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OR **CBSE 2023**

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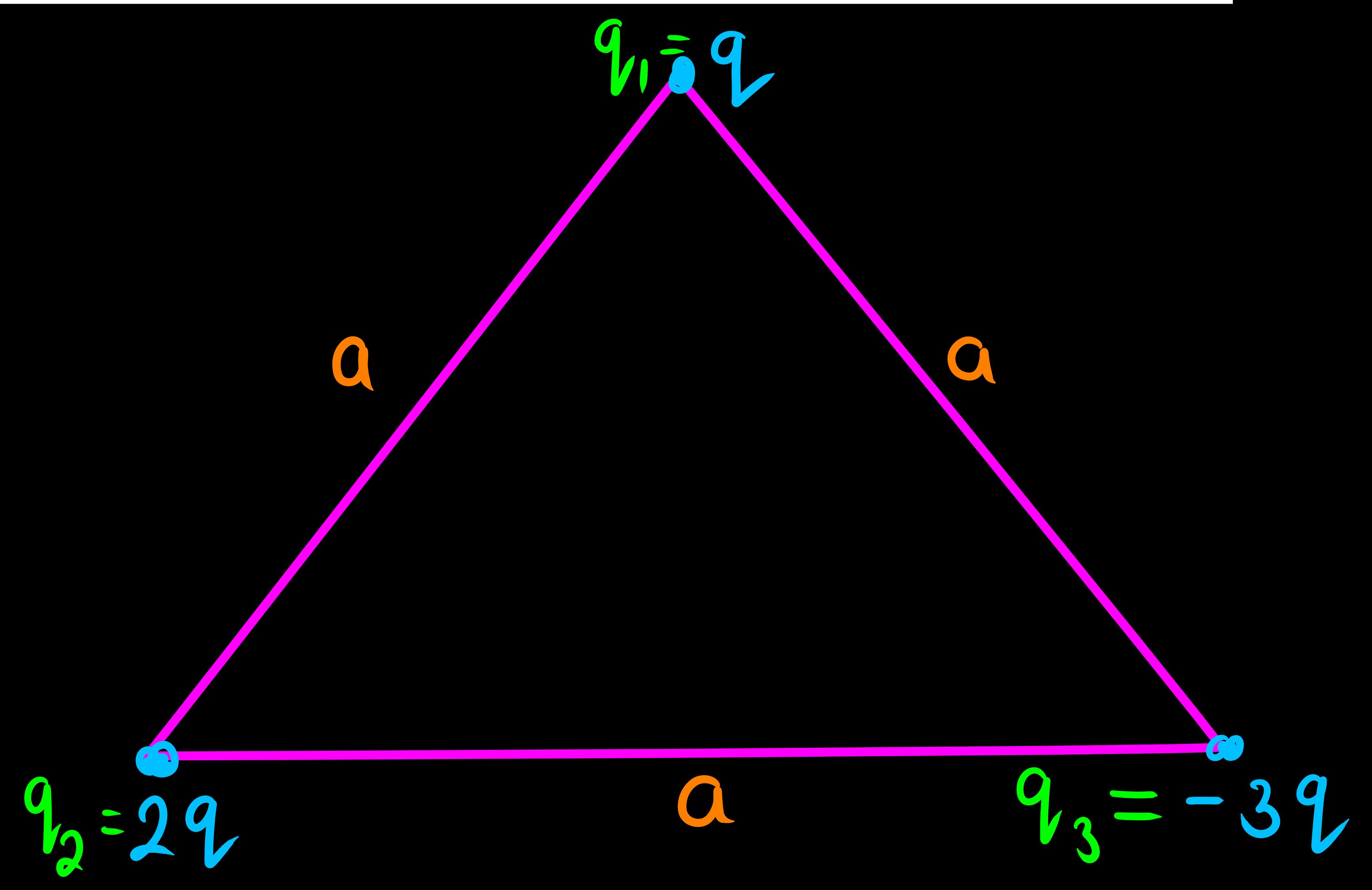

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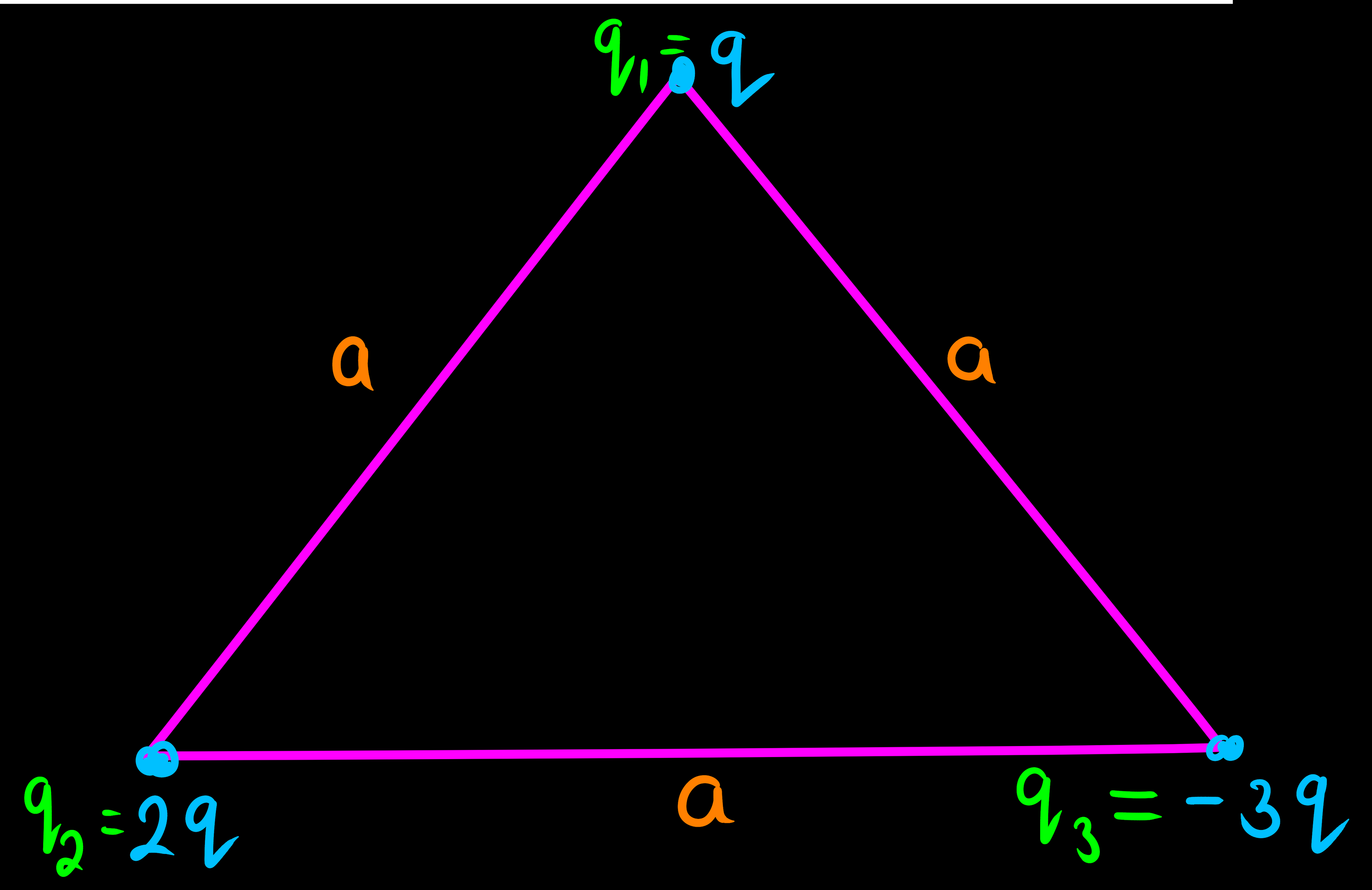

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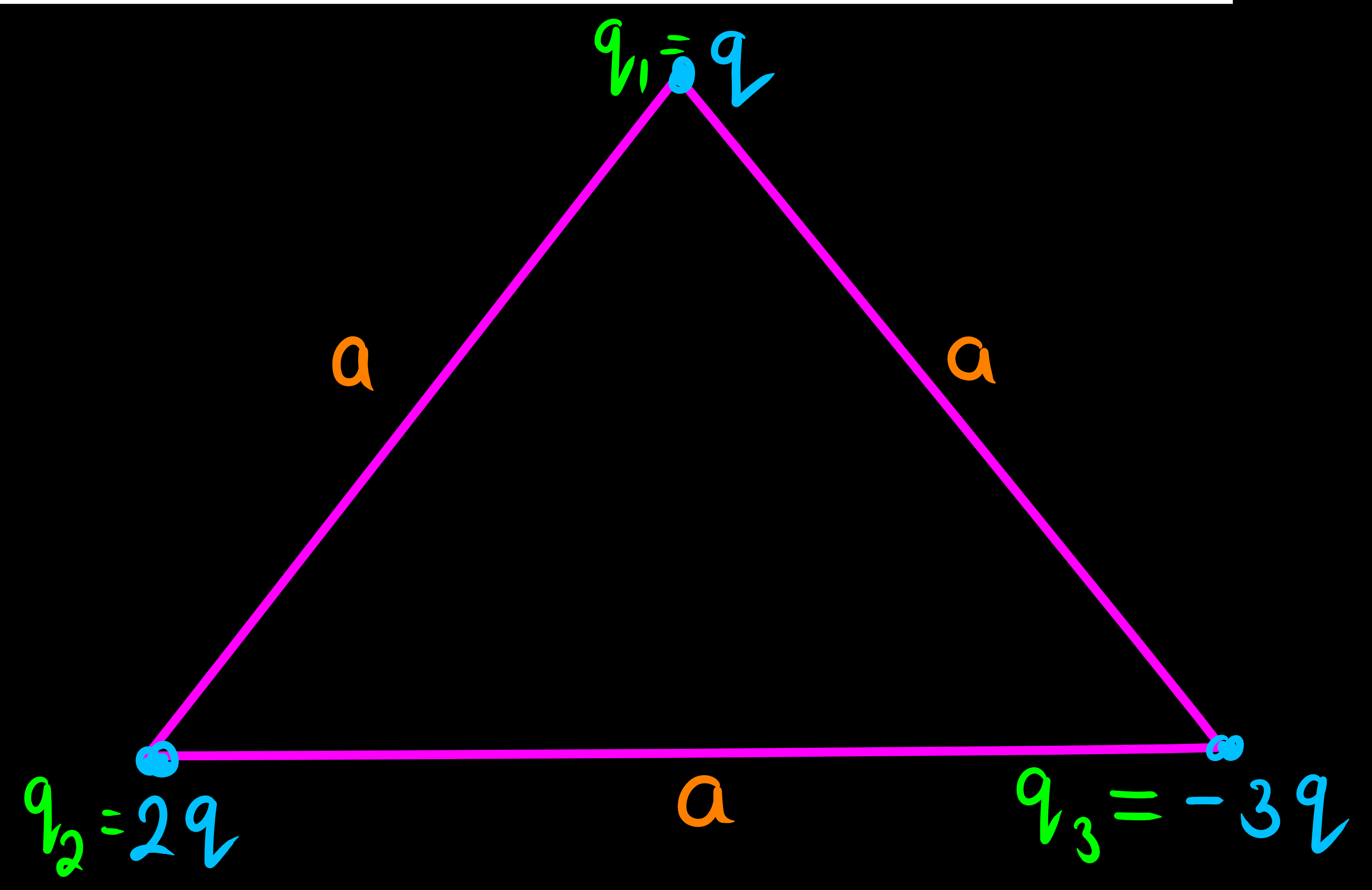

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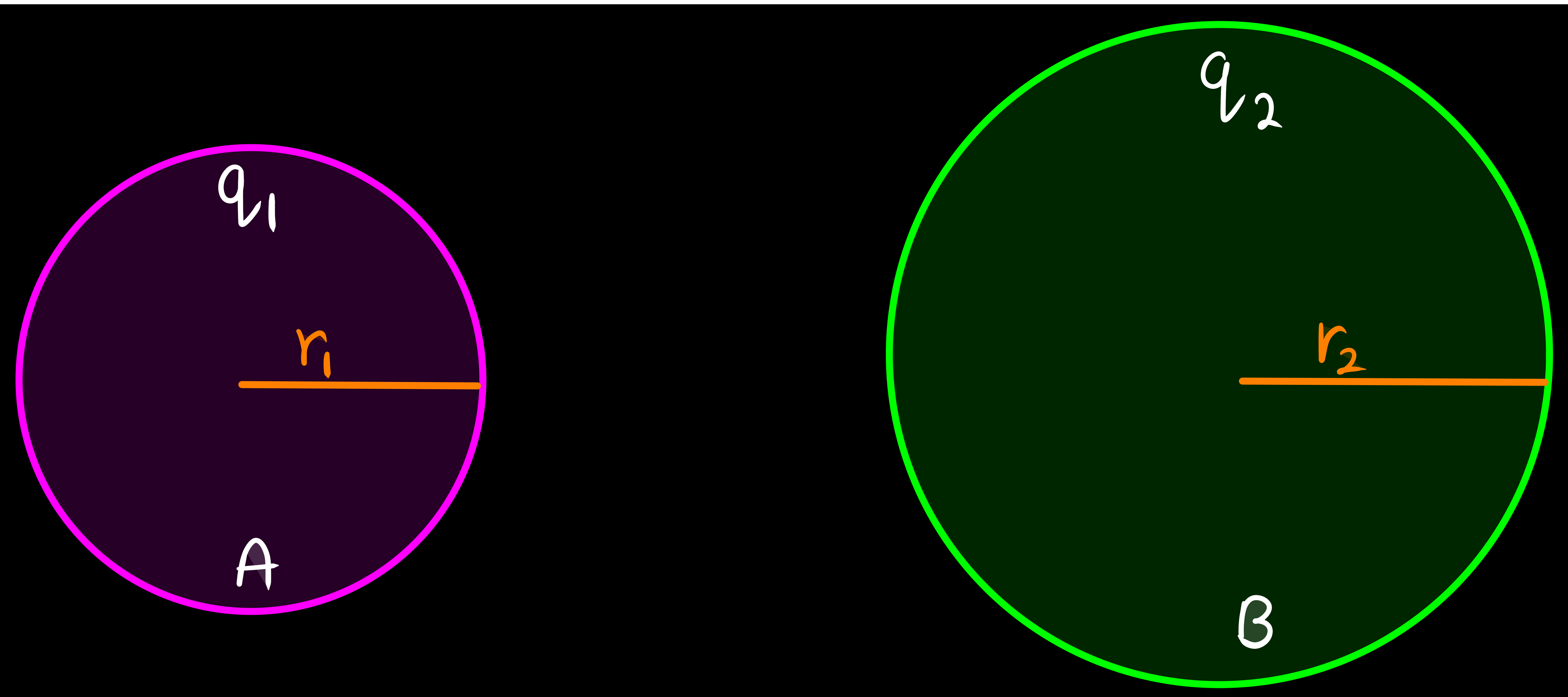

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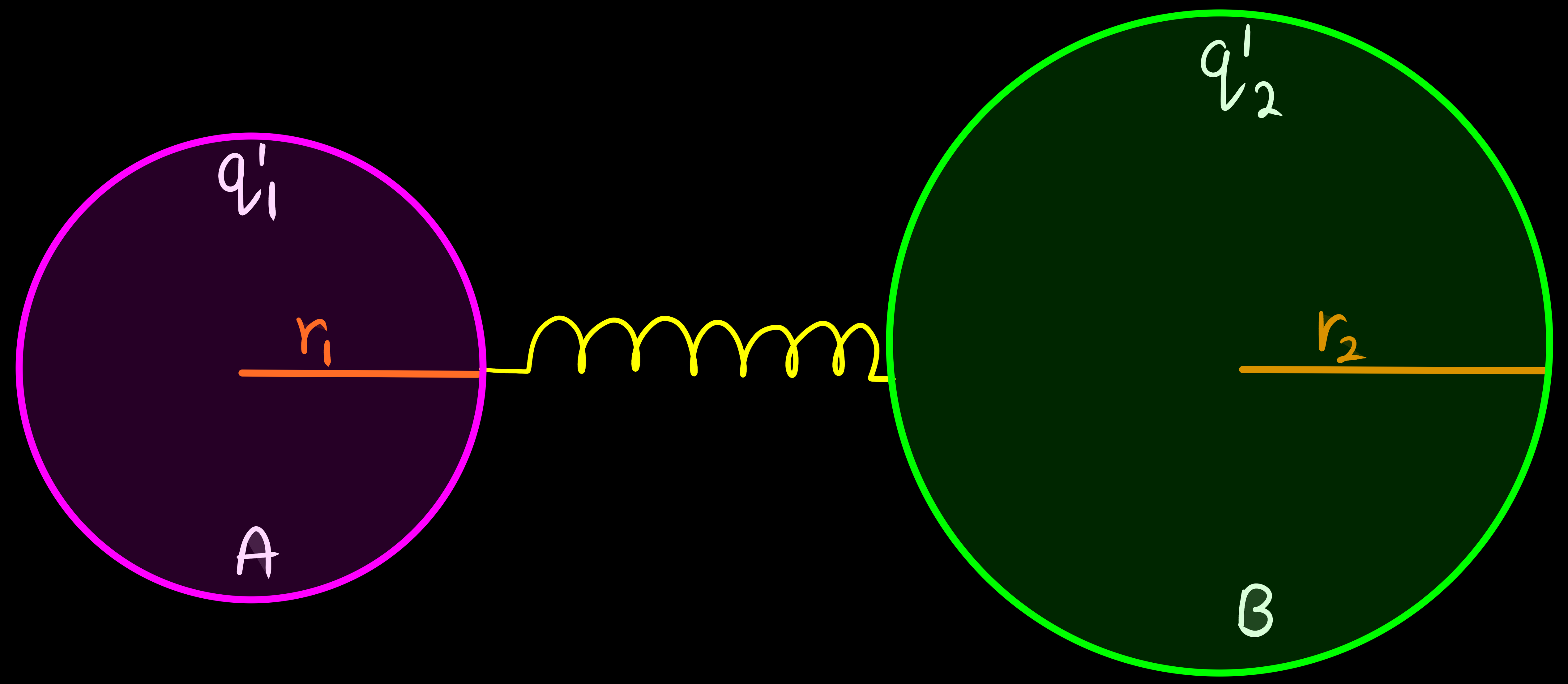

using conservation of charge -

$$\underbrace{q_1' + q_2'}_{\text{final charge}} = \underbrace{q_1 + q_2}_{\text{initial charge}}$$

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$$V_1 = V_2$$

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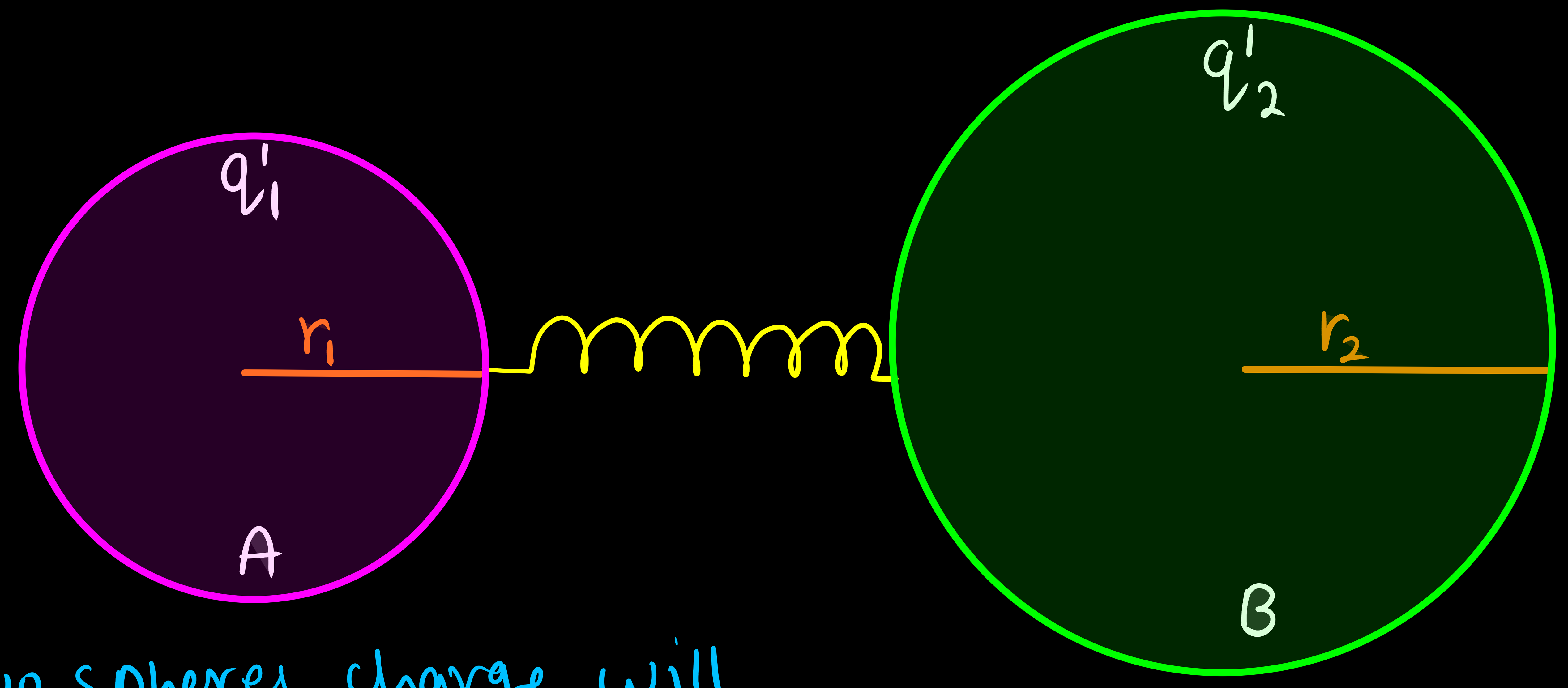

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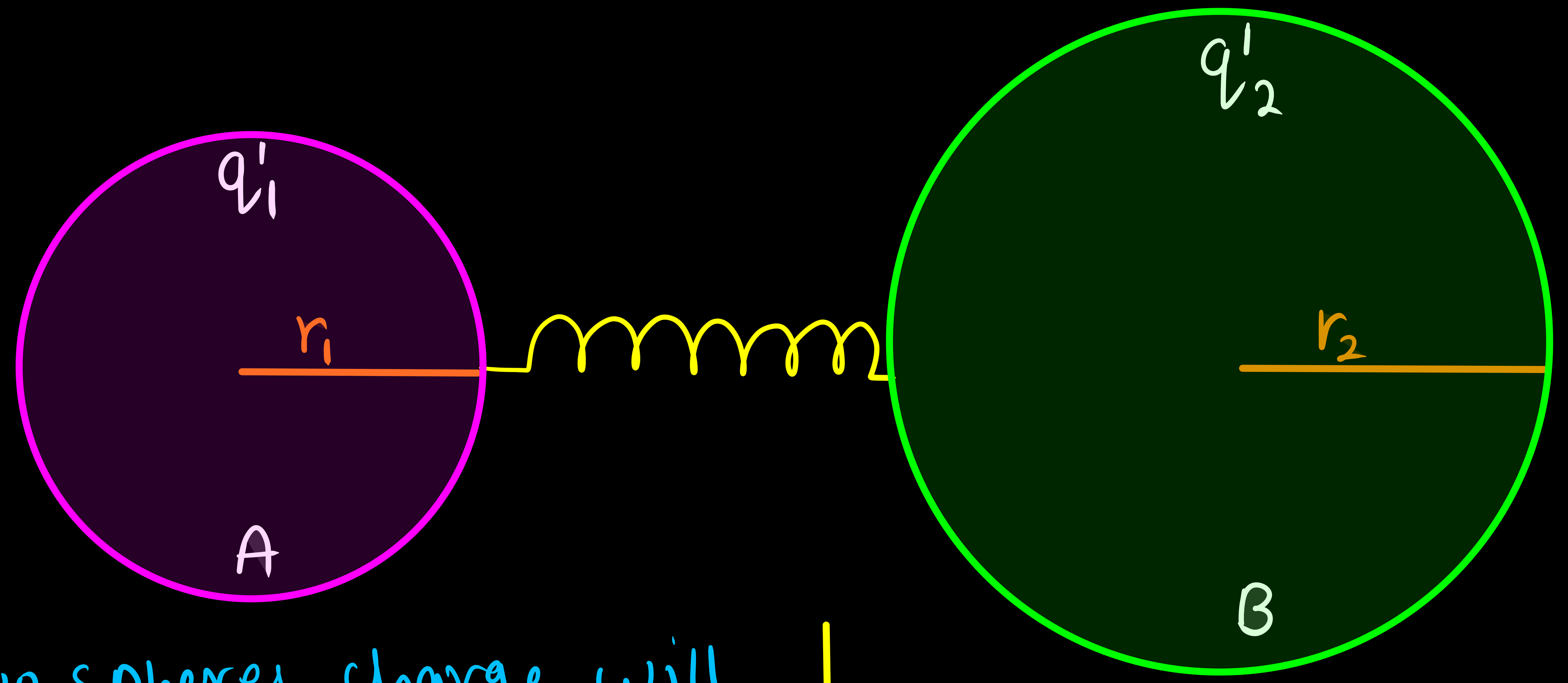

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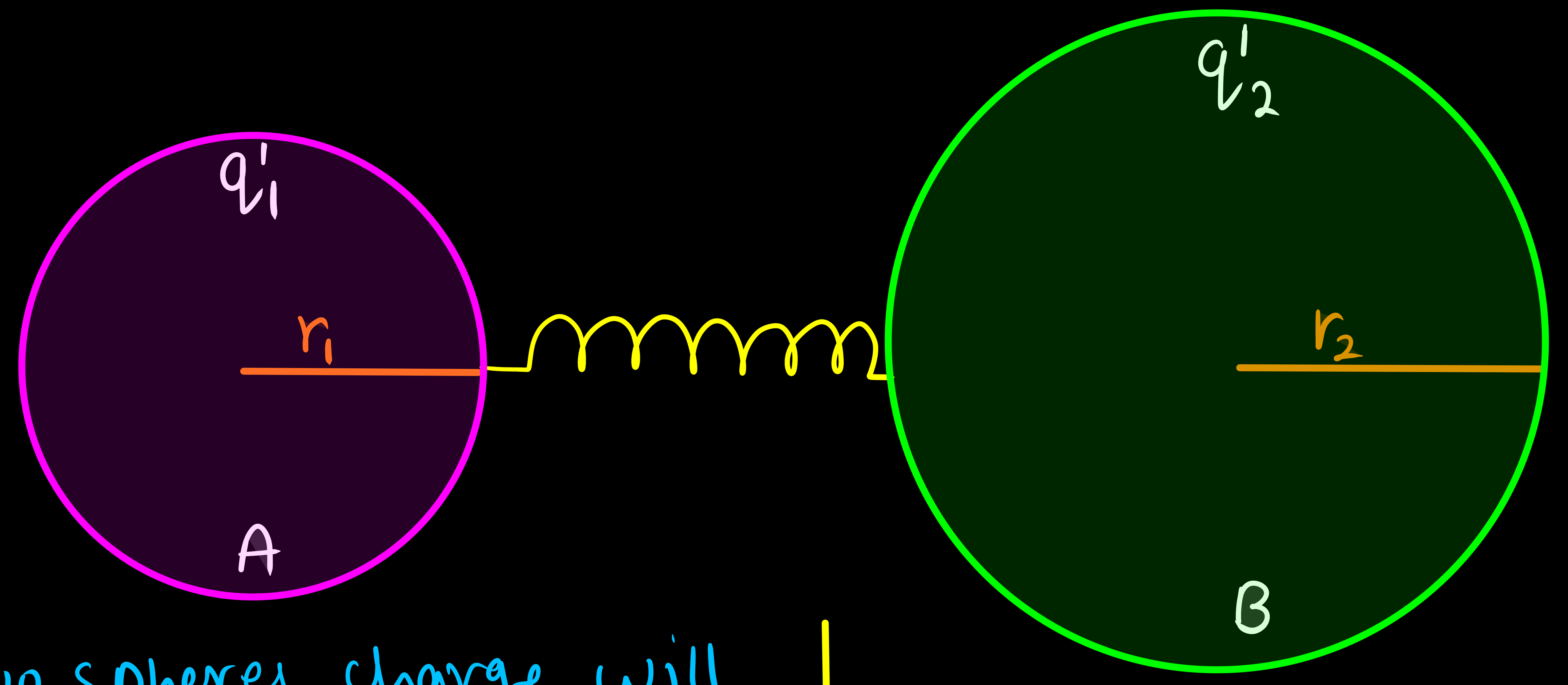

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1. Two charges + q each are kept '2a' distance apart. A third charge – 2q is placed midway between them. The potential energy of the system is – **1**

(A) $\dfrac{q^2}{8\pi\varepsilon_0 a}$

(B) $-\dfrac{6q^2}{8\pi\varepsilon_0 a}$

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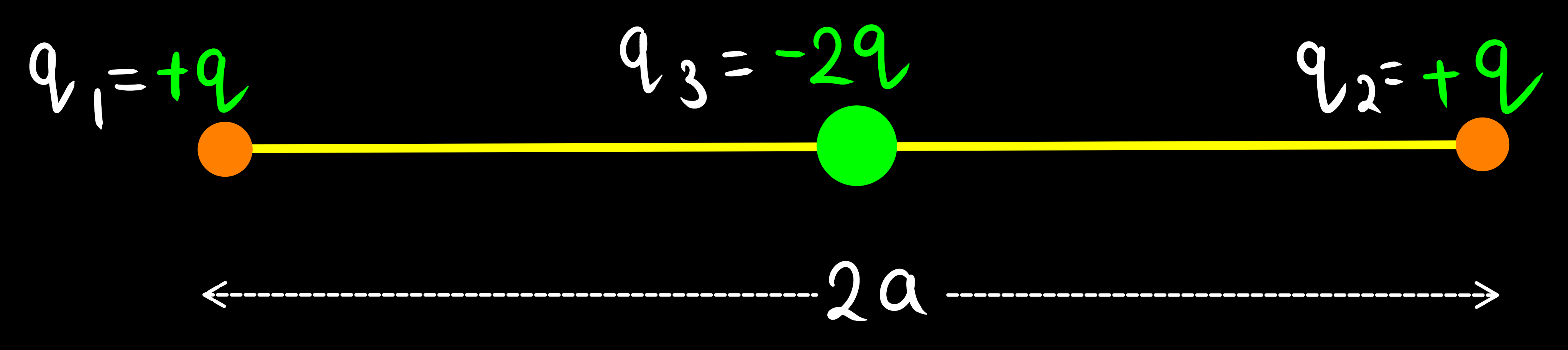

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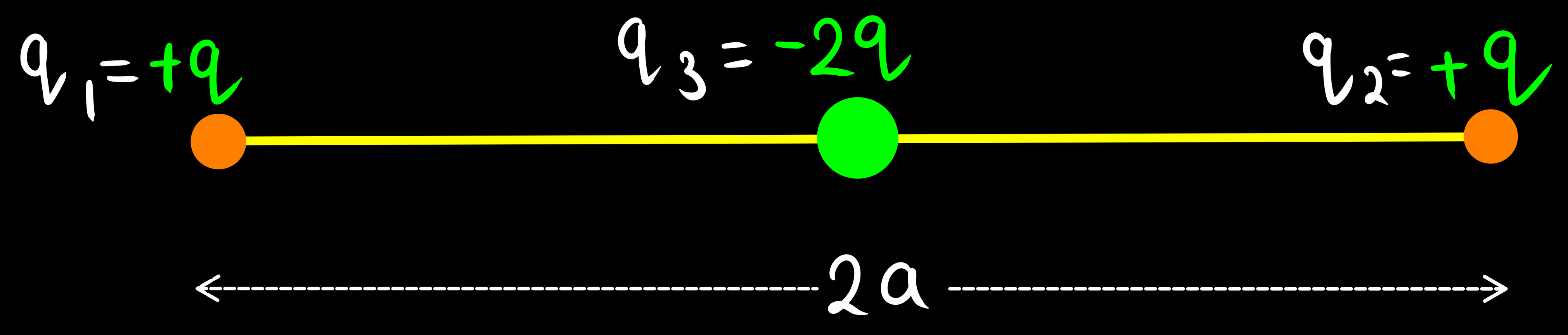

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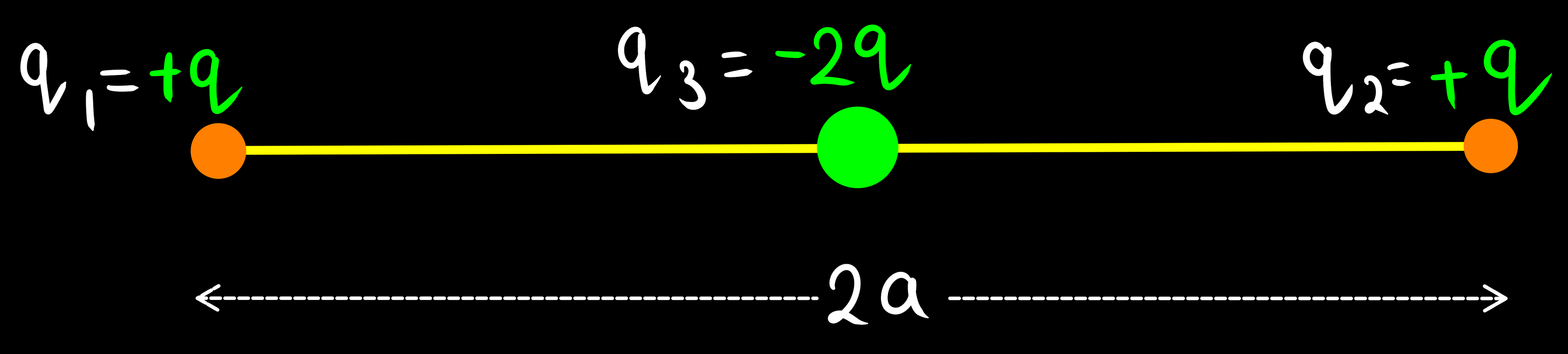

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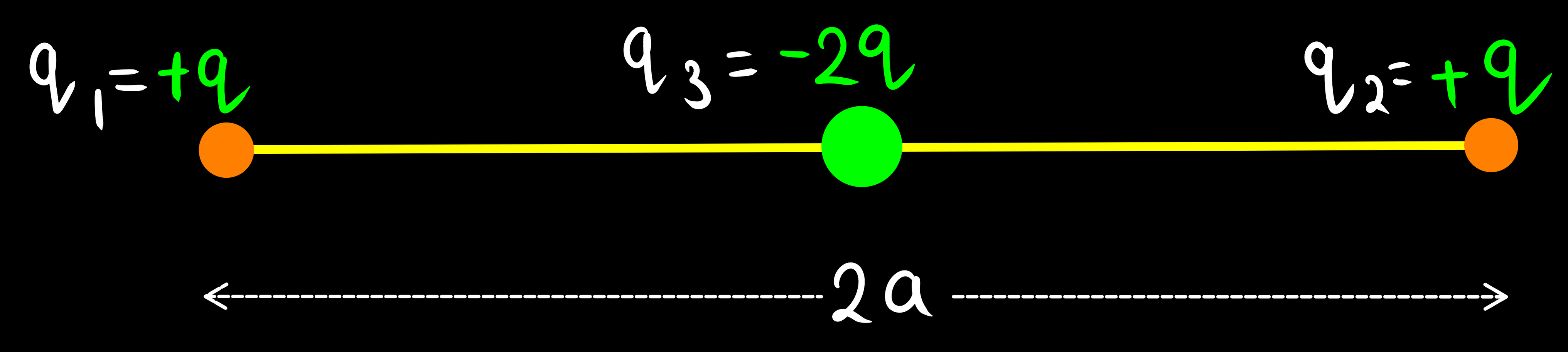

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$$U = \frac{1}{4\pi\varepsilon_0} \times \frac{(-7q^2)}{2a} = \underline{\underline{\frac{-7q^2}{8\pi\varepsilon_0 a}}}$$

34. Electrostatics deals with the study of forces, fields and potentials arising from static charges. Force and electric field, due to a point charge is basically determined by Coulomb's law. For symmetric charge configurations, Gauss's law, which is also based on Coulomb's law, helps us to find the electric field. A charge/a system of charges like a dipole experience a force/torque in an electric field. Work is required to be done to provide a specific orientation to a dipole with respect to an electric field.

Answer the following questions based on the above :

(a) Consider a uniformly charged thin conducting shell of radius R. Plot a graph showing the variation of $|\vec{E}|$ with distance r from the centre, for points $0 \le r \le 3R$. → Refer your notebook. *1*

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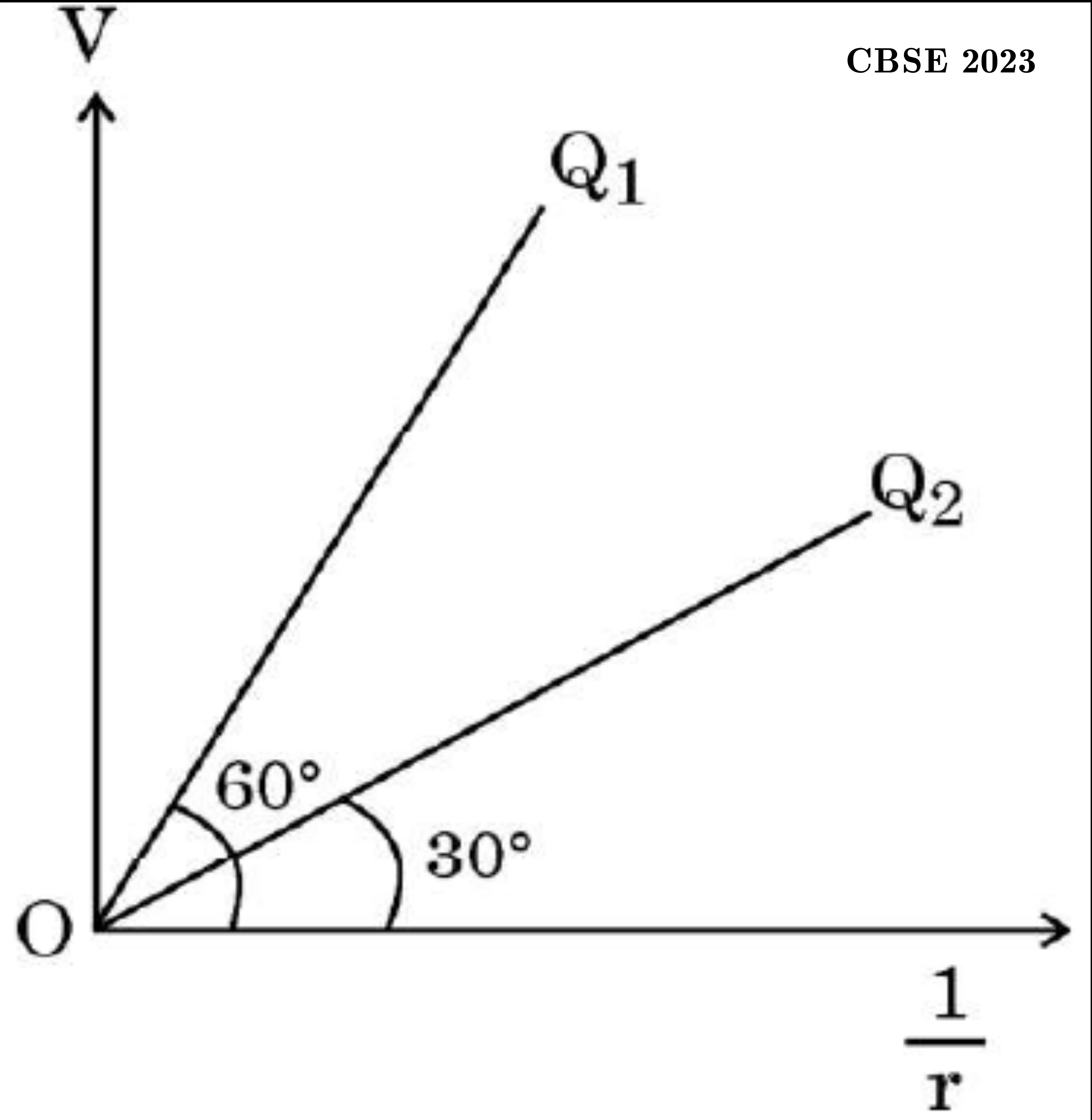

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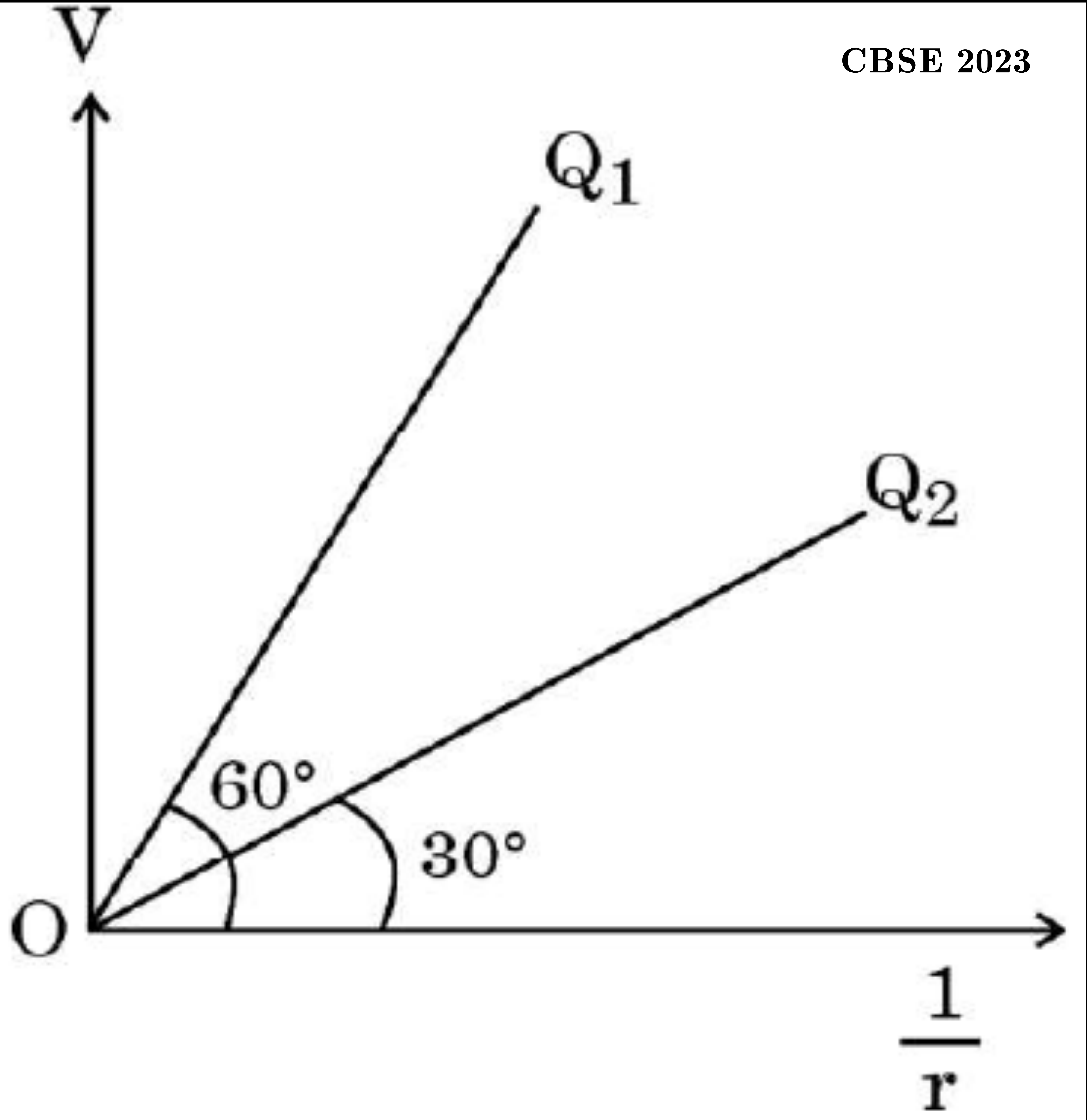

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CBSE 2023

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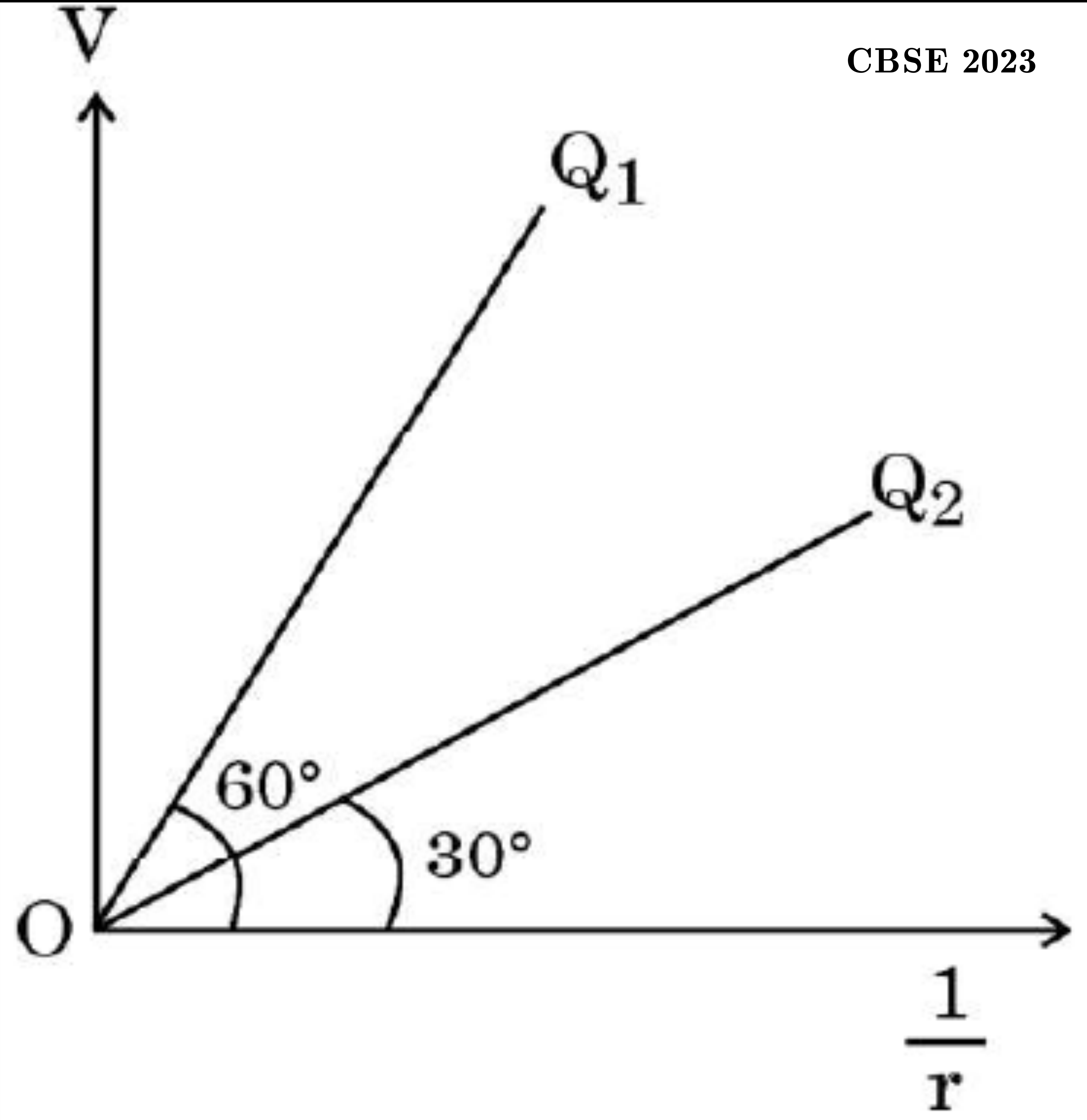

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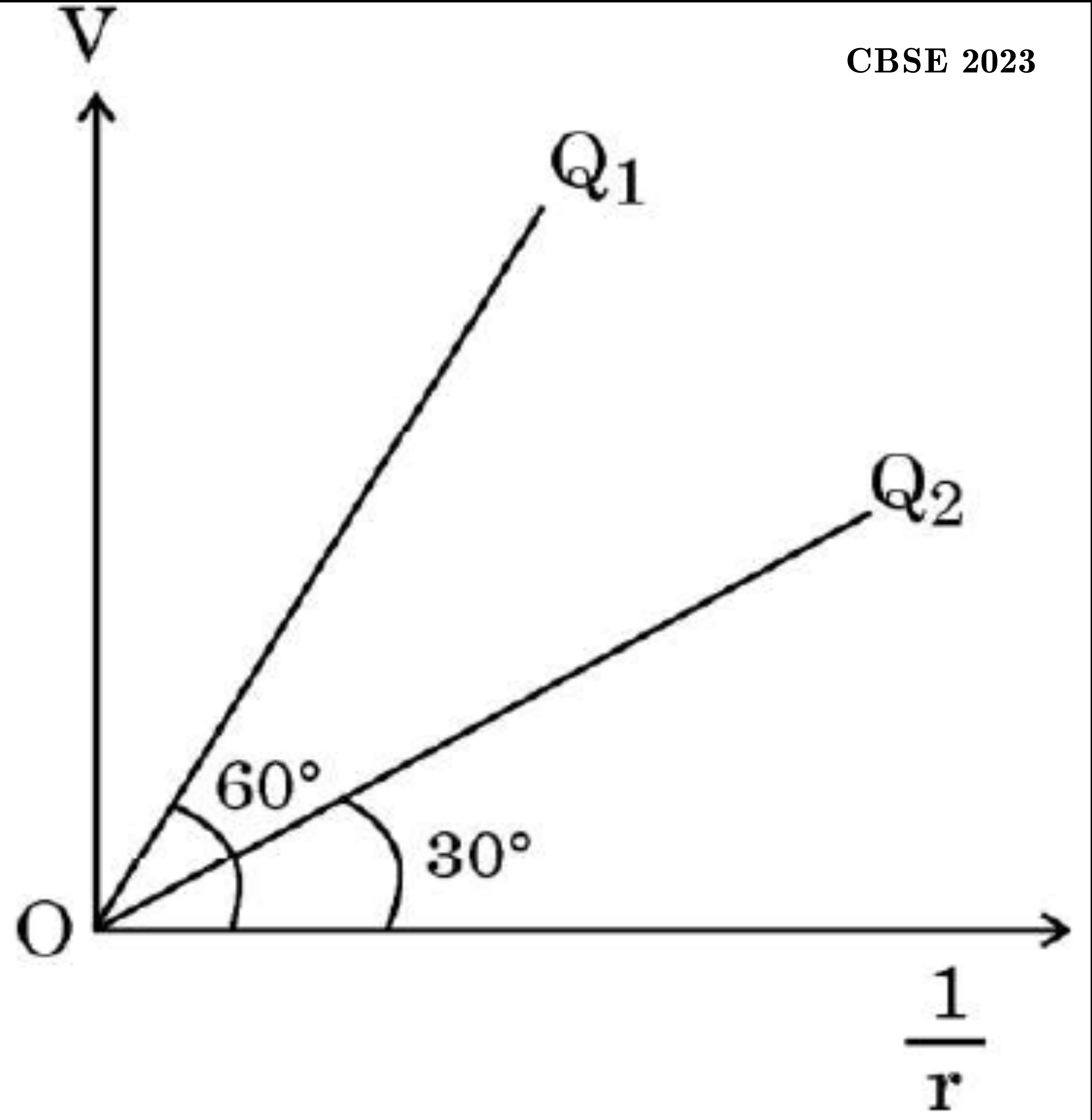

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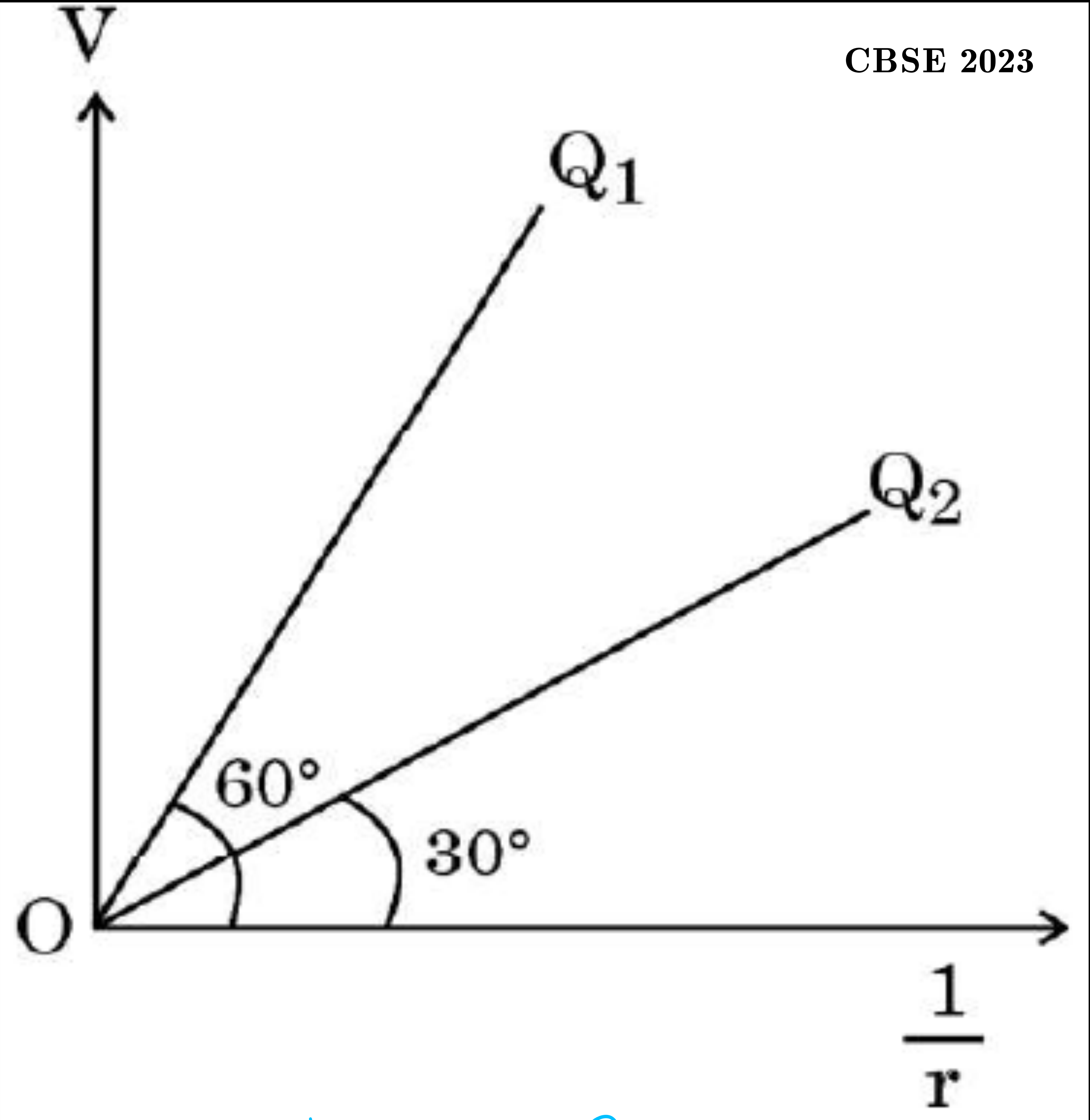

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$\tan\theta_2 = KQ_2$ -(2)

Divide eqⁿ (1) by (2)

$\frac{KQ_1}{KQ_2} = \frac{\tan\theta_1}{\tan\theta_2}$

$\frac{Q_1}{Q_2} = \frac{\tan 60°}{\tan 30°}$

CBSE 2023

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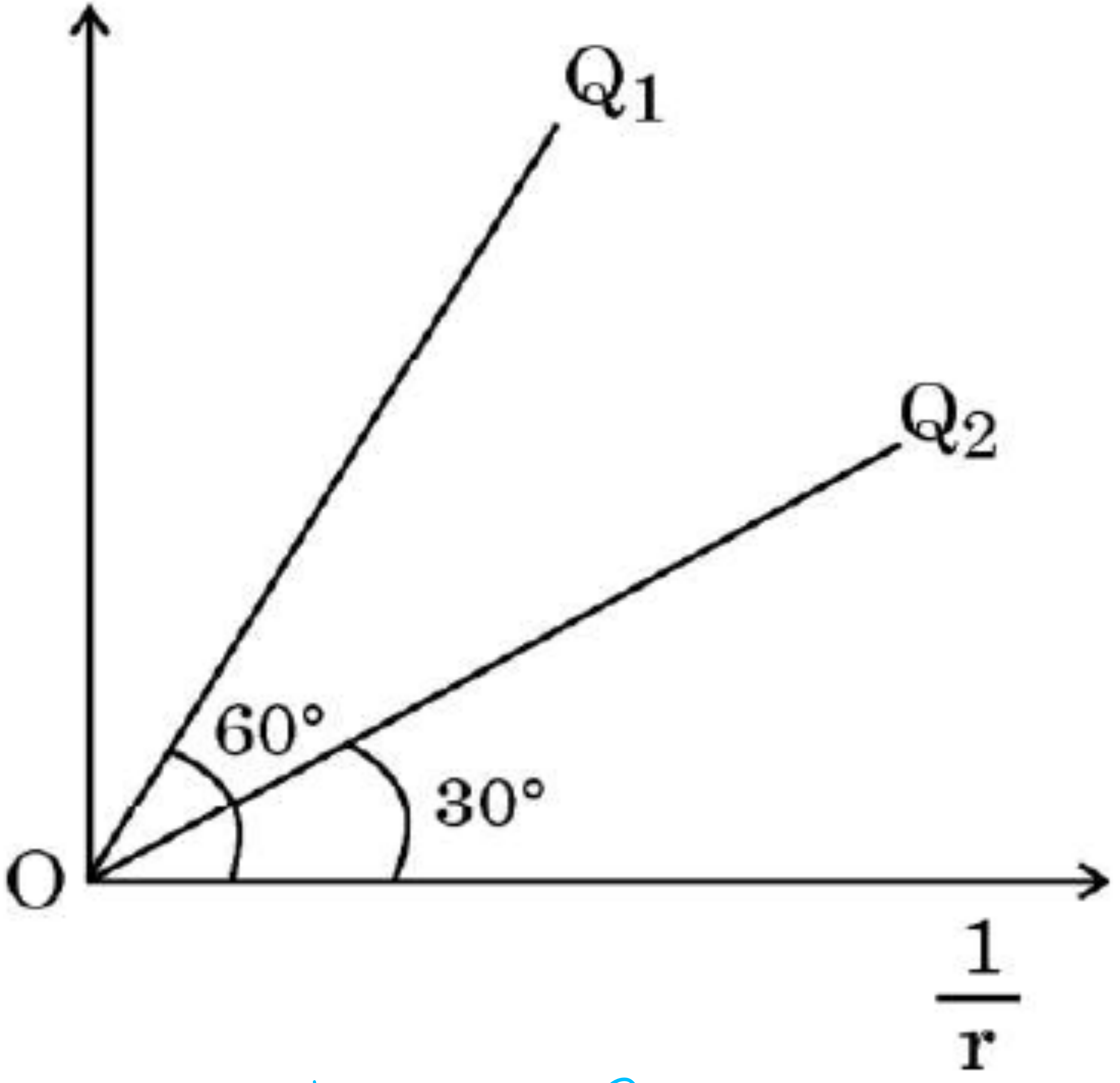

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Divide eqⁿ ① by ②

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$\frac{Q_1}{Q_2} = \frac{\tan 60^\circ}{\tan 30^\circ}$

$\frac{Q_1}{Q_2} = \frac{\sqrt{3}}{\frac{1}{\sqrt{3}}}$

$\boxed{\frac{Q_1}{Q_2} = 3}$

(c) An electric dipole of dipole moment of 6×10^{-7} C-m is kept in a uniform electric field of 10^4 N/C such that the dipole moment and the electric field are parallel. Calculate the potential energy of the dipole. *2*

OR

(c) An electric dipole of dipole moment $\vec{p}$ is initially kept in a uniform electric field $\vec{E}$ such that $\vec{p}$ is perpendicular to $\vec{E}$. Find the amount of work done in rotating the dipole to a position at which $\vec{p}$ becomes antiparallel to $\vec{E}$. **CBSE 2023** *2*

c) i) $p = 6 \times 10^{-7}$ C·m
$E = 10^4$ N/C
$\theta = 0^\circ$

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OR

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c) i) $P = 6 \times 10^{-7}$ C·m

$E = 10^4$ N/C

$\theta = 0^\circ$

$U = -PE\cos\theta$

$U = -6 \times 10^{-7} \times 10^4 \times \cos(0)$

$\boxed{U = -6 \times 10^{-3}\ J}$

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CBSE 2023

(c) An electric dipole of dipole moment of 6×10^{-7} C-m is kept in a uniform electric field of 10^4 N/C such that the dipole moment and the electric field are parallel. Calculate the potential energy of the dipole. 2

OR

(c) An electric dipole of dipole moment $\vec{p}$ is initially kept in a uniform electric field $\vec{E}$ such that $\vec{p}$ is perpendicular to $\vec{E}$. Find the amount of work done in rotating the dipole to a position at which $\vec{p}$ becomes antiparallel to $\vec{E}$.

CBSE 2023 2

c) i) $P = 6 \times 10^{-7}$ C·m

$E = 10^4$ N/C

$\theta = 0^\circ$

$U = -PE\cos\theta$

$U = -6 \times 10^{-7} \times 10^4 \times \cos(0)$

$\boxed{U = -6 \times 10^{-3}\ \text{J}}$

c) ii) $\theta_i = 90^\circ$

$\theta_f = 180^\circ$

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CBSE 2023

c) ii) $\theta_i = 90^\circ$

$\theta_f = 180^\circ$

$\Delta U = -PE(\cos\theta_f - \cos\theta_i)$

$\Delta U = -PE(\cos 180^\circ - \cos 90^\circ)$

$\Delta U = -PE(-1 - 0)$

$\boxed{\Delta U = PE} = W$

(b) (i) Define electric potential at a point and write its SI unit.

(ii) Two capacitors are connected in series. Derive an expression of the equivalent capacitance of the combination.

(iii) Two point charges + q and – q are located at points (3a, 0) and (0, 4a) respectively in x-y plane. A third charge Q is kept at the origin. Find the value of Q, in terms of q and a, so that the electrostatic potential energy of the system is zero. *5*

(b) (i) Define electric potential at a point and write its SI unit.

$\hookrightarrow \frac{W_{\infty P}}{q}$ $\hookrightarrow \frac{J}{C}$ or volt

(ii) Two capacitors are connected in series. Derive an expression of the equivalent capacitance of the combination. $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$

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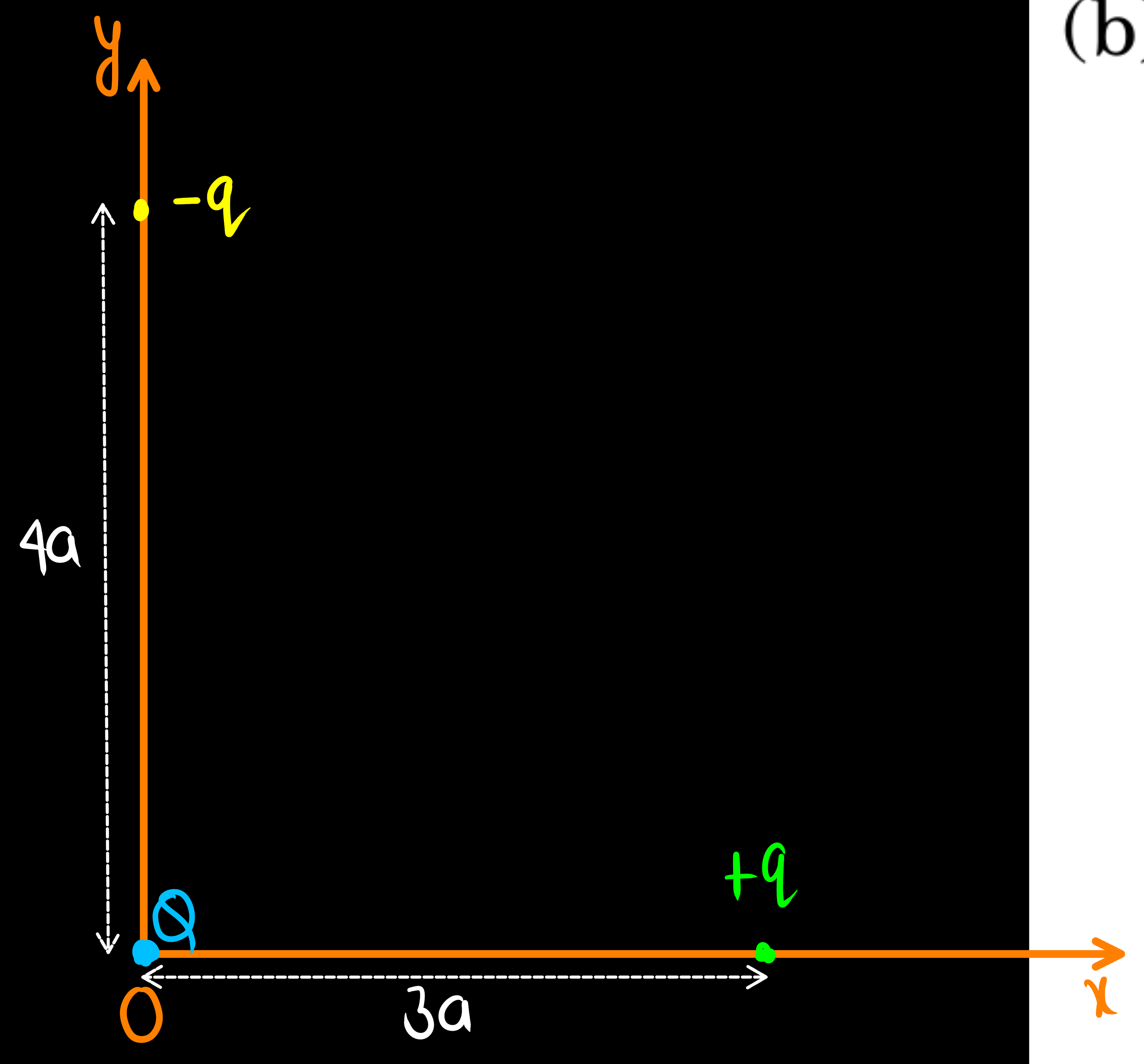

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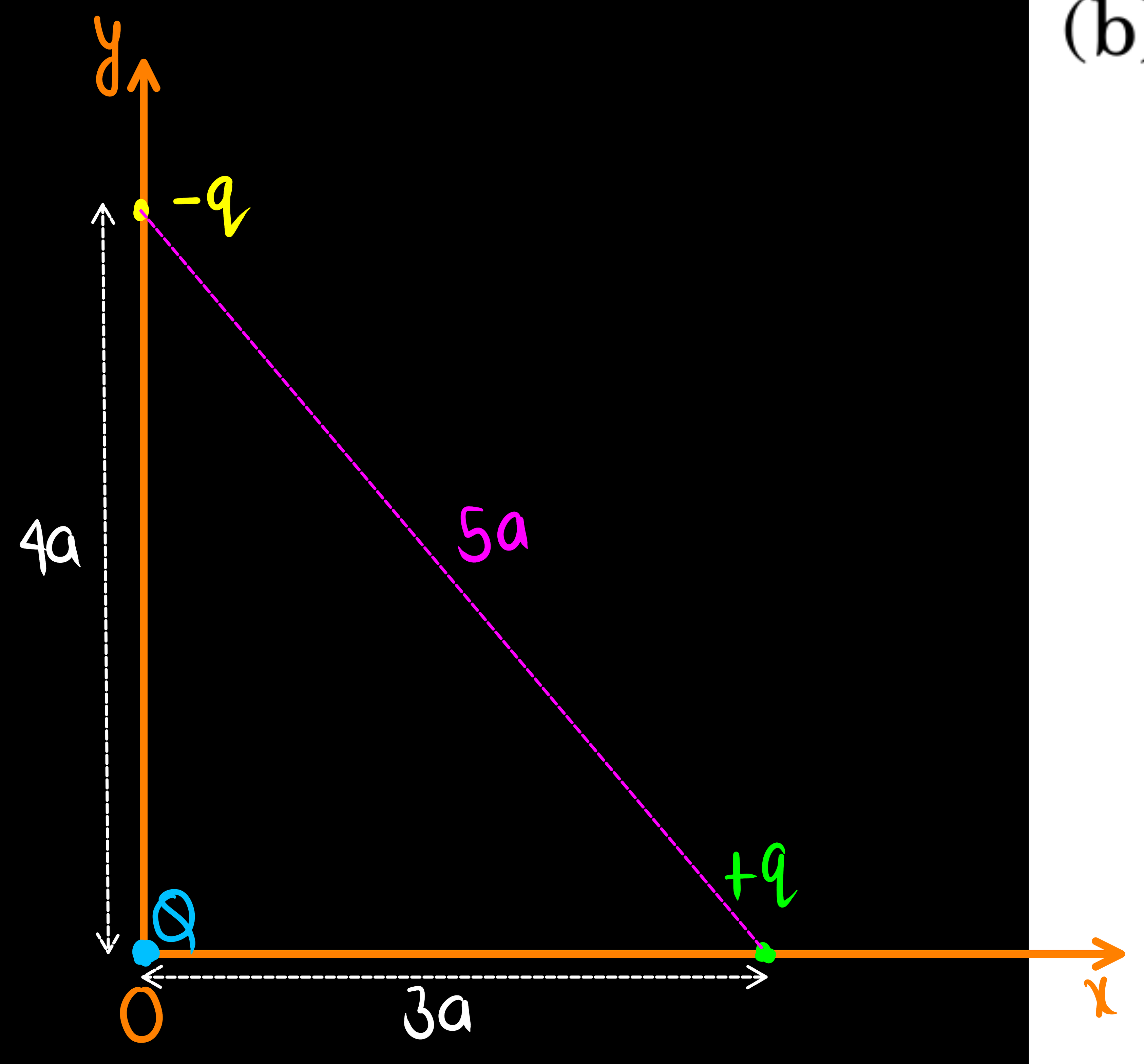
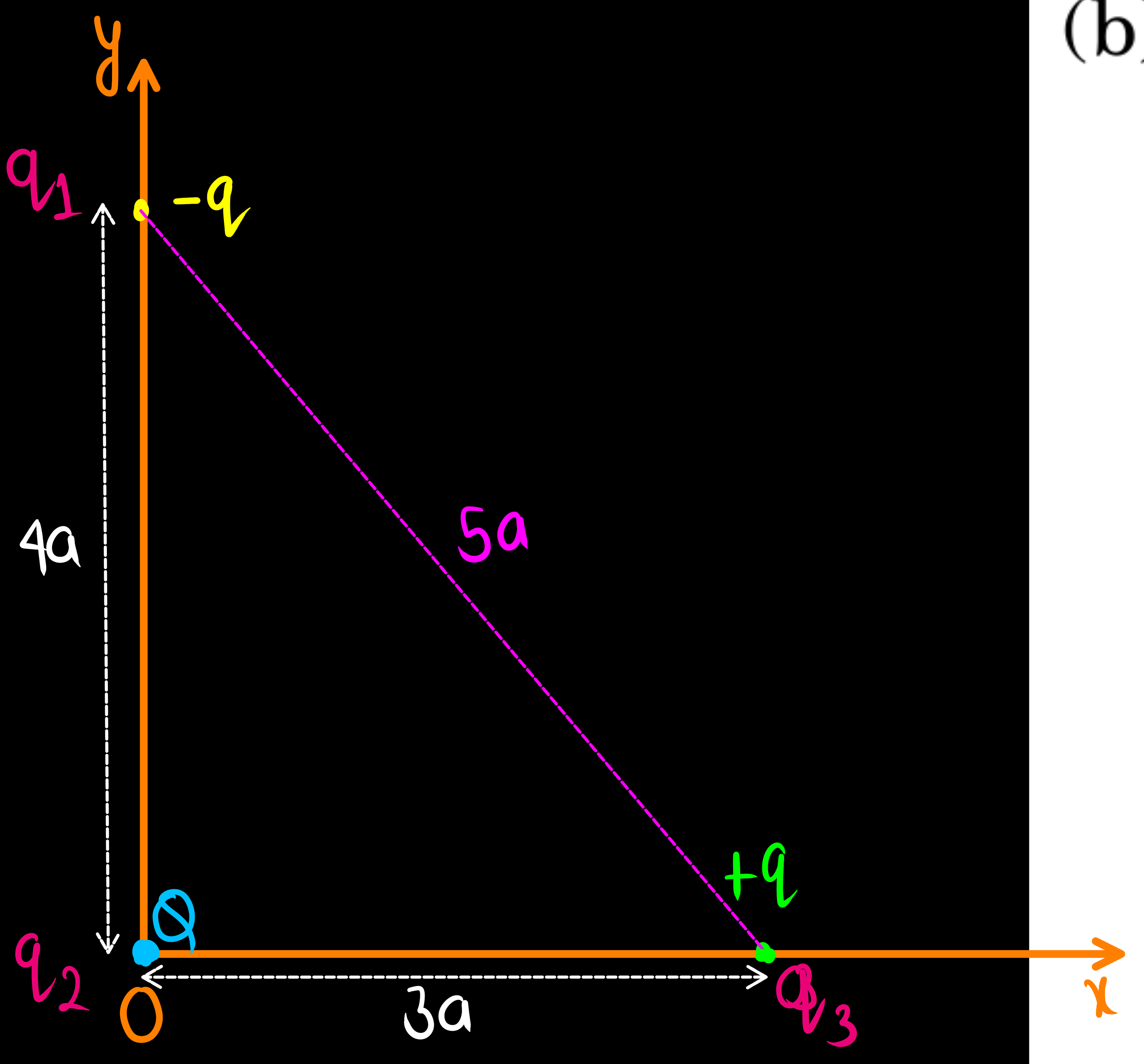


Given - $U = 0$



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Given- $U = 0$

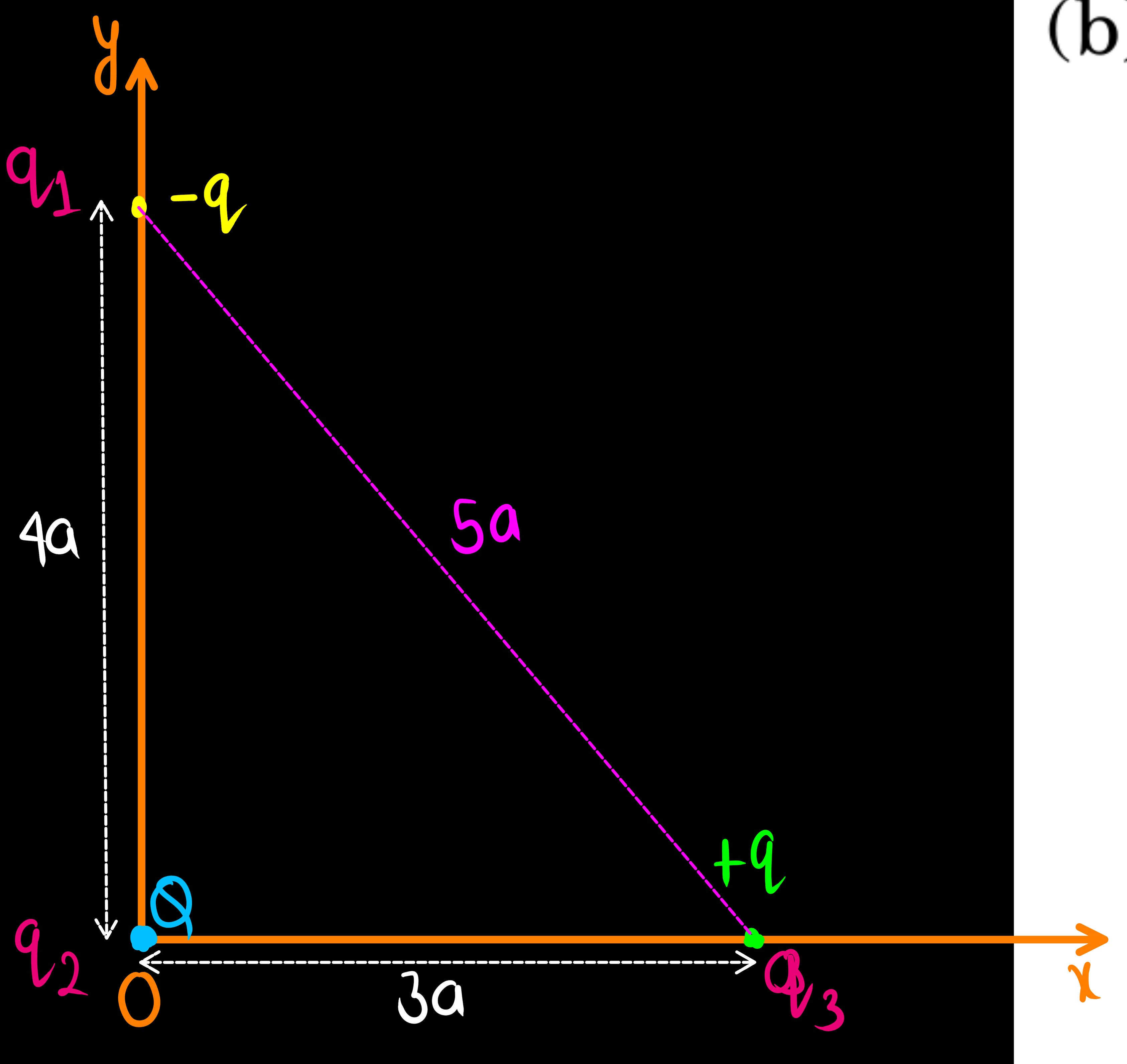
$$\frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right) = 0$$

$$\left(-\frac{qQ}{4a} - \frac{q^2}{5a} + \frac{qQ}{3a}\right) = 0$$

$$\frac{qQ}{3a} - \frac{qQ}{4a} = \frac{q^2}{5a}$$

$$\frac{4qQ - 3qQ}{12a} = \frac{q^2}{5a}$$

$$\frac{qQ}{12a} = \frac{q^2}{5a}$$



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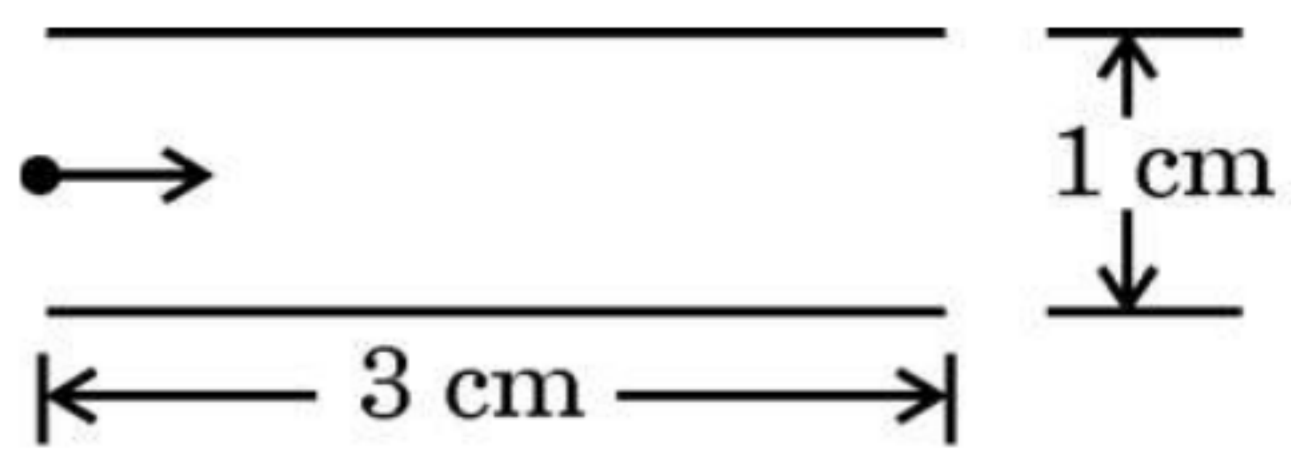
$$\frac{4qQ - 3qQ}{12a} = \frac{q^2}{5a}$$

$$\frac{\cancel{q}Q}{12\cancel{a}} = \frac{q^{\cancel{2}}}{5\cancel{a}}$$

$$\boxed{Q = \frac{12}{5}q}$$

34. A beam of electrons moving horizontally with a velocity of 3×10^7 m/s enters a region between two plates as shown in the figure. A suitable potential difference is applied across the plates such that the electron beam just strikes the edge of the lower plate.



Answer the following questions based on the above :

(a) How long does an electron take to strike the edge ? *1*

(b) What is the shape of the path followed by the electron and why ? *1*

(c) Find the potential difference applied. *2*

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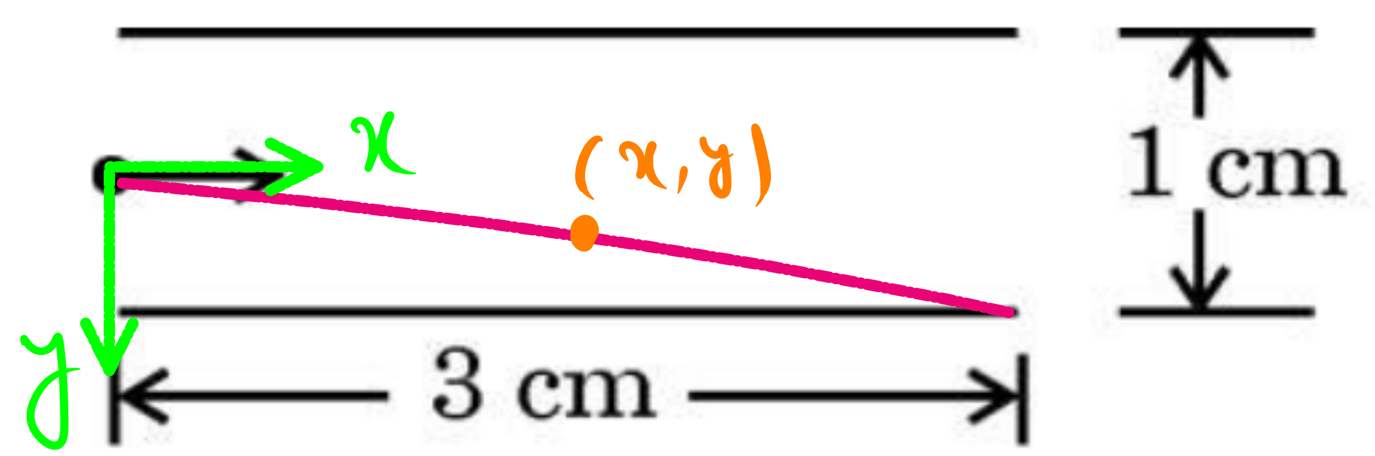

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a) Motion along x-axis –

$u_x = 3\times10^7\ ms^{-1}$

$x_0 = 0$

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using $S_x = U_x t + \frac{1}{2} a_x t^2$

$x - \underbrace{x_0}_{0} = u_x t + \frac{1}{2} \times 0 \times t^2$

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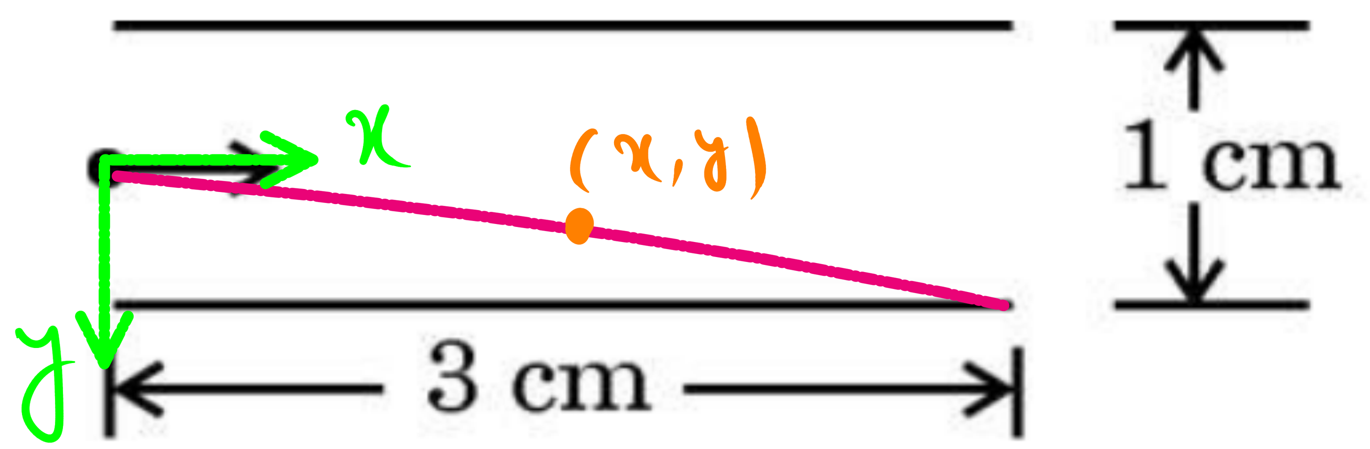

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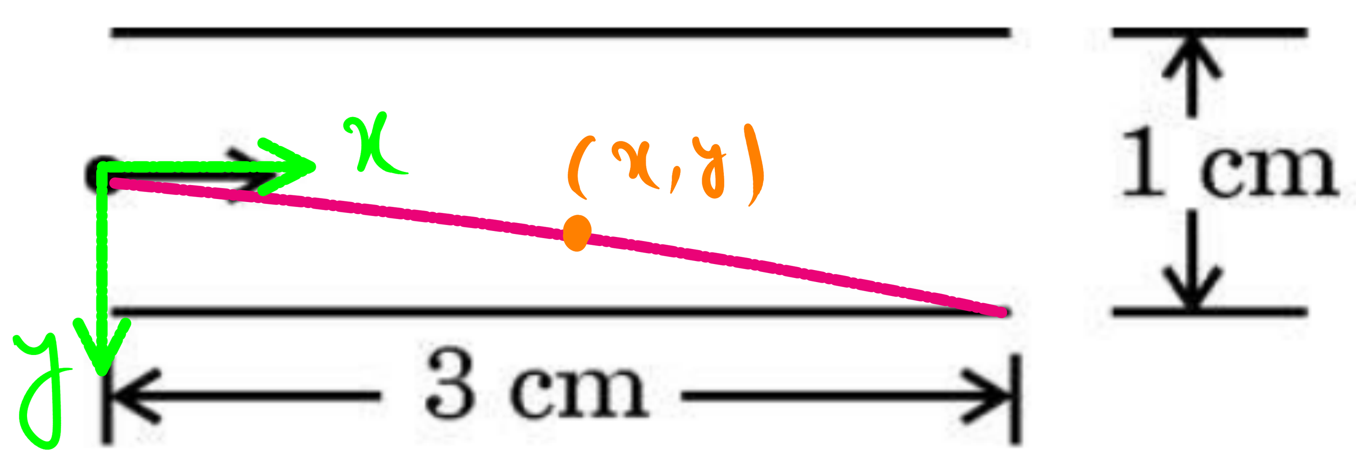

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$\underbrace{x - x_0}_{=0} = u_x t + \frac{1}{2} \times 0 \times t^2$

$x = u_x t$

$t = \frac{x}{u_x}$ — (1)

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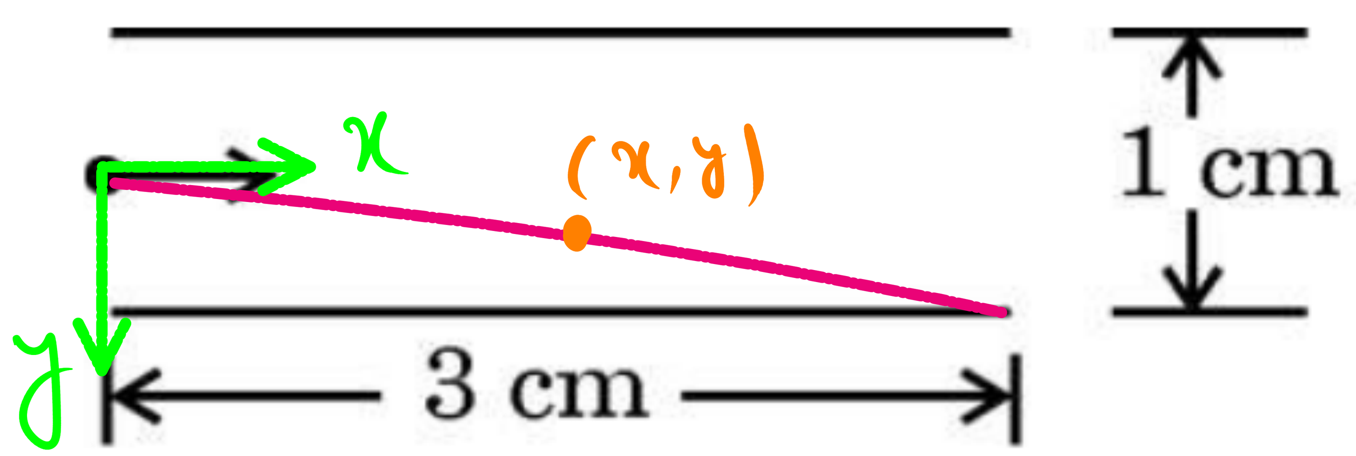

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$x = u_x t$

$t = \frac{x}{u_x}$ — (1)

$t = \frac{3\times10^{-2}\ m}{3\times10^{7}\ ms^{-1}}$

$\boxed{t = 10^{-9}\ s}$

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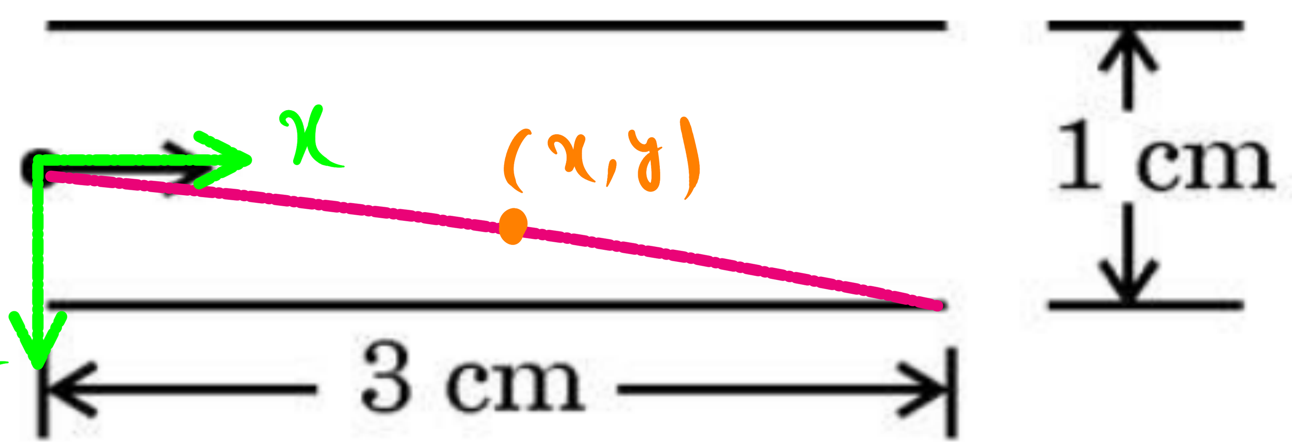

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$t = \frac{3 \times 10^{-2} \text{ m}}{3 \times 10^7 \text{ ms}^{-1}}$

$\boxed{t = 10^{-9} \text{ s}}$

b) Shape of the path – Parabola

$y = \frac{1}{2} a_y t^2 \quad (\because u_y = 0)$

$y = \frac{1}{2} \frac{eE}{m_e} t^2 \quad (\because a_y = \frac{eE}{m_e})$

$\boxed{y = \frac{1}{2} \frac{eE}{m_e} \frac{x^2}{u_x^2}}$ — (2)

↳ eqⁿ of parabola

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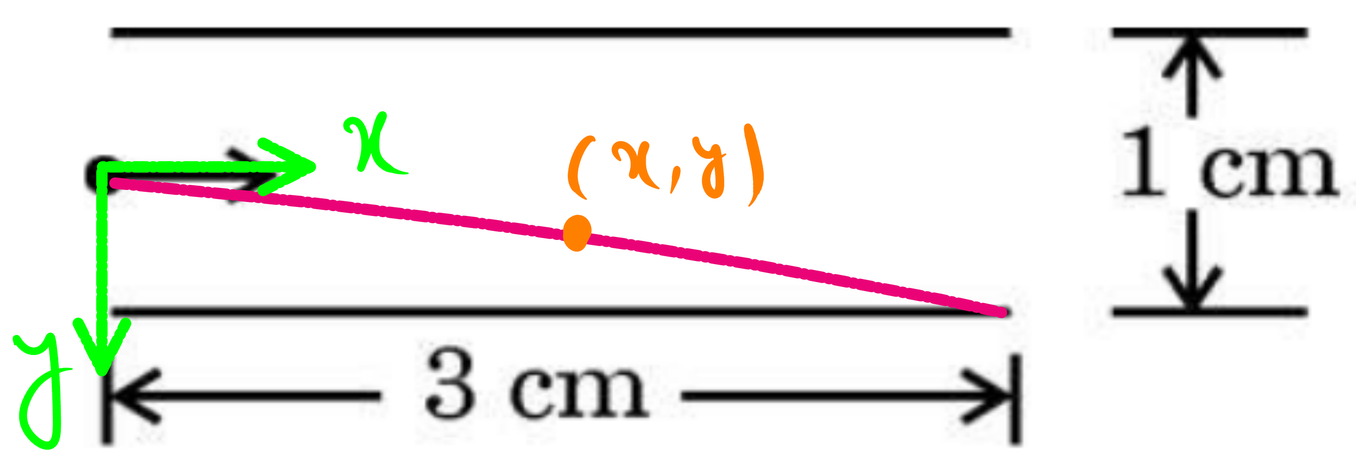

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↳ eqⁿ of parabola

When $x = 3\ cm = 3\times10^{-2}\ m$, $y = 0.5\ cm = 5\times10^{-3}\ m$

from eqⁿ (2)

$5\times10^{-3} = \frac{1}{2} \times \frac{1.6\times10^{-19} \times E}{9.1\times10^{-31}} \times \frac{9\times10^{-4}}{9\times10^{14}}$

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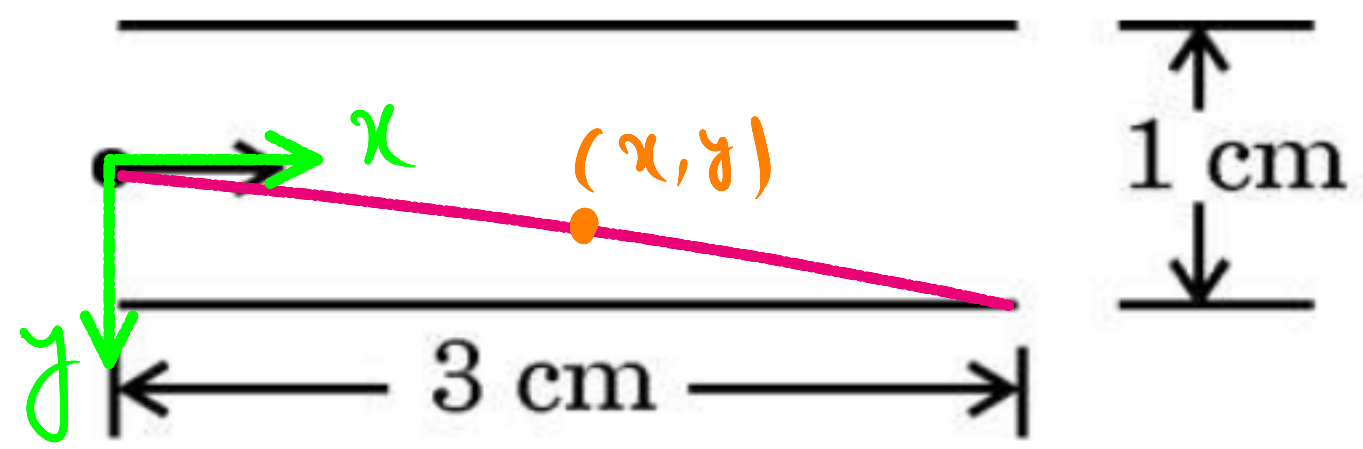

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$$\underset{0}{x - x_0} = u_x t + \frac{1}{2}\times 0 \times t^2$$

$$x = u_x t$$

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$$y = \frac{1}{2}a_y t^2 \quad (\because u_y = 0)$$

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When $x = 3\ cm = 3\times10^{-2}\ m$, $y = 0.5\ cm = 5\times10^{-3}\ m$

from eqn (2)

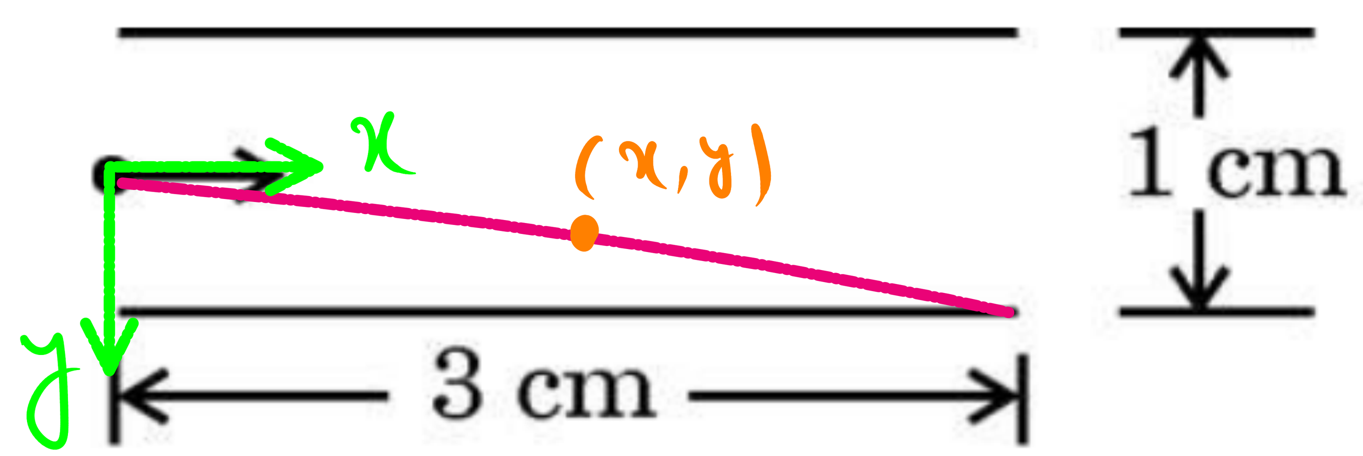
$$5\times10^{-3} = \frac{1}{\cancel{2}}\times\frac{\overset{0.8}{\cancel{1.6}}\times10^{-19}\times E}{9.1\times10^{-31}}\times\frac{\cancel{9}\times10^{-4}}{\cancel{9}\times10^{14}}$$

$$5\times10^{-3} = \frac{0.8}{9.1}\times10^{-6}\times E$$

$$E = \frac{5\times9.1}{0.8}\times10^{3}$$

$$E = 56.875\times10^{3}\ \frac{V}{m}$$

34. A beam of electrons moving horizontally with a velocity of 3×10^7 m/s enters a region between two plates as shown in the figure. A suitable potential difference is applied across the plates such that the electron beam just strikes the edge of the lower plate.



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$5\times10^{-3} = \frac{0.8}{9.1}\times10^{-6}\times E$

$E = \frac{5\times9.1}{0.8}\times10^{3}$

$E = 56.875\times10^{3}\ \frac{V}{m}$

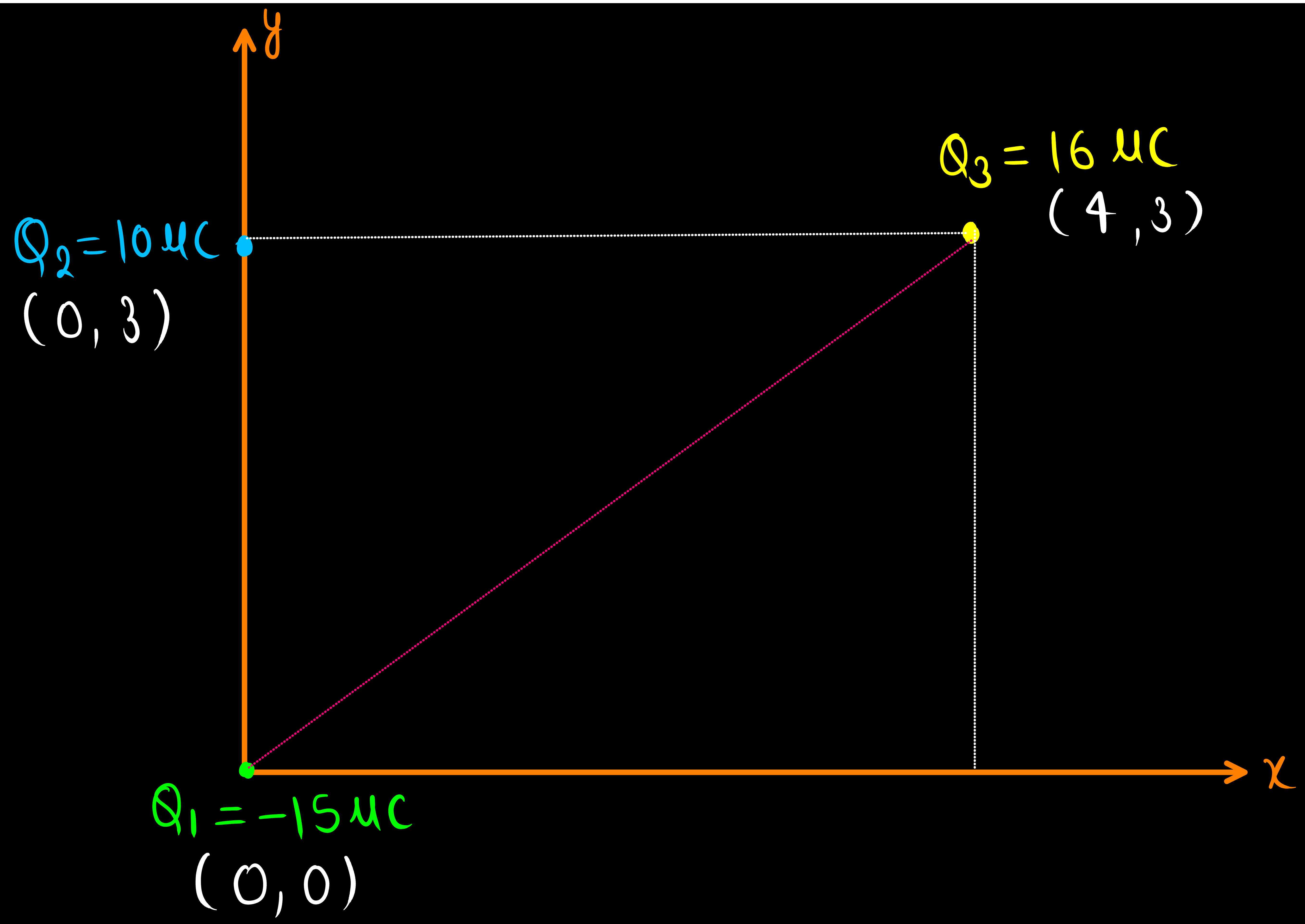
$V = Ed$

$V = 56.875\times10^{+3}\ \frac{V}{m}\times10^{-2}\ m$

$\boxed{V = 568.75\ V}$

28. Three point charges Q_1 ($-15\ \mu C$), Q_2 ($10\ \mu C$) and Q_3 ($16\ \mu C$) are located at (0 cm, 0 cm), (0 cm, 3 cm) and (4 cm, 3 cm) respectively. Calculate the electrostatic potential energy of this system of charges. *3*

28. Three point charges Q_1 (-15 μC), Q_2 (10 μC) and Q_3 (16 μC) are located at (0 cm, 0 cm), (0 cm, 3 cm) and (4 cm, 3 cm) respectively. Calculate the electrostatic potential energy of this system of charges. *3*



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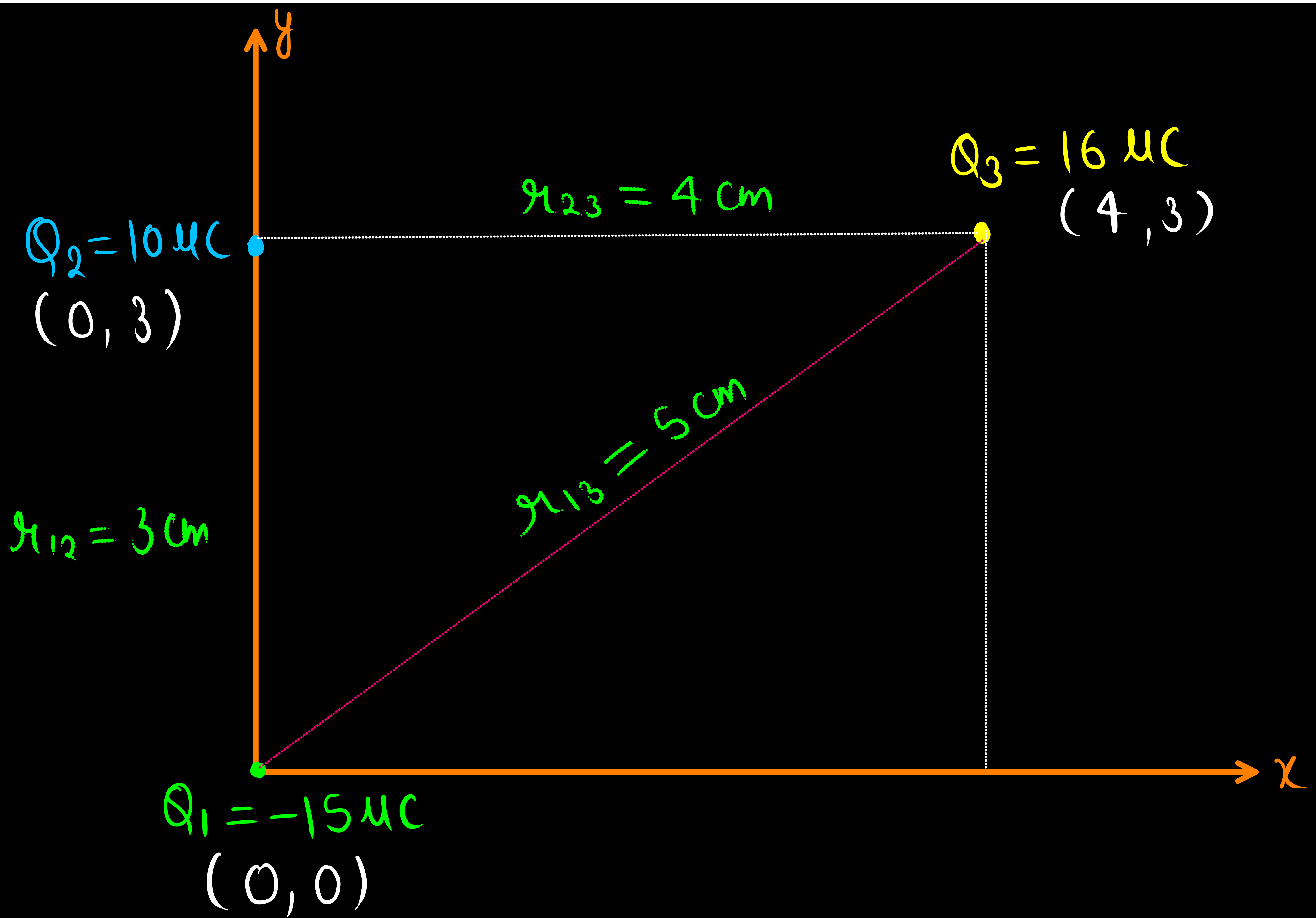
$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1 Q_2}{r_{12}} + \frac{Q_1 Q_3}{r_{13}} + \frac{Q_2 Q_3}{r_{23}}\right]$$

$$+ \frac{10\times10^{-6}\times16\times10^{-6}}{4\times10^{-2}}\Big]$$



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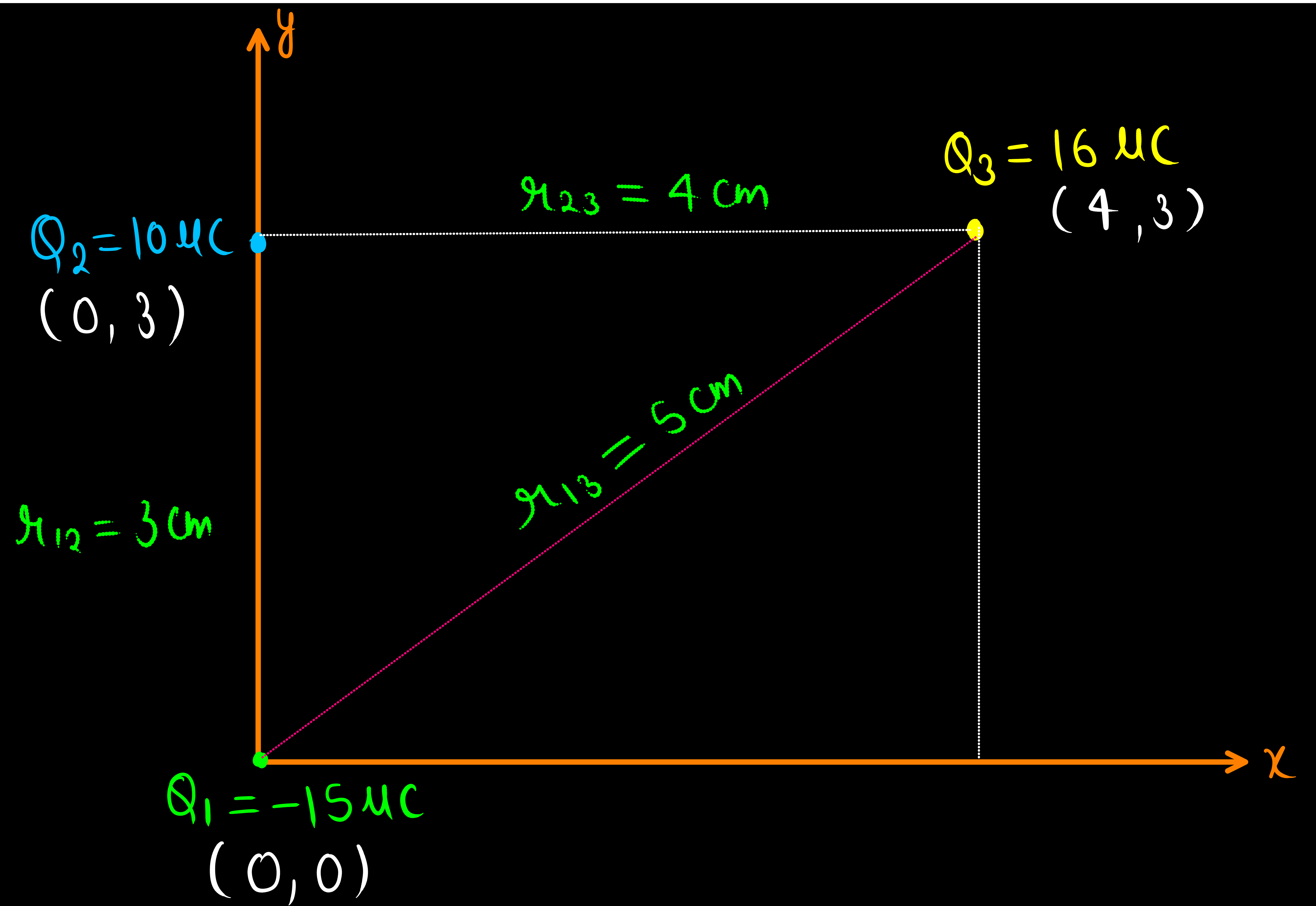
$$U = \frac{9\times10^{9}\times10^{-12}}{10^{-2}}\left[-50 - 48 + 40\right]$$



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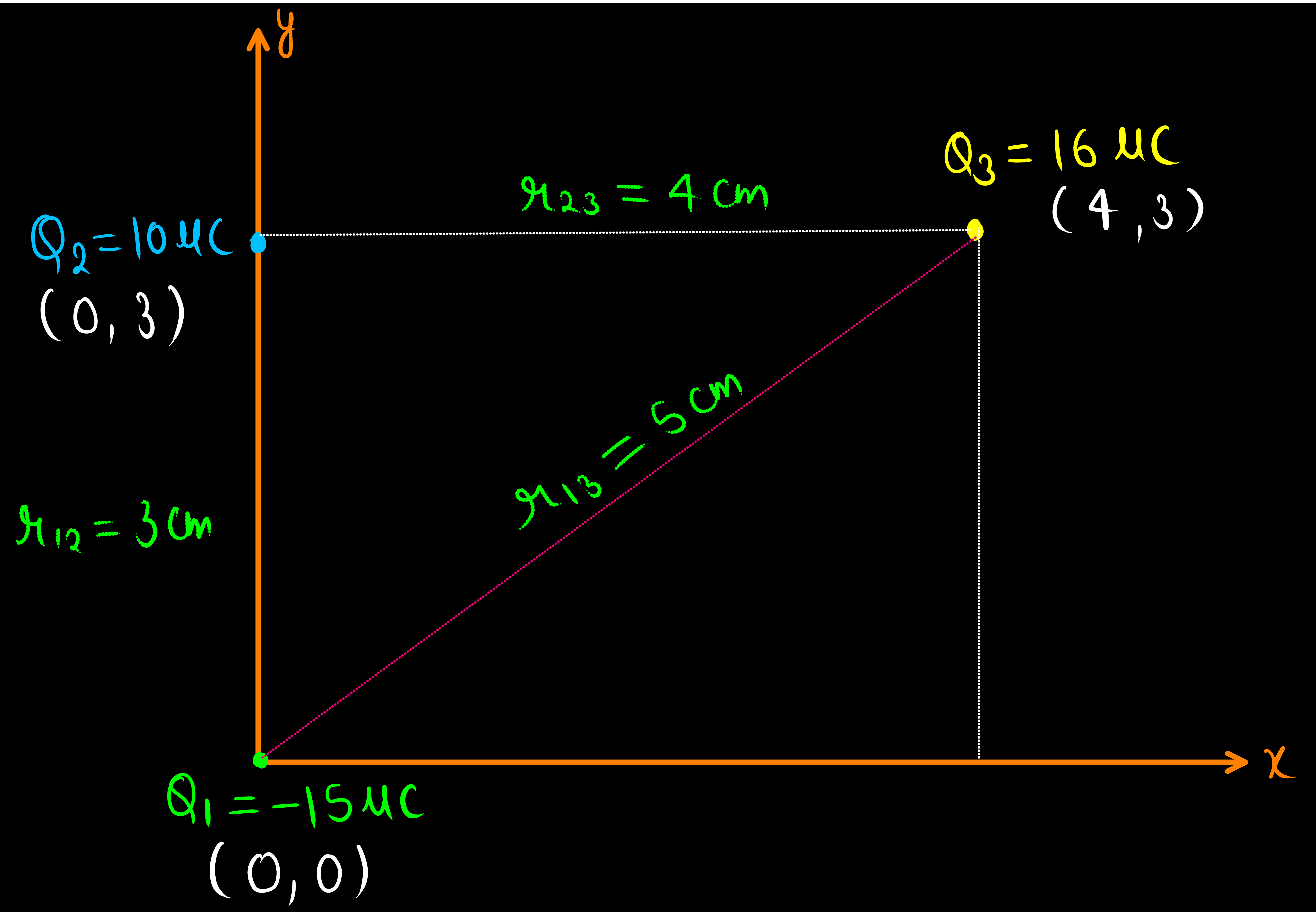
$$U = \frac{9\times10^{9}\times10^{-12}}{10^{-2}}\left[-50 - 48 + 40\right]$$

$$U = 9\times10^{-1}\times(-58)$$

$$\boxed{U = 52{\cdot}2\ \text{J}}$$



28. Three point charges Q_1 (–15 μC), Q_2 (10 μC) and Q_3 (16 μC) are located at (0 cm, 0 cm), (0 cm, 3 cm) and (4 cm, 3 cm) respectively. Calculate the electrostatic potential energy of this system of charges. *3*

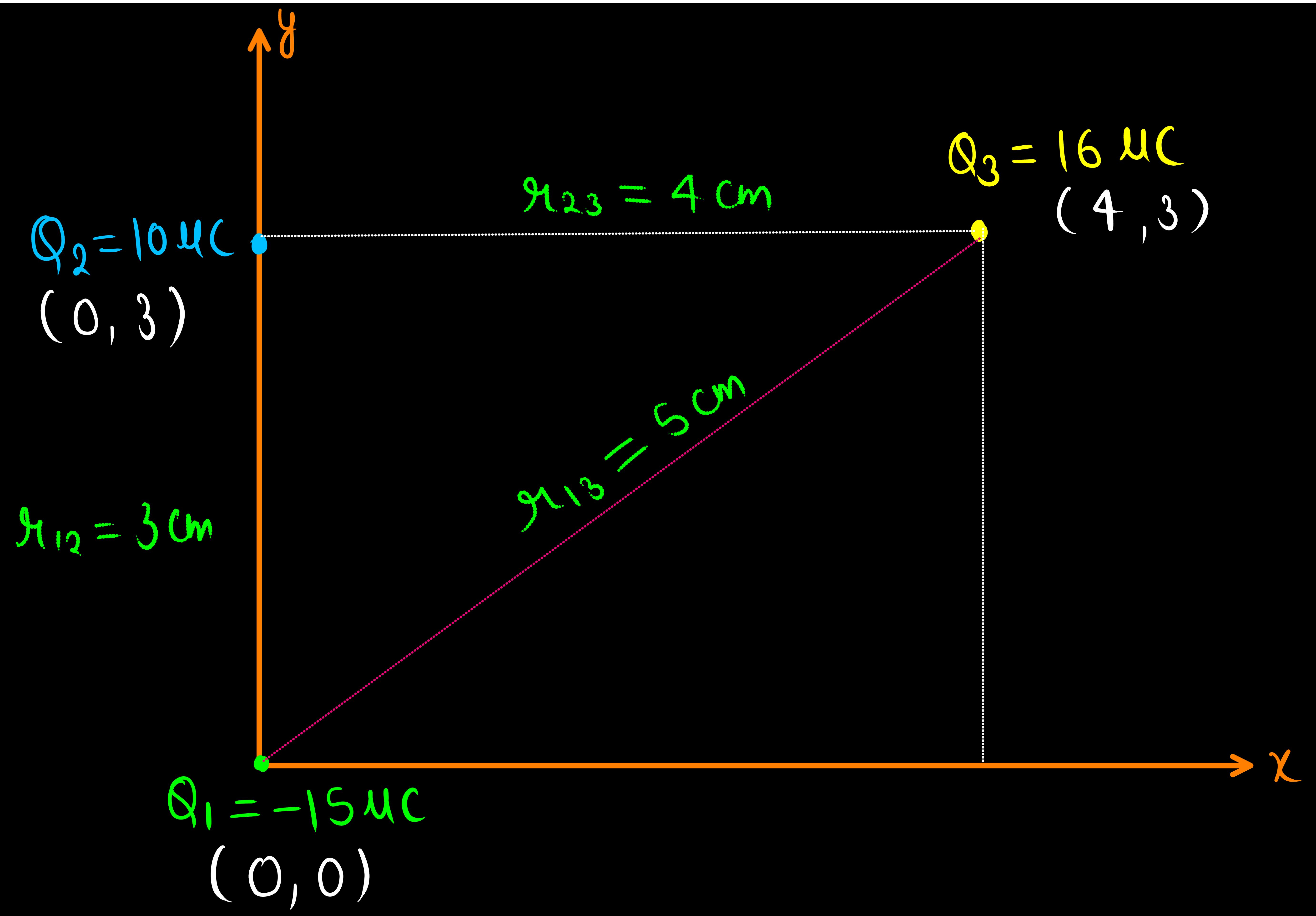
$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1Q_2}{r_{12}} + \frac{Q_1Q_3}{r_{13}} + \frac{Q_2Q_3}{r_{23}}\right]$$

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{-\overset{5}{\cancel{15}}\times10^{-6}\times10\times10^{-6}}{\cancel{3}\times10^{-2}} - \frac{\overset{3}{\cancel{15}}\times10^{-6}\times16\times10^{-6}}{\cancel{5}\times10^{-2}} + \frac{10\times10^{-6}\times\overset{4}{\cancel{16}}\times10^{-6}}{\cancel{4}\times10^{-2}}\right]$$

$$U = \frac{9\times10^{9}\times10^{-12}}{10^{-2}}\left[-50 - 48 + 40\right]$$

$$U = 9\times10^{-1}\times(-58)$$

$$\boxed{U = 52.2\ \text{J}}$$



30. A 100 μF capacitor is charged by a 12 V battery.

(a) How much electrostatic energy is stored by the capacitor ?

(b) The capacitor is disconnected from the battery and connected in parallel to another uncharged 100 μF capacitor. What is the electrostatic energy stored by the system ? *3*

a) $C = 100\ \mu F$

$V = 12\ V$

$U = \frac{1}{2} C V^2$

$U = \frac{1}{\cancel{2}} \times 100 \times 10^{-6} \times \cancel{12}^{6} \times 12$

$\boxed{U = 72 \times 10^{-4}\ J}$

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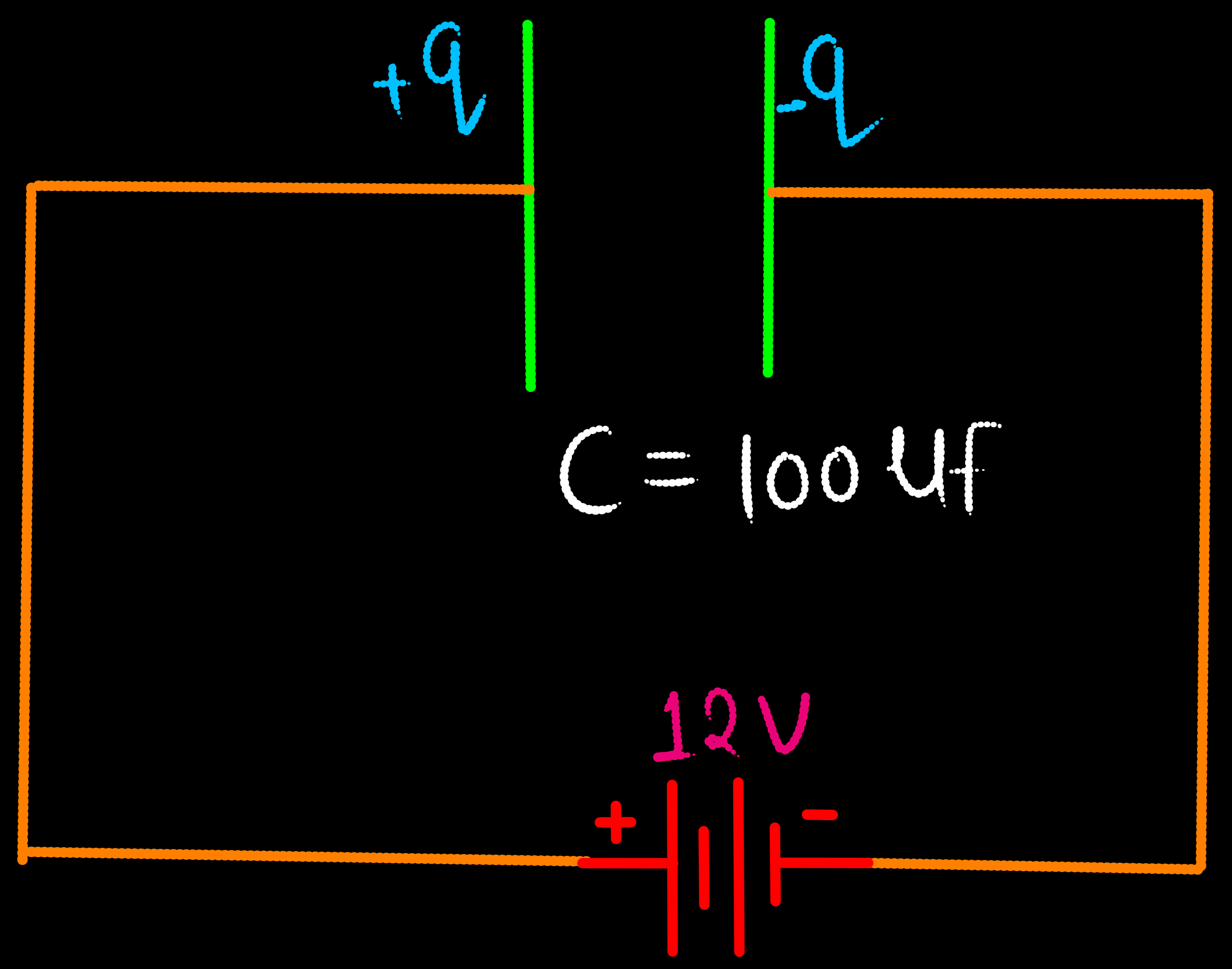

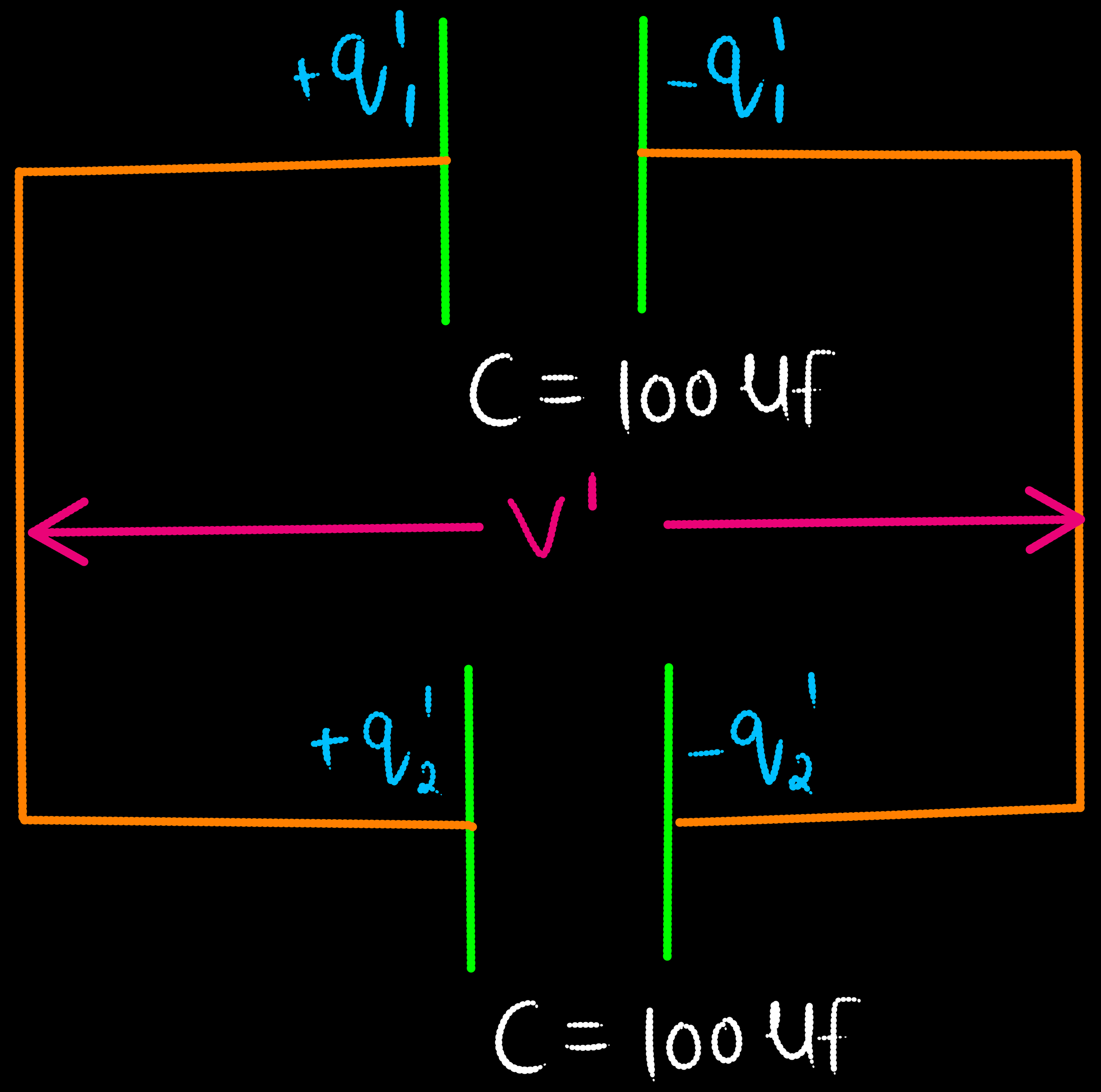

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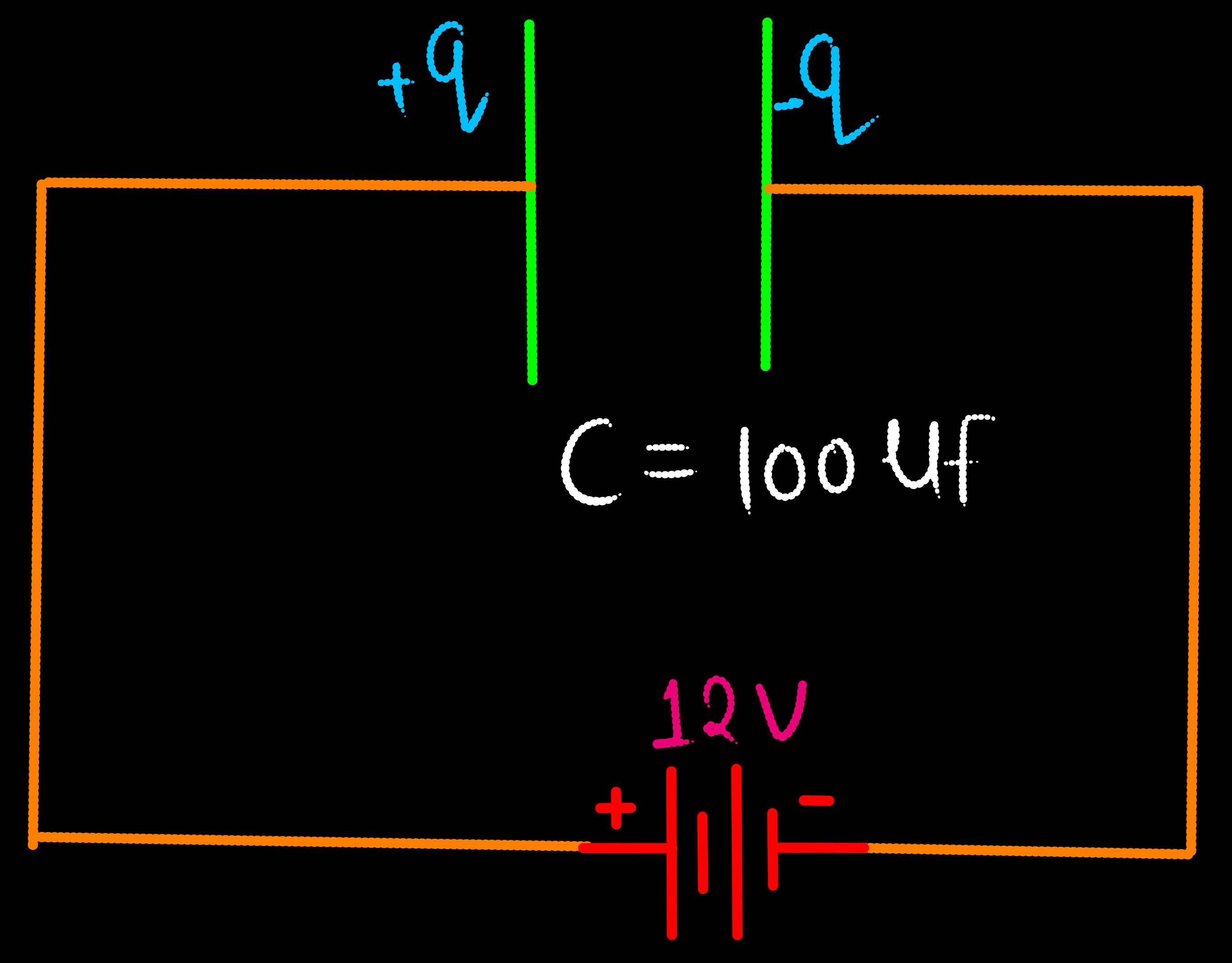
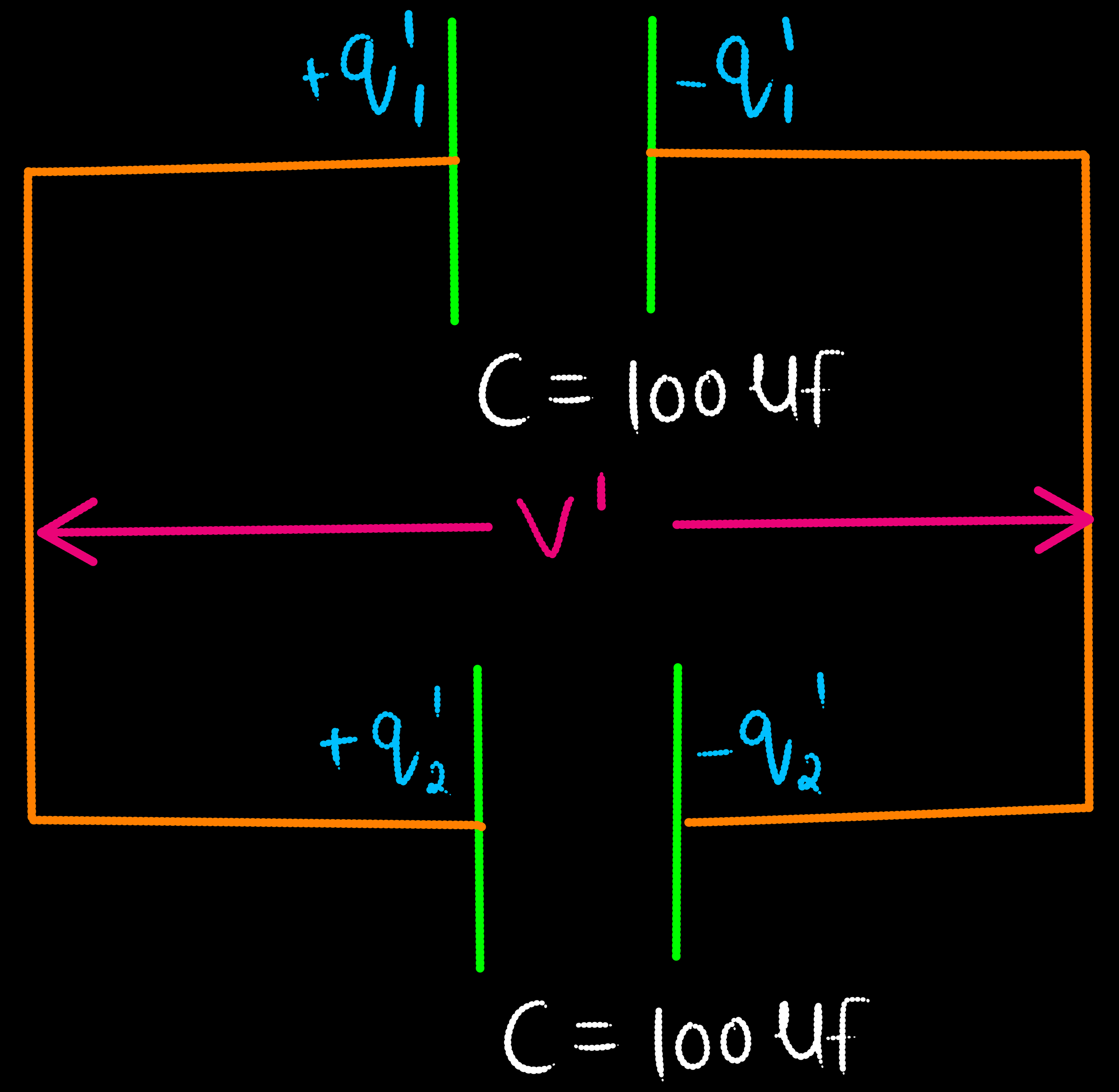
b) $q_1' + q_2' = q$

Also, $V_1 = V_2$





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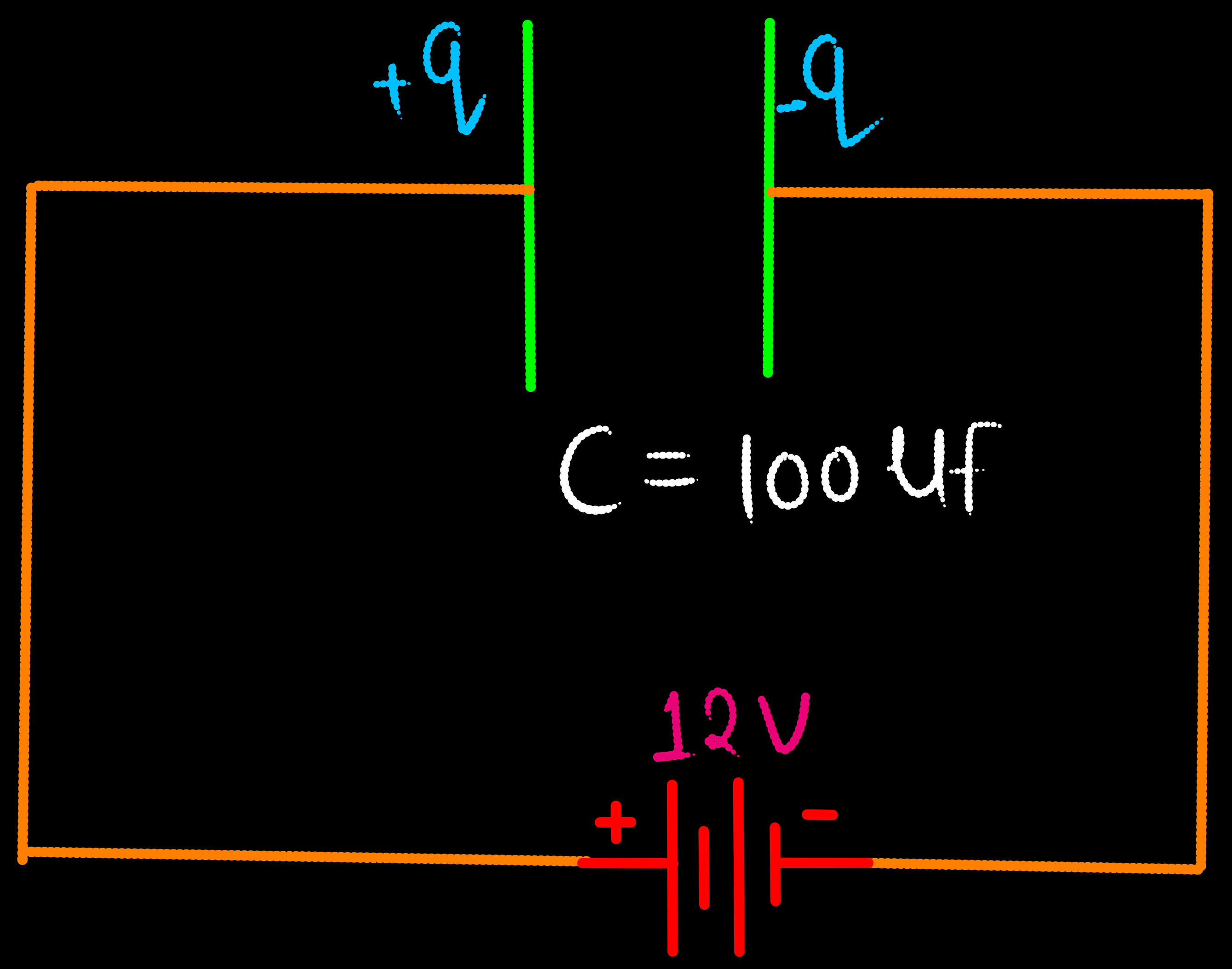

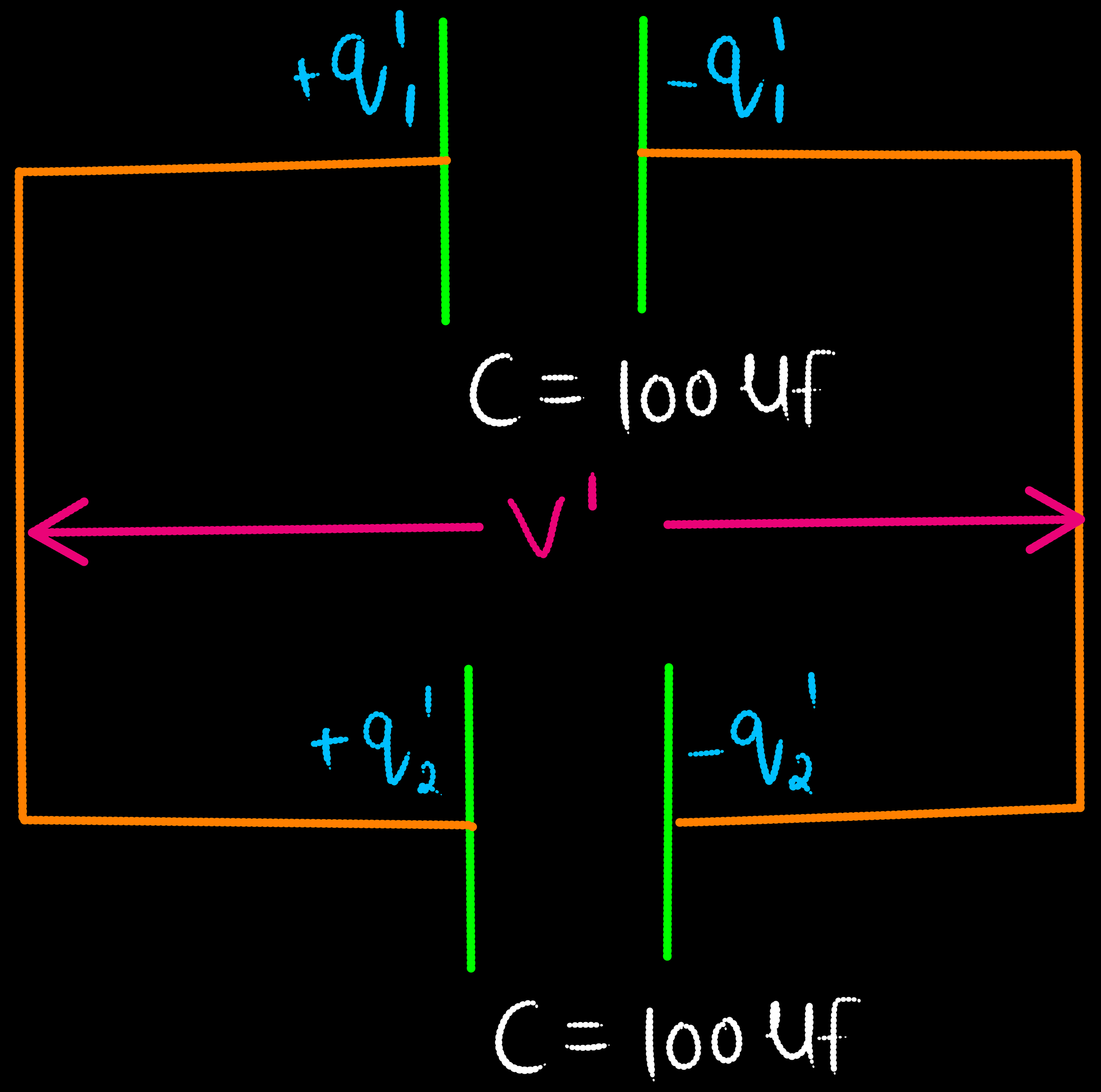

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$U = \frac{1}{2} C V^2$

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$\boxed{U = 72 \times 10^{-4}\ J}$

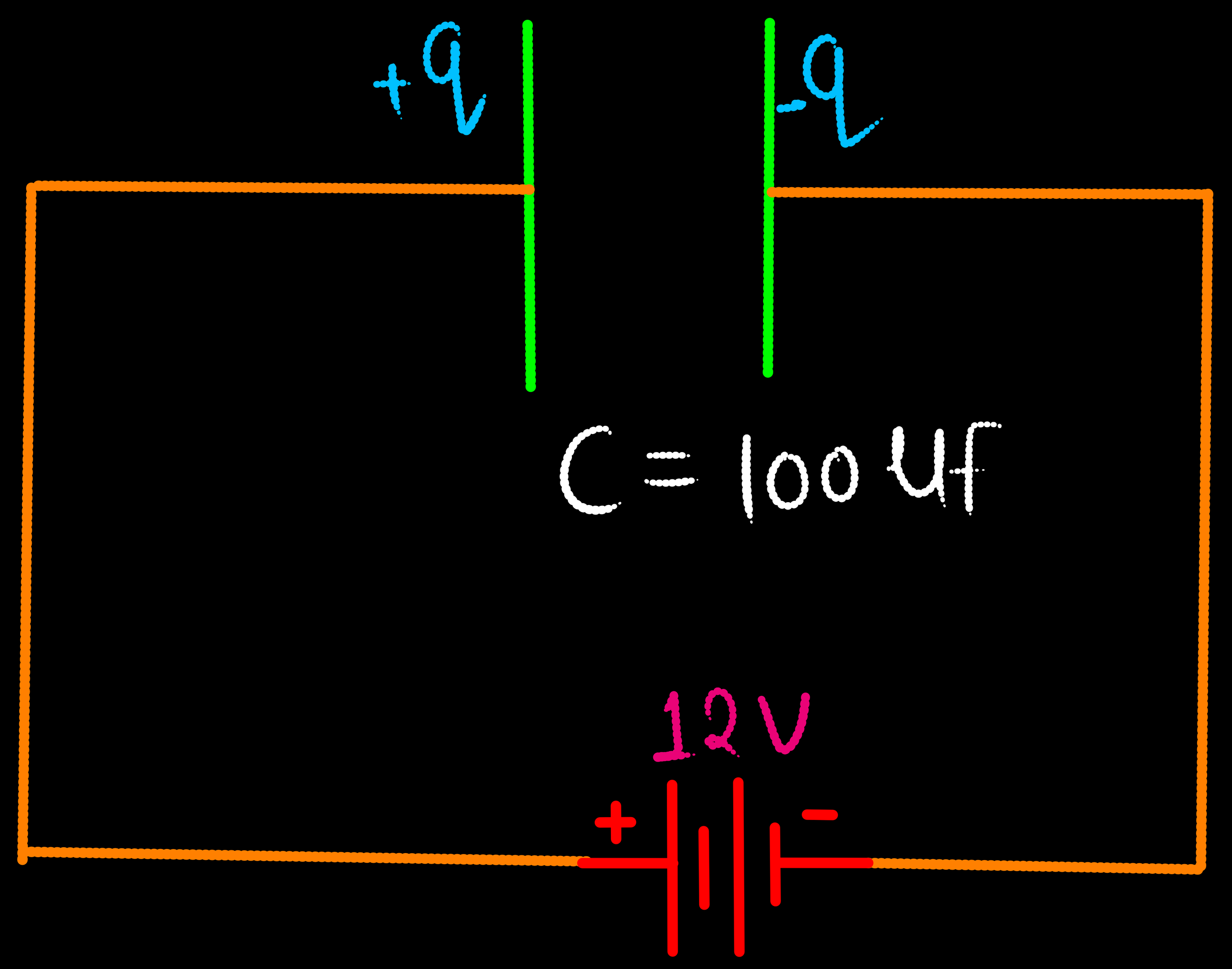
b) $q_1' + q_2' = q$

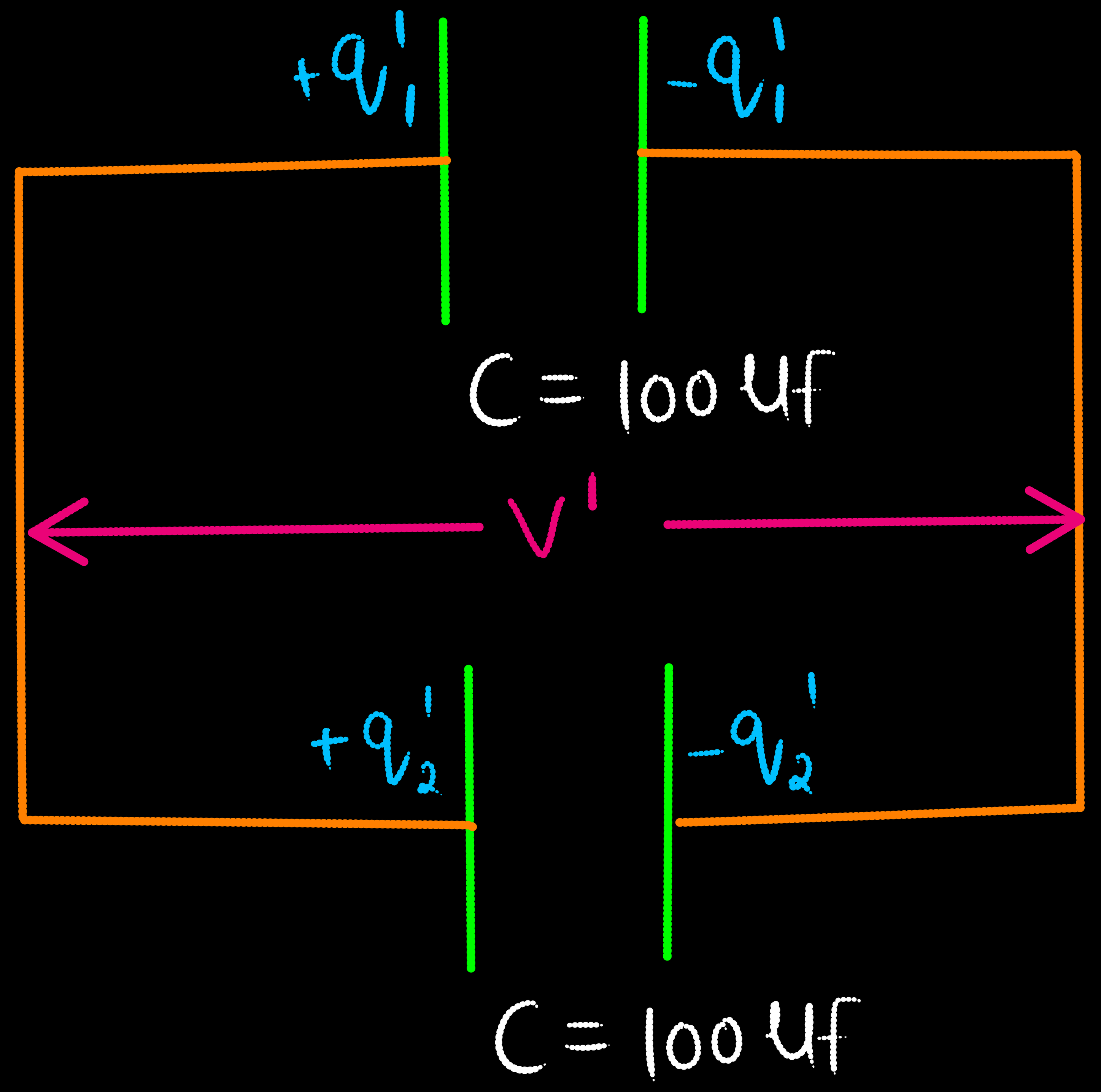
Also, $V_1 = V_2$

$\frac{q_1'}{\cancel{C}} = \frac{q_2'}{\cancel{C}}$

$q_1' = q_2' = \frac{q}{2}$

$V' = \frac{q_1'}{C} = \frac{q}{2C} = \frac{V}{2}$





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b) $q_1' + q_2' = q$

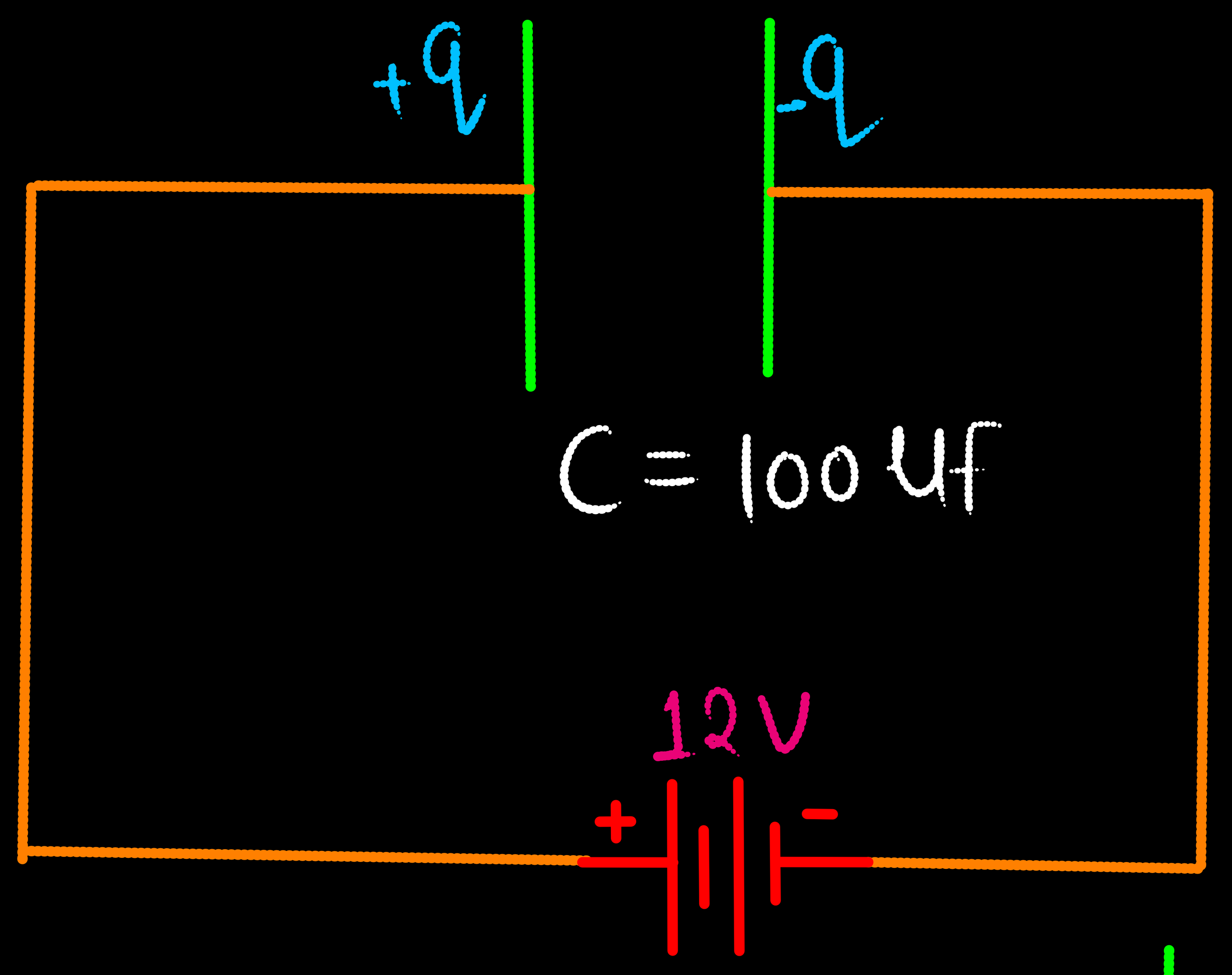
Also, $V_1 = V_2$

$\frac{q_1'}{\cancel{C}} = \frac{q_2'}{\cancel{C}}$

$q_1' = q_2' = \frac{q}{2}$

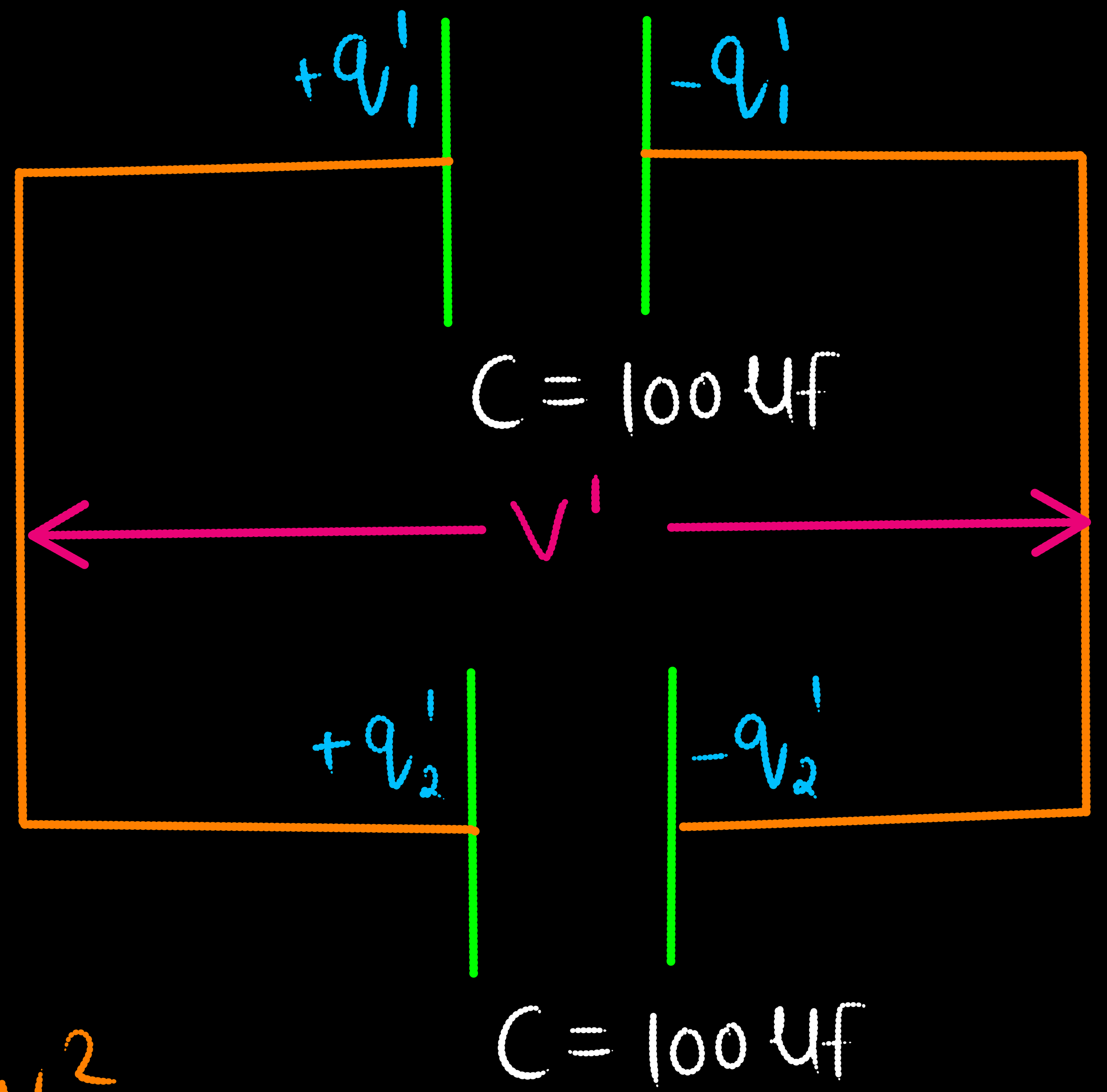
$V' = \frac{q_1'}{C} = \frac{q}{2C} = \frac{V}{2}$

$C' = C + C = 2C$



$U' = \frac{1}{2} C' V'^2$

$U' = \frac{1}{2} \times 2C \times \frac{V^2}{4}$

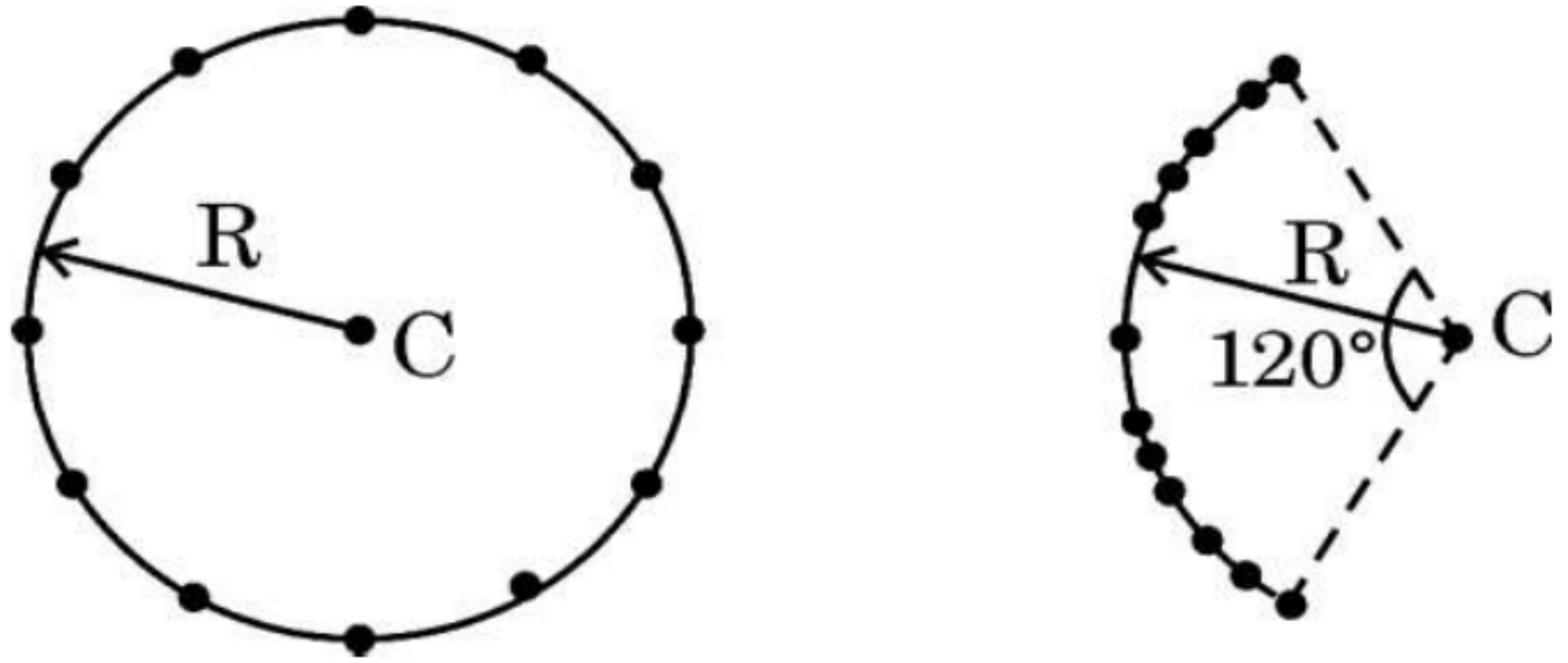


$U' = \frac{1}{2} \times \frac{1}{2} C V^2$

$\boxed{U' = \frac{1}{2} U = 36 \times 10^{-4}\ J}$

26. (a) Twelve negative charges of same magnitude are equally spaced and fixed on the circumference of a circle of radius R as shown in Fig. (i). Relative to potential being zero at infinity, find the electric potential and electric field at the centre C of the circle.

(b) If the charges are unequally spaced and fixed on an arc of 120° of radius R as shown in Fig. (ii), find electric potential at the centre C. *3*



(i) (ii)

(b) (i) Consider two identical point charges located at points (0, 0) and (a, 0).

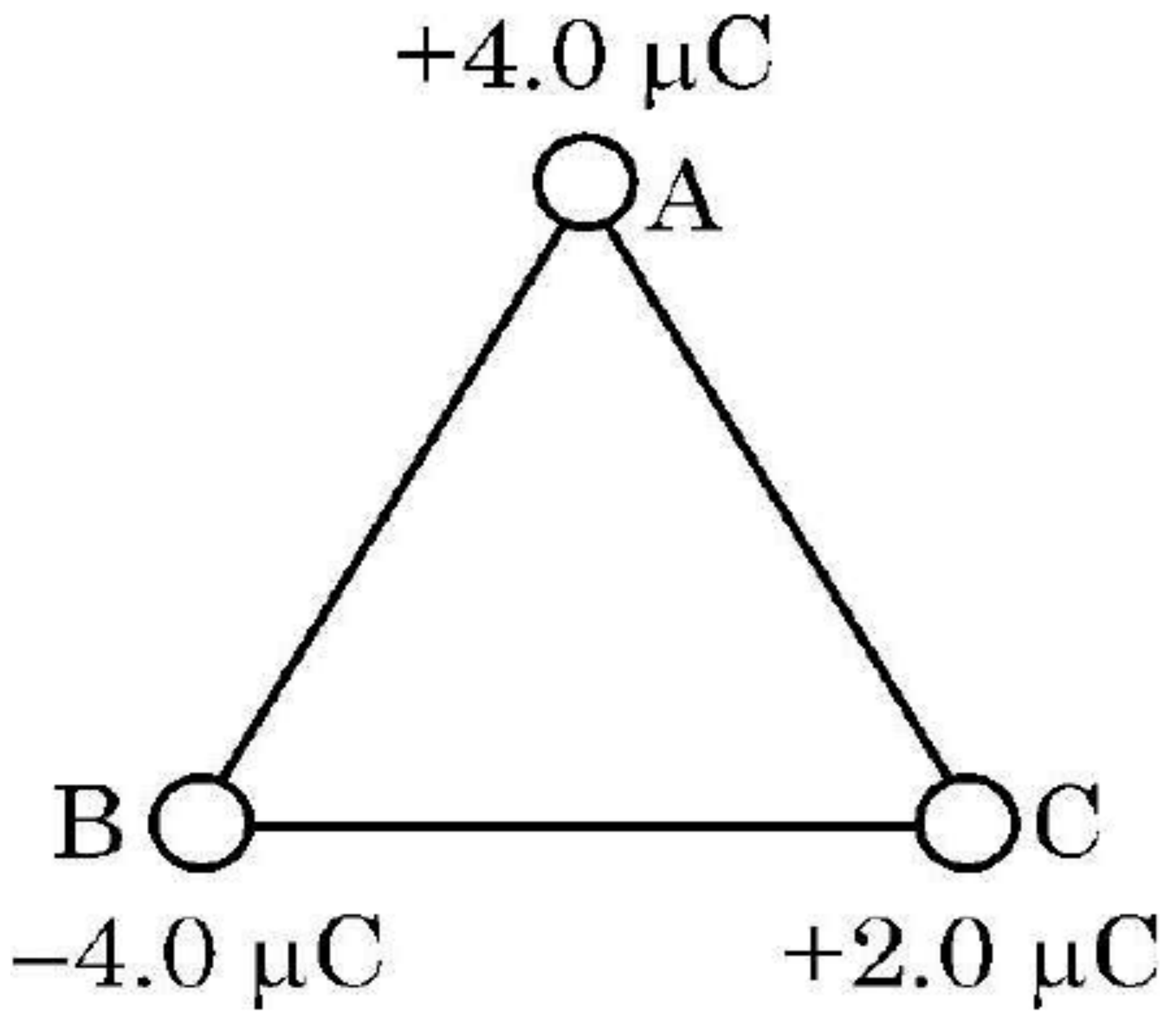
(1) Is there a point on the line joining them at which the electric field is zero ?

(2) Is there a point on the line joining them at which the electric potential is zero ?

Justify your answers for each case.

(ii) State the significance of negative value of electrostatic potential energy of a system of charges.

Three charges are placed at the corners of an equilateral triangle ABC of side 2.0 m as shown in figure. Calculate the electric potential energy of the system of three charges.



28. (a) Two charged conducting spheres of radii a and b are connected to each other by a wire. Find the ratio of the electric fields at their surfaces. **3**

OR

(b) A parallel plate capacitor (A) of capacitance C is charged by a battery to voltage V. The battery is disconnected and an uncharged capacitor (B) of capacitance 2C is connected across A. Find the ratio of

(i) final charges on A and B.

(ii) total electrostatic energy stored in A and B finally and that stored in A initially.

18. **Assertion (A) :** Work done in moving a charge around a closed path, in an electric field is always zero.

Reason (R) : Electrostatic force is a conservative force. **1**

12. The capacitors, each of 4 μF are to be connected in such a way that the effective capacitance of the combination is 6 μF. This can be achieved by connecting **1**

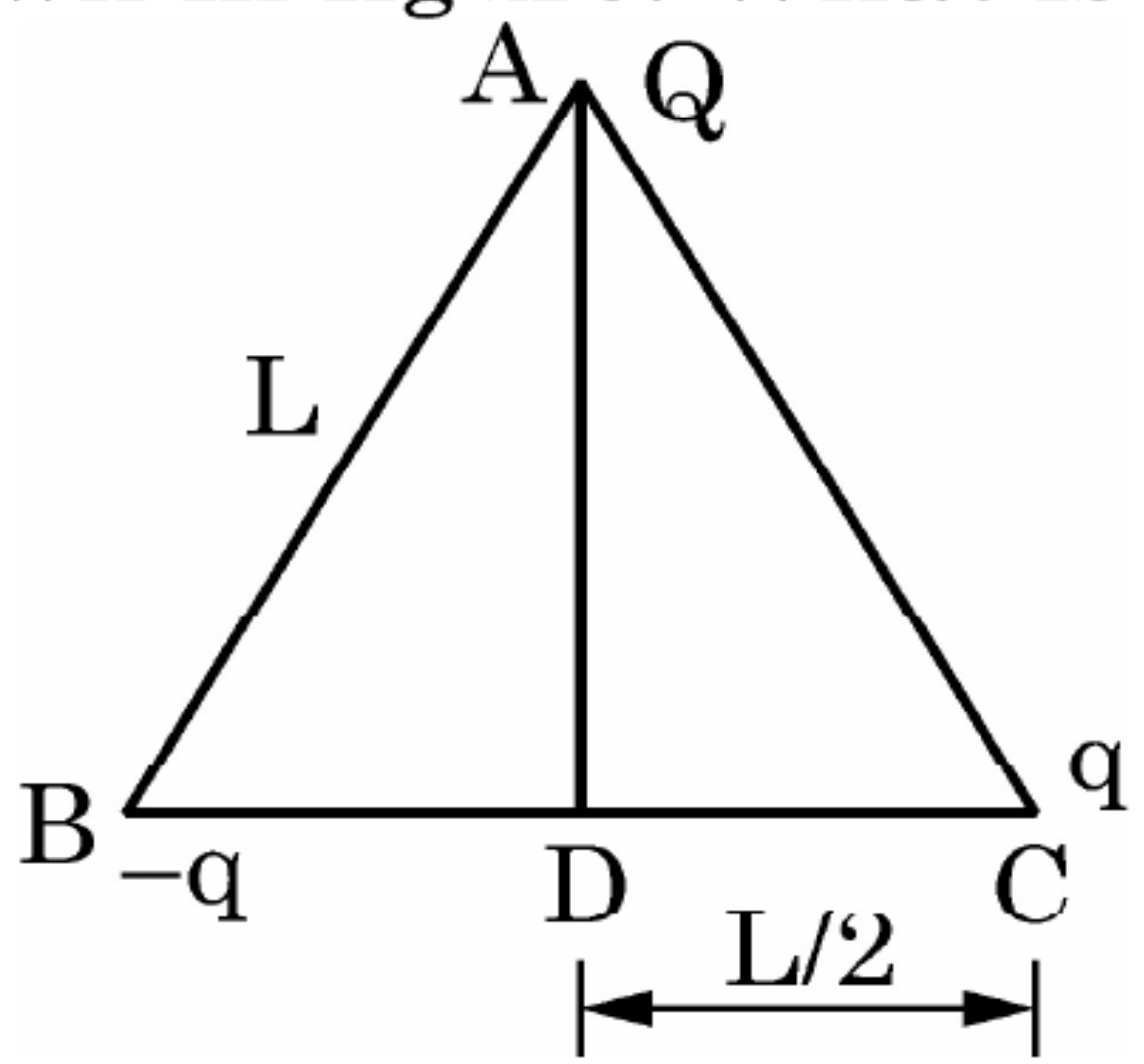
(A) All three in parallel

(B) All three in series

(C) Two of them connected in series and the combination in parallel to the third.

(D) Two of them connected in parallel and the combination in series to the third.

22. Three point charges Q, q and – q are kept at the vertices of an equilateral triangle of side L as shown in figure. What is **2**

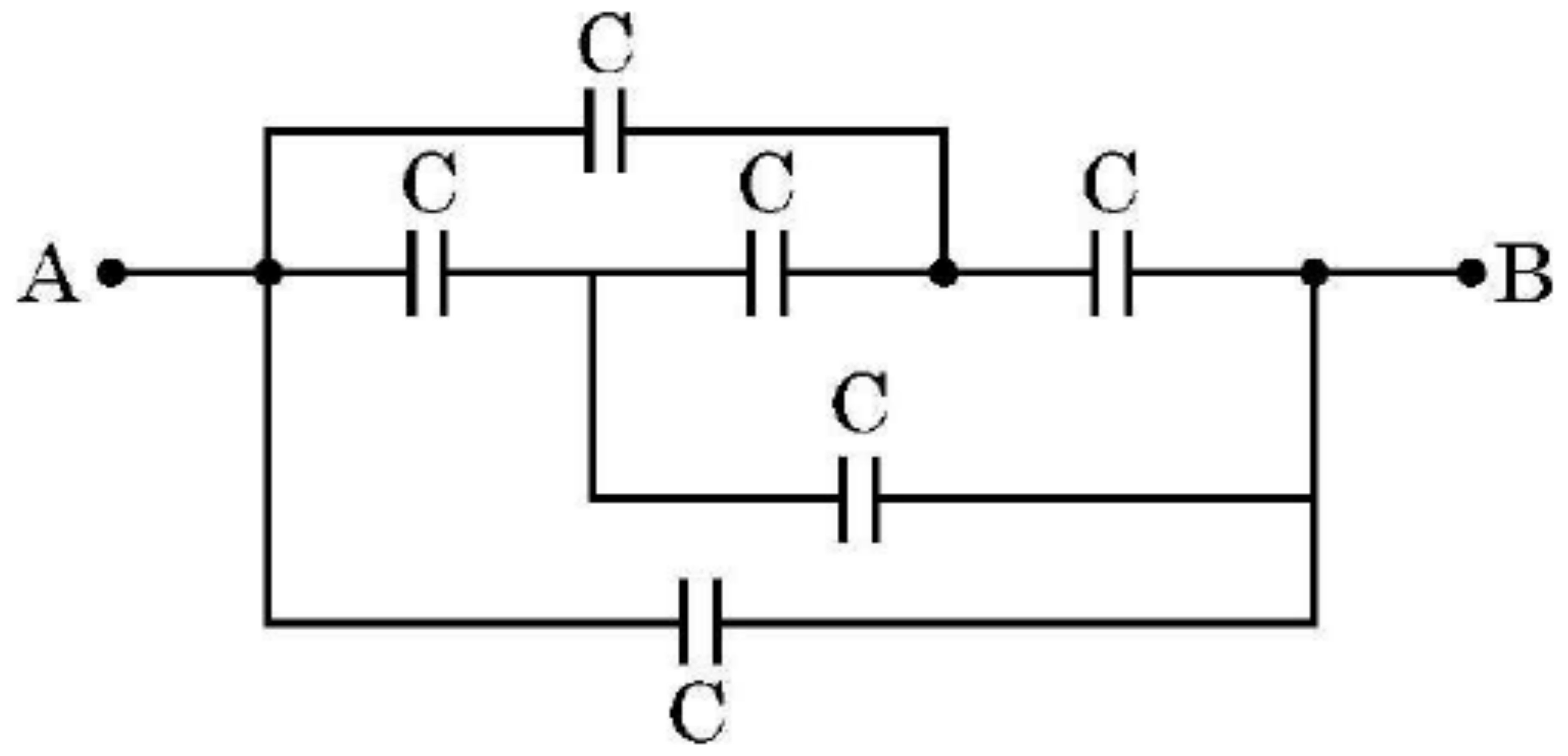


(i) the electrostatic potential energy of the arrangement ? and

(ii) the potential at point D ?

35. A capacitor is a system of two conductors separated by an insulator. The two conductors have equal and opposite charges with a potential difference between them. The capacitance of a capacitor depends on the geometrical configuration (shape, size and separation) of the system and also on the nature of the insulator separating the two conductors. They are used to store charges. Like resistors, capacitors can be arranged in series or parallel or a combination of both to obtain desired value of capacitance. **4**

(i) Find the equivalent capacitance between points A and B in the given diagram.

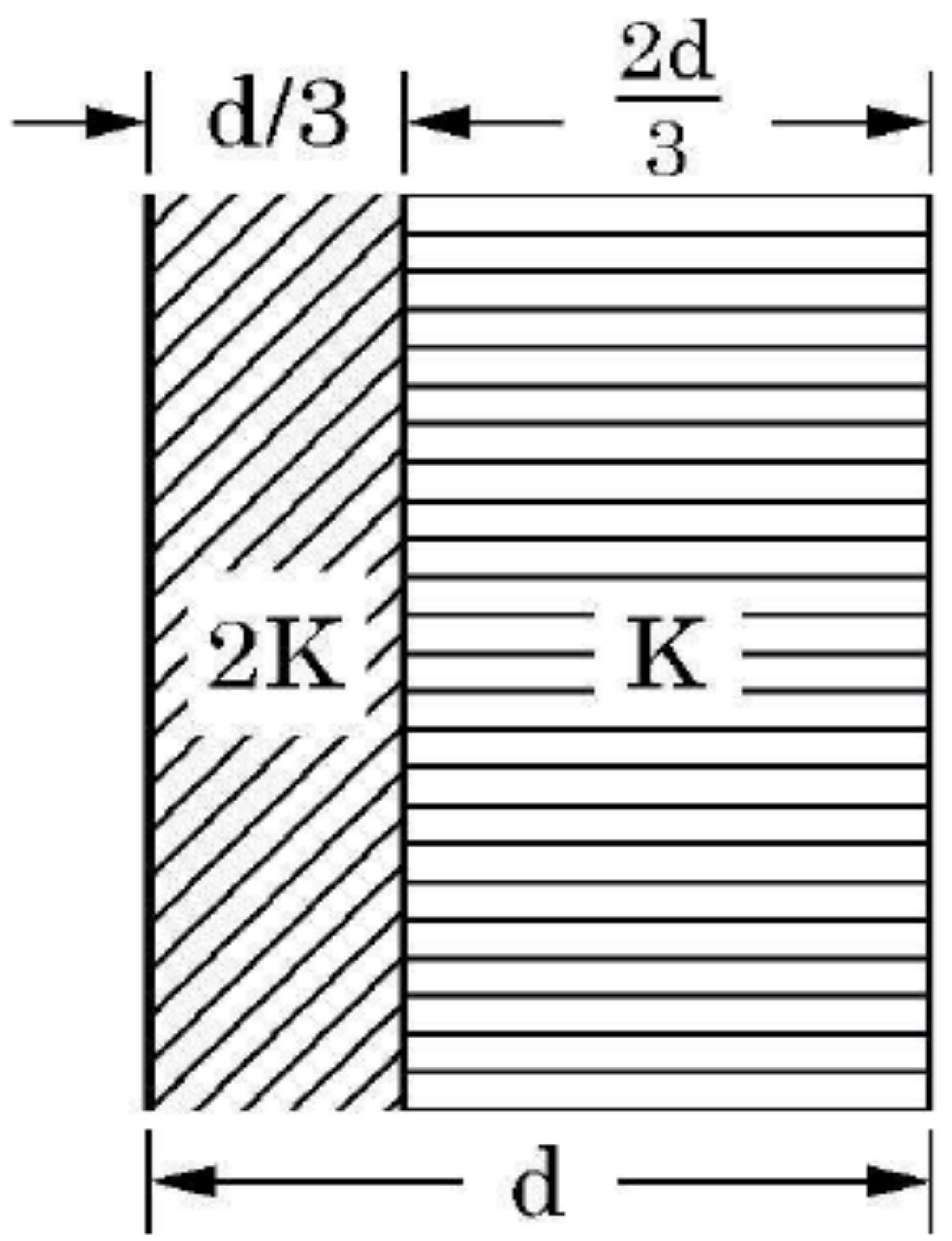


(ii) A dielectric slab is inserted between the plates of a parallel plate capacitor. The electric field between the plates decreases. Explain.

(iii) A capacitor A of capacitance C, having charge Q is connected across another uncharged capacitor B of capacitance 2C. Find an expression for (a) the potential difference across the combination and (b) the charge lost by capacitor A.

OR

(iii) Two slabs of dielectric constants 2K and K fill the space between the plates of a parallel plate capacitor of plate area A and plate separation d as shown in figure. Find an expression for capacitance of the system.



22. Depict the orientation of an electric dipole in (a) stable and (b) unstable equilibrium in an external uniform electric field.
Write the potential energy of the dipole in each case. **2**

34. Case Study : A charged body inside an electric field.

A charged latex sphere of mass $1{\cdot}85 \times 10^{-13}$ kg is held stationary in between two horizontal plates which are separated by a distance $0{\cdot}62$ cm. The potential difference between the plates is $1{\cdot}24 \times 10^{3}$ V with the upper plate being positive.

Based on the above facts, answer the following questions :

(i) What is the nature of charge on the latex sphere ? *1*

(ii) What is the direction of electric field between the plates ? *1*

(iii) What is the magnitude of electric field between the plates ? *2*

OR

(iii) What is the magnitude of charge on the latex sphere ? (Take $g = 10\ ms^{-2}$) *2*

(b) (i) How will the capacitance of a parallel plate capacitor change if :

(1) the plates area is doubled ?

(2) the separation between the plates is doubled ?

(ii) The effective capacitance of three capacitors of the same capacitance connected in series is 1 μF. Find the : *5*

(1) effective capacitance if they are connected in parallel.

(2) ratio of energy stored in the parallel combination of the capacitors to that in the series combination, if the combinations are connected to the same source one by one.

17. *Assertion (A) :* The electrostatic field $\vec{E}$ is a conservative field.

Reason (R) : Line integral of electric field $\vec{E}$ around a closed path is non zero.

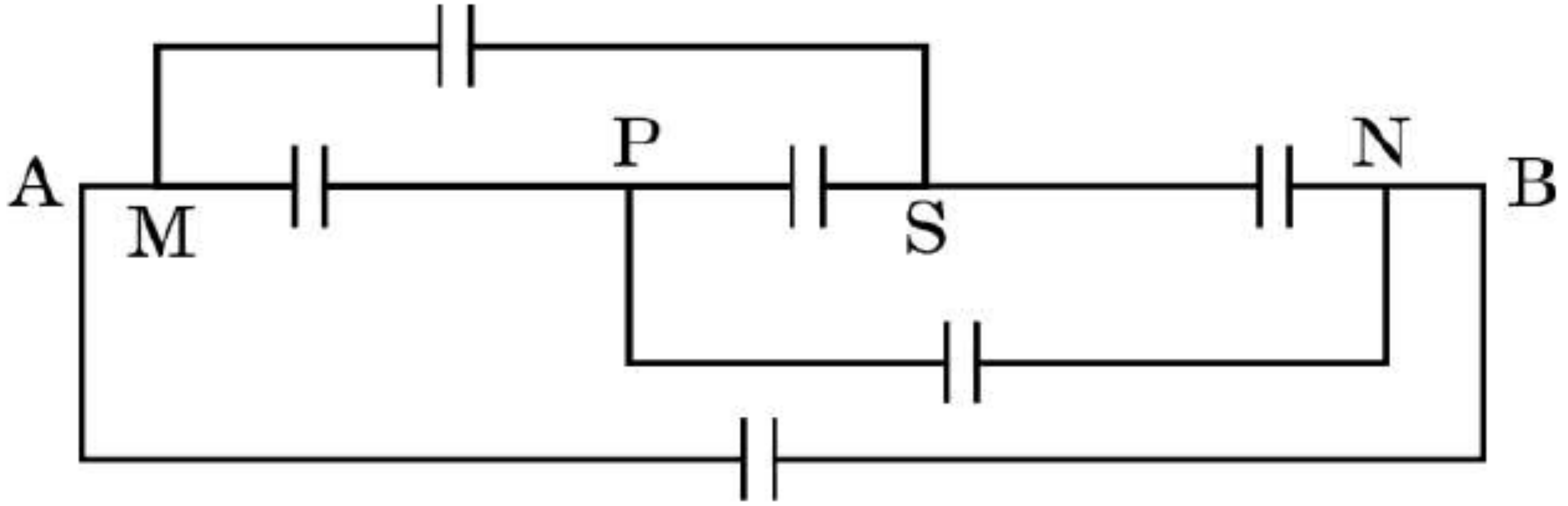
A parallel plate capacitor is an arrangement of two identical metal plates kept parallel, a small distance apart. The capacitance of a capacitor depends on the size and separation of the two plates and also on the dielectric constant of the medium between the plates. Like resistors, capacitors can also be arranged in series or parallel or a combination of both. By virtue of electric field between the plates, charged capacitors store energy.

(a) The capacitance of a parallel plate capacitor increases from 10 μF to 80 μF on introducing a dielectric medium between the plates. Find the dielectric constant of the medium. *1*

(b) n capacitors, each of capacitance C, are connected in series. Find the equivalent capacitance of the combination. *1*

(c) A capacitor is charged to a potential (V) by connecting it to a battery. After some time, the battery is disconnected and a dielectric is introduced between the plates. How will the potential difference between the plates, and the energy stored in it be affected ? Justify your answer. *2*

(c) Find the equivalent capacitance between points A and B, if capacitance of each capacitor is C. *2*



24. (a) A uniform electric field E of 500 N/C is directed along +x axis. O, B and A are three points in the field having x and y coordinates (in cm) (0, 0), (4, 0) and (0, 3) respectively. Calculate the potential difference between the points (i) O and A, and (ii) O and B. *2*

OR

(b) Three point charges 1 μC, –1 μC and 2 μC are kept at the vertices A, B and C respectively of an equilateral triangle of side 1 m. A_1, B_1 and C_1 are the midpoints of the sides AB, BC and CA respectively. Calculate the net amount of work done in displacing the charge from A to A_1, from B to B_1 and from C to C_1. *2*

33. (a) (i) Draw equipotential surfaces for an electric dipole.

(ii) Two point charges q_1 and q_2 are located at $\vec{r}_1$ and $\vec{r}_2$ respectively in an external electric field $\vec{E}$. Obtain an expression for the potential energy of the system.

(iii) The dipole moment of a molecule is 10^{-30} Cm. It is placed in an electric field $\vec{E}$ of 10^5 V/m such that its axis is along the electric field. The direction of $\vec{E}$ is suddenly changed by 60° at an instant. Find the change in the potential energy of the dipole, at that instant.

30. Dielectrics play an important role in design of capacitors. The molecules of a dielectric may be polar or non-polar. When a dielectric slab is placed in an external electric field, opposite charges appear on the two surfaces of the slab perpendicular to electric field. Due to this an electric field is established inside the dielectric.

The capacitance of a capacitor is determined by the dielectric constant of the material that fills the space between the plates. Consequently, the energy storage capacity of a capacitor is also affected. Like resistors, capacitors can also be arranged in series and/or parallel.

(i) Which of the following is a polar molecule ?

(A) O_2 (B) H_2

(C) N_2 (D) HCl

(ii) Which of the following statements about dielectrics is correct ?

(A) A polar dielectric has a net dipole moment in absence of an external electric field which gets modified due to the induced dipoles.

(B) The net dipole moments of induced dipoles is along the direction of the applied electric field.

(C) Dielectrics contain free charges.

(D) The electric field produced due to induced surface charges inside a dielectric is along the external electric field.

(iii) When a dielectric slab is inserted between the plates of an isolated charged capacitor, the energy stored in it :

(A) increases and the electric field inside it also increases.

(B) decreases and the electric field also decreases.

(C) decreases and the electric field increases.

(D) increases and the electric field decreases.

(iv) (a) An air-filled capacitor with plate area A and plate separation d has capacitance C_0. A slab of dielectric constant K, area A and thickness $\left(\frac{d}{5}\right)$ is inserted between the plates. The capacitance of the capacitor will become

(A) $\left[\frac{4K}{5K+1}\right]C_0$ (B) $\left[\frac{K+5}{4}\right]C_0$

(C) $\left[\frac{5K}{4K+1}\right]C_0$ (D) $\left[\frac{K+4}{5K}\right]C_0$

OR

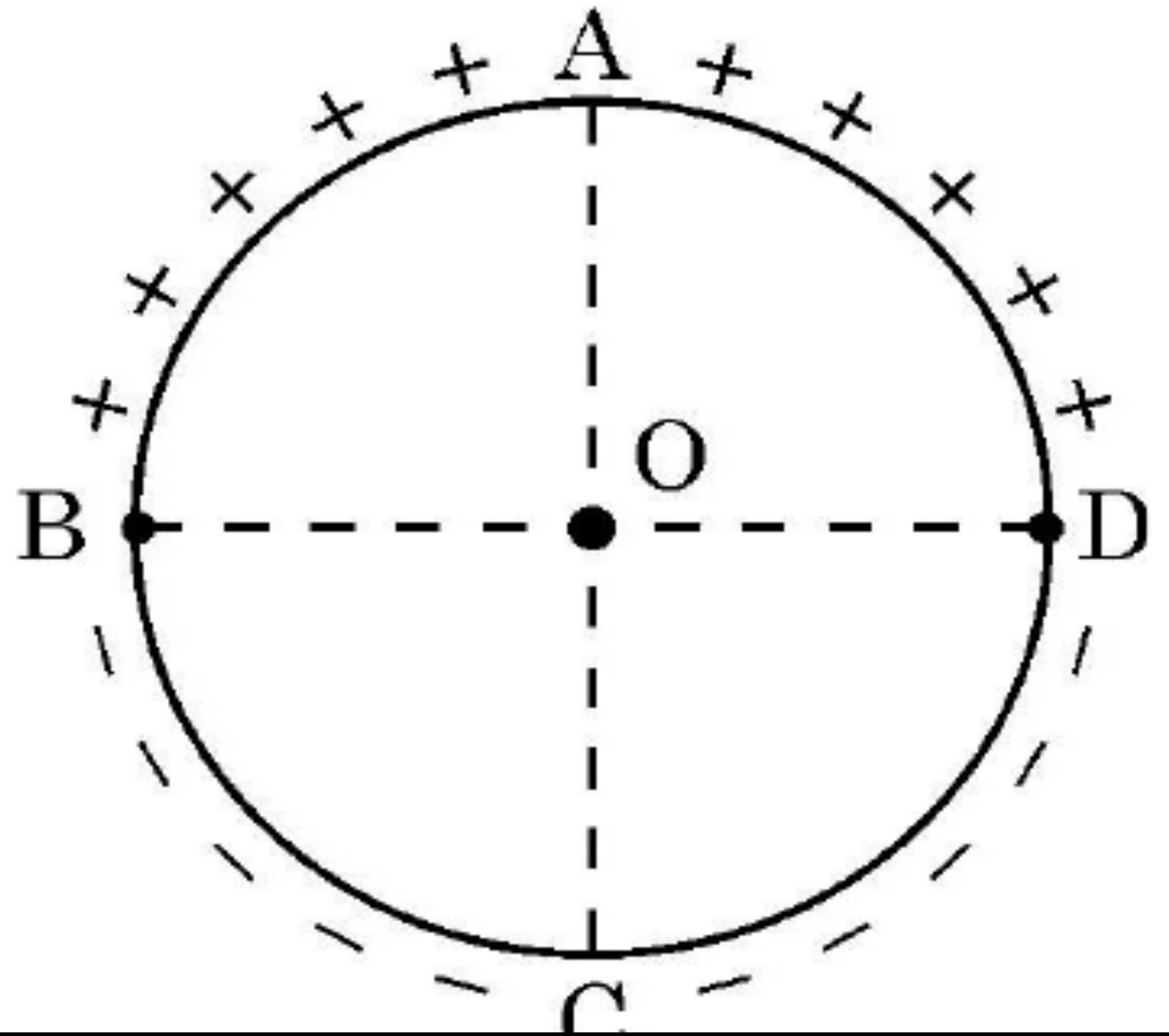
(iv) (b) Two capacitors of capacitances 2 C_0 and 6 C_0 are first connected in series and then in parallel across the same battery. The ratio of energies stored in series combination to that in parallel is

(A) $\frac{1}{4}$ (B) $\frac{1}{6}$

(C) $\frac{2}{15}$ (D) $\frac{3}{16}$

15. **Assertion (A)** : Equal amount of positive and negative charges are distributed uniformly on two halves of a thin circular ring as shown in figure. The resultant electric field at the centre O of the ring is along OC.

Reason (R) : It is so because the net potential at O is not zero.



31. (a) (i) A dielectric slab of dielectric constant 'K' and thickness 't' is inserted between plates of a parallel plate capacitor of plate separation d and plate area A. Obtain an expression for its capacitance.

(ii) Two capacitors of different capacitances are connected first (1) in series and then (2) in parallel across a dc source of 100 V. If the total energy stored in the combination in the two cases are 40 mJ and 250 mJ respectively, find the capacitance of the capacitors. **5**

23. Two conducting spherical shells A and B of radii R and 2R are kept far apart and charged to the same charge density σ. They are connected by a wire. Obtain an expression for final potential of shell A. **3**

1. An electric dipole of dipole moment $\vec{p}$ is kept in a uniform electric field $\vec{E}$. The amount of work done to rotate it from the position of stable equilibrium to that of unstable equilibrium will be **1**

(A) 2 pE (B) –2 pE

(C) pE (D) zero

23. A thin spherical conducting shell of radius R has a charge q. A point charge Q is placed at the centre of the shell. Find (i) The charge density on the outer surface of the shell and (ii) the potential at a distance of (R/2) from the centre of the shell. **3**

1. Three point charges, each of charge q are placed on vertices of a triangle ABC, with AB = AC = 5L, BC = 6L. The electrostatic potential at midpoint of side BC will be **1**

(A) $\frac{11}{48}\frac{q}{\pi\varepsilon_0 L}$

(B) $\frac{8q}{36\pi\varepsilon_0 L}$

(C) $\frac{5q}{24\pi\varepsilon_0 L}$

(D) $\frac{1}{16}\frac{q}{\pi\varepsilon_0 L}$

23. The electric field in a region is given by

$$\vec{E} = (10x + 4)\,\hat{i}$$

where x is in m and E is in N/C. Calculate the amount of work done in taking a unit charge from

(i) (5 m, 0) to (10 m, 0)

(ii) (5 m, 0) to (5 m, 10 m) **3**

31. (a) (i) Obtain the expression for the capacitance of a parallel plate capacitor with a dielectric medium between its plates.

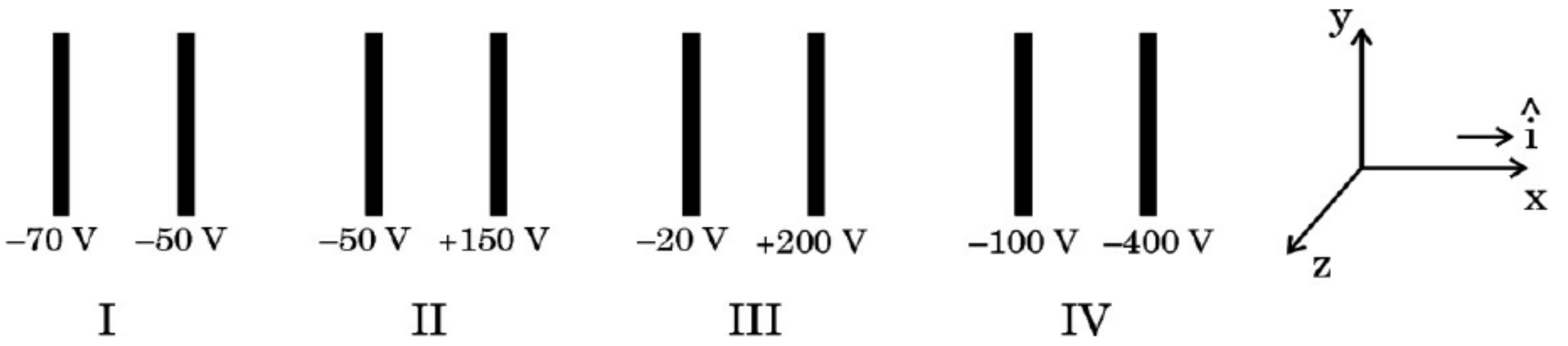
(ii) A charge of 6 μC is given to a hollow metallic sphere of radius 0·2 m. Find the potential at (i) the surface and (ii) the centre of the sphere. *5*

OR

(b) (i) A charge + Q is placed on a thin conducting spherical shell of radius R. Use Gauss's theorem to derive an expression for the electric field at a point lying (i) inside and (ii) outside the shell.

(ii) Show that the electric field for same charge density (σ) is twice in case of a conducting plate or surface than in a nonconducting sheet. *5*

29. The figure shows four pairs of parallel identical conducting plates, separated by the same distance 2·0 cm and arranged perpendicular to x-axis. The electric potential of each plate is mentioned. The electric field between a pair of plates is uniform and normal to the plates.



(i) For which pair of the plates is the electric field $\vec{E}$ along $\hat{i}$? *1*

(A) I (B) II

(C) III (D) IV

(ii) An electron is released midway between the plates of pair IV. It will : *1*

(A) move along $\hat{i}$ at constant speed

(B) move along $-\hat{i}$ at constant speed

(C) accelerate along $\hat{i}$

(D) accelerate along $-\hat{i}$

(iii) Let V_0 be the potential at the left plate of any set, taken to be at x = 0 m. Then potential V at any point ($0 \leq x \leq 2$ cm) between the plates of that set can be expressed as : *1*

(A) $V = V_0 + \alpha x$ (B) $V = V_0 + \alpha x^2$

(C) $V = V_0 + \alpha x^{1/2}$ (D) $V = V_0 + \alpha x^{3/2}$

where α is a constant, positive or negative.

(iv) (a) Let E_1, E_2, E_3 and E_4 be the magnitudes of the electric field between the pairs of plates, I, II, III and IV respectively. Then : *1*

(A) $E_1 > E_2 > E_3 > E_4$ (B) $E_3 > E_4 > E_1 > E_2$

(C) $E_4 > E_3 > E_2 > E_1$ (D) $E_2 > E_3 > E_4 > E_1$

OR

(b) An electron is projected from the right plate of set I directly towards its left plate. It just comes to rest at the plate. The speed with which it was projected is about :
(Take (e/m) $= 1{\cdot}76 \times 10^{11}$ C/kg) *1*

(A) $1{\cdot}3 \times 10^5$ m/s (B) $2{\cdot}6 \times 10^6$ m/s

(C) $6{\cdot}5 \times 10^5$ m/s (D) $5{\cdot}2 \times 10^7$ m/s

1. The plates P_1 and P_2 of a 2 μF capacitor are at potentials 25 V and – 25 V respectively. The charge on plate P_1 will be :

(A) 0·02 mC

(B) 0·1 mC

(C) 0·1 μC

(D) 1 μC

1. An isolated conductor, with a cavity, has a net charge +Q. A point charge +q is inside the cavity. The charges on the cavity wall and the outer surface are respectively :

(A) 0 and Q

(B) – q and Q – q

(C) – q and Q + q

(D) 0 and Q – q

2. A proton is taken from point P_1 to point P_2, both located in an electric field. The potentials at points P_1 and P_2 are -5 V and $+5$ V respectively. Assuming that kinetic energies of the proton at points P_1 and P_2 are zero, the work done on the proton is :

(A) $-1{\cdot}6 \times 10^{-18}$ J (B) $1{\cdot}6 \times 10^{-18}$ J

(C) Zero (D) $0{\cdot}8 \times 10^{-18}$ J

1. Consider a group of charges q_1, q_2, q_3 ... such that $\Sigma q \neq 0$. Then equipotentials at a large distance, due to this group are approximately :

(A) Plane

(B) Spherical surface

(C) Paraboloidal surface

(D) Ellipsoidal surface

32. (a) (i) Obtain an expression for the electric potential due to a small dipole of dipole moment $\vec{p}$, at a point $\vec{r}$ from its centre, for much larger distances compared to the size of the dipole.

(ii) Three point charges q, 2q and nq are placed at the vertices of an equilateral triangle. If the potential energy of the system is zero, find the value of n. *5*

1. The capacitance of a parallel plate capacitor having a medium of dielectric constant K = 4 in between the plates is C. If this medium is removed, then the capacitance of the capacitor becomes :

(A) 4C (B) C

(C) $\frac{C}{4}$ (D) 2C

32. (a) (i) Derive an expression for potential energy of an electric dipole $\vec{p}$ in an external uniform electric field $\vec{E}$. When is the potential energy of the dipole (1) maximum, and (2) minimum ?

(ii) An electric dipole consists of point charges $-1{\cdot}0$ pC and $+1{\cdot}0$ pC located at (0, 0) and (3 mm, 4 mm) respectively in x – y plane. An electric field $\vec{E} = \left(\frac{1000\ V}{m}\right)\hat{i}$ is switched on in the region. Find the torque $\vec{\tau}$ acting on the dipole. *5*

OR

(b) (i) An electric dipole (dipole moment $\vec{p} = p\,\hat{i}$), consisting of charges – q and q, separated by distance 2a, is placed along the x-axis, with its centre at the origin. Show that the potential V, due to this dipole, at a point x, (x >> a) is equal to $\frac{1}{4\pi\varepsilon_0} \cdot \frac{\vec{p}\cdot\hat{i}}{x^2}$.

(ii) Two isolated metallic spheres S_1 and S_2 of radii 1 cm and 3 cm respectively are charged such that both have the same charge density $\left(\frac{2}{\pi}\times 10^{-9}\right) C/m^2$. They are placed far away from each other and connected by a thin wire. Calculate the new charge on sphere S_1. *5*

22. Three point charges Q_1, Q_2 and Q_3 are located in x – y plane at points (– d, 0), (0, 0) and (d, 0) respectively. Q_1 and Q_3 are identical and Q_2 is positive. What will be the nature and value of Q_1 so that the potential energy of the system is zero ? *3*

2. Ten capacitors, each of capacitance 1 μF, are connected in parallel to a source of 100 V. The total energy stored in the system is equal to :

(A) 10^{-2} J

(B) 10^{-3} J

(C) $0 \cdot 5 \times 10^{-3}$ J

(D) $5 \cdot 0 \times 10^{-2}$ J

31. (a) (i) A capacitor of capacitance C is charged to a potential difference V by a battery. The battery is disconnected and the separation between the plates is halved. How will the following quantities be affected ?

(1) Capacitance of the capacitor

(2) Electric field between the plates

(3) Energy stored in the capacitor

Justify your answer in each case.

(ii) A capacitor of 20 μF is charged to 30 V. It is then connected to an uncharged 30 μF capacitor. Calculate the charges on each capacitor in equilibrium. *5*

OR

(b) (i) Obtain an expression for electric potential at a distance r from a point charge Q.

(ii) Two point charges of 10 μC and – 5 μC are placed at (– 3 cm, 0) and (6 cm, 0) in an external electric field $E = \frac{A}{r^2}$, where $A = 1{\cdot}8 \times 10^5$ N C^{-1} m^2. Calculate the electrostatic energy of the system. *5*

(iv) (b) A electric dipole consists of two point charges $+ 2$ pC and $- 2$ pC, separated by a distance 1 mm. It is kept in a uniform electric field of 2×10^5 NC^{-1}. The amount of work done in rotating it from its position of stable to unstable equilibrium will be : *1*

(A) 2×10^{-10} J

(B) 4×10^{-10} J

(C) 8×10^{-10} J

(D) $1 \cdot 6 \times 10^{-11}$ J

(iii) Two identical small electric dipoles, each of dipole moment $\vec{p}$ are arranged perpendicular to each other such that their negative charges coincide. The magnitude of the net dipole moment of the arrangement will be : *1*

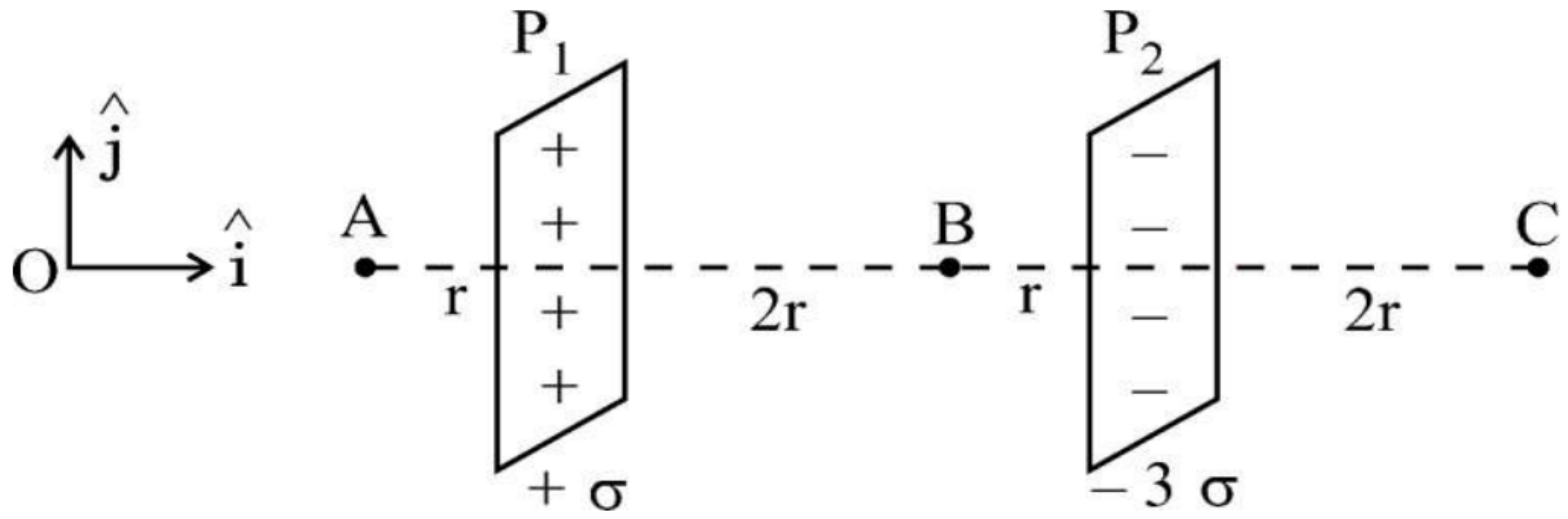
(A) p (B) 2p

(C) $p\sqrt{2}$ (D) $\frac{p}{\sqrt{2}}$

8. Two particles A and B of the same mass but having charges q and 4q respectively, are accelerated from rest through different potential differences V_A and V_B such that they attain same kinetic energies. The value of $\left(\frac{V_A}{V_B}\right)$ is :

(A) $\frac{1}{4}$ (B) $\frac{1}{2}$ (C) 2 (D) 4

(b) Two large plane sheets P_1 and P_2 having charge densities $+\sigma$ and -3σ respectively are arranged parallel to each other as shown in the figure. Find the net electric field ($\vec{E}$) at points A, B and C. *3*



23. Two point charges of 10 μC and 20 μC are located at points (– 4 cm, 0, 0) and (5 cm, 0, 0) respectively, in a region with electric field $E = \frac{A}{r^2}$, where $A = 2 \times 10^6\ NC^{-1}\ m^2$ and $\vec{r}$ is the position vector of the point under consideration. Calculate the electrostatic potential energy of the system. *3*

1. Three points charges + q, – 4q and + 2q are kept at the vertices of an equilateral triangle of side ‘a’. The electrostatic potential energy of this system of charges is :

(A) $-\frac{1}{4\pi\,\varepsilon_0}\left(\frac{q^2}{a^2}\right)$

(B) $+\frac{1}{4\pi\,\varepsilon_0}\left(\frac{8q^2}{a^2}\right)$

(C) $+\frac{1}{4\pi\,\varepsilon_0}\left(\frac{6q^2}{a}\right)$

(D) $-\frac{1}{4\pi\,\varepsilon_0}\left(\frac{10q^2}{a}\right)$

25. Explain the polarization of a dielectric medium filled inside a charged capacitor. How does the capacity of a capacitor increase due to filling ? What is dielectric constant of a dielectric ? *3*

29. The electric potential at a point in an electric field is the work done in bringing a unit positive charge from infinity to this point. If the potential difference between any two points at a surface is zero, the surface is called an equipotential surface. The shape of an equipotential surface can give direction of electric field at a point on it. It may be a closed surface or an open surface, depending on the charges creating the electric field.

(i) The shape of equipotential surface due to an isolated point charge is : *1*

(A) ellipsoidal, with charge at its one foci
(B) plane surface not passing through point charge
(C) spherical with charge at its centre
(D) cylindrical with charge at its axis

(ii) The equipotential surfaces in a uniform electric field acting along + Z direction are : *1*

(A) planes parallel to the XY plane
(B) concentric spherical surfaces
(C) planes parallel to the YZ plane
(D) planes parallel to the XZ plane

(iii) Which of the following statements is ***not*** true for equipotential surfaces ? *1*

(A) Potentials at two equipotential surfaces are different.

(B) No work is done in moving a charge on an equipotential surface.

(C) Equipotential surfaces always enclose some volume.

(D) Two equipotential surfaces do not intersect each other.

(iv) (a) The angle between the electric field at a point and outward normal at that point on an equipotential surface is : *1*

(A) $90°$ (B) $45°$

(C) $30°$ (D) $0°$

OR

(iv) (b) A and B are two equipotential surfaces around a point charge Q. Surface A is closer to the charge than surface B. If a test charge is released between them, it will : *1*

(A) remain stationary

(B) move from A to B

(C) move from B to A

(D) move around Q in a circular path between the equipotential surfaces A and B

(b) (i) Obtain an expression for the capacitance of a parallel plate capacitor.

(ii) Two identical plates, each of area A having surface charge densities $+\sigma$ and $-\sigma$, respectively, are separated by a distance d in air and a dielectric of dielectric constant K is filled between them. Write the expressions for : *5*

(1) the potential difference between the plates

(2) capacitance of the capacitor so formed

(3) energy stored in this capacitor