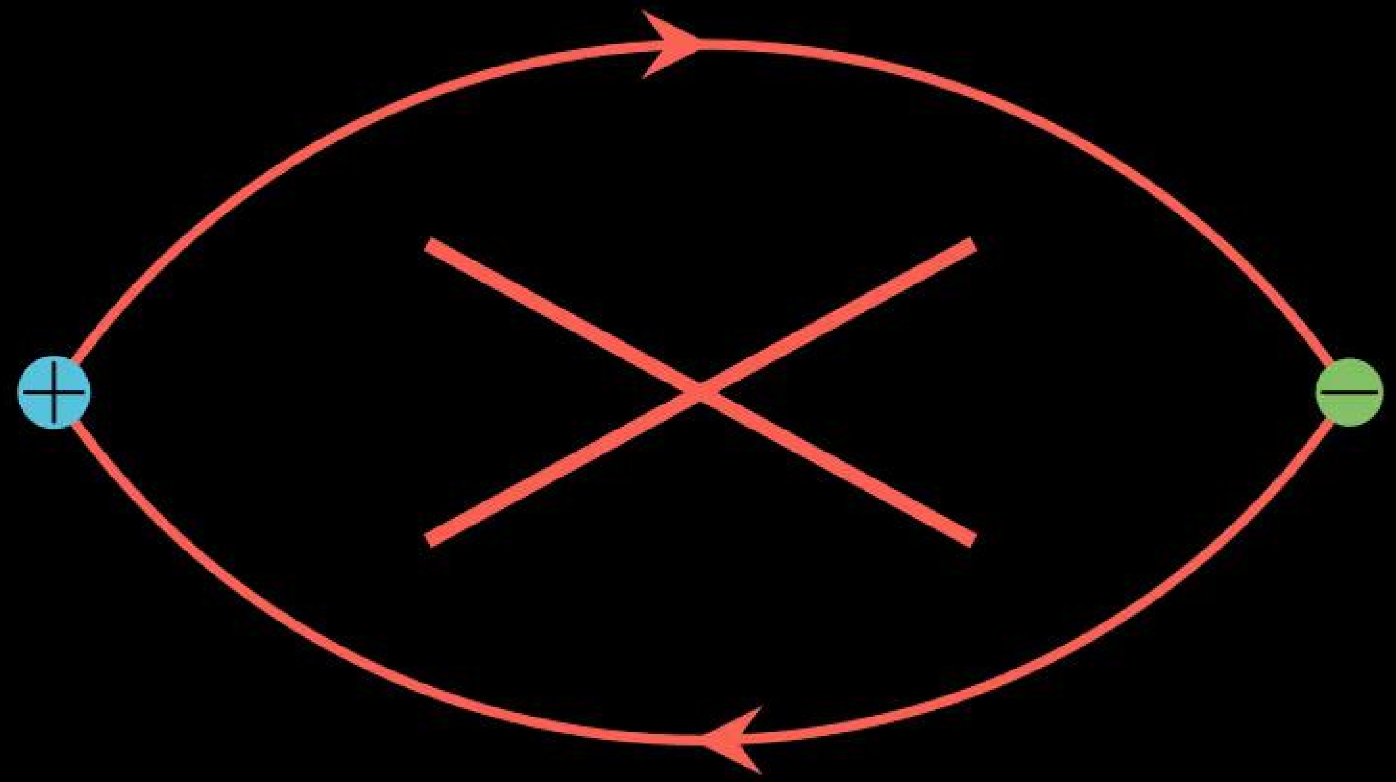
Properties of Electric Field Lines

- (5) In a charge-free region, electric field lines can be taken to be continuous curves without any breaks.



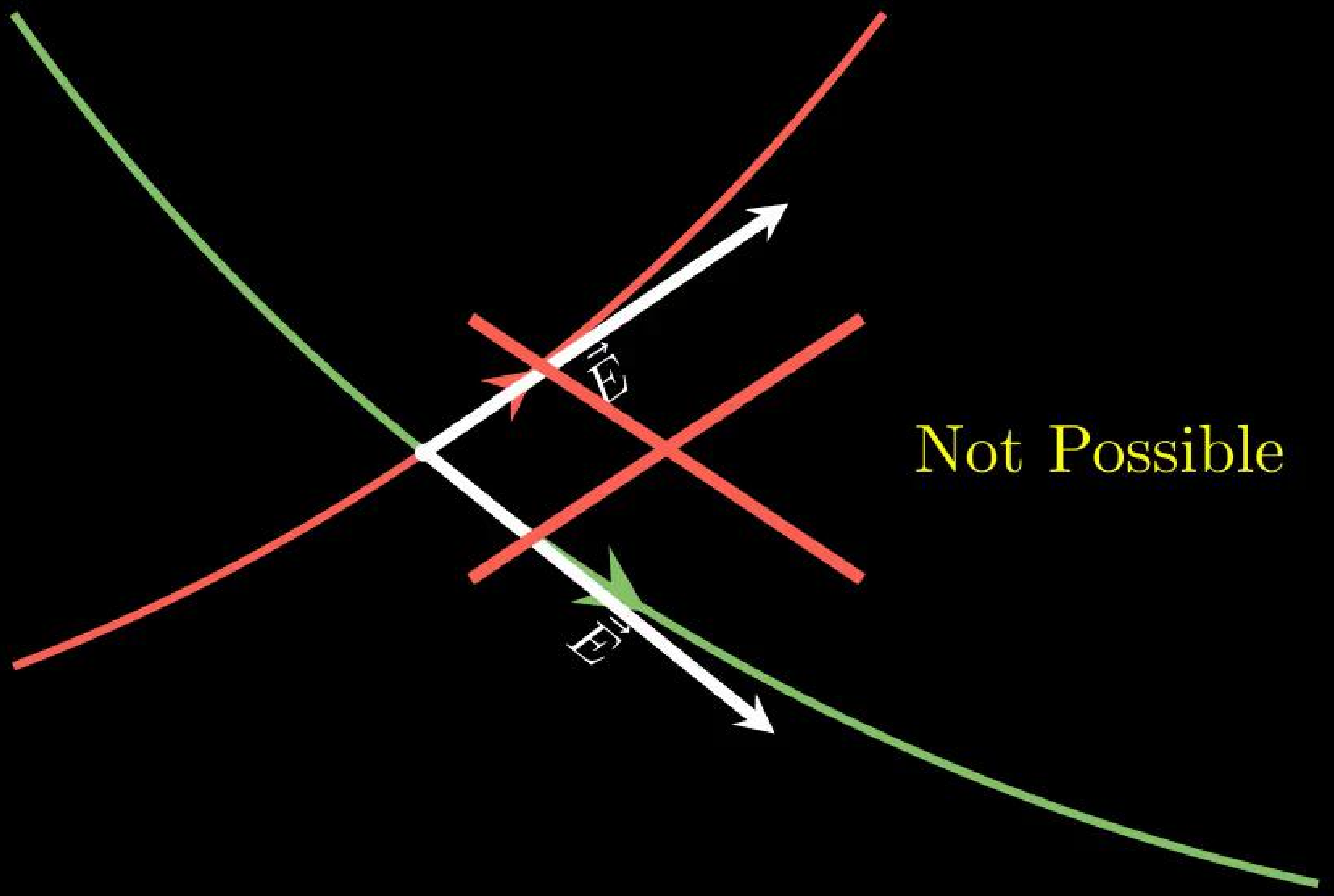
Properties of Electric Field Lines

- (6) Electric field lines do not form close loops. This follows from the conservative nature of electric field.



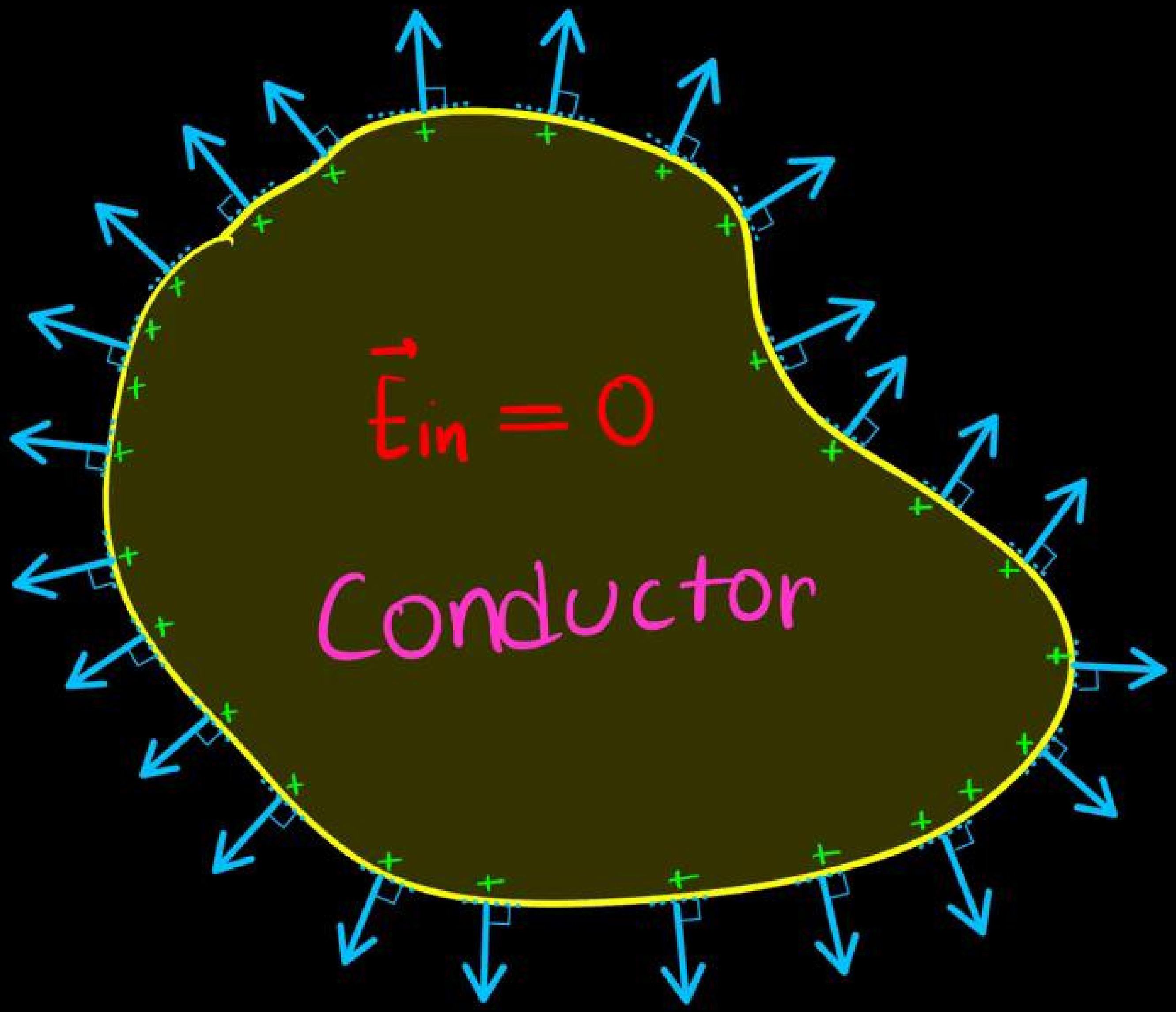
Properties of Electric Field Lines

- (7) Two field lines can never cross each other. Because, if they did the electric field at the point of intersection will have two directions, which is not possible.

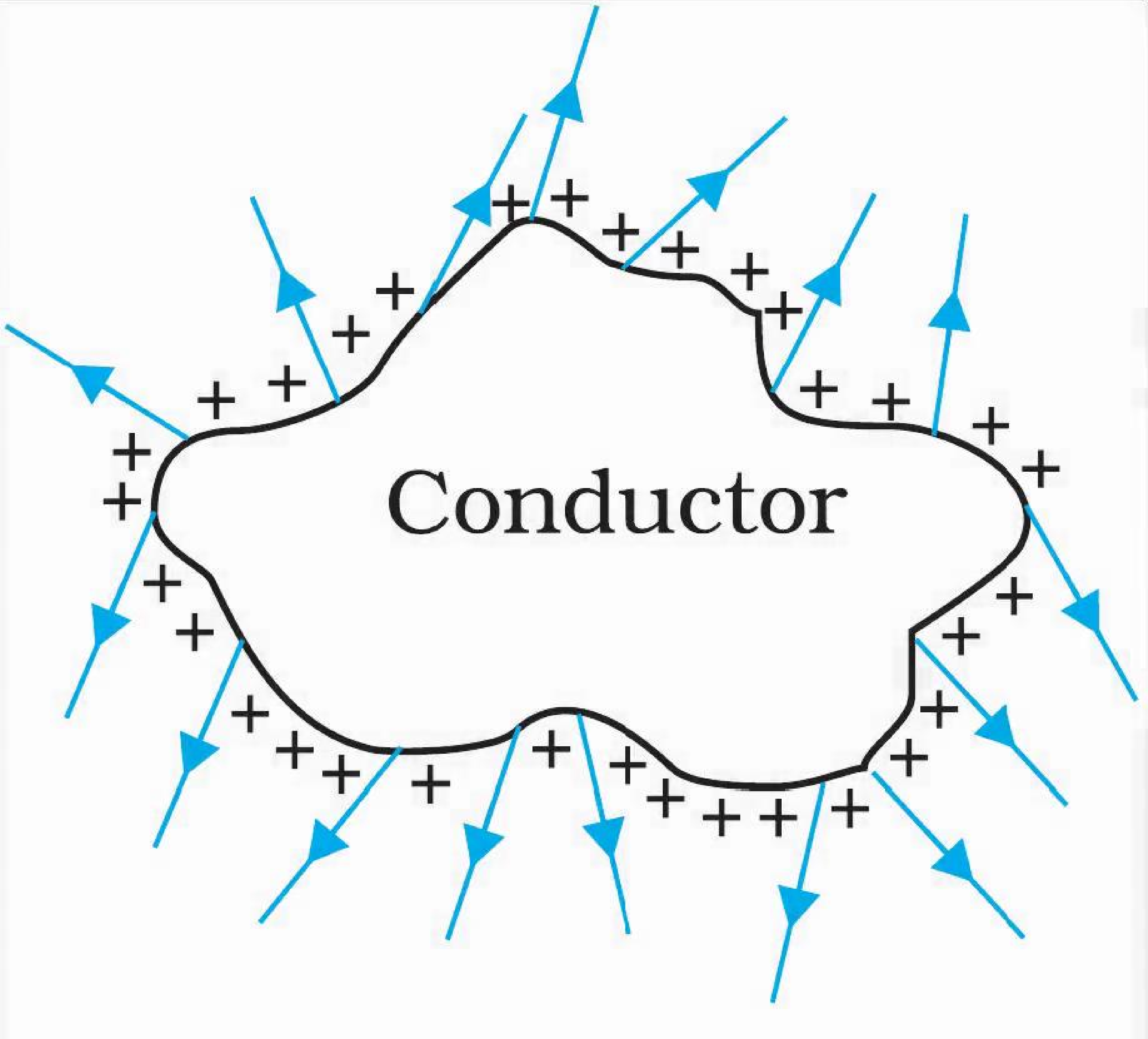


Properties of Electric Field Lines

- (8) Field lines are always perpendicular at the surface of a conductor but they never enter inside the conductor because there is no electrostatic field inside the conductor.

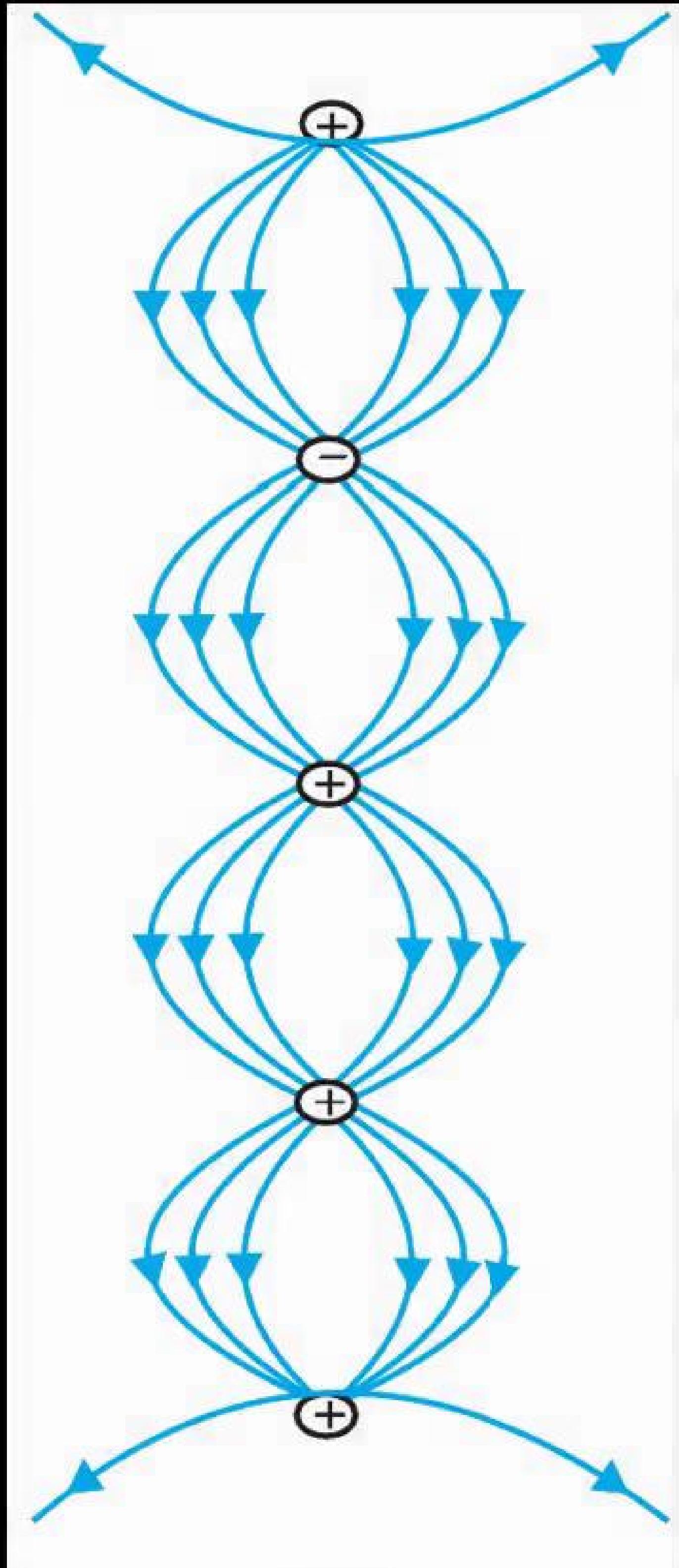


Example 29 :Which among the curves shown in Figure cannot possibly represent electrostatic field lines?



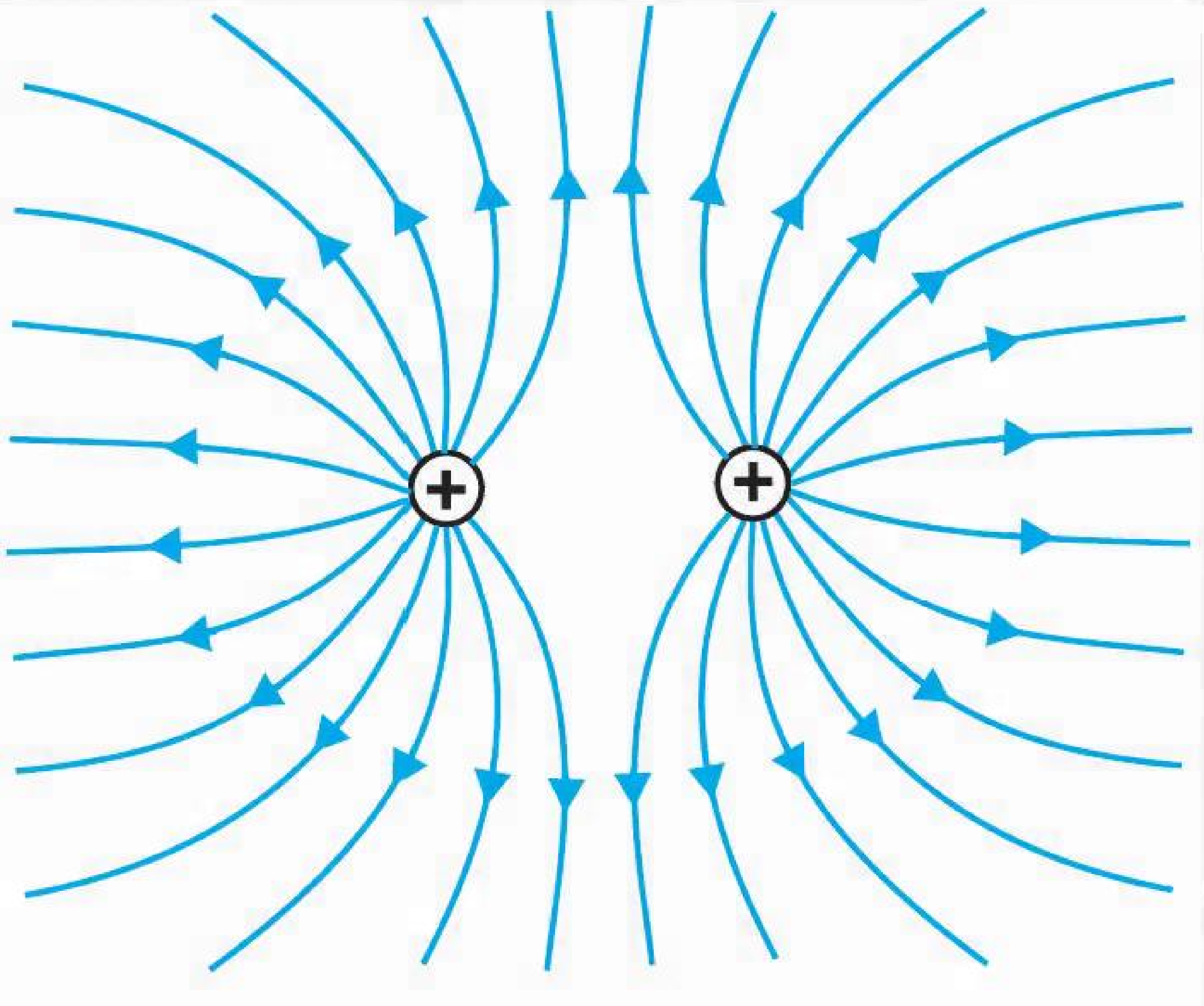
(a)

Example 29 :Which among the curves shown in Figure cannot possibly represent electrostatic field lines?



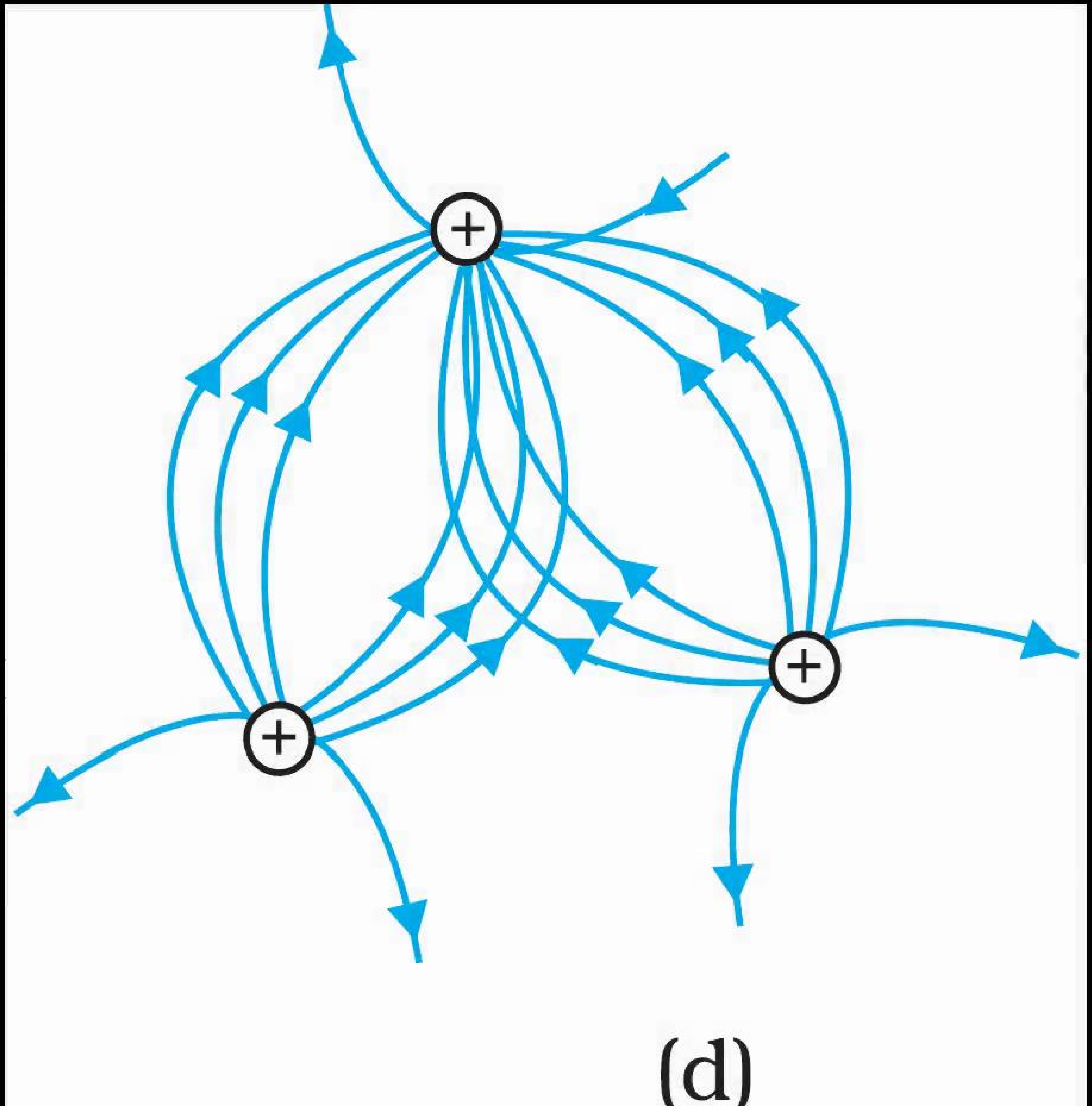
(b)

Example 29 :Which among the curves shown in Figure cannot possibly represent electrostatic field lines?

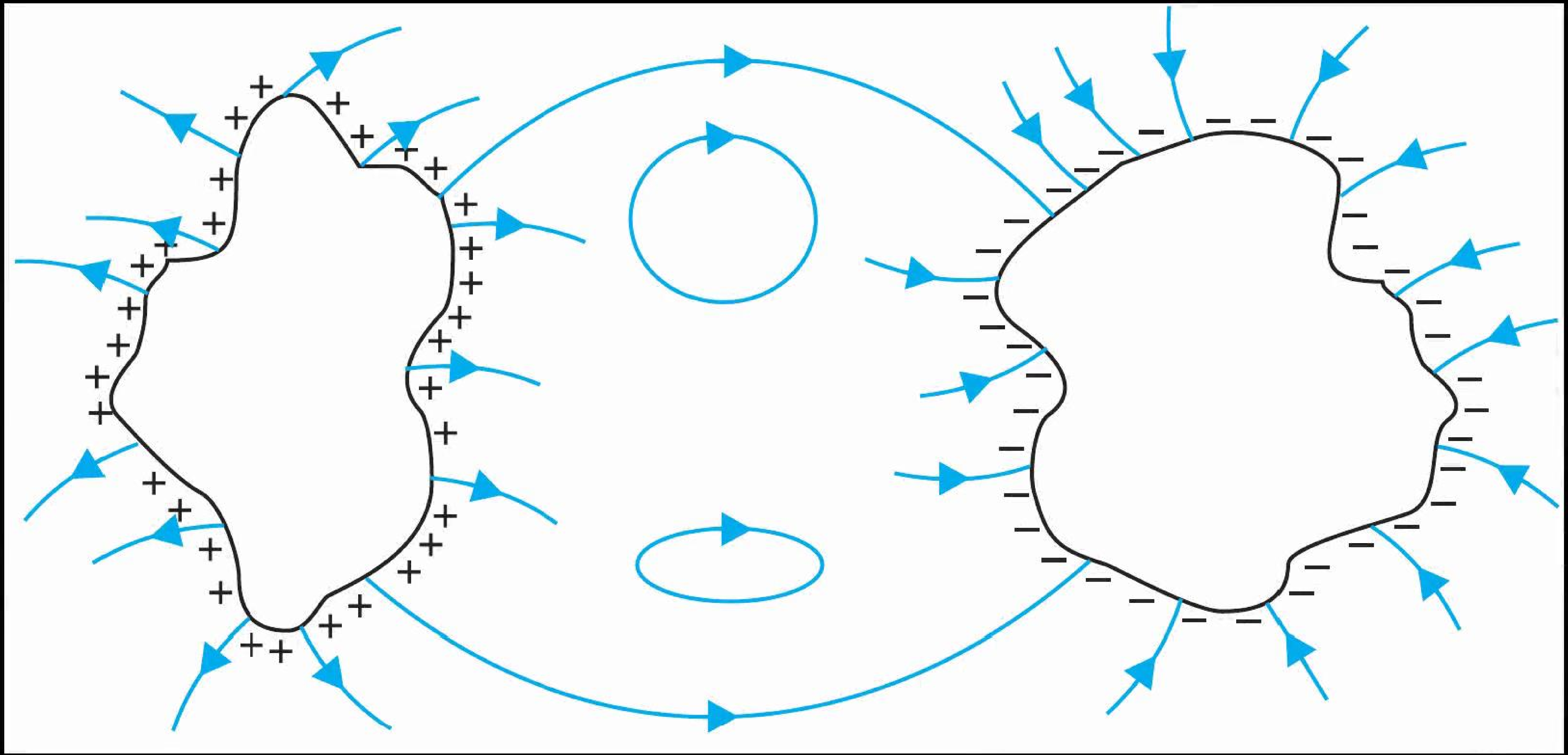


(c)

Example 29 :Which among the curves shown in Figure cannot possibly represent electrostatic field lines?



Example 29 :Which among the curves shown in Figure cannot possibly represent electrostatic field lines?

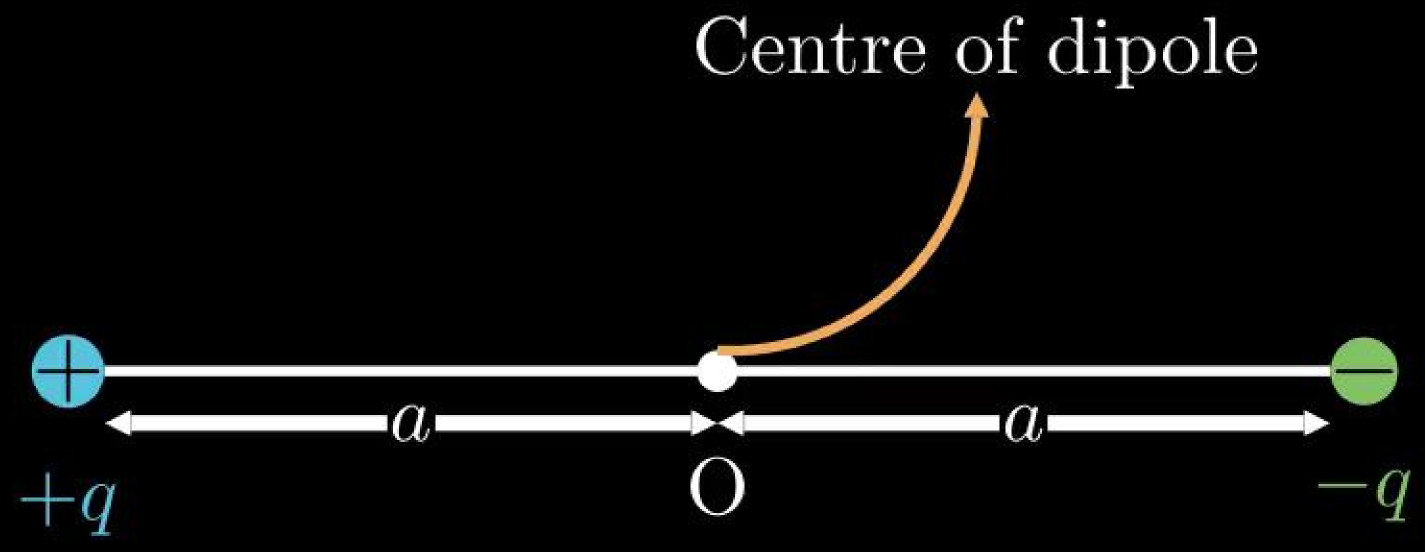


Electric Dipole and Dipole moment

- Electric Dipole: An electric dipole is a pair of two equal and opposite point charges $(+q, -q)$ seperated by a very small distance $(2a)$.

- Practically, it is an atom or molecule in which centre of positive charge does not coincides with the centre of negative charge.

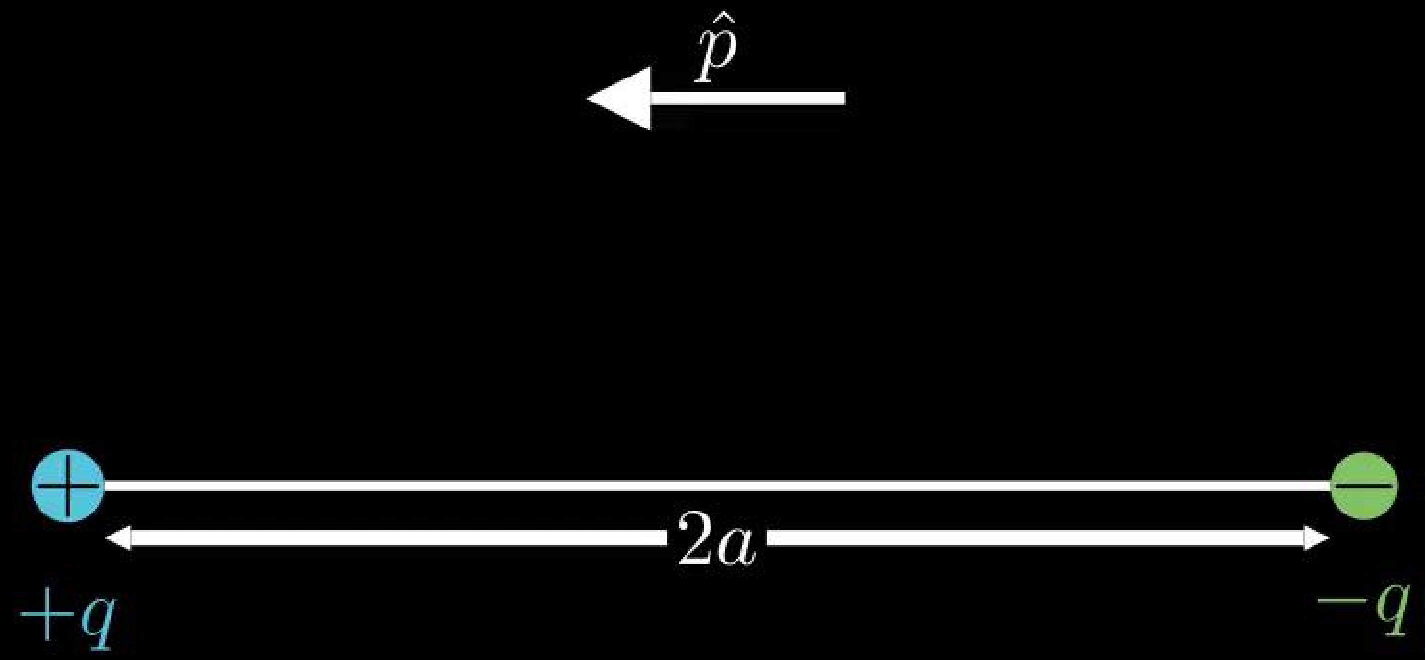
- Example of polar molecules - HCl, H_2O molecules



Electric Dipole and Dipole moment

- Dipole Moment ($\vec{p}$) : The strength of an electric dipole is measured by a **vector quantity** known as electric dipole moment ($\vec{p}$)

- Which is the product of the charge (q) and separation ($2a$) between the charges.



- $\vec{p} = q \times 2a\ \hat{p}$

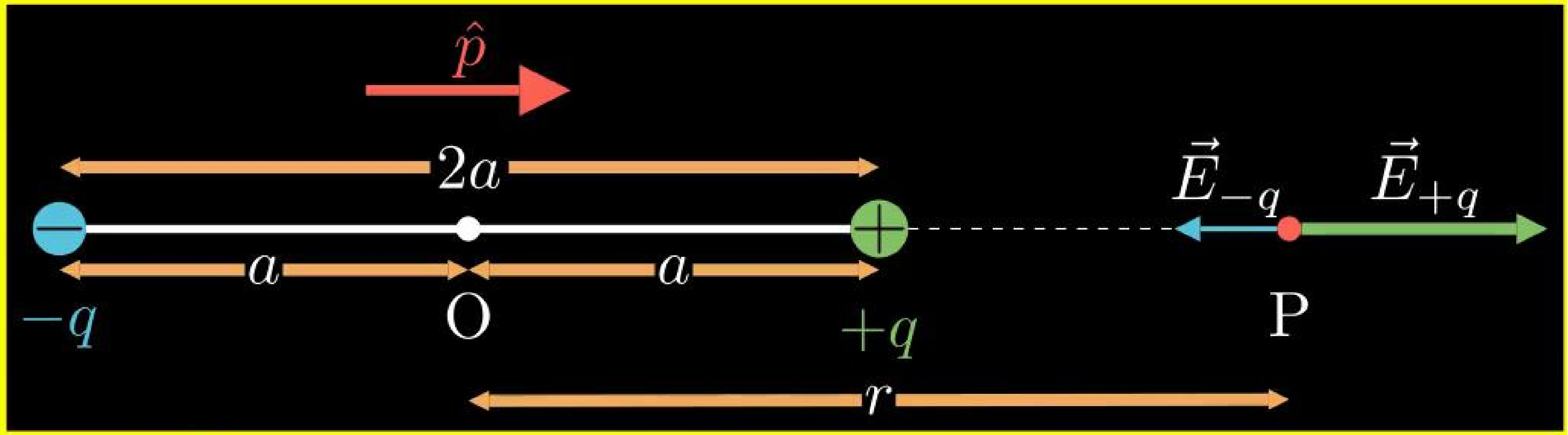
- The **direction** of electric dipole moment is along the axis of the dipole **pointing from the negative charge to the positve charge** ($\hat{p}$)

- S.I unit of $\vec{p}$: C m

- Dimensions: $[\vec{p}] = [\mathrm{ATL}]$

Electric Field Due to An Electric Dipole

(i) For Points on the Axis :



- Consider an electric dipole $(-q, +q)$ of length $(2a)$.
- Let, P be a point on the axis at a distance r from the centre (O) of the dipole.
- We have to determine the electric field $(\vec{E}_{ax})$ at point P.
- Electric field at P due to $(-q)$

$$\vec{E}_{-q} = \frac{1}{4\pi\epsilon_0}\frac{q}{(r+a)^2}\,(-\hat{p})$$

- Electric field at P due to $(+q)$

$$\vec{E}_{+q} = \frac{1}{4\pi\epsilon_0}\frac{q}{(r-a)^2}\,(\hat{p})$$

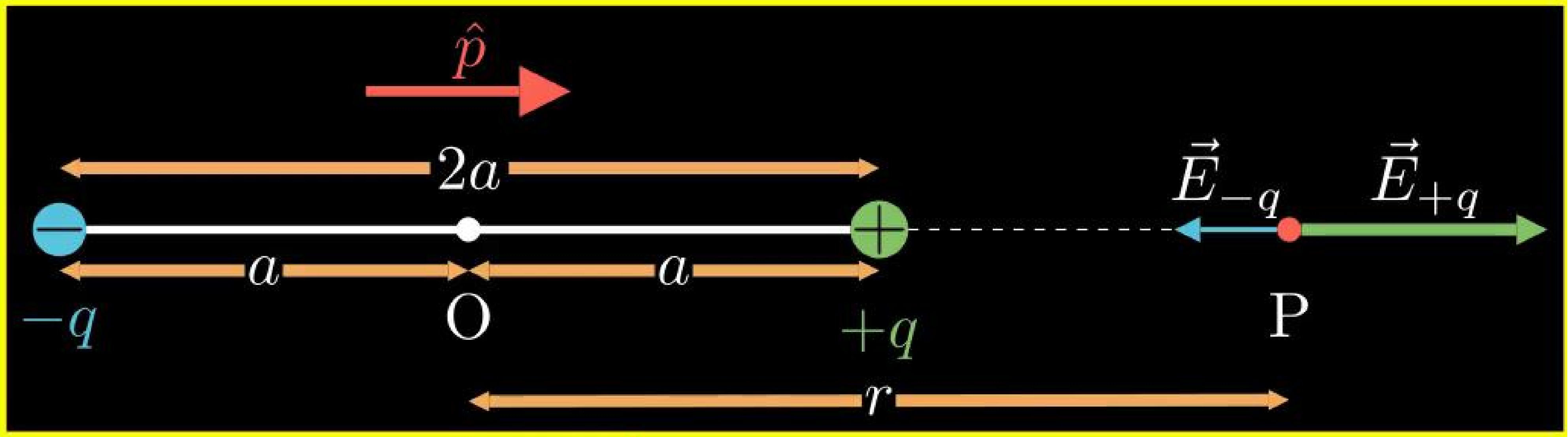
- The resultant field $(\vec{E}_{ax})$ at P will be

$$\vec{E}_{ax} = \vec{E}_{+q} + \vec{E}_{-q}$$

$$\vec{E}_{ax} = \frac{q}{4\pi\epsilon_0}\left(\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right)\hat{p}$$

Electric Field Due to An Electric Dipole

(i) For Points on the Axis :



$$\vec{E}_{ax} = \frac{q}{4\pi\epsilon_0}\left(\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right)\hat{p}$$

$$\vec{E}_{ax} = \frac{q}{4\pi\epsilon_0}\left(\frac{(r+a)^2-(r-a)^2}{(r-a)^2\times(r+a)^2}\right)\hat{p}$$

$$\vec{E}_{ax} = \frac{q}{4\pi\epsilon_0}\left(\frac{(r^2+a^2+2ar)-(r^2+a^2-2ar)}{(r^2-a^2)^2}\right)\hat{p}$$

$$\vec{E}_{ax} = \frac{q}{4\pi\epsilon_0}\left(\frac{r^2+a^2+2ar-r^2-a^2+2ar}{(r^2-a^2)^2}\right)\hat{p}$$

$$\vec{E}_{ax} = \frac{q}{4\pi\epsilon_0}\left(\frac{4ar}{(r^2-a^2)^2}\right)\hat{p} = \frac{1}{4\pi\epsilon_0}\left(\frac{2\times q\times 2a\times\hat{p}\times r}{(r^2-a^2)^2}\right)$$

$(\because \vec{p} = q\times 2a\ \hat{p})$

$$\vec{E}_{ax} = \frac{1}{4\pi\epsilon_0}\left(\frac{2\vec{p}\times r}{(r^2-a^2)^2}\right)$$

- For point dipole $(r >> a)$

$(r^2-a^2)\approx r^2$

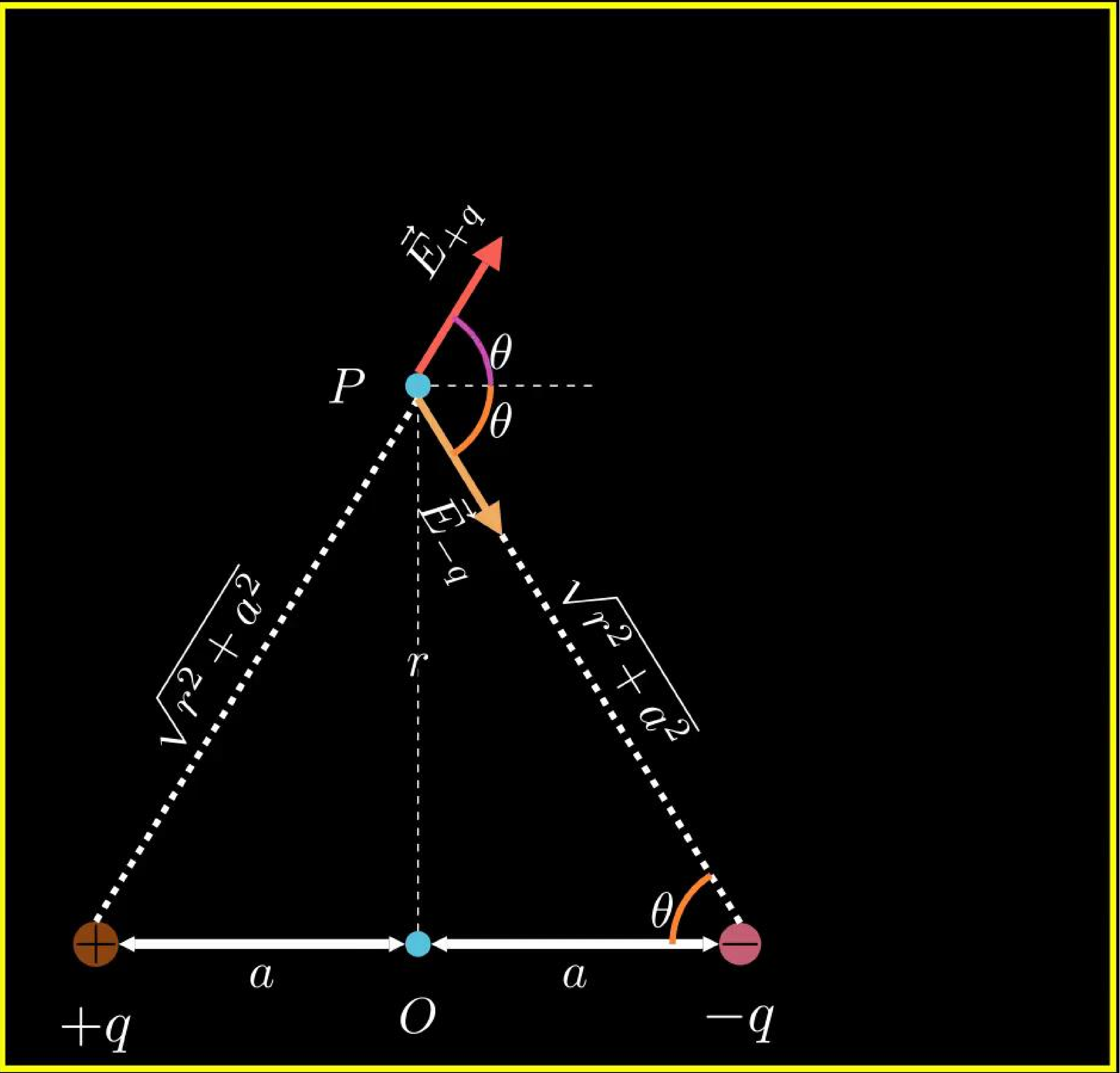
$$\boxed{\vec{E}_{ax} = \frac{1}{4\pi\epsilon_0}\left(\frac{2\vec{p}}{r^3}\right)}$$

Electric Field Due to An Electric Dipole

(ii) For Points on the Equitorial Plane :

- In this case, the point P is situated at point P on equitorial plane at a distance r from centre of dipole(O).
- The distance of point P from each charge is $(\sqrt{r^2 + a^2})$
- We have to determine the electric field $(\vec{E}_{eq})$ at point P.
- Magnitude of Electric field at P due to $(+q)$ and $(-q)$

$$|\vec{E}_{+q}| = |\vec{E}_{-q}| = \frac{1}{4\pi\epsilon_0}\frac{q}{(r^2+a^2)} = \text{E}$$

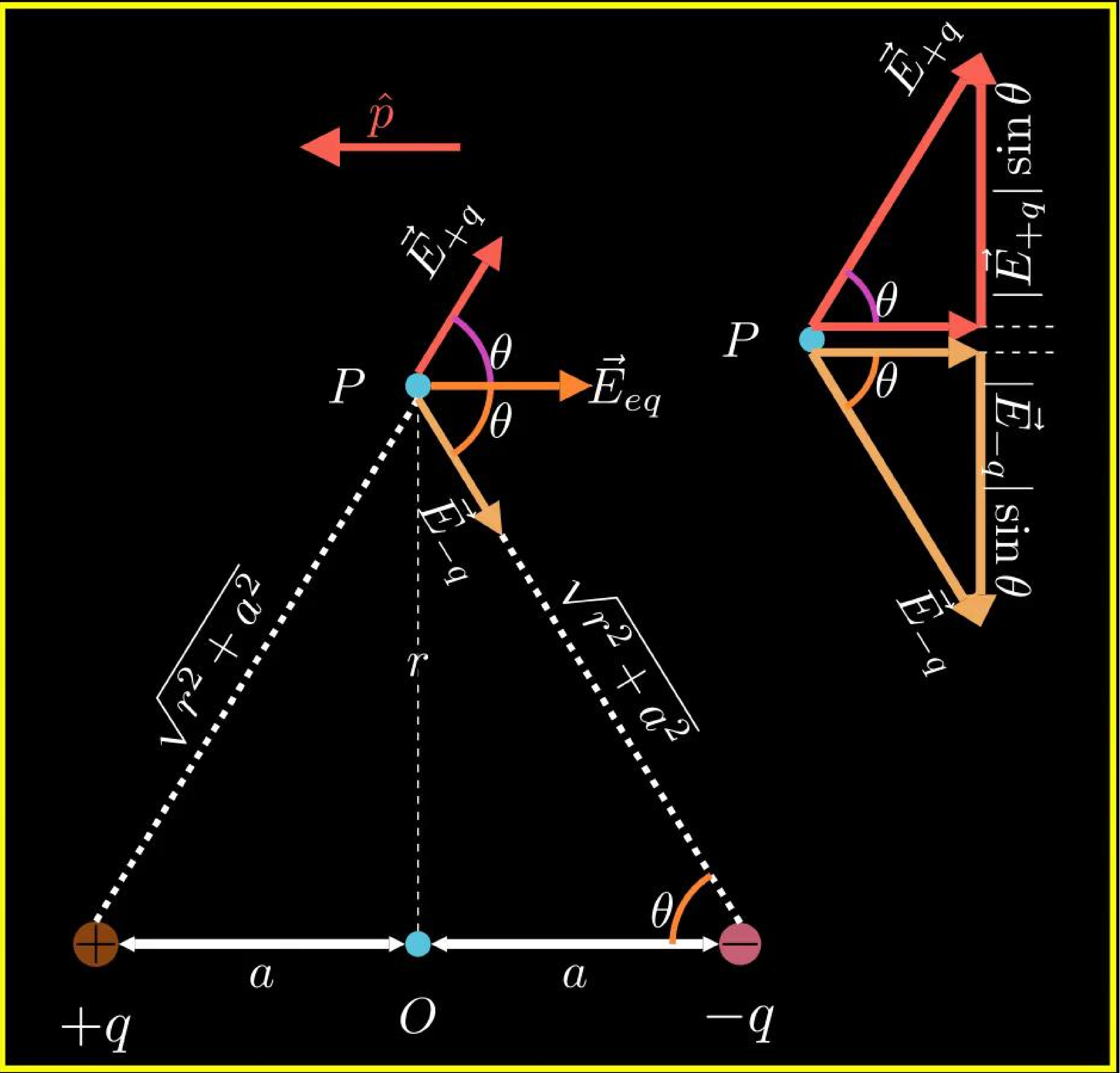


Electric Field Due to An Electric Dipole

(ii) For Points on the Equitorial Plane :

- On resolving $\vec{E}_{+q}$ and $\vec{E}_{-q}$ into two components.
- The components perpndicular to the dipole axis ($|\vec{E}_{+q}|\sin\theta$ and $|\vec{E}_{-q}|\sin\theta$) cancel each other.
- The components along the dipole axis ($|\vec{E}_{+q}|\cos\theta$ and $|\vec{E}_{-q}|\cos\theta$), being in the same direction, add up.
- The total electric field $\vec{E}_{eq}$ is opposite to $\hat{p}$

$$\vec{E}_{eq} = \left(|\vec{E}_{+q}|\cos\theta + |\vec{E}_{-q}|\cos\theta\right)(-\hat{p})$$
$$= -2E\cos\theta\ \hat{p}$$



Electric Field Due to An Electric Dipole

(ii) For Points on the Equitorial Plane :

$$\vec{E}_{eq} = \left(|\vec{E}_{+q}|\cos\theta + |\vec{E}_{-q}|\cos\theta\right)(-\hat{p})$$

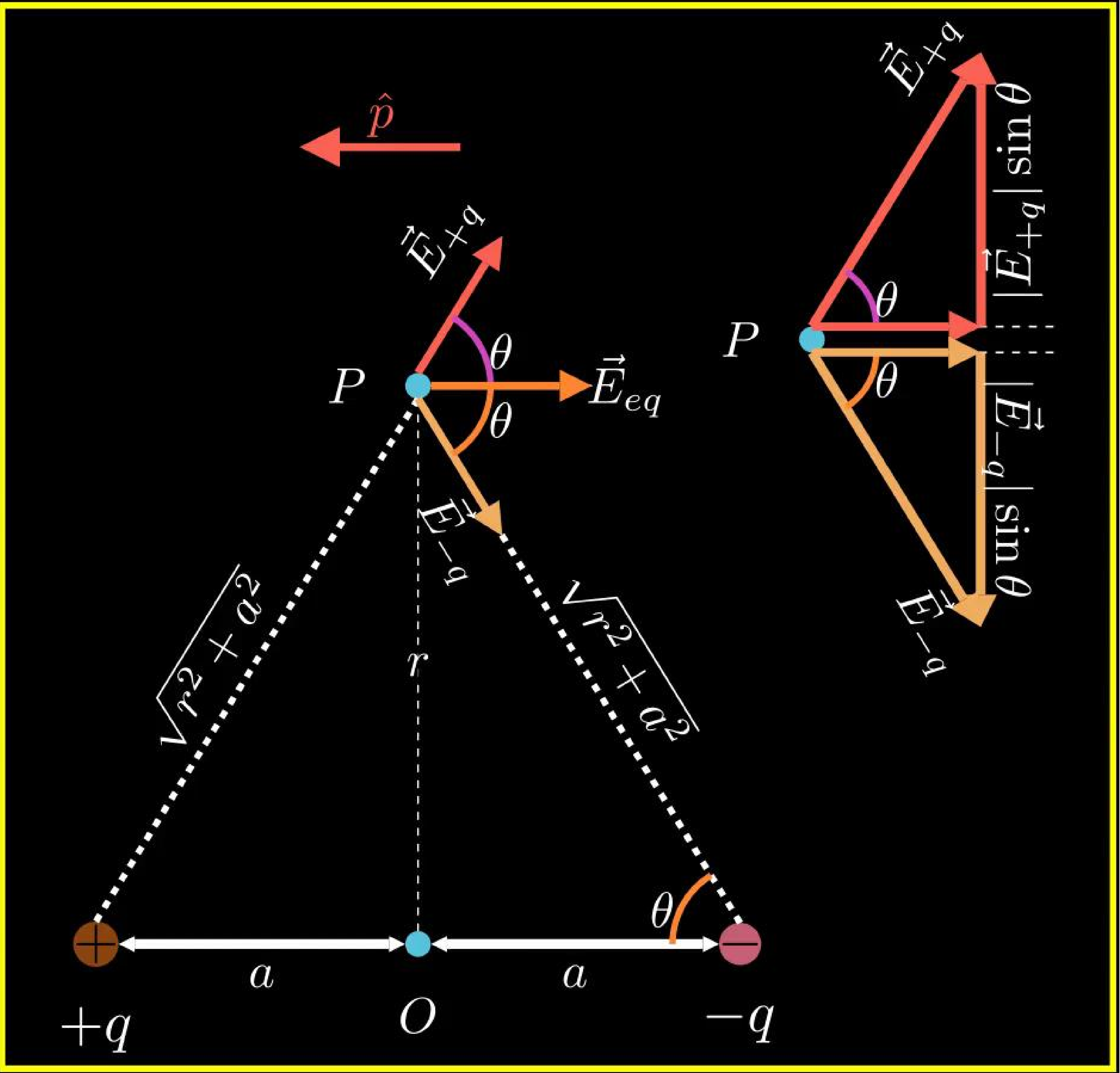
$$= -2E\cos\theta\ \hat{p}$$

$$= -2 \times \frac{1}{4\pi\epsilon_0}\frac{q}{(r^2+a^2)} \times \frac{a}{\sqrt{r^2+a^2}}\ \hat{p}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{-2qa\ \hat{p}}{(r^2+a^2)^{3/2}}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{-\vec{p}}{(r^2+a^2)^{3/2}} \quad (\because \vec{p} = q \times 2a\ \hat{p})$$

- For point dipole $(r >> a)(\therefore r^2 + a^2 \approx r^2)$



Electric Field Due to An Electric Dipole

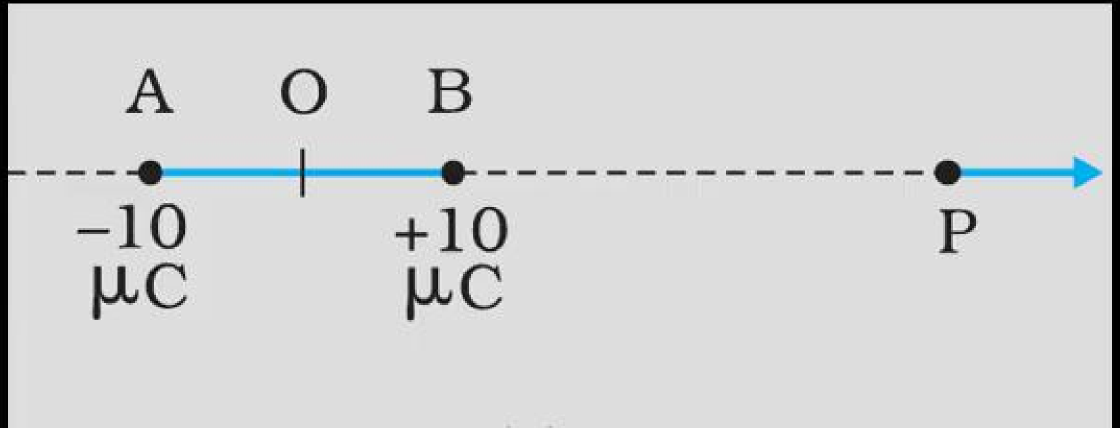
- For point dipole Or $r >> a$

$$\vec{E}_{ax} = \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{r^3} \text{ and } \vec{E}_{eq} = \frac{1}{4\pi\epsilon_0}\frac{-\vec{p}}{r^3}$$

$$\vec{E}_{ax} = -2 \times \vec{E}_{eq}$$

- Notice the important point that the dipole field at large distances falls off not as $\frac{1}{r^2}$ but as $\frac{1}{r^3}$.
- The magnitude and the direction of the dipole field depends not only on the distance r but also on the angle between the position vector $\vec{r}$ and the dipole moment $\vec{p}$.

Example 30 : Two charges $\pm 10\mu C$ are placed 5.0 mm apart. Determine the electric field at (a) a point P on the axis of the dipole 15 cm away from its centre O on the side of the positive charge, as shown in Fig. and (b) a point Q, 15 cm away from O on a line passing through O and normal to the axis of the dipole, as shown in Fig.



(a)

Solution :

- Given: $q = 10\ \mu C = 10 \times 10^{-6} C = 10^{-5}\ C$

  Length of dipole $2a = 5\ mm = 5 \times 10^{-3}\ m$

  Distance of point P and Q from centre of dipole $r = 15\ cm = 15 \times 10^{-2}\ m$

- Find: Electric field at (a) Axial point and (b) Equitorial point

  $p = q \times 2a$ (Magnitude of dipole moment)

  $= 10^{-5} \times 5 \times 10^{-3} = 5 \times 10^{-8} Cm$

- (a) Since, $r = 60 \times a$ OR $r >> a$

$$\therefore E_P = \frac{1}{4\pi\epsilon_0}\frac{2 \times p}{r^3}$$

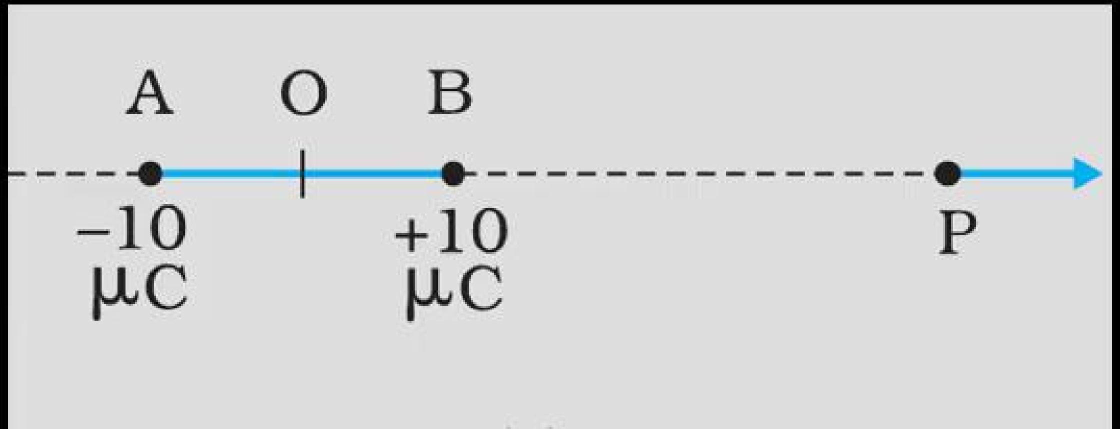
$$= \frac{9 \times 10^9 \times 2 \times 5 \times 10^{-8}}{(15 \times 10^{-2})^3}$$

$$= \frac{9 \times 10^2}{3375 \times 10^{-6}}$$

$$E_P = 2.67 \times 10^5\ N/C$$

(Direction from -ve to +ve charge)

Example 30 : Two charges $\pm 10\mu C$ are placed 5.0 mm apart. Determine the electric field at (a) a point P on the axis of the dipole 15 cm away from its centre O on the side of the positive charge, as shown in Fig. and (b) a point Q, 15 cm away from O on a line passing through O and normal to the axis of the dipole, as shown in Fig.



(a)

Solution :

- (a) Since, $r = 60 \times a$ OR $r >> a$

$$\therefore E_P = \frac{1}{4\pi\epsilon_0}\frac{2 \times p}{r^3}$$

$$= \frac{9 \times 10^9 \times 2 \times 5 \times 10^{-8}}{(15 \times 10^{-2})^3}$$

$$= \frac{9 \times 10^2}{3375 \times 10^{-6}}$$

$$E_P = 2.67 \times 10^5\ N/C$$

(Direction from -ve to +ve charge)

- (b) Since, $r >> a$

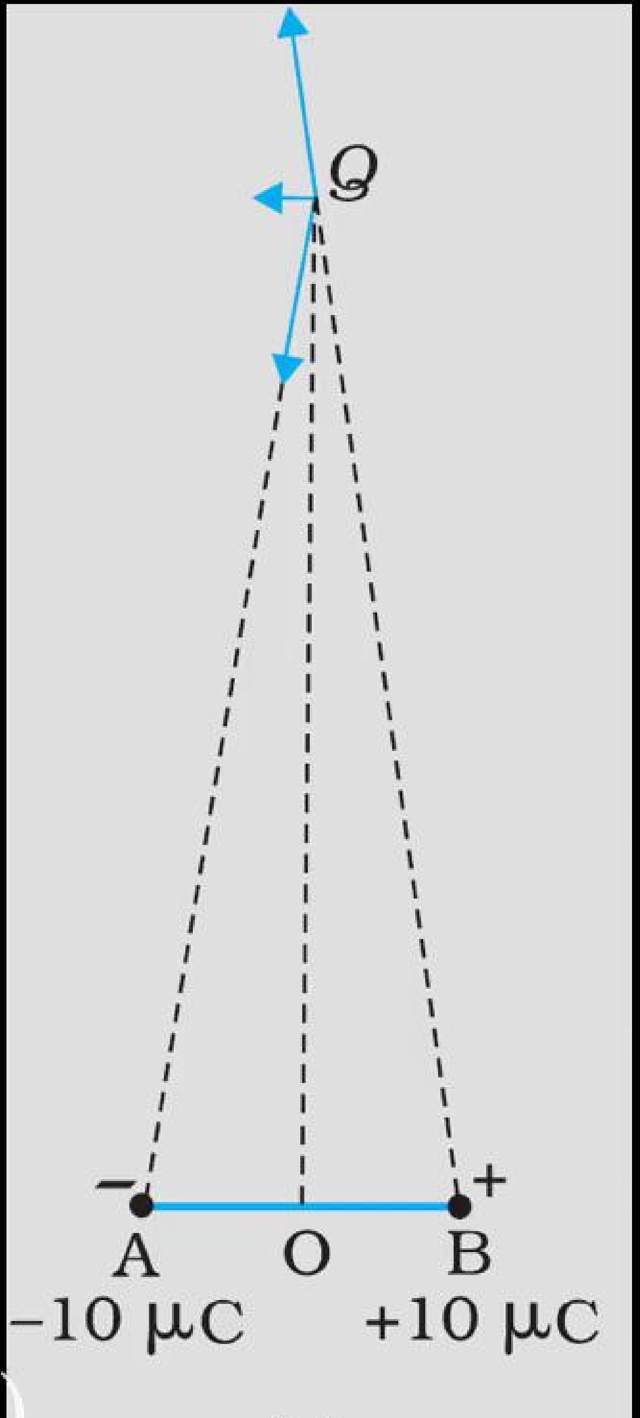
$$\therefore E_Q = \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}$$

$$E_Q = \frac{1}{2} \times E_P$$

$$E_Q = \frac{2.67 \times 10^5\ N/C}{2}$$

$$E_Q = 1.33 \times 10^5\ N/C$$

(Direction from +ve to -ve charge)



(b)

Example 31 : Two opposite charges each of magnitude 2 μC are 1 cm apart. Find electric field at a distance of 5 cm from the mid-point on axial line of the dipole. Also find the field on equatorial line at the same distance from mid-point.

Solution :

- Given: $q = 2\ \mu C = 2 \times 10^{-6} C$

  Length of dipole $2a = 1\ cm = 10^{-2}\ m$

  Distance of point from centre of dipole $r = 5\ cm = 5 \times 10^{-2}\ m$

- Find: Electric field at (a) Axial point and (b) Equitorial point

  $p = q \times 2a$ (Magnitude of dipole moment)

  $= 2 \times 10^{-6} \times 10^{-2} = 2 \times 10^{-8} Cm$

- (a) Since, $r = 10 \times a$ In this case

$$\therefore E_{ax} = \frac{1}{4\pi\epsilon_0}\frac{2 \times p \times r}{(r^2 - a^2)^2}$$

$$= \frac{9 \times 10^9 \times 2 \times 2 \times 10^{-8} \times 5 \times 10^{-2}}{((5 \times 10^{-2})^2 - (0.5 \times 10^{-2})^2)^2}$$

$$= \frac{18}{(25 \times 10^{-4} - 0.25 \times 10^{-4})^2}$$

$$= \frac{18}{(24.75 \times 10^{-4})^2}\ N/C$$

$$= \frac{18}{612.56 \times 10^{-8}}\ N/C$$

$$E_{ax} = 2.93 \times 10^6\ N/C$$

Example 31 : Two opposite charges each of magnitude 2 μC are 1 cm apart. Find electric field at a distance of 5 cm from the mid-point on axial line of the dipole. Also find the field on equatorial line at the same distance from mid-point.

Solution :

- (a) Since, $r = 10 \times a$ In this case

$$\therefore E_{ax} = \frac{1}{4\pi\epsilon_0}\frac{2 \times p \times r}{(r^2 - a^2)^2}$$

$$= \frac{9 \times 10^9 \times 2 \times 2 \times 10^{-8} \times 5 \times 10^{-2}}{\left((5 \times 10^{-2})^2 - (0.5 \times 10^{-2})^2\right)^2}$$

$$= \frac{18}{(25 \times 10^{-4} - 0.25 \times 10^{-4})^2}$$

$$= \frac{18}{(24.75 \times 10^{-4})^2}\ N/C$$

$$= \frac{18}{612.56 \times 10^{-8}}\ N/C$$

$$E_{ax} = 2.93 \times 10^6\ N/C$$

$$(b)\ E_{eq} = \frac{1}{4\pi\epsilon_0}\frac{p}{(r^2 + a^2)^{3/2}}$$

$$= \frac{9 \times 10^9 \times 2 \times 10^{-8}}{\left((5 \times 10^{-2})^2 + (0.5 \times 10^{-2})^2\right)^{3/2}}$$

$$= \frac{180}{(25.25 \times 10^{-4})^{3/2}}$$

$$= \frac{180}{(126.88 \times 10^{-6})}$$

$$E_{eq} = 1.42 \times 10^6\ N/C$$

Example 32 : Two charges of $+25 \times 10^{-9}$ C and -25×10^{-9} C are placed 6 m apart. Find the electric field intensity ratio at points 4 m from the centre of the dipole (i) on axial line (ii) on equitorial line.

(a) $\dfrac{1000}{49}$ (b) $\dfrac{49}{1000}$

(c) $\dfrac{500}{49}$ (d) $\dfrac{49}{500}$

Note: Do not use small dipole formula!! Since, $r < a$ in this case.

Example 33 : The electric force on a point charge situated on the axis of a short dipole is F. If the charge is shifted along the axis to double the distance, the electric force acting will be

(a) $4F$

(b) $\frac{F}{2}$

(c) $\frac{F}{4}$

(d) $\frac{F}{8}$

Solution:

Dipole in a Uniform External Field

- Consider an electric dipole of dipole moment ($\vec{p}$) placed in a uniform electric field ($\vec{E}$)

$\vec{p} = q \times 2a\ \hat{p} \rightarrow$ (Dipole moment Vector)

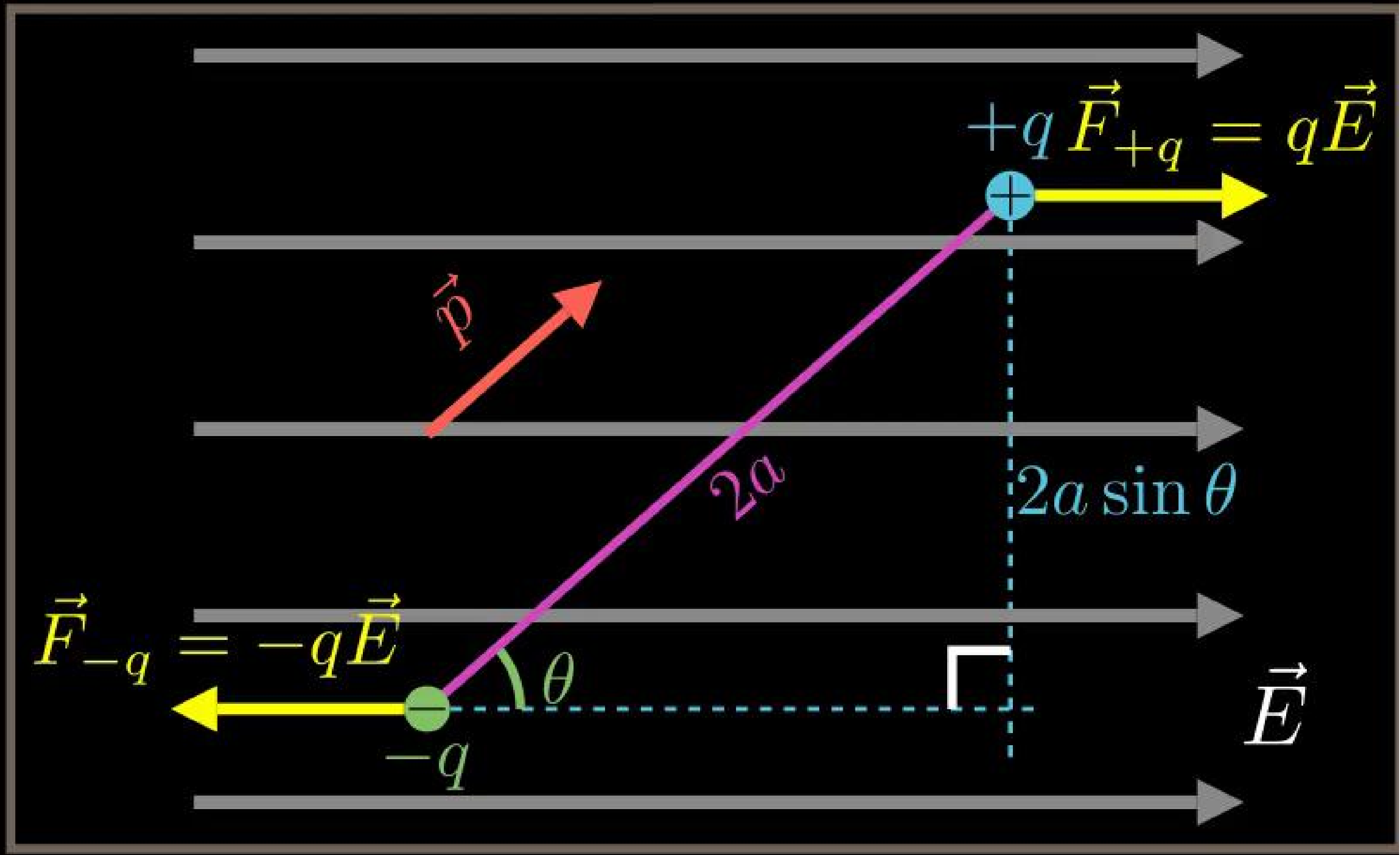
- Force on $+q$ charge due to electric filed :

$\vec{F}_{+q} = q\vec{E}$ (Along E)

- Force on $-q$ charge due to electric filed :

$\vec{F}_{-q} = -q\vec{E}$ (Opposite to E)

- Net force on the dipole : $\vec{F}_{net} = \vec{F}_{+q} + \vec{F}_{-q} = 0$
- The two forces are equal and opposite and act at different points resulting a net torque ($\vec{\tau}$) (couple) on the dipole.



- $|\vec{\tau}| =$ force $\times$ perpendicular distance

$|\vec{\tau}| = qE \times 2a\sin\theta$

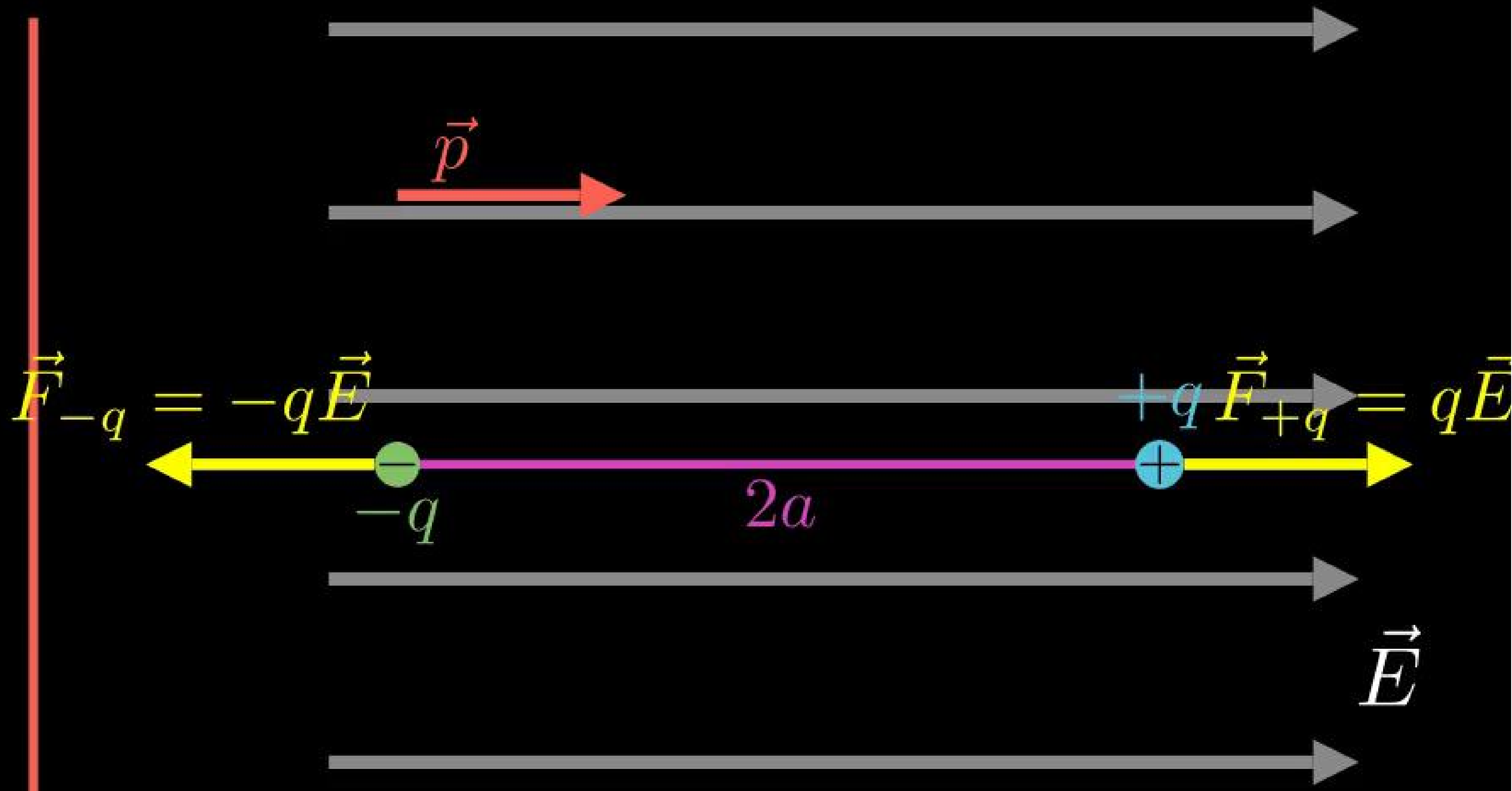
$\boxed{|\vec{\tau}| = pE\sin\theta}$

- In vector form: $\boxed{\vec{\tau} = \vec{p} \times \vec{E}}$

Dipole in a Uniform External Field

- Direction of $\vec{\tau}$: Perpendicular to the plane containing $\vec{p}$ and $\vec{E}$
- Case 1 : if $\theta = 0°$

$|\vec{\tau}| = pE\sin(0°) = 0$ (Stable equilibrium.)



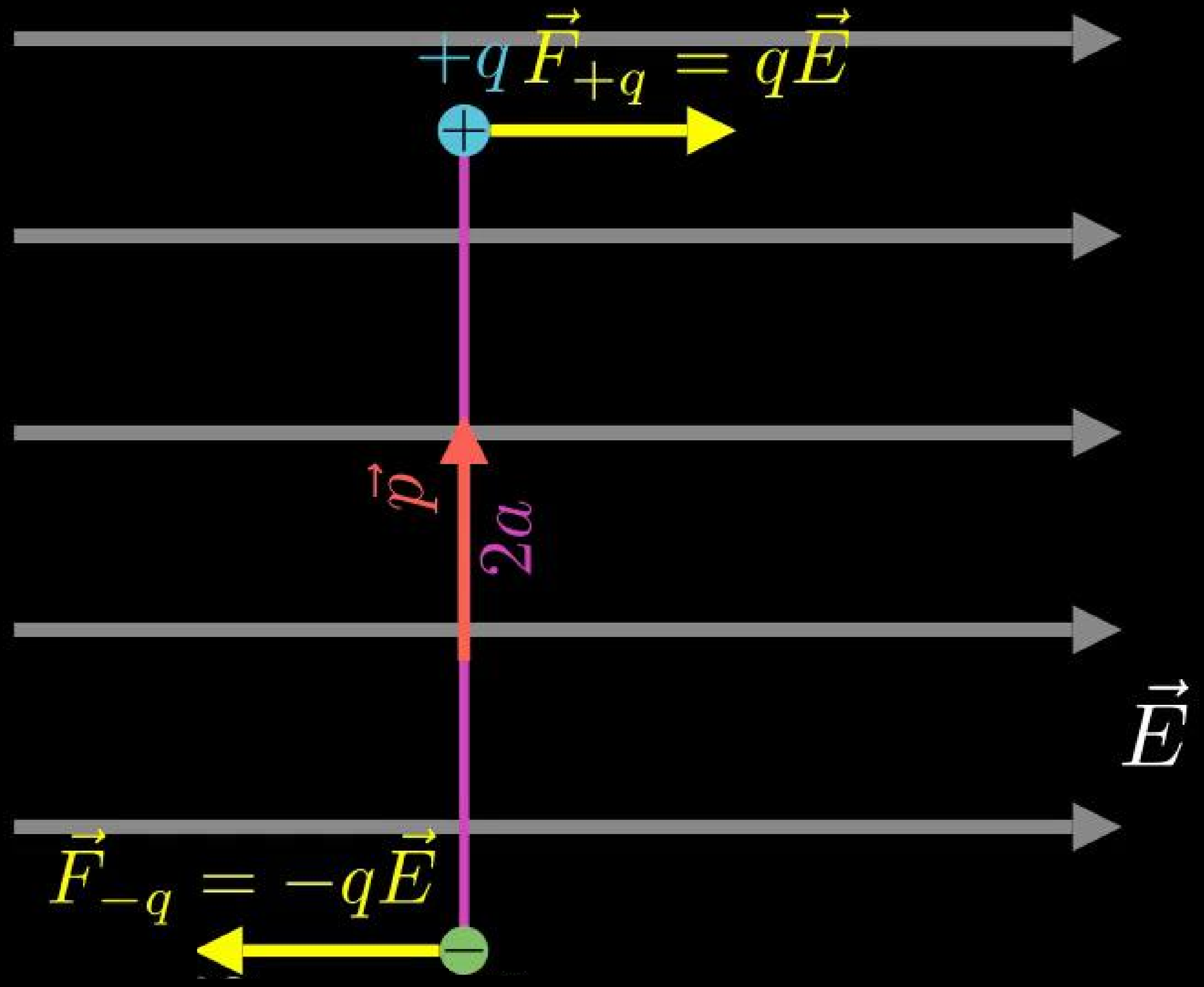
Dipole in a Uniform External Field

- Direction of $\vec{\tau}$: Perpendicular to the plane containing $\vec{p}$ and $\vec{E}$
- Case 1 : if $\theta = 0°$

$|\vec{\tau}| = pE\sin(0°) = 0$ (Stable equilibrium.)

- Case 2 : if $\theta = 90°$

$|\vec{\tau}| = pE\sin(90°) = pE$ (Maximum Torque.)



Dipole in a Uniform External Field

- Direction of $\vec{\tau}$: Perpendicular to the plane containing $\vec{p}$ and $\vec{E}$
- Case 1 : if $\theta = 0°$

$|\vec{\tau}| = pE\sin(0°) = 0$ (Stable equilibrium.)

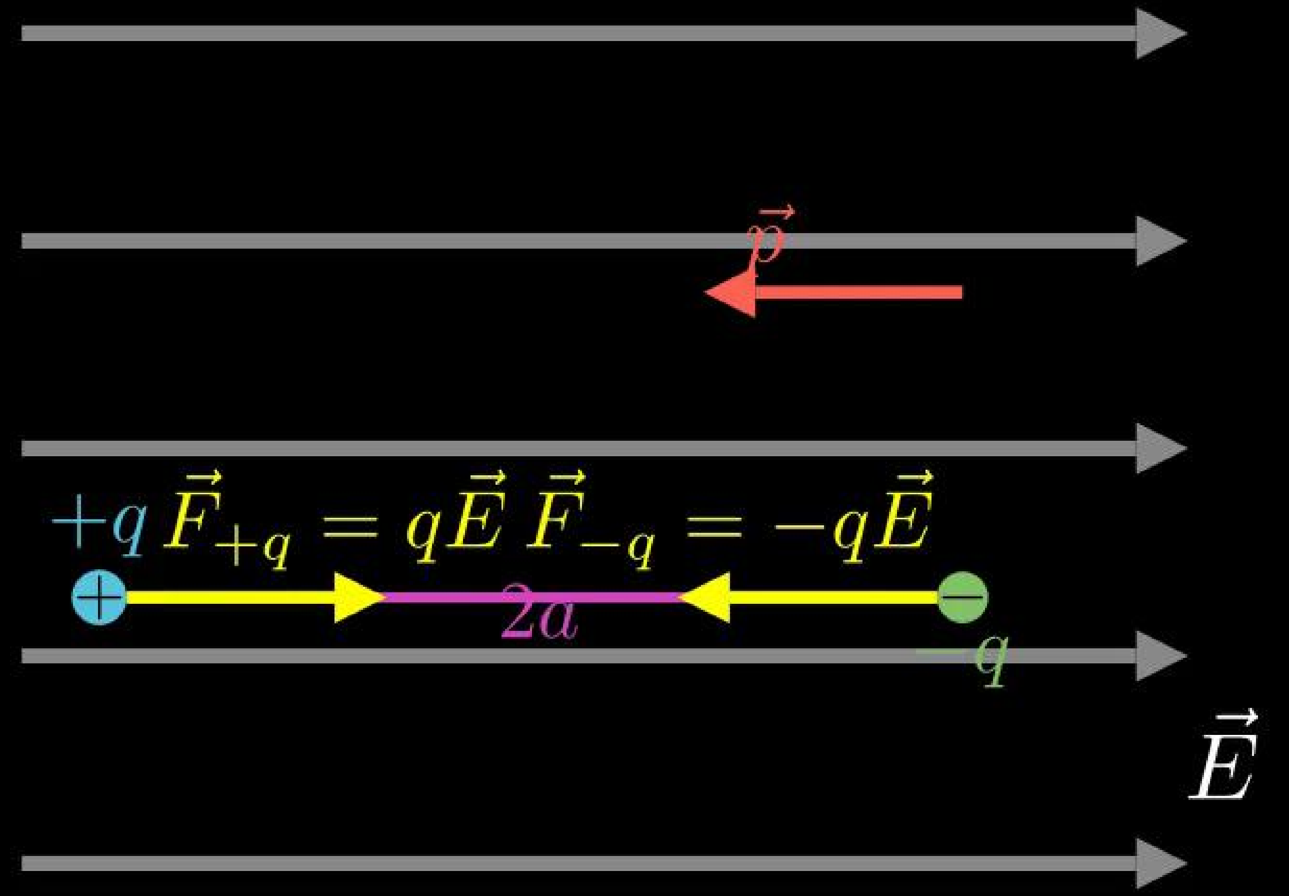
- Case 2 : if $\theta = 90°$

$|\vec{\tau}| = pE\sin(90°) = pE$ (Maximum Torque.)

- Case 3 : if $\theta = 180°$

$|\vec{\tau}| = pE\sin(180°) = 0$ (Unstable equilibrium.)

- If the field is not uniform, then the net-force on the dipole will be non-zero. So, in that case there will be both translation and rotational motion of the dipole.



Example 34 : 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 5×10^{4} NC^{-1} . Calculate the magnitude of the torque acting on the dipole.

Solution :

- Given: $p = 4 \times 10^{-9}$ C m, $\theta = 30°$, $E = 5 \times 10^{4}$ NC^{-1}
- Find: Magnitude of torque acting on the dipole ($|\vec{\tau}|$)

$$|\vec{\tau}| = pE \sin\theta$$
$$= 4 \times 10^{-9} \times 5 \times 10^{-4} \times \sin(30°)$$
$$= 20 \times 10^{-13} \times \frac{1}{2}$$
$$= 10 \times 10^{-13}$$
$$\boxed{|\vec{\tau}| = 10^{-12}\ Nm}$$

Example 35 : An electric dipole consists of two opposite charges of magnitude 0.2 μC each, separated by a distance of 2 cm. The dipole is placed in an external field of 2×10^5 N/C. What maximum torque does the field exert on the dipole?

Solution :

- Given: $q = 0.2\ \mu C = 0.2 \times 10^{-6}$ C, $2a = 2\ cm = 2 \times 10^{-2}\ m$, $E = 2 \times 10^5\ \mathrm{NC}^{-1}$
- Find: Maximum torque acting on the dipole τ_{max}
- Torque : $\tau = pE\sin\theta$
- For maximum value of torque, $\sin\theta = 1$

$$\therefore \tau_{max} = pE$$

$$\tau_{max} = (q \times 2a) \times E$$

$$= 0.2 \times 10^{-6} \times 2 \times 10^{-2} \times 2 \times 10^5$$

$$\boxed{\tau_{max} = 0.8 \times 10^{-3}\ Nm}$$

Example 36 : An electric dipole is placed at an angle 60° with an electric field of strength 4×10^5 N/C. It experiences a torque equal to $8\sqrt{3}$ Nm. Calculate the charge on the dipole, if dipole is of length 4 cm.

(a) 10^{-1} C (b) 10^{-2} C

(c) 10^{-3} C (d) 10^{-4} C