Unit 19 · Electric Charges

ANSWER KEY · FOR TEACHERS

Full marks 37

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. electrons
2. conservation
3. quantized
4. conductor
5. induction
6. discharging
7. relative permittivity
8. superposition

Each carries 0.5 mark. **K · 4**

2 Match the columns

1. metals → **b.** free electrons
2. salt solution → **a.** positive and negative ions
3. a gas after a spark → **e.** ions and electrons
4. silicon (a semiconductor) → **c.** electrons and holes

Each carries 0.5 mark. **K · 2**

3 Multiple choice

i. **c.** becomes positive, with a charge equal in size to the rod's **U · 1**

Electrons move from the wool to the rod: the wool is left with as much positive charge as the rod gained negative charge (conservation of charge).

ii. **c.** 2.4×10^{-19} C **A · 1**

Charge is quantized, Q = ne: 2.4×10^{-19} C is 1.5e, not a whole number of electrons.

iii. **b.** 12 N **A · 1**

$F \propto Q_1Q_2/r^2$: the product of the charges is 4 times larger and r^2 is 4 times larger, so F is unchanged.

iv. **b.** $C^2/(N\ m^2)$ **K · 1**

From $F = Q_1Q_2/(4\pi\varepsilon_0 r^2)$, $\varepsilon_0 = Q_1Q_2/(4\pi F r^2)$: $C^2/(N\ m^2)$.

v. **c.** 10 cm **U · 1**

Uniformly charged spheres act as point charges at their centers: r = 2 + 6 + 2 = 10 cm.

4 Very short answers

a. **MARKING SCHEME** **K · 1**

✓ Ions (Na^+ and Cl^-).

b. **MARKING SCHEME** **K · 1**

✓ $F \propto Q_1Q_2$ and $F \propto 1/r^2$, along the line joining the charges.

c. **MARKING SCHEME** **U · 1**

✓ 6.25×10^{18}.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

5 Short answers

a. MARKING SCHEME — U · 2

- ✓ In humid air, a thin film of water forms on surfaces and water molecules in the air carry charge away, so charge leaks away (the surfaces and air conduct a little).
- ✓ In dry air, charge built up by walking (rubbing) stays on the body until it jumps as a spark to the metal handle.

b. MARKING SCHEME — U · 2

- ✓ In water the Coulomb force between the sodium and chloride ions is about 80 times weaker than in air (ε replaces ε_0).
- ✓ The weakened attraction lets the jostling water molecules pull the ions apart, so the crystal dissolves.

c. MARKING SCHEME — A · 2

- ✓ Each has half of the original positive charge.
- ✓ Electrons flow from the uncharged sphere to the charged one until the charge spreads equally over the two identical conductors (total charge conserved).

6 Long answer

ANSWER — U · 4

Bring the negative rod near the sphere: the sphere's free electrons are pushed to its far side, leaving the near side positive. Touch the sphere with a finger: the repelled electrons flow out through the body to the Earth. Take the finger away, so they can't come back. Then take the rod away: the sphere has lost electrons, so it is left positively charged, and the charge spreads evenly over it. If the rod were removed first, while the finger still touched the sphere, electrons would flow back from the Earth and the sphere would end up uncharged.

MARKING SCHEME

- ✓ The rod near the sphere pushes free electrons to the far side (diagram).
- ✓ Touching with a finger earths it: electrons flow away to the Earth.
- ✓ Finger removed, then rod: the sphere is left positive, the charge spread evenly (diagram).
- ✓ If the rod went first, electrons would flow back from the Earth and the sphere would be uncharged.

7 Numerical problems

a. ANSWER — A · 3

$n = Q/e = 3.2 \times 10^{-9} \div 1.6 \times 10^{-19} =$ **2.0×10^{10}** electrons.

Mass gained $= 2.0 \times 10^{10} \times 9.11 \times 10^{-31} =$ **1.8×10^{-20} kg**, far too little to measure.

MARKING SCHEME

- ✓ $n = Q/e$.
- ✓ 2.0×10^{10} electrons.
- ✓ 1.8×10^{-20} kg.

b. ANSWER — A · 4

From A (like charges, a push away from A, east): $F(A) = 9.0 \times 10^{9} \times 4.0 \times 10^{-6} \times 2.0 \times 10^{-6} \div 0.30^2 =$ **0.80 N east**.

From B (unlike, a pull towards B, north): $F(B) = 9.0 \times 10^{9} \times 6.0 \times 10^{-6} \times 2.0 \times 10^{-6} \div 0.40^2 =$ **0.675 N north**.

At right angles: $F = \sqrt{(0.80^2 + 0.675^2)} =$ **1.05 N**, at $\tan^{-1}(0.675/0.80) =$ **40° north of east**.

MARKING SCHEME

- ✓ F(A) = 0.80 N, east.
- ✓ F(B) = 0.675 N, north.
- ✓ Added as vectors: F = 1.05 N.
- ✓ Direction 40° north of east.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

c. ANSWER A · 3

Before: $F = 9.0 \times 10^9 \times 6.0 \times 10^{-6} \times 2.0 \times 10^{-6} \div 0.20^2 =$ **2.7 N, attractive**.
On touching, the total charge, +4.0 μC, is shared equally: +2.0 μC each.
After: $F = 9.0 \times 10^9 \times (2.0 \times 10^{-6})^2 \div 0.20^2 =$ **0.90 N, repulsive**.

MARKING SCHEME

- ✓ 2.7 N attractive.
- ✓ Each sphere +2.0 μC after touching.
- ✓ 0.90 N repulsive.

8 Think

ANSWER HA · 3

The comb's charge pulls the paper's charges slightly apart inside its molecules: the side near the comb takes the opposite charge, the far side the same charge. The opposite charge is nearer, and the force falls off as $1/r^2$, so the attraction beats the repulsion and the paper is pulled in. Once it touches, some of the comb's charge passes to the paper; now both carry the same kind of charge, and they repel.

MARKING SCHEME

- ✓ The comb pulls the paper's charges apart: opposite charge on the near side.
- ✓ The near charge is closer, and $F \propto 1/r^2$, so the net force is attractive.
- ✓ After touching, the paper gets charge of the same sign as the comb and is repelled.

9 Activity: Which charges attract?

(not marked)

WHAT STUDENTS SHOULD FIND

The other rubbed plastics (strip, balloon, comb) repel the hanging strip: they have the same charge, negative (polythene takes electrons from wool). The wool attracts it: it has lost the electrons the plastic gained, so it is positive, an equal and opposite charge. Uncharged tissue paper is attracted too, so attraction alone doesn't prove a charge; only repulsion does.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Static Electricity** (exhibit): These foam beads weigh so little that the small electric forces between charges, attracting and repelling, are enough to make them jump and cling.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	9	11	14	3	**37**

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking