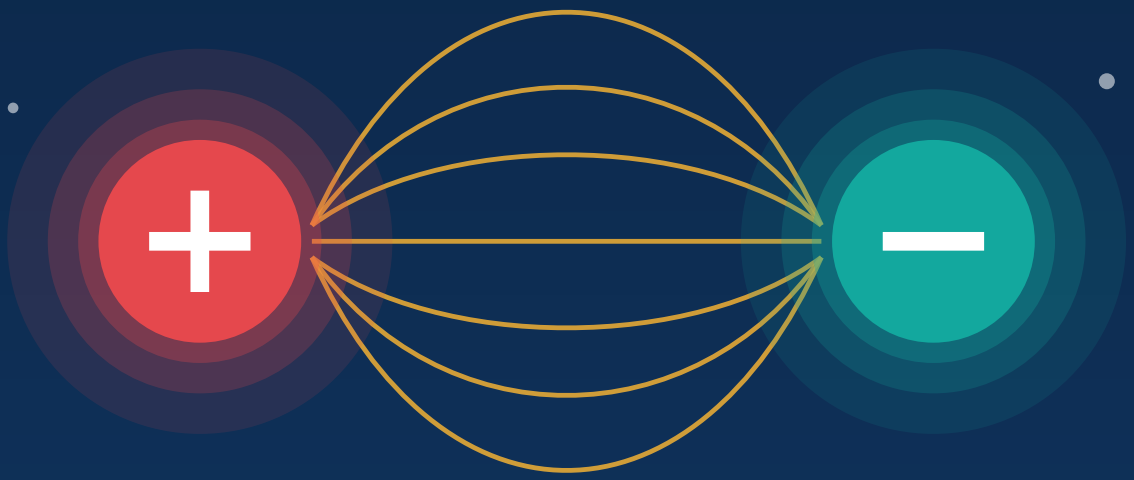
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ELECTROSTATICS

10th Class Physics • Chapter 13

Complete Exercise Solutions

- MCQs with Explanations
- Review Questions
- Conceptual Questions
- Numerical Problems

MULTIPLE CHOICE QUESTIONS

Choose the correct answer from the following choices:

i. A positive electric charge

(a) attracts other positive charge

✓ **(b) repels other positive charge**

(c) attracts a neutral charge

(d) repels a neutral charge

✓ **Correct Answer: (b) repels other positive charge**

Explanation: According to the fundamental law of electrostatics, like charges repel each other and unlike charges attract each other. Since both charges are positive, they will repel each other.

ii. An object gains excess negative charge after being rubbed against another object, which is:

(a) neutral

(b) negatively charged

✓ **(c) positively charged**

(d) either a, b or c

✓ **Correct Answer: (c) positively charged**

Explanation: The law of conservation of charge states that charge cannot be created or destroyed, only transferred. If one object gains negative electrons, the other object must lose those same electrons. Losing electrons leaves the second object with a net positive charge.

iii. Two uncharged objects A and B are rubbed against each other. When object B is placed near a negatively charged object C, the two objects repel each other. Which of the following statements is true about object A?

(a) remains uncharged

✓ **(b) becomes positively charged**

(c) becomes negatively charged

(d) unpredictable

✓ **Correct Answer: (b) becomes positively charged**

Explanation: Object B repels the negatively charged object C. Since like charges repel, object B must also be negatively charged. Because objects A and B were initially neutral and rubbed together, the electrons transferred from A to B (making B negative). Therefore, object A lost electrons and became positively charged.

iv. When you rub a plastic rod against your hair several times and put it near some bits of paper, the pieces of papers are attracted towards it. What does this observation indicate?

✓ **(a) the rod and the paper are oppositely charged**

(b) the rod acquires a positive charge

(c) the rod and the paper have the same charges

(d) the rod acquires a negative charge

✓ **Correct Answer: (a) the rod and the paper are oppositely charged**

Explanation: Rubbing the rod charges it via friction. When brought near neutral paper, the charged rod induces a temporary opposite charge on the near surface of the paper (polarization). The attraction is between the charge on the rod and the induced opposite charge on the paper.

v. According to Coulomb's law, what happens to the attraction of two oppositely charged objects as their distance of separation increases?

(a) increases

✓ **(b) decreases**

(c) remains unchanged

(d) cannot be determined

✓ **Correct Answer: (b) decreases**

Explanation: Coulomb's law states that electrostatic force is inversely proportional to the square of the distance between the charges ($F \propto 1/r^2$). Therefore, as the distance (r) increases, the force of attraction decreases.

vi. The Coulomb's law is valid for the charges which are

(a) moving and point charges

(b) moving and non-point charges

✓ **(c) stationary and point charges**

(d) stationary and large size charges

✓ **Correct Answer: (c) stationary and point charges**

Explanation: Coulomb's law is strictly valid for point charges (charges with negligible size compared to the distance between them) that are stationary (at rest). Moving charges produce magnetic fields, which complicates the force interaction.

vii. A positive and a negative charge are initially 4 cm apart. When they are moved closer together so that they are now only 1 cm apart, the force between them is

(a) 4 times smaller than before

(b) 4 times larger than before

(c) 8 times larger than before

✓ **(d) 16 times larger than before**

✓ **Correct Answer: (d) 16 times larger than before**

Explanation: $F \propto 1/r^2$. The distance becomes 1/4 of its original value (4 cm → 1 cm). The force becomes $(1 / (1/4))^2 = 4^2 = 16$ times larger.

viii. Five joules of work is needed to shift 10 C of charge from one place to another. The potential difference between the places is

✓ **(a) 0.5 V**

(b) 2 V

(c) 5 V

(d) 10 V

✓ **Correct Answer: (a) 0.5 V**

Explanation: Potential difference (V) is work done per unit charge. V = W/Q = 5 J / 10 C = 0.5 V.

ix. Two small charged spheres are separated by 2 mm. Which of the following would produce the greatest attractive force?

(a) +1q and +4q

(b) −1q and −4q

(c) +2q and +2q

✓ **(d) +2q and −2q**

✓ **Correct Answer: (d) +2q and −2q**

Explanation: Attractive force occurs only between opposite charges. Options (a), (b), and (c) involve like charges and thus produce repulsive forces. Option (d) is the only pair with opposite charges, making it the only attractive force among the choices.

x. Electric field lines

(a) always cross each other

✓ **(b) never cross each other**

(c) cross each other in the region of strong field

(d) cross each other in the region of weak field

✓ **Correct Answer: (b) never cross each other**

Explanation: If electric field lines crossed, it would imply that at the point of intersection, the electric field has two different directions simultaneously, which is physically impossible.

xi. Capacitance is defined as

(a) VC

✓ **(b) Q/V**

(c) QV

(d) V/Q

✓ **Correct Answer: (b) Q/V**

Explanation: The capacitance (C) of a capacitor is defined as the ratio of the charge (Q) stored on one plate to the potential difference (V) across the plates. C = Q/V. Its unit is Farad.

REVIEW QUESTIONS

13.1. How can you show by simple experiments that there are two types of electric charges?

Answer: Suspend a glass rod rubbed with silk freely. Bring another glass rod rubbed with silk near it. They will repel. Now bring an ebonite rod rubbed with fur near the suspended glass rod. They will attract. This shows that the charge on the glass rod is different from the charge on the ebonite rod (like charges repel, unlike attract), proving there are two types of charges.

13.2. Describe the method of charging bodies by electrostatic induction.

Answer: Bring a charged body near an uncharged conductor. The free electrons in the conductor are either attracted or repelled, causing a separation of charge (polarization). If the conductor is temporarily connected to the ground, electrons flow to/from the earth. Disconnecting the ground and then removing the charged body leaves the conductor with a net charge opposite to that of the inducing body.

13.3. How does electrostatic induction differ from charging by friction?

Answer: Charging by friction involves physical contact and the actual transfer of electrons from one material to another. Electrostatic induction does not involve contact; it redistributes the existing charges within a conductor due to the proximity of a charged body.

13.4. What is gold leaf electroscope? Discuss its working principle with a labelled diagram.

Answer: A gold leaf electroscope is a device used to detect the presence and nature of electric charge.

Working Principle: It works on the principle that like charges repel each other. When a charged object touches the metal disc, the charge travels down the brass rod to the gold leaf. Both the rod and the leaf acquire the same charge and repel each other, causing the leaf to diverge.

Diagram: A glass jar containing a brass rod. A metal disc is on top, outside the jar. A thin gold leaf is attached to the bottom of the rod inside.

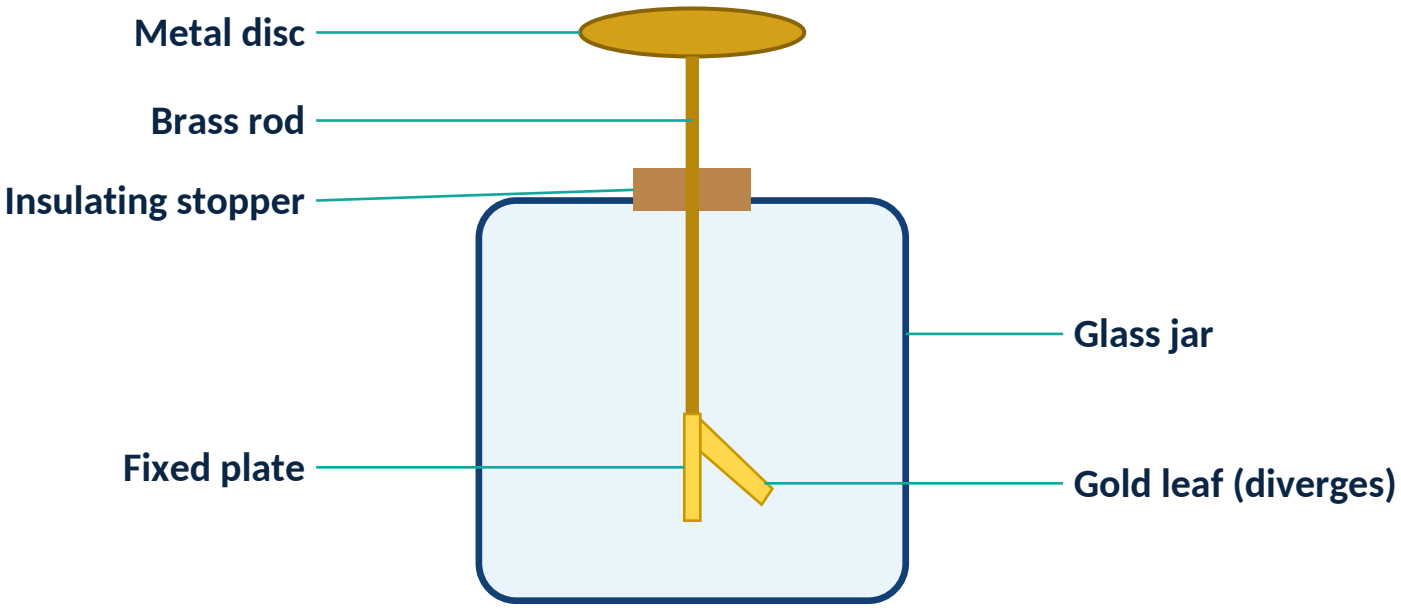


Fig: Gold Leaf Electroscope

13.5. Suppose you have a glass rod which becomes positively charged when you rub it with wool. Describe how would you charge the electroscope (i) negatively (ii) positively.

Answer: **(i) Negatively:** Bring the positive glass rod near the disc of the neutral electroscope (do not touch). This induces a negative charge on the disc. Ground the disc momentarily with your finger; electrons flow from the ground to neutralize the positive charge. Remove your finger, then remove the rod. The electroscope is left with a net negative charge.
(ii) Positively: Simply touch the positively charged glass rod directly to the metal disc of the electroscope. Electrons will transfer from the electroscope to the rod, leaving the electroscope positively charged.

13.6. With the help of electroscope how can you find presence of charge on a body.

Answer: Bring the body near the metal disc of a neutral electroscope. If the gold leaves diverge (open up), it indicates that the body is carrying an electric charge.

13.7. Describe how you would determine the nature of the charge on a body by using electroscope.

Answer: First, charge the electroscope with a known charge (e.g., negative). Then bring the unknown charged body near the disc. If the leaves diverge more, the body has the same charge (negative). If the leaves collapse slightly, the body has the opposite charge (positive).

13.8. Explain Coulomb's law of electrostatics and write its mathematical form.

Answer: Coulomb's law states that the electrostatic force of attraction or repulsion between two point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the distance between them.
Mathematical form: $F = k\, q_1 q_2 / r^2$

13.9. What is meant by electric field and electric intensity?

Answer: **Electric Field:** The region or space around a charged body where its electric force can be experienced by another charge.
Electric Intensity: The force experienced per unit positive charge placed at a point in the electric field. ($E = F/q$).

13.10. Is electric intensity a vector quantity? What will be its direction?

Answer: Yes, electric intensity is a vector quantity. Its direction is the same as the direction of the force acting on a positive test charge (it points away from a positive charge and towards a negative charge).

13.11. How would you define potential difference between two points? Define its unit.

Answer: The potential difference between two points is the amount of work done in moving a unit positive charge from one point to the other. Its SI unit is the Volt (V). 1 Volt = 1 Joule / Coulomb.

13.12. Show that potential difference can be described as energy transfer per unit charge between the two points.

Answer: Since V = W/Q, where W is the work done (energy transferred) and Q is the charge. This equation mathematically shows that the potential difference is the energy transferred per unit charge.

13.13. What do you mean by the capacitance of a capacitor? Define units of capacitance.

Answer: The capacitance of a capacitor is its ability to store electric charge. It is the ratio of the charge on one plate to the potential difference between the plates (C = Q/V). Its unit is Farad (F). 1 F = 1 C/V.

13.14. Derive the formula for the equivalent capacitance for a series combination of a number of capacitors.

Answer: In a series combination, the charge (Q) on each capacitor is the same. The total potential difference is the sum of voltages: $V = V_1 + V_2 + V_3$.
Since V = Q/C, we get $Q/C_{eq} = Q/C_1 + Q/C_2 + Q/C_3$. Dividing by Q:
$$\mathbf{1/C_{eq} = 1/C_1 + 1/C_2 + 1/C_3}$$

13.15. Discuss different types of capacitors.

Answer: **1. Variable Capacitors:** Used in radio tuning; capacitance can be changed by manually rotating interleaved plates.
2. Fixed Capacitors: Capacitance is fixed. Examples include paper capacitors (foil separated by paper), mica capacitors (mica sheets), and electrolytic capacitors (used for high capacitance in power supplies).

13.16. What is difference between variable and fixed type capacitor?

Answer: A variable capacitor allows the user to physically change its capacitance by moving its plates, whereas the capacitance of a fixed capacitor is set during manufacturing and cannot be altered.

13.17. Enlist some uses of capacitors.

Answer: 1. Storing electrical energy.
2. Tuning radio frequencies.
3. Smoothing/filtering power supplies.
4. Coupling and bypassing in circuits.
5. Timing circuits.

13.18. Discuss one application of static electricity.

Answer: **Electrostatic Precipitators:** Used in factory chimneys to remove smoke and dust particles. The dust particles are given a negative charge as they pass through a charged wire, and are then attracted to positively charged plates, cleaning the exhaust gas.

13.19. What are hazards of static electricity?

Answer: 1. Sparks can ignite flammable gases or liquids, causing fires (e.g., at gas stations).
2. Static discharge can damage sensitive electronic components like computer chips.
3. It can cause clothing to cling and dust to stick to surfaces.

CONCEPTUAL QUESTIONS

13.1. An electrified rod attracts pieces of paper. After a while these pieces fly away! Why?

Answer: Initially, the electrified rod polarizes the neutral paper pieces, inducing an opposite charge on the nearer side, causing attraction. When they touch the rod, the paper pieces acquire the same charge as the rod. Due to the repulsion between like charges, they fly away.

13.2. How much negative charge has been removed from a positively charged electroscope, if it has a charge of 7.5×10^{-11} C?

Answer: A positive charge means the object has lost electrons. Therefore, an equal amount of negative charge has been removed. So, $\mathbf{7.5 \times 10^{-11}}$ **C** of negative charge has been removed.

13.3. In which direction will a positively charged particle move in an electric field?

Answer: A positively charged particle will move in the direction of the electric field lines (from a region of higher potential to lower potential, or away from positive charges and towards negative charges).

13.4. Does each capacitor carry equal charge in series combination? Explain.

Answer: Yes, in a series combination, the same charge is induced on each capacitor plate because the charge has only one path to flow. The plates connected to each other share the induced charge, resulting in an equal amount of charge on all capacitors.

13.5. Each capacitor in parallel combination has equal potential difference between its two plates. Justify the statement.

Answer: In a parallel combination, all the left plates are connected to one common point and the right plates to another. The potential difference is simply the difference in voltage between these two common wires. Thus, every capacitor directly experiences the full battery voltage.

13.6. Perhaps you have seen a gasoline truck trailing a metal chain beneath it. What purpose does the chain serve?

Answer: The metal chain acts as a grounding wire. Friction between the moving truck and the air can build up static charge. The chain safely conducts this charge to the ground, preventing a static spark that could ignite the highly flammable gasoline.

13.7. If a high-voltage power line fell across your car while you were in the car, why should you not come out of the car?

Answer: The metal body of the car acts as a Faraday cage. The electric current travels along the exterior metal shell and safely to the ground. If you step out, your body may create a path for the high-voltage current to the ground, causing severe electrocution (step potential).

13.8. Explain why, a glass rod can be charged by rubbing when held by hand but an iron rod cannot be charged by rubbing, if held by hand?

Answer: Glass is an insulator, so the charge stays localized on the rubbed area. Iron is a conductor; if held by hand, any charge transferred by friction will immediately flow through your body to the ground, leaving the rod neutral.

NUMERICAL PROBLEMS

13.1. The charge of how many negatively charged particles would be equal to 100 μC. Assume one negative particle is 1.6×10^{-19} C.

Solution: Given: Total charge Q = 100 μC = 100×10^{-6} C = 10^{-4} C
Charge of one electron e = 1.6×10^{-19} C
Number of particles n = Q / e
n = $10^{-4} / (1.6 \times 10^{-19}) = (1/1.6) \times 10^{15} = 0.625 \times 10^{15} =$ **6.25×10^{14}**

13.2. Two point charges q_1 = 10 μC and q_2 = 5 μC are placed at a distance of 150 cm. What will be the Coulomb's force between them? Also find the direction of the force.

Solution: Given: $q_1 = 10 \times 10^{-6}$ C, $q_2 = 5 \times 10^{-6}$ C
r = 150 cm = 1.5 m, k = 9×10^9 N m^2/C^2
$F = k q_1 q_2 / r^2 = [9 \times 10^9 \times (10 \times 10^{-6}) \times (5 \times 10^{-6})] / (1.5)^2$
$F = (450 \times 10^{-3}) / 2.25 = 0.45 / 2.25 =$ **0.2 N**
Direction: Since both charges are positive, the force is repulsive (directed away from each other).

13.3. The force of repulsion between two identical positive charges is 0.8 N, when the charges are 0.1 m apart. Find the value of each charge.

Solution: Given: F = 0.8 N, r = 0.1 m, $q_1 = q_2 = q$
$F = k q^2 / r^2 \Rightarrow q^2 = F r^2 / k$
$q^2 = [0.8 \times (0.1)^2] / (9 \times 10^9) = 0.008 / (9 \times 10^9) = 8.88 \times 10^{-13}$
$q = \sqrt{(8.88 \times 10^{-13})} = \sqrt{(88.8 \times 10^{-14})}$
$q \approx$ **9.4×10^{-7} C**

13.4. Two charges repel each other with a force of 0.1 N when they are 5 cm apart. Find the forces between the same charges when they are 2 cm apart.

Solution: Given: $F_1 = 0.1$ N, $r_1 = 5$ cm, $r_2 = 2$ cm, $F_2 = ?$
By Coulomb's law, $F \propto 1/r^2$ (for same charges)
$F_2/F_1 = (r_1/r_2)^2 = (5/2)^2 = 25/4 = 6.25$
$F_2 = 6.25 \times F_1 = 6.25 \times 0.1 =$ **0.625 N**

13.5. The electric potential at a point in an electric field is 10^4 V. If a charge of +100 µC is brought from infinity to this point. What would be the amount of work done on it?

Solution: Given: $V = 10^4$ V, $q = 100\ \mu C = 100 \times 10^{-6}\ C = 10^{-4}\ C$
$W = V \times q = 10^4 \times 10^{-4} =$ **1 J**

13.6. A point charge of +2 C is transferred from a point at potential 100 V to a point at potential 50 V. What would be the energy supplied by the charge?

Solution: Given: $q = +2$ C, $V_1 = 100$ V, $V_2 = 50$ V
Change in potential $\Delta V = V_2 - V_1 = 50 - 100 = -50$ V
Work done $W = q\,\Delta V = 2 \times (-50) = -100$ J
The negative sign indicates that the charge is losing energy. The energy supplied by the charge is **100 J**.

13.7. A capacitor holds 0.06 coulombs of charge when fully charged by a 9 volt battery. Calculate capacitance of the capacitor.

Solution: Given: $Q = 0.06$ C, $V = 9$ V
$C = Q/V = 0.06 / 9 \approx$ **6.67×10^{-3} F** (or 6.67 mF)

13.8. A capacitor holds 0.03 coulombs of charge when fully charged by a 6 volt battery. How much voltage would be required for it to hold 2 coulombs of charge?

Solution: First, find capacitance: $C = Q_1/V_1 = 0.03 / 6 = 0.005$ F
Now find new voltage: $V_2 = Q_2/C = 2 / 0.005 =$ **400 V**

13.9. Two capacitors of capacitances 6 µF and 12 µF are connected in series with 12 V battery. Find the equivalent capacitance of the combination. Find the charge and the potential difference across each capacitor.

Solution: **Given:** $C_1 = 6$ µF, $C_2 = 12$ µF, $V = 12$ V
For series: $1/C_{eq} = 1/C_1 + 1/C_2 = 1/6 + 1/12 = 3/12 = 1/4$
$C_{eq} =$ **4 µF**
Total charge $Q = C_{eq} \times V = 4$ µF $\times$ 12 V = **48 µC**
In series, charge on each capacitor is the same: $Q_1 = Q_2 =$ **48 µC**
Potential difference across C_1: $V_1 = Q_1/C_1 = 48/6 =$ **8 V**
Potential difference across C_2: $V_2 = Q_2/C_2 = 48/12 =$ **4 V**

13.10. Two capacitors of capacitances 6 µF and 12 µF are connected in parallel with a 12 V battery. Find the equivalent capacitance of the combination. Find the charge and the potential difference across each capacitor.

Solution: Given: $C_1 = 6\ \mu F$, $C_2 = 12\ \mu F$, $V = 12\ V$

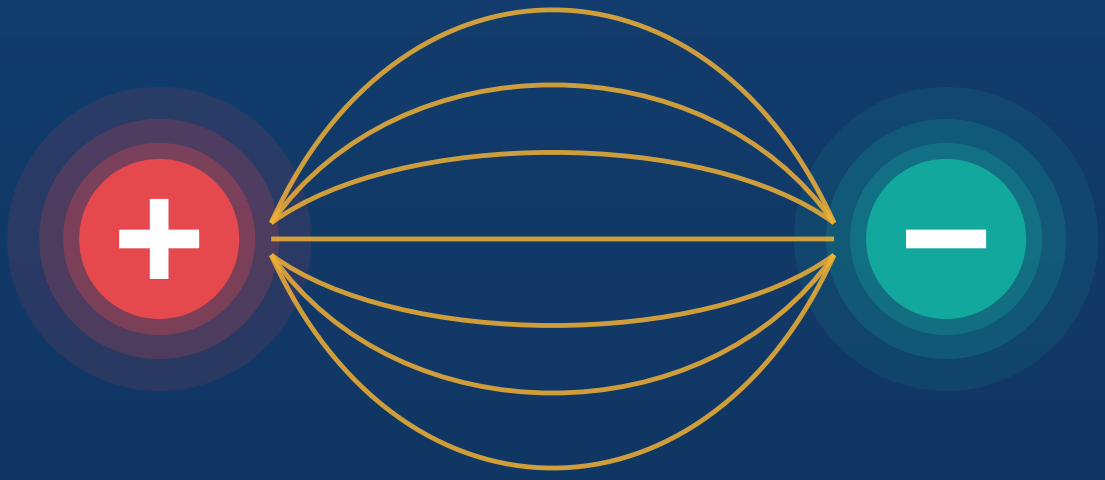
For parallel: $C_{eq} = C_1 + C_2 = 6 + 12 = \mathbf{18\ \mu F}$

In parallel, the potential difference across each capacitor is the same as the battery voltage: $V_1 = V_2 = \mathbf{12\ V}$

Charge on C_1: $Q_1 = C_1 \times V = 6\ \mu F \times 12\ V = \mathbf{72\ \mu C}$

Charge on C_2: $Q_2 = C_2 \times V = 12\ \mu F \times 12\ V = \mathbf{144\ \mu C}$

(Total charge $Q = 72 + 144 = 216\ \mu C$)



Thank You!

Keep Learning, Keep Shining

End of Chapter 13: Electrostatics

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