Unit 19 · Electric Charges

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 30

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

1 Spot the error

ANSWER U · 3

For uniformly charged spheres, r is measured between their **centers**: r = 1.0 + 4.0 + 1.0 = 6.0 cm. F = $9.0 \times 10^9 \times (3.0 \times 10^{-6})^2 \div (0.060)^2$ = **22.5 N**, repulsive.

MARKING SCHEME

- ✓ The error: r must be from center to center, not between the surfaces.
- ✓ r = 6.0 cm.
- ✓ F = 22.5 N (repulsive).

2 Work backwards

ANSWER A · 3

i. $F = kq^2/r^2$, so $q = \sqrt{(Fr^2/k)} = \sqrt{(0.90 \times 0.050^2 \div 9.0 \times 10^9)}$ = **5.0×10^{-7} C** (0.50 μC), both positive or both negative.

ii. If positive: $n = 5.0 \times 10^{-7} \div 1.6 \times 10^{-19}$ = **3.1×10^{12}** electrons removed.

MARKING SCHEME

- ✓ $q = \sqrt{(Fr^2/k)}$.
- ✓ $q = 5.0 \times 10^{-7}$ C.
- ✓ $n = 3.1 \times 10^{12}$.

3 Check the readings

ANSWER HA · 3

If $F \propto 1/r^2$, then $F \times r^2$ is the same for every reading: $7.2 \times 4 = 28.8$; $3.2 \times 9 = 28.8$; $1.4 \times 16 = 22.4$; $1.15 \times 25 = 28.8$; $0.80 \times 36 = 28.8$. Four of them agree, so the law holds; the reading at **4.0 cm** is wrong. It should be $28.8 \div 16$ = **1.8 mN**.

MARKING SCHEME

- ✓ $F \times r^2$ (or F against $1/r^2$) tested for every reading.
- ✓ The 4.0 cm reading doesn't fit (22.4 against 28.8).
- ✓ It should be 1.8 mN.

4 Predict, then explain

ANSWER HA · 3

q rests where the two pushes are equal: $kQ/x^2 = k(4Q)/(0.30 - x)^2$, so $(0.30 - x)/x = 2$ and **x = 10 cm** from +Q. Along the line it is **stable**: nudged towards +Q, the push from +Q grows faster than the other, sending it back. A negative q feels two pulls that also balance at 10 cm, but nudged towards either charge, that pull grows and wins: **unstable**.

MARKING SCHEME

- ✓ x = 10 cm from +Q, worked from equal forces.
- ✓ Positive q: stable along the line (the nearer push grows and sends it back).
- ✓ Negative q: still balanced there, but unstable.

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5 Estimate it

ANSWER A · 3

i. $n = 8 \times 10^{23} \div 10^{12} = 8 \times 10^{11}$ electrons, so $q = 8 \times 10^{11} \times 1.6 \times 10^{-19} \approx \mathbf{1.3 \times 10^{-7}\ C}$. $F = 9.0 \times 10^{9} \times (1.3 \times 10^{-7})^2 \div 1^2 \approx \mathbf{1.5 \times 10^{-4}\ N}$.

ii. $F(g) = 6.67 \times 10^{-11} \times 0.003^2 \div 1^2 = 6 \times 10^{-16}$ N. The electric force is about $\mathbf{2 \times 10^{11}}$ **times** larger, from a tiny imbalance of charge.

MARKING SCHEME

- ✓ $q \approx 1.3 \times 10^{-7}$ C.
- ✓ $F \approx 1.5 \times 10^{-4}$ N.
- ✓ Gravity 6×10^{-16} N: the electric force is about 10^{11} times larger.

6 Show that

MARKING SCHEME A · 2

- ✓ $1/(4\pi \times 8.85 \times 10^{-12}) = 8.99 \times 10^{9}$.
- ✓ Units N $m^2/C^2 \times C^2/m^2$ = N.

7 A real setting

MARKING SCHEME A · 3

- ✓ Flowing petrol and sliding on seats charge things by friction.
- ✓ A spark from built-up charge can set petrol vapour on fire.
- ✓ Metal (conducting) paths to the ground carry the charge away before it builds up.

8 Which explanation fits the evidence?

ANSWER HA · 3

Kriti's. Walls, a ceiling and fresh paper weren't rubbed, and it would be a strange chance for all of them to carry exactly the opposite charge. Any neutral object is attracted by induction (in insulators, polarization of the molecules): the near side takes the opposite charge, and since it is nearer, its attraction beats the repulsion of the far side ($F \propto 1/r^2$).

MARKING SCHEME

- ✓ Kriti's explanation.
- ✓ Many objects that were never charged all attract the balloon, so they can't all happen to carry opposite charges.
- ✓ Neutral objects are attracted because the opposite charge is induced on the nearer side, and the force falls as $1/r^2$.

9 Correct the misconceptions

ANSWER U · 3

1. Rubbing **moves electrons**: the glass loses electrons to the silk and is left positive; no charge is created.
2. In induction the rod **keeps all its charge**: it only pushes the sphere's free charges about; nothing crosses.
3. The force is about 80 times **smaller** in water: its permittivity is about 80 times ε_0, and ε replaces ε_0 in Coulomb's law. Density has nothing to do with it.

MARKING SCHEME

- ✓ Friction transfers electrons; it doesn't create charge.
- ✓ In induction no charge crosses: the rod keeps its charge.
- ✓ The force is smaller in water ($\varepsilon \approx 80\varepsilon_0$), not larger.

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10 Think

ANSWER HA · 2

Charges come in two kinds that cancel, and large bodies such as the Earth and the Moon are almost exactly neutral, so their electric forces cancel out. Mass comes in one kind only, so gravitational forces always add up, and for bodies that size they win.

MARKING SCHEME

- ✓ Large bodies are almost exactly neutral: positive and negative charges cancel.
- ✓ Mass only adds (gravity is always attractive), so gravity dominates on large scales.

11 Make your own

ANSWER HA · 2

For example $+1.0\ \mu C$ and $-4.0\ \mu C$, 0.19 m apart: $F = 9.0 \times 10^{9} \times 1.0 \times 10^{-6} \times 4.0 \times 10^{-6} \div 0.19^{2} = 1.0$ N, attractive. Any pair with $kQ_1Q_2/r^2 = 1.0$ N is right.

MARKING SCHEME

- ✓ Charges and distance whose kQ_1Q_2/r^2 is worked out to 1.0 N.
- ✓ Attraction or repulsion stated correctly from the signs.

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	0	6	11	13	**30**

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