

قياس المجال الكهربائي



تم تحميل هذا الملف من موقع المناهج الإماراتية

موقع المناهج ← المناهج الإماراتية ← الصف الثاني عشر المتقدم ← فيزياء ← الفصل الأول ← ملفات متنوعة ← الملف

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المزيد من مادة
فيزياء:

إعداد: عبدالرحمن عصام عيد

التواصل الاجتماعي بحسب الصف الثاني عشر المتقدم



صفحة المناهج
الإماراتية على
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الرياضيات

اللغة الانجليزية

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التربية الاسلامية

المواد على تلغرام

المزيد من الملفات بحسب الصف الثاني عشر المتقدم والمادة فيزياء في الفصل الأول

شرح وأسئلة المجالات الكهربائية وقانون جاوس

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الموقع والزمن فيزياء تاسع انسباير inspire G9 Physics when and Where

2

امتحان تكويني مع الإجابات نص سردي بعنوان (أحلام صغيرة)

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شرح الجهاز الغطائي: الأنسجة وطبقات الجلد

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تطبيق المناهج على Play Google (أندرويد)

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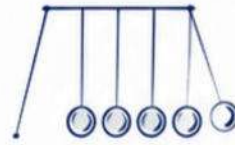
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مصدرك الأول

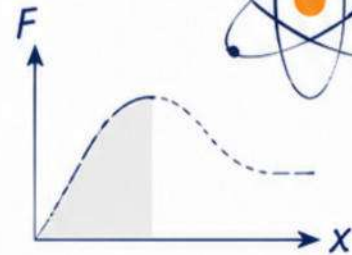
— للعلامة —

الكاملة

في الفيزياء



$$E = mc^2$$



استاذ

عبدالرحمن عصام عيد



معك خطوة بخطوة
نحو التفوق والتميز



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Einsteinabdo

Einstein_AE



Section 1 Measuring Electric Field

Creating and Measuring Electric Fields

Electric Field

The change in the properties of the **space surrounding a charged object**, in which any other charge experiences a **force**. The forces exerted by electric fields can **do work**, transferring energy from the field to another charged object.

How Can You Measure an Electric Field?

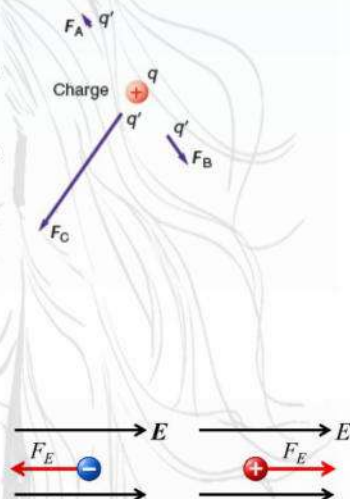
Place a small **positive test charge** q' at some point. If an **electric force** acts on it, then there is an **electric field** at that point.

The **field strength** equals the force on the positive test charge divided by the magnitude of the test charge:

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

Unit N/C:

- The force on a **positive** charge is **in the same direction as the field**.
- The force on a **negative** charge is **opposite** to the field direction.
- Field strength is measured in **newtons per coulomb** (N/C).



Note

An electric field must be measured using only a **very small test charge**, because the test charge also exerts a force on the source charge q and could change the field being measured.

Worked Example 1 A positive test charge of $5.0 \times 10^{-6}\text{C}$ is placed in an electric field that exerts a force of $2.0 \times 10^{-4}\text{N}$ on it. What is the magnitude of the field strength?

Solution:

$$E = \frac{F}{q'} = \frac{2.0 \times 10^{-4}\text{N}}{5.0 \times 10^{-6}\text{C}} = 40 \text{ N/C}$$

Worked Example 2 A **negative** charge of $2.0 \times 10^{-8}\text{C}$ experiences a force of **0.060 N to the right**. What are the magnitude and direction of the field?

Solution:

$$E = \frac{0.060 \text{ N}}{2.0 \times 10^{-8}\text{C}} = 3.0 \times 10^6 \text{ N/C}$$

The charge is negative, so the field is **opposite** to the force: **to the left**.

Worked Example 3 A positive charge of $3.0 \times 10^{-7}\text{C}$ is placed in a field of **27 N/C** directed **south**. What is the force on the charge?

Solution:

$$F = qE = (3.0 \times 10^{-7}\text{C})(27 \text{ N/C}) = 8.1 \times 10^{-6}\text{N} [\text{south}]$$

Check Your Understanding

Question (1): A charge of $-5 \mu\text{C}$ placed in an electric field experiences a force of **2 mN north**.

What are the **magnitude and direction of the field**?

- Ⓐ 400 N/C south Ⓑ 400 N/C north
Ⓒ 100 N/C south Ⓓ $2.5 \times 10^{-3} \text{ N/C}$ south

Question (2): A negative charge of $-2 \times 10^{-10} \text{ C}$ experiences a force of $5 \times 10^{-6} \text{ N}$ to the right.

What are the **magnitude and direction of the field**?

- Ⓐ $4 \times 10^{-5} \text{ N/C}$ to the right Ⓑ $2.5 \times 10^4 \text{ N/C}$ to the left
Ⓒ $2.2 \times 10^4 \text{ N/C}$ to the right Ⓓ $1 \times 10^{-15} \text{ N/C}$ to the right

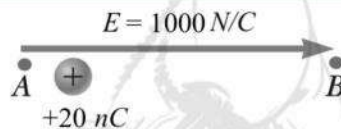
Question (3): A negative charge of $-2 \times 10^{-7} \text{ C}$ is placed in a field of 20 N/C directed east.

What is the **electric force** on the charge?

- Ⓐ $4.0 \times 10^{-6} \text{ N}$ east Ⓑ $1.0 \times 10^{-8} \text{ N}$ east
Ⓒ $4.0 \times 10^{-6} \text{ N}$ west Ⓓ $1.0 \times 10^{-8} \text{ N}$ west

Question (4): A uniform field of 1000 N/C points from A to B.

What are the **magnitude and direction** of the force on a $+20 \text{ nC}$ charge placed near A?



- Ⓐ $2.0 \times 10^{-5} \text{ N}$ from A to B Ⓑ $2.0 \times 10^{-5} \text{ N}$ from B to A
Ⓒ $2.0 \times 10^{-11} \text{ N}$ from A to B Ⓓ $2.0 \times 10^{-11} \text{ N}$ from B to A

Question (5): A test charge of $+1.6 \mu\text{C}$ at point a near a point charge q experiences an electric force of 0.68 N .

What is the **magnitude of the field** at a?

- Ⓐ $4.3 \times 10^5 \text{ N/C}$ Ⓑ $1.09 \times 10^{-6} \text{ N/C}$
Ⓒ $4.3 \times 10^2 \text{ N/C}$ Ⓓ $2.4 \times 10^{-6} \text{ N/C}$

Question (6): The direction of the electric field is the direction of the:

- Ⓐ work done to move the test charge Ⓑ electric potential difference
Ⓒ force on a negative test charge Ⓓ force on a positive test charge

Written Question (1): Answer briefly:

- (1) What are the **two properties** a test charge must have?
(2) How is the **direction** of the electric field determined?

Solution:

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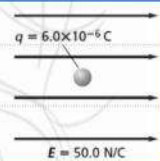
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Written Question (2): A negative charge of $5.0 \times 10^{-9}\text{C}$ is placed where the field is 1200 N/C to the right. What is the **force** on it?

Solution:

Written Question (3): A positive test charge of $6.0 \times 10^{-6}\text{C}$ is placed in an electric field of 50.0 N/C , as shown in the figure. What is the **magnitude of the force** on it?

Solution:



Written Question (4): The electric field in the atmosphere is about 150 N/C downward.

- (1) What is the **direction of the force** on a negatively charged particle?
- (2) Find the **electric force** on an electron ($q = -1.602 \times 10^{-19}\text{C}$)
- (3) Compare it with the **gravitational force** on the electron ($m = 9.1 \times 10^{-31}\text{kg}$).

Solution:

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Electric Field of a Point Charge

Coulomb's law gives the force between the source charge q and the test charge q' : $F = k \frac{qq'}{r^2}$. Dividing by q' gives the electric field of a point charge:

$$E = \frac{F}{q'} = k \frac{q}{r^2}$$

Symbol	Quantity	Unit / Value
E	Electric field strength	N/C
q	Source charge	C
r	Distance from the charge	m
k	Coulomb's constant	$9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$

Unit Conversions

$$1 \text{ nC} = 10^{-9} \text{ C} \quad 1 \mu\text{C} = 10^{-6} \text{ C} \quad 1 \text{ cm} = 10^{-2} \text{ m}$$

Important Notes

Inverse-square law: $E \propto \frac{1}{r^2}$ — doubling the distance makes the field strength **one quarter** of what it was. Use the **magnitude** of the charge $|q|$ in the formula; the **sign** of the charge only gives the **direction** (away from a positive charge, toward a negative charge).

Comparing Two Fields (Ratios)

Because $E \propto \frac{q}{r^2}$, the ratio of two fields cancels k :

$$\frac{E_1}{E_2} = \frac{q_1}{q_2} \times \frac{r_2^2}{r_1^2}$$

Worked Example 4 What is the magnitude of the field strength **1.2 m** from a point charge of $4.2 \times 10^{-6} \text{ C}$? What is it at **twice** that distance?

At 1.2 m:

$$E = k \frac{q}{r^2} = (9.0 \times 10^9) \frac{4.2 \times 10^{-6}}{(1.2)^2} = 2.6 \times 10^4 \text{ N/C}$$

At 2.4 m:

$$E' = \frac{E}{4} = 6.6 \times 10^3 \text{ N/C}$$

Worked Example 5 What is the electric field at a position **1.6 m east** of a point charge of $+7.2 \times 10^{-6} \text{ C}$?

Solution:

$$E = (9.0 \times 10^9) \frac{7.2 \times 10^{-6}}{(1.6)^2} = 2.5 \times 10^4 \text{ N/C [east]}$$

The charge is positive, so the field points **away** from it (east).

Worked Example 6 The electric field strength **0.25 m** from a small sphere is **450 N/C** **toward** the sphere. What is the charge on the sphere?

Solution:

$$q = \frac{Er^2}{k} = \frac{(450)(0.25)^2}{9.0 \times 10^9} = 3.1 \times 10^{-9} \text{C}$$

The field points **toward** the sphere, so the charge is **negative**: $q = -3.1 \times 10^{-9} \text{C}$.

Worked Example 7 How far from a point charge of $2.4 \times 10^{-6} \text{C}$ must a test charge be placed to measure a field of **360 N/C**?

Solution:

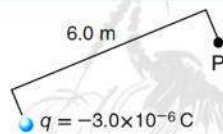
$$r = \sqrt{\left(\frac{kq}{E}\right)} = \sqrt{\left(\frac{(9.0 \times 10^9)(2.4 \times 10^{-6})}{360}\right)} = 7.7 \text{ m}$$

Check Your Understanding

Question (7): What is the **magnitude of the field strength** **20 cm** away from a point charge of **33 nC**?

- (a) $1.48 \times 10^{-3} \text{N/C}$ (b) $7.43 \times 10^{-3} \text{N/C}$
 (c) $7.43 \times 10^3 \text{N/C}$ (d) $1.48 \times 10^3 \text{N/C}$

Question (8): Point P is **6.0 m** from a point charge $q = -3.0 \times 10^{-6} \text{C}$. What is the **electric field** at P?



- (a) **750 N/C**, toward the charge (b) **750 N/C**, away from the charge
 (c) **4500 N/C**, toward the charge (d) **4500 N/C**, away from the charge

Question (9): The electric field strength **0.25 m** from a point charge is $9.4 \times 10^5 \text{N/C}$.

What is the **magnitude of the charge**?

- (a) $1.6 \mu\text{C}$ (b) $5.0 \mu\text{C}$
 (c) $6.5 \mu\text{C}$ (d) 1.6C

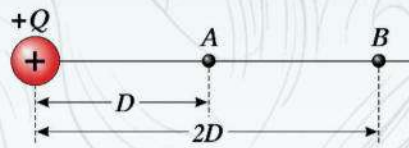
Question (10): Point a is **0.5 m** from a point charge Q. The field strength at a is $9.0 \times 10^4 \text{N/C}$ in the direction shown. What is the **charge** Q?



- (a) $+2.5 \mu\text{C}$ (b) $-2.5 \mu\text{C}$
 (c) $+5.0 \mu\text{C}$ (d) $-5.0 \mu\text{C}$

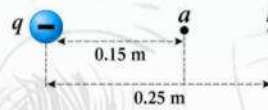
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Question (11): Points A and B are at distances D and $2D$ from the charge $+Q$. If the field strength at A is E , what is the **field strength at B**?



- (a) $\frac{E}{4}$ (b) $4E$
(c) $2E$ (d) $\frac{E}{2}$

Question (12): In the figure, the field strength at point b is 900 N/C . What is the **field strength at point a**?



- (a) 2500 N/C (b) 324 N/C
(c) 1500 N/C (d) 540 N/C

Written Question (5): What is the **electric field strength** 20.0 cm from a point charge of $8.0 \times 10^{-6} \text{ C}$?

Solution:

Written Question (6): The field strength at point P, which is 15.0 cm from charge Q, is $6.0 \times 10^6 \text{ N/C}$.



- (1) Calculate the **charge Q**.
(2) A test charge of $-0.25 \mu\text{C}$ is placed at P. Find the **magnitude and direction** of the force on it.

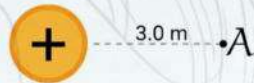
Solution:

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Written Question (7): A positive charge of $15.0 \mu\text{C}$ is 3.0 m from point A.



- (1) Calculate the **magnitude of the field strength** at A and show its **direction**.
- (2) A charge q at A experiences a force of 6.0 N **opposite** to the field direction. Find the **magnitude** and **type** of charge q .

Solution:

Written Question (8): How does the electric field strength at a point change if:

Solution:

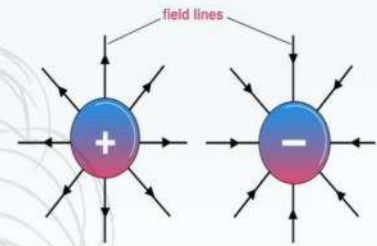
- the **test charge** is doubled?
- the **source charge** is doubled?
- the **distance** from the charge is doubled?
- the **distance** is halved?
- the **source charge** is halved?

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Electric Field Lines

Field lines give a picture of the field around a charge:

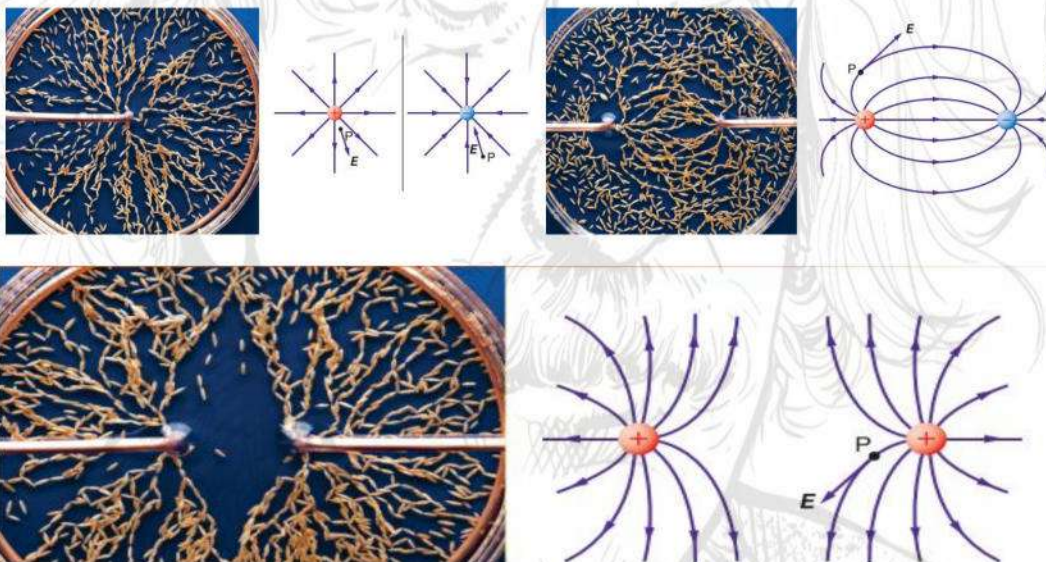
- Around a point charge, the lines spread out **radially**.
- **The direction** of the field at any point is the **tangent** to the field line at that point.
- Lines point **outward** from a **positive** charge and **inward** toward a **negative** charge.
- Lines are **close together** near the charge (strong field) and **farther apart** away from it (weaker field).



Visualizing Field Lines

A person touching the terminal of a **Van de Graaff generator** becomes charged; the charges on the hairs **repel**, so the hairs follow the field lines.

Grass seeds suspended in an insulating liquid (mineral oil) become polarized and line up along the field, forming a pattern of field lines.



Reading Field Lines

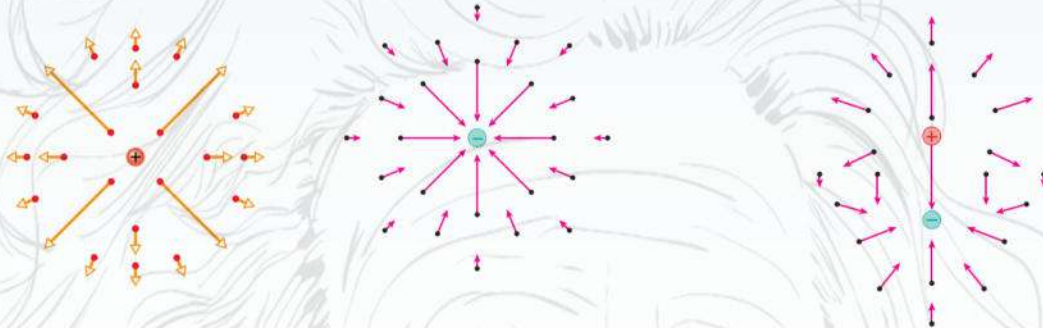
Property	How it is found from the drawing	Physical meaning
Direction of the field	The tangent to the line at the point	Direction of the force on a positive test charge at that point
Strength of the field	Density of the lines (spacing between them)	Close lines → strong field; Far-apart lines → weak field

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Chapter 1 Electric Fields

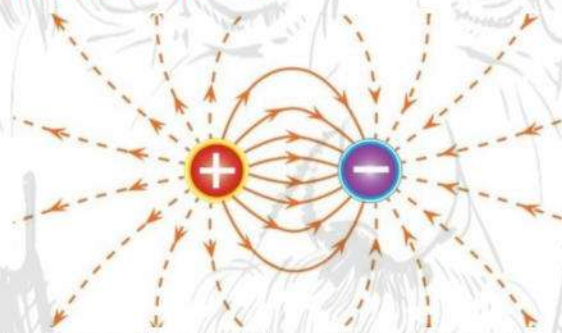
Properties of Electric Field Lines

1. **Start and end:** They always start on the **positive charge** and enter (end on) the **negative charge**.
- ✓ A **positive charge** ($+q$): field lines always point **outward** (away from the charge).
- ✓ A **negative charge** ($-q$): field lines always point **inward** (toward the charge).



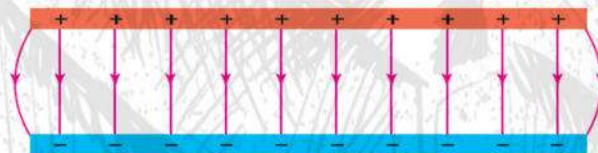
The field around a single positive charge and a single negative charge — the field around two unlike charges.

2. **Physical nature: Imaginary lines** with no material existence; they are used as a geometric tool to illustrate and picture the field in space.
3. **No crossing:** Field lines **never cross each other**.



Field lines between two unlike charges: they leave the positive charge and enter the negative charge without crossing.

4. **Density and strength:** They are **close together** where the field is **strong**, and **far apart** where the field is **weak**.
5. **Spreading in space:** They spread out around the charged object in **three dimensions** (a three-dimensional field, not just a flat one).
6. The direction of the field is found by placing a **small positive test charge**; the field direction is the same as the direction of the force on it, so it always points **from the positive plate to the negative plate**.

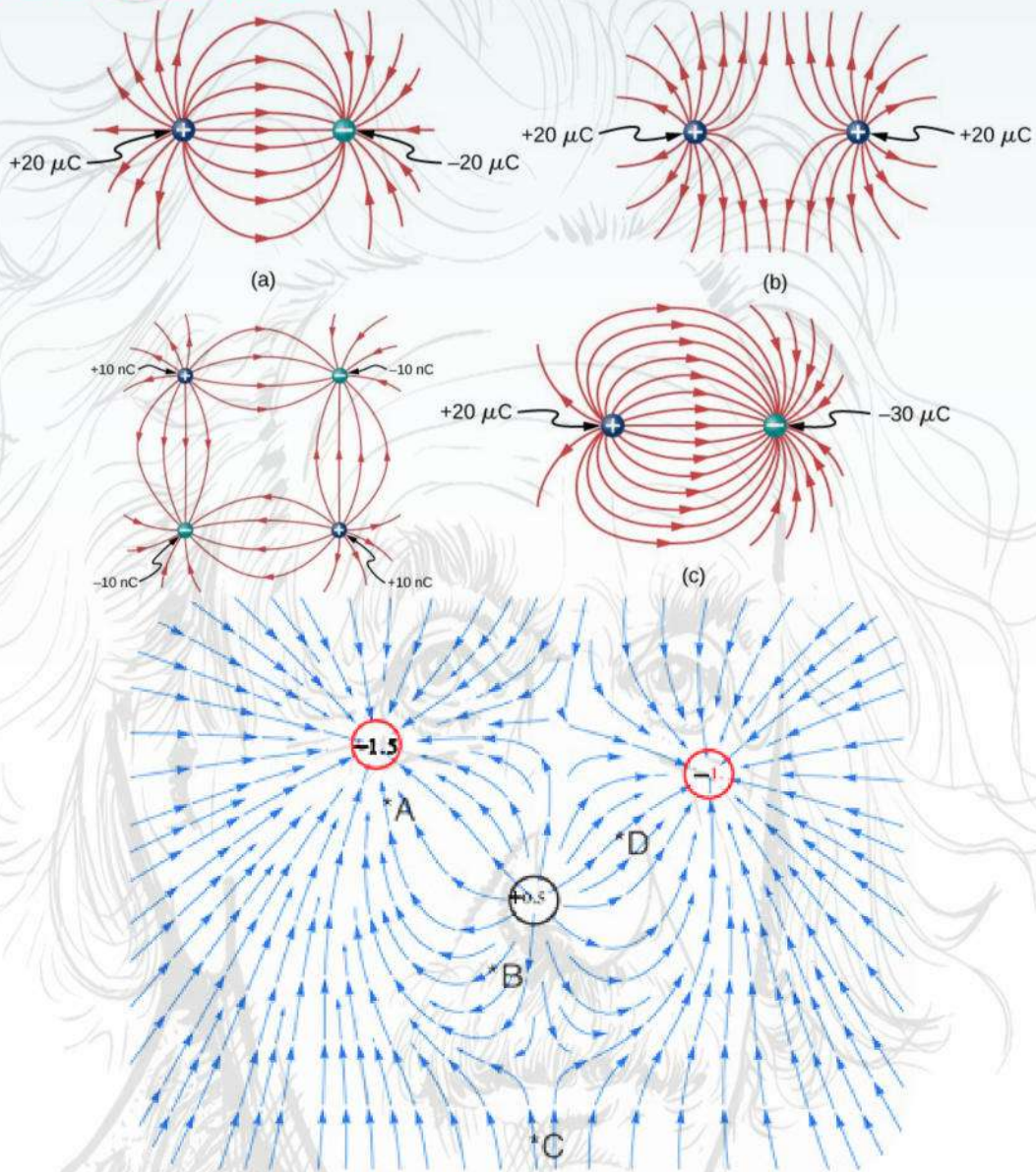


Uniform electric field

The uniform electric field between two parallel plates with opposite charges.

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Field lines around a group of charges

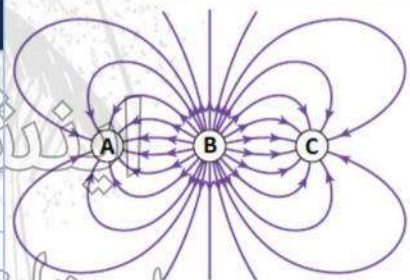


Check Your Understanding

Question (13): The figure shows the field lines produced by charges A, B, and C.

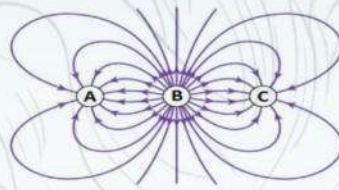
Which statement about the charges is **correct**?

Option	Positive charges	Negative charges	Order of magnitude
(a)	A, C	B	$A > B > C$
(b)	B	A, C	$B > A = C$
(c)	B	A, C	$B > A > C$
(d)	A, B, C	None	$B > A = C$



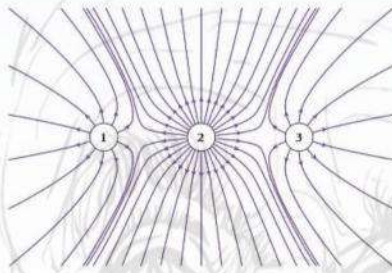
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Question (14): For the same three charges A, B, and C, which statement is **NOT** correct?



- (a) $q_A = q_C$
 (b) $q_B > -q_C$
 (c) $q_B > -q_A$
 (d) $q_A = -q_C$

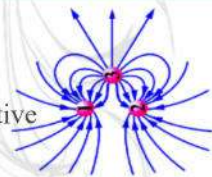
Question (15): What are the **signs** of the charges in the arrangement shown?



- (a) 1, 2, and 3 are negative
 (b) 1, 2, and 3 are positive
 (c) 1 and 3 are positive, 2 is negative
 (d) 1 and 3 are negative, 2 is positive

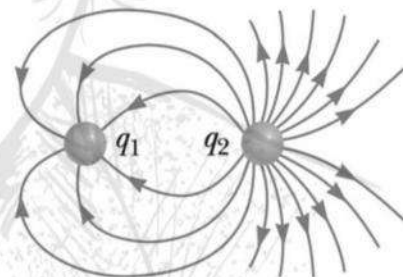
Question (16): What are the **signs** of the charges shown?

- (a) 1, 2, and 3 are negative
 (b) 1, 2, and 3 are positive
 (c) 1 and 2 are positive, 3 is negative
 (d) 1 and 2 are negative, 3 is positive



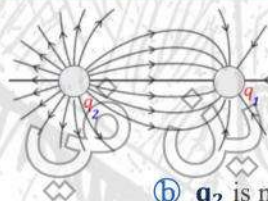
Question (17): Which statement about charges q_1 and q_2 is **correct**?

Option	Type of q_1	Type of q_2	Comparison
(a)	Positive	Negative	$q_1 > q_2$
(b)	Positive	Negative	$q_2 > q_1$
(c)	Negative	Positive	$q_1 > q_2$
(d)	Negative	Positive	$q_2 > q_1$



Question (18): The field lines are between two unlike, unequal charges q_1 and q_2 . Which statement is **correct**?

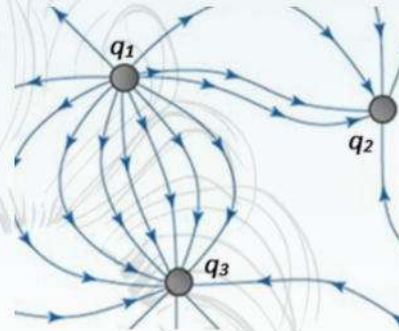
- (a) q_2 is positive and larger than q_1
 (b) q_2 is negative and larger than q_1
 (c) q_2 is positive and smaller than q_1
 (d) q_2 is negative and smaller than q_1



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Question (19): Which row gives the **correct type** of charges q_1 , q_2 , and q_3 ?

Option	q_1	q_2	q_3
(a)	-	+	+
(b)	+	-	-
(c)	+	-	+
(d)	-	+	-



Relationship Between the Number of Field Lines and the Magnitude of the Charge

1. The Physical Concept

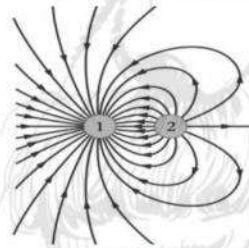
The **number of field lines** (n) leaving a positive charge or entering a negative charge is **directly proportional** to the **magnitude of the charge** that produces them ($|q|$).

2. The Mathematical Form (Ratio and Proportion)

$$\frac{|q_1|}{|q_2|} = \frac{n_1}{n_2}$$

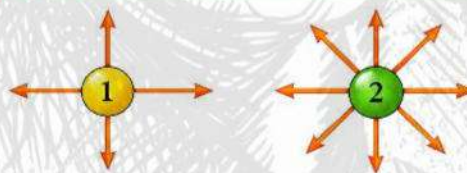
- ✓ $|q_1|, |q_2|$: the magnitude of each of the two charges (**absolute value**).
- ✓ n_1, n_2 : the number of field lines connected to each charge.

Question (20): Which of the following could represent the **correct charges** 1 and 2?



- (a) $+32 \mu\text{C}$ and $-16 \mu\text{C}$ (b) $-32 \mu\text{C}$ and $+16 \mu\text{C}$
 (c) $-16 \mu\text{C}$ and $+32 \mu\text{C}$ (d) $-32 \mu\text{C}$ and $-32 \mu\text{C}$

Question (21): What is a **possible value** of the two charges shown?



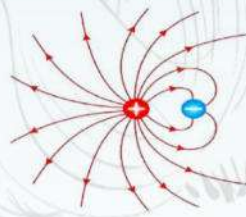
- (a) $q_1 = 1 \text{ C}, q_2 = -2 \text{ C}$ (b) $q_1 = 1 \text{ C}, q_2 = 2 \text{ C}$
 (c) $q_1 = 2 \text{ C}, q_2 = -1 \text{ C}$ (d) $q_1 = -2 \text{ C}, q_2 = 1 \text{ C}$

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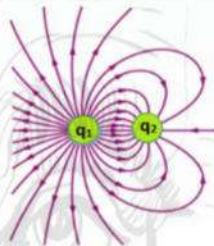
Chapter 1 Electric Fields

Question (22): Based on the field lines shown, if the positive charge is $+24 \mu\text{C}$, what is the magnitude of the negative charge?



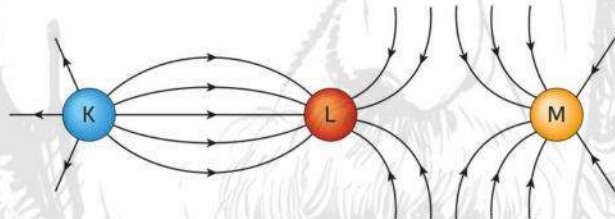
- (a) $-48 \mu\text{C}$ (b) $-12 \mu\text{C}$
 (c) $-6 \mu\text{C}$ (d) $-24 \mu\text{C}$

Question (23): The figure shows the field around two point charges q_1 and q_2 . Which statement is correct?



- (a) $q_1 = -2q_2$ (b) $q_2 = -2q_1$
 (c) $q_1 = 2q_2$ (d) $q_2 = 2q_1$

Written Question (9): Based on the **density of the electric field lines** shown in the figure:

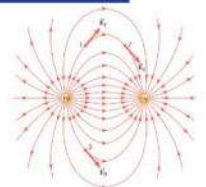


- What is the type of charge K and of charges L, M?
- If charge L equals $6.0 \mu\text{C}$, what is the magnitude of charges K, M?

Solution:

Direction of the Electric Field ($\vec{E}$)

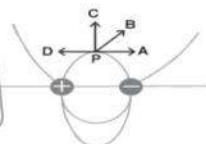
It is the **direction of the tangent** drawn to the field line at that point, which is the same as the **direction of the electric force** on a **positive test charge** placed at that point.



Question (24): The figure shows the electric field pattern around two charges that are equal in magnitude and opposite in sign. Which of the arrows shown represents the direction of the electric field vector at point P?

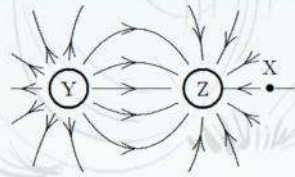
- (a) A
 (c) C

- (b) B
 (d) D



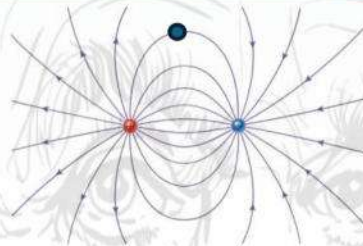
Question (25): The figure shows two equal point charges Y and Z.

What happens if a **negative** test charge is placed at point X?



- (a) It moves to the left
- (b) It moves to the right
- (c) It does not move
- (d) It moves upward

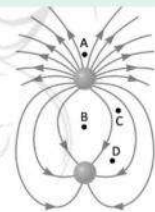
Question (26): The figure shows the electric field lines between two-point charges that are equal in magnitude and opposite in sign. What is the direction of the electric force on a **positive** test charge placed at point P?



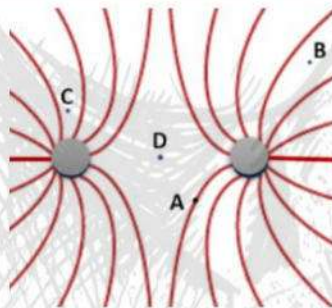
- (a) To the left
- (b) To the right
- (c) Downward
- (d) Upward

Question (27): **Rank** the magnitudes of the electric field at points A, B, C, and D.

- (a) $A > B > C > D$
- (b) $B > D > C > A$
- (c) $D > C > B > A$
- (d) $A > C > D > B$



Question (28): At which position is the electric field **equal to zero**?



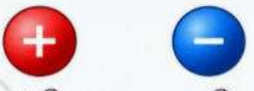
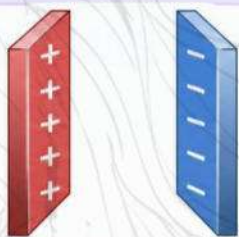
- (a) A
- (b) B
- (c) C
- (d) D

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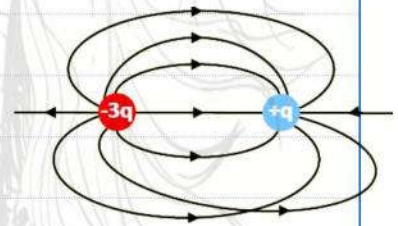
Chapter 1 Electric Fields

Written Question (10): Draw the electric field lines for each case:

1 A single positive charge and a single negative charge 	2 Two like charges, equal in magnitude  Two equal positives Two equal negatives	3 Two unlike charges, equal in magnitude  +Q -Q
4 A positive charge and a negative charge twice its magnitude  +Q -2Q	5 Two oppositely charged parallel plates 	

Written Question (11): A student drew the field lines around $-3q$ and $+q$. Write the **three mistakes**.

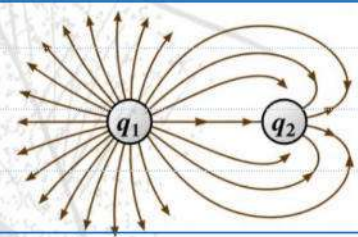
Solution:



Written Question (12): The diagram shows the field lines around two charges.

- What is the **type** of each charge?
- Which relation is correct: $q_1 = q_2$, $q_1 > q_2$, or $q_1 < q_2$? **Justify** your answer.

Solution:

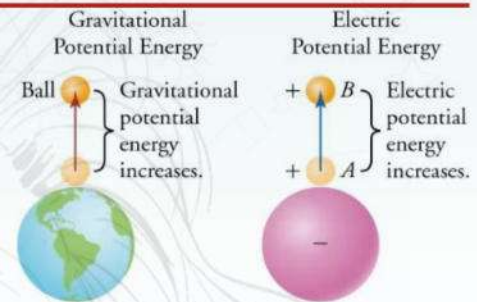


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Section 2 Applications of Electric Fields

Electric Potential Difference

The **gravitational potential energy** of a ball increases when an external force lifts it **against** the gravitational field. Similarly, to separate two **unlike** charges from each other, you must do work against the attraction between them; this energy is stored as **electric potential energy**. The larger the test charge, the greater the increase in ΔPE .



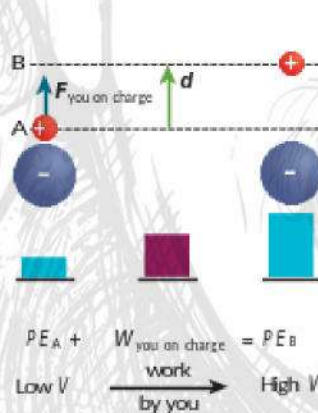
Electric Potential Difference (ΔV)

The **work done** to move a **positive test charge** between two points in an electric field, divided by the **magnitude** of the test charge. It is also called **voltage**, and it is measured with a **voltmeter**.

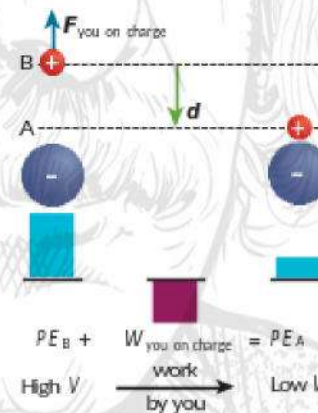
$$\Delta V = \frac{W_{on q'}}{q'} \quad 1 V = 1 J/C$$

- Moving two **unlike** charges **apart** $\rightarrow \Delta V$ is **positive** (potential increases).
- Moving two **unlike** charges **closer together** $\rightarrow \Delta V$ is **negative** (potential decreases).
- $\Delta V = V_B - V_A$; do not confuse ΔV with the unit **V** (volt).
- ΔV is **positive** if the potential energy increases (moving **against** the direction of E), and **negative** if it decreases (moving **with** the direction of E).

Positive Electric Potential Difference



Negative Electric Potential Difference

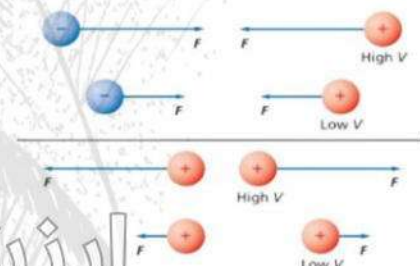


Equipotential and the Reference Point of Potential

If you move a test charge along a **circular path** around a charge, the force is always **perpendicular** to the motion, so **no work is done** and $\Delta V = 0$.

Positions with zero potential difference between them are at **equipotential (equal potential)**.

The potential of any point can be taken as zero; usually we take $V_{\infty} = 0$.



Gaining or Losing Electric Potential Energy

Moving against the field

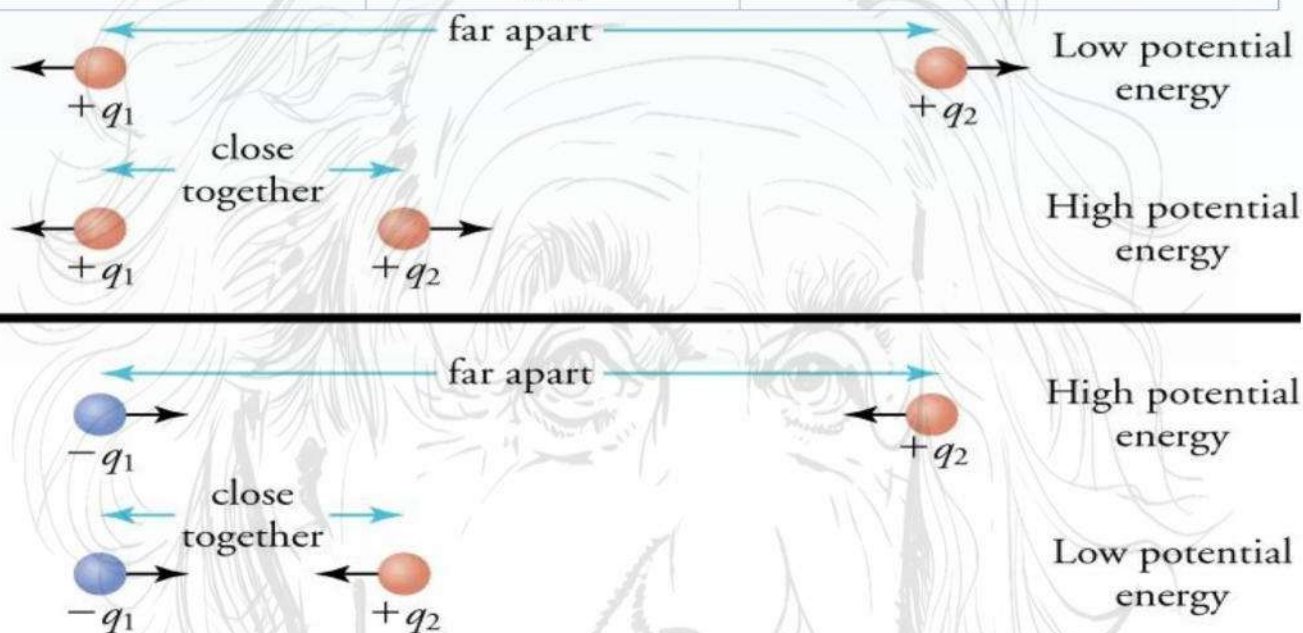
- You do **positive work**.
- Electric potential energy **increases**.
- Example: separating two **unlike** charges; pushing two **like** charges toward each other.

Moving with the field

- **The field** does the work.
- Electric potential energy **decreases**.
- Example: two **like** charges moving apart; two **unlike** charges coming together.

Chapter 1 Electric Fields

Charge movement	Work done	Change in potential energy	ΔV
+ charge away from +	Negative (the field does the work)	Decreases	Negative
+ charge toward +	Positive (you do the work)	Increases	Positive
+ charge away from -	Positive (you do the work)	Increases	Positive
+ charge toward -	Negative (the field does the work)	Decreases	Negative



Worked Example 8 How much work is done on a charge of 3.0 C when it is moved through a potential difference of 1.5 V ?

Solution:

$$W = q\Delta V = (3.0 \text{ C})(1.5 \text{ V}) = 4.5 \text{ J}$$

Worked Example 9 An electron in an old television picture tube passes through a potential difference of $18\,000 \text{ V}$. How much work is done on it?

Solution:

$$W = q\Delta V = (1.602 \times 10^{-19} \text{ C})(1.8 \times 10^4 \text{ V}) = 2.9 \times 10^{-15} \text{ J}$$

Worked Example 10 A 12 V car battery contains $1.44 \times 10^6 \text{ C}$ of usable charge. How much work can it do before it needs to be recharged?

Solution:

$$W = q\Delta V = (1.44 \times 10^6 \text{ C})(12 \text{ V}) = 1.7 \times 10^7 \text{ J}$$

Check Your Understanding

Question (29): As a positive test charge moves **away from** a positive charge, its potential energy:

- Ⓐ increases
- Ⓑ decreases
- Ⓒ doubles
- Ⓓ remains the same

Question (30): The SI derived unit of **potential difference** is the:

- (a) ohm (b) volt
(c) joule (d) coulomb

Question (31): Electric potential difference is measured **in**:

- (a) newtons per coulomb (b) coulombs per joule
(c) joules per coulomb (d) volts per coulomb

Question (32): How much **work** is done when a charge of **3.5 C** is moved through a potential difference of **4.5 V**?

- (a) $-16 J$ (b) $16 J$
(c) $7.8 J$ (d) $-7.8 J$

Question (33): If $2.0 \times 10^2 J$ of work is needed to move one coulomb from a positive plate to a negative plate, what is the **potential difference** between the plates?

- (a) $1.6 \times 10^{-19} V$ (b) $5.0 \times 10^{-3} V$
(c) $2.0 \times 10^3 V$ (d) $2.0 \times 10^2 V$

Question (34): Which of the following **best describes** electric potential difference?

- (a) the work needed to move a positive test charge between two points divided by the magnitude of the test charge
(b) the magnitude of a positive test charge divided by the work needed to move it
(c) the electrostatic force on a positive test charge divided by its magnitude
(d) the magnitude of a positive test charge multiplied by the force on it

Question (35): When the potential difference between two positions is **zero**, the positions are:

- (a) polar (b) in equilibrium
(c) close together (d) at equipotential (equal potential)

Question (36): Which statement is **true** about equipotential positions?

- (a) The work done to move a charge between any two of them equals zero
(b) The electric potential at each of them must equal zero
(c) The electric force on a charge at each of them must equal zero
(d) The electric field at each of them must equal zero

Question (37): Two positive charges: q_a at (0, 0) and q_b at A. What happens when q_b is moved to position B?



- (a) The potential energy does not change (b) The electric potential energy decreases
(c) The potential energy equals zero (d) The potential energy increases

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Question (38): Now q_a is positive and q_b is negative. What happens when q_b is moved from A to B?



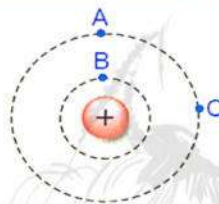
- (a) The potential energy does not change
- (b) The electric potential energy decreases
- (c) The potential energy equals zero
- (d) The potential energy increases

Question (39): Charge q_2 is moved from its position to point (a), at the same distance R from q_1 . What happens?



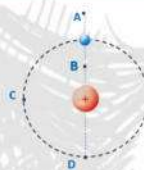
- (a) The potential energy increases
- (b) The potential energy equals zero
- (c) The electric potential decreases
- (d) The potential energy does not change

Question (40): The broken lines represent two equipotential surfaces around a positive charge. Which statement describes the **potential at B**?



- (a) It equals the potential at C
- (b) It equals the potential at A
- (c) It is less than the potential at C
- (d) It is greater than the potential at A

Question (41): The figure shows an electron in an atom. To which point should it be moved so that its electric potential energy **increases**?



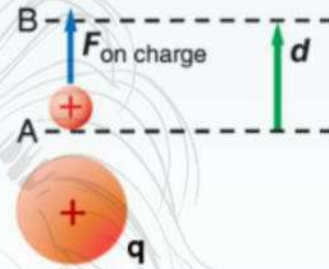
- (a) A
- (b) B
- (c) C
- (d) D

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Question (42): A **positive** test charge is moved from A to B, away from a positive charge q .

Which row is correct?

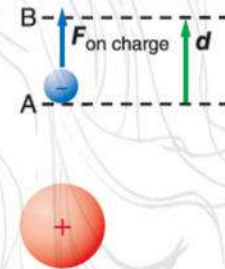
	Potential difference between A and B $V_B - V_A$	Change in potential energy of the test charge ΔPE
(a)	Negative	Negative
(b)	Positive	Positive
(c)	Positive	Negative
(d)	Negative	Positive



Question (43): A **negative** test charge is moved from A to B, away from a positive charge.

Which row is correct?

	Potential difference between A and B $V_B - V_A$	Change in potential energy of the test charge ΔPE
(a)	Negative	Negative
(b)	Positive	Positive
(c)	Positive	Negative
(d)	Negative	Positive



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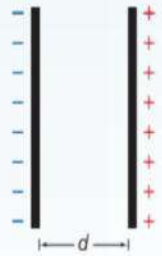
Chapter 1 Electric Fields

The Uniform Electric Field: $\Delta V = Ed$

A **uniform electric field** is produced by placing two large, flat, conducting metal plates **parallel** to each other, one **positive** and the other **negative**.

Between the plates the field is **constant** (except at the edges), and it points from the **positive** plate to the **negative** plate.

The electric potential is **higher near the positive plate**: it increases in the direction **opposite** to the field.



$$\Delta V = Ed \quad W = q\Delta V = qEd$$

Worked Example 11 The electric field strength between two large parallel plates is 6000 N/C , and the distance between them is 0.05 m . What is the electric potential difference between them?

Solution:

$$\Delta V = Ed = (6000 \text{ N/C})(0.05 \text{ m}) = 300 \text{ V} = 3 \times 10^2 \text{ V}$$

Worked Example 12 A potential difference of 275 V is applied to two plates that are 0.35 cm apart. What is the electric field strength?

Solution:

$$E = \frac{\Delta V}{d} = \frac{275 \text{ V}}{0.0035 \text{ m}} = 7.9 \times 10^4 \text{ N/C}$$

Worked Example 13 The electric field strength in a particle accelerator is $4.5 \times 10^5 \text{ N/C}$. How much work is done to move a proton 25 cm through it?

Solution:

$$W = qEd = (1.602 \times 10^{-19})(4.5 \times 10^5)(0.25) = 1.8 \times 10^{-14} \text{ J}$$

Check Your Understanding

Question (44): What is the **electric potential difference** between two plates that are 18 cm apart with a field strength of $4.8 \times 10^3 \text{ N/C}$ between them?

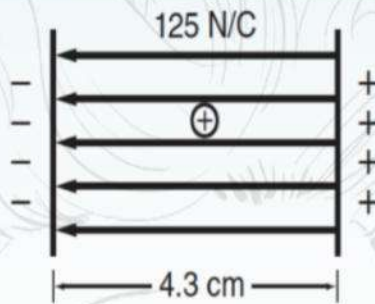
- (a) 27 V (b) 27 kV
(c) 0.86 kV (d) 86 V

Question (45): A voltmeter reads 47.0 V across two oppositely charged plates that are 5.0 cm apart. What is the **magnitude of the electric field strength**?

- (a) $1.1 \times 10^{-3} \text{ N/C}$ (b) $9.4 \times 10^3 \text{ N/C}$
(c) $9.4 \times 10^2 \text{ N/C}$ (d) $1.1 \times 10^{-2} \text{ N/C}$

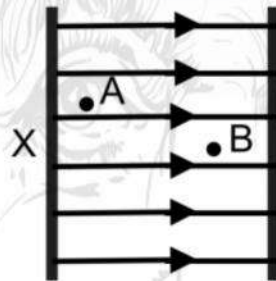
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Question (46): How much **work** is done on a proton to move it from the negative plate to the positive plate **4.3 cm** away if the field strength is **125 N/C**?



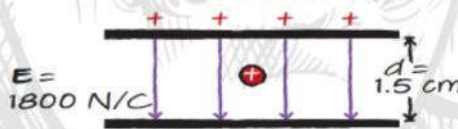
- (a) $5.4 J$ (b) $1.1 \times 10^{-16} J$
 (c) $5.5 \times 10^{-23} J$ (d) $8.6 \times 10^{-19} J$

Question (47): The figure shows the electric field lines between plates X and Y. Which statement is **correct**?



- (a) The potential at A is greater than at B (b) The field at A is greater than at B
 (c) The potential of plate Y is less than that of plate X (d) A and C

Written Question (13): Two charged parallel plates are **1.5 cm** apart, and the electric field strength between them is **1800 N/C**.



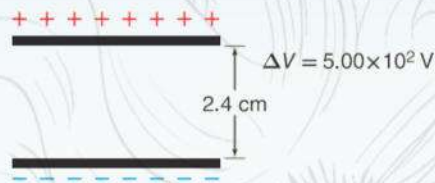
- (a) What is the **electric potential difference** between the plates?
 (b) How much **work** is needed to move a proton from the negative plate to the positive plate?

Solution:

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Written Question (14): What is the **magnitude of the electric field strength** between the two metal plates shown in the figure?

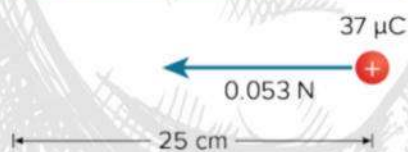


Solution:

Written Question (15): When a potential difference of **125 V** is applied to two parallel plates, the field strength between them is **$4.25 \times 10^3 \text{ N/C}$** . What is the distance between the plates?

Solution:

Written Question (16): A force of **0.053 N** is needed to move a charge of **37 μC** a distance of **25 cm** in a uniform electric field. What is the **electric potential difference** between the two points?



Solution:

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Written Question (17): A negative charge $q = -5 \times 10^{-6} \text{C}$ is between two charged plates A and B. The field strength between the plates is 120 N/C and the distance between them is 2.5 cm .

- Find the **magnitude of the electric force** on the charge.
- In which **direction** will the charge move?
- Calculate the **work** done to move the charge between the plates.

✎ **Solution:**

Written Question (18): Two charged plates A and B are 0.15 m apart. The work done to move a charge of $1.8 \times 10^{-6} \text{C}$ from A to B is $2.7 \times 10^{-4} \text{J}$.

- Find the **electric potential difference** between the plates.
- Calculate the **electric force** on the charge.
- Draw the **electric field lines** between the plates, showing their direction.

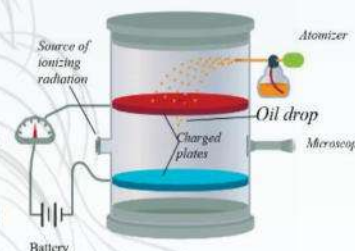
✎ **Solution:**

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Millikan's Oil-Drop Experiment and Charges in Equilibrium

An important application of the uniform electric field between two parallel plates is measuring the **charge of the electron**:

- Tiny oil drops are sprayed from an **atomizer** and become charged by **friction**.
- Some drops fall through a hole into the space between the plates.
- An electric potential difference is applied, and the field exerts a force on the charged drops.
- When the top plate is positive enough, the **negative** drops rise. ΔV is adjusted until a drop is **suspended**.
- Then the downward **weight** equals the upward **electric force**.



$$F_g = F_e \Rightarrow mg = qE \Rightarrow q = \frac{mg}{E}$$

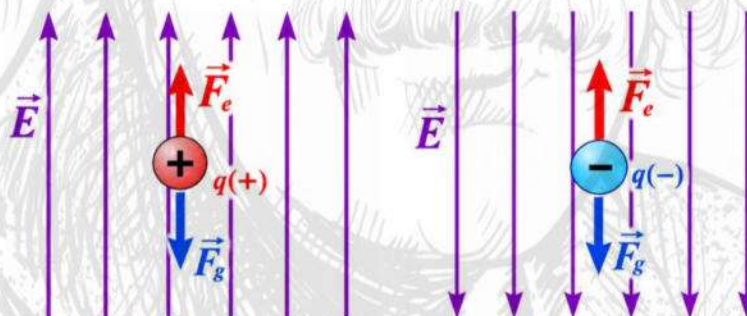
Quantization of Charge

Millikan found that any charge is an **integer multiple** of the elementary charge $e = 1.60 \times 10^{-19} \text{C}$: $q = \pm ne$ (n = a whole number of electrons). That is, charge is **quantized**.

Condition for Equilibrium

For a charged object to stay **suspended**, the net vertical force must be zero: the electric force $|q|E$ must point **upward** to balance the weight mg .

Direction of field E	Required charge	Reason
Upward $\uparrow$	Positive (+)	The force on a + charge is in the direction of E
Downward $\downarrow$	Negative (-)	The force on a - charge is opposite to E



Check Your Understanding

Question (48): A pith ball weighing 0.09 N is placed in a **downward** electric field of $5 \times 10^4 \text{ N/C}$. What charge (**magnitude and sign**) will keep it suspended?

- Ⓐ $-2.3 \times 10^{-7} \text{C}$
Ⓑ $-1.8 \times 10^{-6} \text{C}$

- Ⓒ $1.2 \times 10^{-6} \text{C}$
Ⓓ 4500 C

Question (49): What uniform electric field (**magnitude and direction**) balances the weight of a proton ($m_p = 1.67 \times 10^{-27} \text{kg}$, $q = +1.60 \times 10^{-19} \text{C}$, $g = 9.8 \text{ m/s}^2$)?

- Ⓐ $1.02 \times 10^{57} \text{ N/C}$ upward
Ⓑ $1.02 \times 10^{-7} \text{ N/C}$ downward

- Ⓒ $9.58 \times 10^7 \text{ N/C}$ downward
Ⓓ $9.58 \times 10^7 \text{ N/C}$ upward

Written Question (19): An oil drop weighing $1.9 \times 10^{-15} \text{ N}$ is suspended in an electric field of $6.0 \times 10^3 \text{ N/C}$. What is the **charge** on the drop? How many **excess electrons** does it carry?

Solution:

Written Question (20): An oil drop carries **one** excess electron and weighs $6.4 \times 10^{-15} \text{ N}$. What **electric field strength** is needed to suspend it?

Solution:

Written Question (21): A **positively** charged oil drop weighing $1.2 \times 10^{-14} \text{ N}$ is suspended between two plates that are **0.64 cm** apart with a potential difference of **240 V** between them.

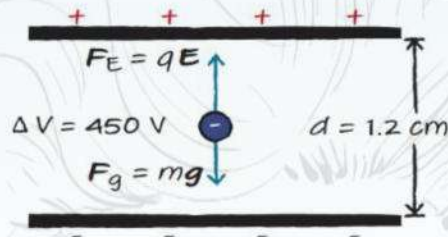
- (a) What is the **charge** on the drop?
- (b) How many **electrons has it lost**?

Solution:

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Chapter 1 Electric Fields

Written Question (22): In Millikan's experiment, an oil drop weighs $2.4 \times 10^{-14} \text{ N}$. The plates are 1.2 cm apart, and the drop is suspended when $\Delta V = 450 \text{ V}$.



- (a) What is the **net charge** on the drop?
(b) If the top plate is positive, how many **excess electrons** are on the drop?

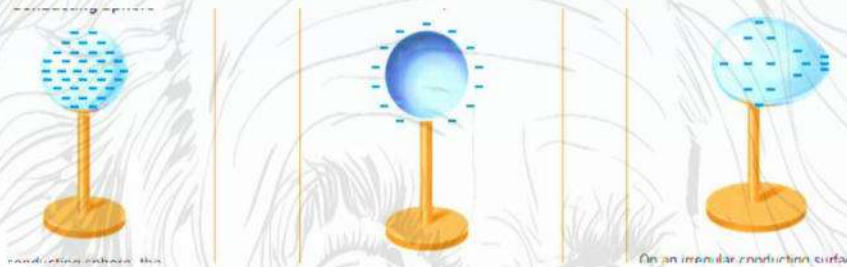
Solution:

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Charges and Fields on Conductors

When a conductor is charged, the charges **repel** each other and spread out to **reduce their electric potential energy**, so they settle on the **outer surface** of the conductor — whether the conductor is **solid or hollow**.

When a charged sphere touches a neutral sphere of the same size, they **share** the charge **equally (charge sharing)**



Charge distribution on a conducting sphere, a hollow sphere, and an irregular conducting surface.

Conductor	Charge distribution	Field
Solid sphere	All the excess charge is on the outer surface , distributed uniformly	Zero inside; outside, like the field of a point charge
Hollow sphere (shell)	The excess charge is on the outer surface only	Zero inside the cavity — the inside is shielded (Faraday cage)
Irregular surface	Charges are closer together at the pointed ends	Strongest near the pointed ends; it may ionize the air and produce sparks , so high-voltage conductors are made smooth

Electric Fields Near Conductors

- The electric field is always **perpendicular** to the surface of a conductor, and the surface is **equipotential**.
- Inside charged **closed metal containers**, a voltmeter reads $\Delta V = 0$ between any two points. Because $\Delta V = Ed$, the field inside is also **zero**: the inside is **shielded** from external fields.

Lightning Rods

If the field is strong enough, charged particles collide with air molecules and produce a stream of ions and electrons — called **plasma**, which is **conducting** — producing a **spark** or **lightning**. A **lightning rod** is placed at the highest point of a building and has a **pointed end** where the field is as strong as possible, so charges coming from the clouds discharge to the rod; a conductor then carries the charge safely **to the ground**.

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Applications of Electrostatic Forces

Application	How it works
Electrostatic painting	Paint droplets are charged by induction ; they repel each other and spread evenly over surfaces such as car bodies.
Photocopiers and laser printers	Static charges attract toner particles to the charged image on the drum before it is transferred to the paper.
Electrostatic precipitators	Smoke particles are charged electrically and are attracted to oppositely charged collectors, then washed away — which reduces air pollution .

Check Your Understanding

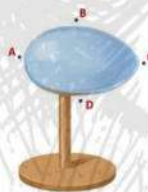
Question (50): Which figure shows the **distribution of excess charge** on a hollow conductor?



Question (51): Which statement is **true** about the field near a conductor?

- (a) The field is always perpendicular to the surface
- (b) The potential difference between any two points on the surface is zero
- (c) The surface of the conductor is equipotential
- (d) All of the above

Question (52): The figure shows an irregular charged conductor. At which point is the electric field **strongest**?

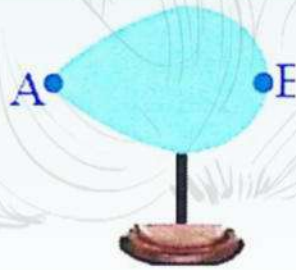


- (a) A
- (c) C

- (b) B
- (d) D

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Question (53): Points A and B are on the surface of the charged conductor shown. Which row gives the **potential** and the **field** at the two points?



(a) $V_B = V_A$; $E_B = E_A$

(c) $V_B = V_A$; $E_B < E_A$

(b) $V_B > V_A$; $E_B > E_A$

(d) $V_B < V_A$; $E_B = E_A$

Question (54): For a charged spherical conductor, the electric potential on its surface is:



(a) constant

(c) dependent on the charge distribution inside

(b) dependent on the type of charge

(d) always zero

Written Question (23):

Describe the charge distribution on a **solid** conducting sphere, a **hollow** conducting sphere, and an **irregular** conducting surface.

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The Van de Graaff Generator

The **Van de Graaff generator** works on the principle of **static electricity** to build up a large charge on a metal dome.

- **Metal dome:** stores the accumulated charge.
- **Belt:** carries the charge from the bottom to the top.
- **Rollers (pulleys):** move the belt and help separate the charge.
- **Metal brush:** transfers charge to and from the belt.



How It Works

- The **lower roller** becomes strongly **negatively** charged, and the belt gains a weaker **positive** charge.
- The negative roller repels electrons from the tips of the brush near A; electrons in the air are attracted to the tips, while **positive ions stick to the belt**.
- The belt carries the positive charge up to the **dome** at B; an **electric motor** does the work that increases the electric potential energy.
- Charges on the dome move to its **outer surface**, so they do not repel the new charges arriving at B.

Written Question (24): Why is the charge not pushed back onto the belt at B?

Solution:

Written Question (25): Why does your hair stand up when you touch the dome?

Solution:



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Capacitors

A **capacitor** is a device used **to store electrical energy**; it consists of **two conductors** separated by an **insulator**.

When it is connected to a source of potential difference, one plate gains a charge of $+q$ and the other a charge of $-q$.



Capacitance (C)

The ratio of the magnitude of the net charge on **one of the plates** to the **electric potential difference** between the plates; it depends on the **geometry** of the capacitor.

$$C = \frac{q}{\Delta V} \quad 1 F = 1 C/V$$

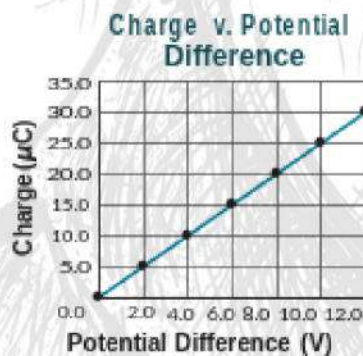
The **farad** is a large unit, so most capacitors are measured in **picofarads** ($10^{-12} F$) and **microfarads** ($10^{-6} F$).
The circuit symbol for a capacitor:



The Charge–Potential Difference Graph

- A graph of q versus ΔV is a **straight line**.
- The **slope** of the line equals the **capacitance C**.
- The **area under the graph** equals the **work done to charge** the capacitor (the stored energy):

$$W = \frac{1}{2} C \Delta V^2 = \frac{1}{2} q \Delta V = \frac{q^2}{2C}$$

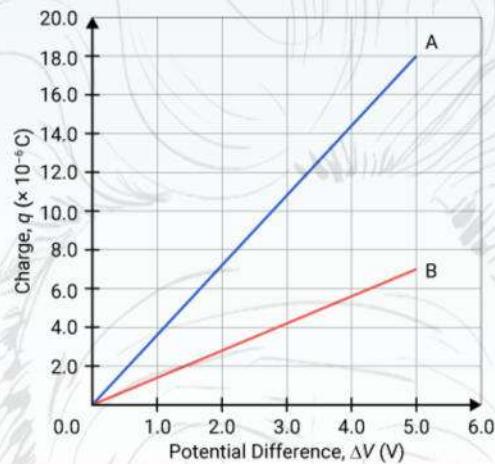


Data Table

Potential Difference (V)	Charge on a Plate (μC)
0.0	0.0
2.0	5.2
4.0	9.7
6.0	15.0
8.0	20.3
10.0	24.7
12.0	30.1

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Worked Example 14 Two capacitors, A and B, are charged, and the figure shows the $q - \Delta V$ graph for each. Find the **capacitance** of each capacitor.



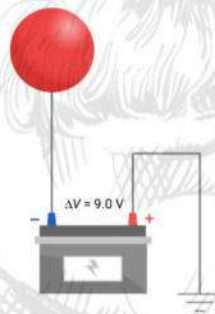
Capacitor A:

$$C_A = \frac{q}{\Delta V} = \frac{18 \times 10^{-6} \text{ C}}{5.0 \text{ V}} = 3.6 \times 10^{-6} \text{ F}$$

Capacitor B:

$$C_B = \frac{7.0 \times 10^{-6} \text{ C}}{5.0 \text{ V}} = 1.4 \times 10^{-6} \text{ F}$$

Worked Example 15 A sphere is connected to the negative terminal of a 9.0 V battery, and the other terminal is connected to the ground. If the capacitance of the (sphere – Earth) system is $C = 3.0 \times 10^{-9} \text{ F}$, what is the **net charge** on the sphere?



Solution:

$$q = C\Delta V = (3.0 \times 10^{-9} \text{ F})(9.0 \text{ V}) = 2.7 \times 10^{-8} \text{ C (negative)}$$

Worked Example 16 A capacitor has a capacitance of $27 \mu\text{F}$ and a potential difference of 45 V across it. What is the charge on its positive plate?

Solution:

$$q = C\Delta V = (27 \times 10^{-6})(45) = 1.2 \times 10^{-3} \text{ C}$$

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Worked Example 17 A $3.3 \mu\text{F}$ capacitor and a $6.8 \mu\text{F}$ capacitor are each connected across a potential difference of 24 V .

(a) Which capacitor has the greater charge? What is it?

(b) Later, the charge on each plate becomes $3.5 \times 10^{-4} \text{ C}$: which capacitor has the greater potential difference across it? What is it?

(a)

$q = C\Delta V$, so the capacitor with the greater capacitance ($6.8 \mu\text{F}$) has the greater charge:

$$q = (6.8 \times 10^{-6})(24) = 1.6 \times 10^{-4} \text{ C}$$

(b)

$\Delta V = q/C$, so the capacitor with the smaller capacitance ($3.3 \mu\text{F}$) has the greater potential difference:

$$\Delta V = \frac{3.5 \times 10^{-4}}{3.3 \times 10^{-6}} = 1.1 \times 10^2 \text{ V}$$

Worked Example 18 A capacitor of $2.2 \mu\text{F}$ has a potential difference of 6.0 V across it.

How much charge is needed to raise the potential difference to 15.0 V ?

Solution:

$$q = C\Delta V = (2.2 \times 10^{-6})(15.0) = 3.3 \times 10^{-5} \text{ C}$$

$$\text{Additional charge: } 3.3 \times 10^{-5} - 1.32 \times 10^{-5} = 2.0 \times 10^{-5} \text{ C}$$

Worked Example 19 When the potential difference across a capacitor is increased from 12.0 V to 14.5 V , the charge on each plate increases by $2.5 \times 10^{-5} \text{ C}$. What is the capacitance of the capacitor?

Solution:

$$C = \frac{\Delta q}{\Delta V} = \frac{2.5 \times 10^{-5} \text{ C}}{2.5 \text{ V}} = 1.0 \times 10^{-5} \text{ F}$$

Check Your Understanding

Question (55): A $0.093 \mu\text{F}$ capacitor stores a charge of $58 \mu\text{C}$. What is the **electric potential difference** across it?

(a) $5.4 \times 10^{-12} \text{ V}$

(b) $1.6 \times 10^{-6} \text{ V}$

(c) $6.2 \times 10^2 \text{ V}$

(d) $5.4 \times 10^3 \text{ V}$

Question (56): A capacitor of $35 \mu\text{F}$ has a potential difference of 50.0 V across it. What is the **charge** on the capacitor?

(a) $1.4 \times 10^{-6} \text{ C}$

(b) $1.8 \times 10^{-3} \text{ C}$

(c) $1.8 \times 10^3 \text{ C}$

(d) 1.75 C

Question (57): The **function** of a capacitor is to:

(a) measure capacitance

(b) store charge

(c) determine the charge on an object

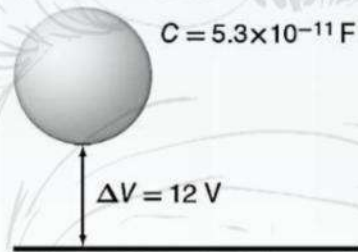
(d) generate electric potential

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Question (58): What is the **unit** of capacitance?

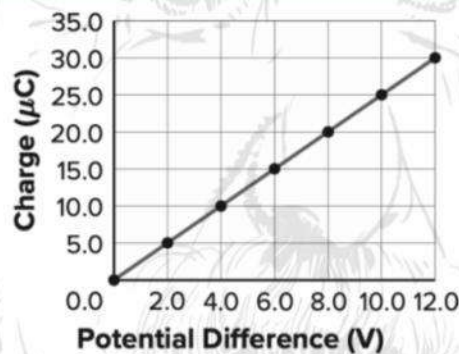
- (a) farad
- (b) joule/coulomb
- (c) volt/coulomb
- (d) coulomb

Question (59): A sphere is charged by a **12 V** battery and suspended above the ground as shown in the figure. What is the **net charge** on the sphere?



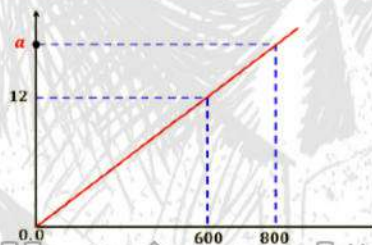
- (a) $3.7 \times 10^{-13} \text{ C}$
- (b) $2.3 \times 10^{11} \text{ C}$
- (c) $6.4 \times 10^{-10} \text{ C}$
- (d) $4.4 \times 10^{-12} \text{ C}$

Question (60): The graph shows the charge on one plate versus the charging potential difference. Calculate the **capacitance**.



- (a) $0.4 \mu\text{F}$
- (b) $2.5 \mu\text{F}$
- (c) 0.4 F
- (d) 2.5 F

Question (61): The graph shows the charge stored on one plate versus the charging potential difference. What is the **charge** (a) on the graph?



- (a) $18 \mu\text{C}$
- (b) $24 \mu\text{C}$
- (c) $16 \mu\text{C}$
- (d) $6 \mu\text{C}$

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Question (62): When a $20 \mu\text{F}$ capacitor is connected to a battery, the charge on its positive plate is $40 \mu\text{C}$. What is the **electric potential difference** between its plates?

+++++

(a) 60.0 V

(b) 800.0 V

(c) 2.00 V

(d) 0.50 V

Question (63): What does the **slope** of a graph of q versus ΔV represent?

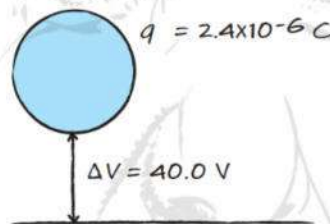
(a) capacitance in volts

(b) capacitance in volts per coulomb

(c) capacitance in farads

(d) electric field in coulombs per volt

Written Question (26): A sphere is connected to the positive (+) terminal of a 40 V battery while the negative (-) terminal is connected to the ground, and the charge on the sphere becomes $2.4 \times 10^{-6} \text{ C}$. What is the **capacitance** of the (sphere – Earth) system?



Solution:

Written Question (27): What is the **charge** on each plate of a $0.47 \mu\text{F}$ capacitor when a potential difference of 12 V is applied across it?

Solution:

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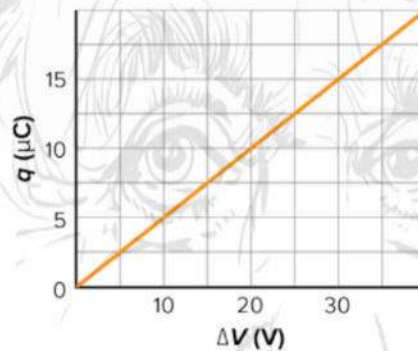
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Written Question (28): A capacitor connected to a **45.0 V** source has a charge of **90.0 μC** . What is its **capacitance**?

Solution:

Written Question (29): The graph shows the charge stored on one plate of a capacitor versus the charging potential difference.



- A. What does the **slope** represent?
- B. What is the **capacitance**?
- C. What does the **area under the line** represent?

Solution:

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Tenth: Key Concepts and Vocabulary

Term	Meaning
Electric field	A region in which charges experience a force; $E = F/q$.
Electric field lines	Imaginary lines that show the direction and strength of the field; they leave the positive charge (+) and point toward the negative charge (-).
Electric potential difference / volt	$\Delta V = W/q$; 1 V = 1 J/C.
Equipotential	The same potential at all points, so no work is done to move a charge between them.
Capacitor / capacitance	Stores charge and energy / $C = q/\Delta V$, measured in farads.

Summary of Equations

Quantity	Equation	Unit
Electric field (definition)	$E = \frac{F}{q'}$	N/C
Field of a point charge	$E = k \frac{q}{r^2}$	N/C
Ratio of lines to charges	$\frac{q_1}{q_2} = \frac{n_1}{n_2}$	—
Electric potential difference	$\Delta V = \frac{W}{q'}$	V = J/C
Uniform field	$\Delta V = Ed$, $W = qEd$	V, J
Millikan / equilibrium	$mg = qE$, $q = ne$	C
Capacitance	$C = \frac{q}{\Delta V}$	F = C/V
Stored energy	$W = \frac{1}{2} C \Delta V^2$	J

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