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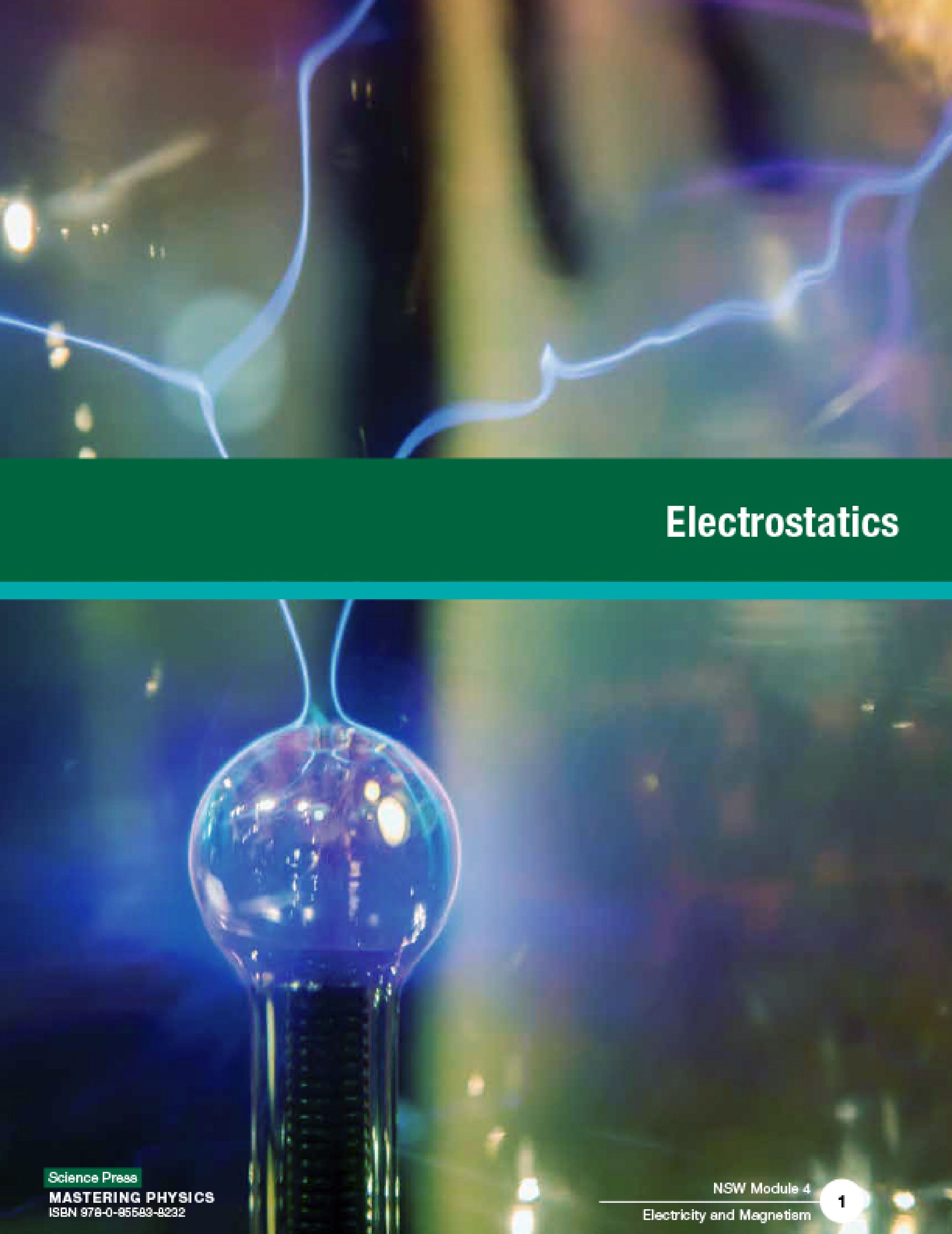

Electrostatics

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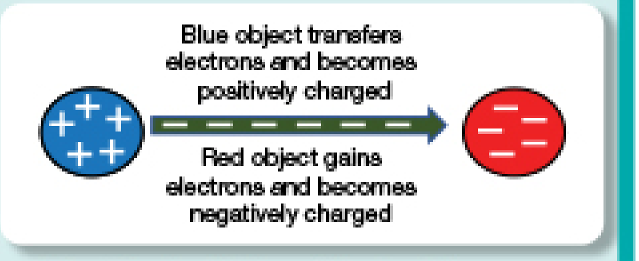
4.1 Electrostatic Charges

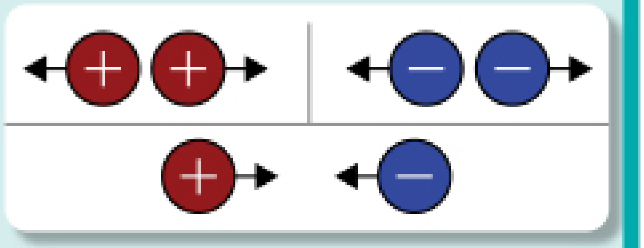
Conduct investigations to describe and analyse qualitatively and quantitatively the processes by which objects become electrically charged.

Electrostatic charges

- **Electrostatics** is the study of electricity which does not flow.
- **Electrostatic charges** form when some insulators are subjected to friction such as when they are rubbed with a cloth, or when air blows over them.
- There are two types of electrostatic charge, **positive** and **negative**.
- Electrostatic charges arise when objects have more or fewer electrons than they normally have.
- In its natural state, all matter is electrically neutral, but atoms of some materials can easily lose their valence electrons (the electrons in their outer energy levels) to another object when either physical or electrical forces are applied to them.
- When this happens, the object from which the electrons move becomes **positively charged**, while the object *gaining* the electrons becomes **negatively charged**.



- From Coulomb's law of electrostatics:
  - Like charges repel.
  - Unlike charges attract.

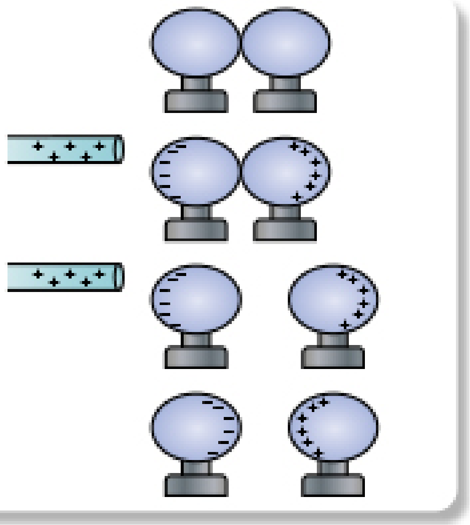


Sample *Questions*

1. Some objects – such as your plastic ruler – can be electrostatically charged by rubbing them with a cloth. Others cannot be charged this way. Explain why some can and some cannot be charged this way.

2. Why does the formation of electrostatic charges involve only electrons transfers and not also proton transfers?

3. (a) Consider the four diagrams shown. Identify what these are showing and explain the process involved.
   (b) This process can also be used to form a *negative* charge on both balls. Explain how this is done.
   (c) This process can also be used to form a *positive* charge on both balls. Explain how this is done.



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The electrostatic charge

- The charge on the electron – the most common magnitude charge for chemical ions and accelerated charged particles in physics, is too small to be a practical unit, especially in electricity.
- The unit we therefore use is the **coulomb** (C) for measuring electrostatic charge, named after Charles Augustin de Coulomb, a French physicist who did many of the early experiments on electrostatics.

- One coulomb (C) is the charge equal to the total charge on 6.25×10^{18} electrons.
- So, 1 coulomb = the charge on 6 250 000 000 000 000 000 electrons
- Therefore the charge on 1 electron = $\frac{1}{6.25 \times 10^{18}} = -1.6 \times 10^{-19}$ C.
- The charge on a proton is $+1.6 \times 10^{-19}$ C.

Sample Questions

1. How many electrons are involved in producing the following charged objects?

(a) Object A with a charge of +4.0 mC.

(b) Object b with a charge of –2.5 μC.

(c) Object C with charge $+6 \times 10^{-8}$ C.

(d) Object D with charge –7.2 nC.

2. What is the charge on each of the following?

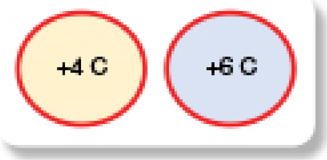
(a) Object which has a deficiency of 6.0×10^{19} electrons.

(b) Object which has an excess of 7.5×10^{18} electrons.

(c) Object which has a deficiency of 4.8×10^{12} electrons.

(d) Object which has an excess of 6×10^{17} electrons.

3. Two charged spheres of identical size carry charges of +4 C and +6 C as shown.

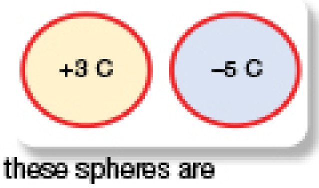


(a) What happens if these spheres are touched together?

(b) What will be the charges on each when they are separated again?

(c) How many electrons move from which sphere to which sphere?

4. Two charged spheres of identical size carry charges of +3 C and –5 C as shown.

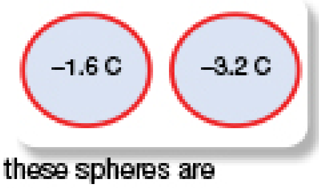


(a) What happens if these spheres are touched together?

(b) What will be the charges on each when they are separated again?

(c) How many electrons move from which sphere to which sphere?

5. Two charged spheres of identical size carry charges of –1.6 C and –3.2 C as shown.

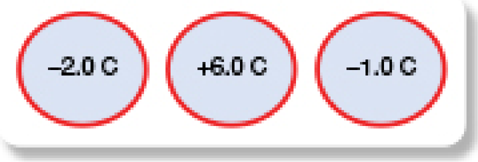


(a) What happens if these spheres are touched together?

(b) What will be the charges on each when they are separated again?

(c) How many electrons move from which sphere to which sphere?

6. Three charged spheres of identical size carry charges of –2.0 C, +6.0 C and –1.0 C as shown.



Describe what happens if these spheres are all touched together?

4.2 Electrostatics Research Assignment

Conduct investigations to describe and analyse qualitatively and quantitatively the processes by which the forces produced by objects as a result of their interaction with charged particles.

Electrostatics research assignment

Sample *Questions*

- Each of the situations/items/processes listed and pictured below shows an interaction of electrostatic forces or electrostatic charges with things in our lives – well – maybe not all our lives, but used by humans as applications somewhere.
- **Choose any three** of the situations listed or shown by pictures, to explain the role of electrostatic charges or the role of electrostatic forces in each.

A Clothes stick together after being run through the dryer.

B Some clothes, especially light, silky material clothes will stick to your body on hot dry days.

C When two balloons are rubbed together, they will attract hair.

D The flowing movement of flammable liquids like petrol through a pipe can build up static electricity. Liquids such as petrol, diesel, and kerosene can accumulate static charge during high velocity flow, and given that electrostatic discharges can ignite the fuel vapour one must be even more careful filling the car and planes at airports.

E Semiconductor devices used in electronics can be very sensitive to the presence of static electricity and can be damaged by a static discharge. The use of antistatic straps is mandatory for researchers using nano devices.

F Sometimes when you walk across a carpeted floor and reach out to a door handle, you get a shock.

G Lightning during a thunderstorm can be wonderful to watch, but also very dangerous and damaging.

H Plasma globes or plasma lamps are attractive and fun.

I Some cars have antistatic straps on the back.

J You may have a Van de Graaff generator in your school. It can be used to demonstrate the generation properties of electrostatic charges. Larger ones, in research laboratories produce enough energy to breaks nuclei of atoms apart. Confine your discussion to the one you have at school.

K Due to the extremely low humidity in space (like none), very large static charges can accumulate on spacecraft causing a major hazard for the electronics used in space vehicles. Walking over the dry terrain as on Mars and the Moon could cause astronauts to accumulate a significant amount of charge. Reaching out to open the airlock on their return to the spacecraft could cause a large static discharge, potentially damaging sensitive electronics. The Mars Rover used to build up 100 V of static charge as it roamed over the surface of Mars until static discharge straps were put on it to carry the charge to 'earth'.

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4.3/4 Variables Affecting Electrostatic Force

Conduct investigations to describe and analyse qualitatively and quantitatively the variables that affect electrostatic forces between objects. Apply the electric field model to account for and quantitatively analyse interactions between charged objects using $F = \frac{1}{4\pi\varepsilon_0} \times \frac{q_1q_2}{r^2}$.

Variables affecting electrostatic force

- The size of the electric force between two objects is affected by the strength of the charge and the distance between the objects. Objects with strong positive and negative charges will have a greater electric force.
- As the distance between the objects decreases, the electrical force increases and vice versa (inverse square law).
- The constant ε_0, commonly called the **vacuum permittivity**, or the **permittivity of free space** or **electric constant**, is a physical constant, which takes into account the ability of the medium in which charged object exists to transmit electric field.
- Its inclusion in the Coulomb equation we use to find electrostatic forces assumes that the charges are in air (or vacuum). The value used is that for vacuum, but the value of the constant for air is insignificantly different for our purposes.
- The interaction of electrostatic charges is summarised by **Coulomb's law of electrostatics** and Coulomb's law.

Coulomb's law of electrostatics

Like static charges **repel** each other.
Unlike static charges attract **each other**.

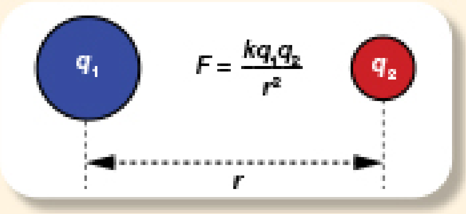
Coulomb's law

The magnitude of the electrostatic force of interaction between two point charges is directly proportional to the magnitudes of charges and inversely proportional to the square of the distance between them.

$$F = \frac{kq_1q_2}{r^2} \quad \text{or} \quad F = \frac{1}{4\pi\varepsilon_0} \times \frac{q_1q_2}{r^2}$$

This equation is the preferred one to use.

Where F = force in newtons (N)
q = charge in coulombs (C)
r = separation in metres (m)
k = constant = 9×10^9 N m^2 C^{-2}
ε_0 = electric constant = 8.85×10^{-12} N^{-1} m^{-2} C^2



Sample *Questions*

1. Two charged particles are 30 cm apart. The force between them is *F*. What would the force be if:

(a) The distance between them is 0.1 m?

(b) The distance between them is 0.6 m?

(c) The distance between them is 2.1 m?

(d) The distance between them 0.03 m?

(e) The value of one charge is halved?

(f) The value of one charge is doubled?

(g) The value of one charge is ×4?

(h) Both charges are halved?

(i) Both of the charges are doubled?

(j) Both charges are increased by ×4?

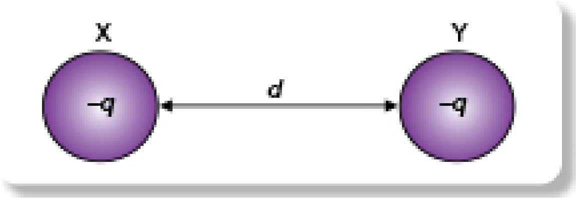
2. Two charges, A, 4.0×10^{-6} C, and B, 2.5×10^{-6} C are 6 mm apart. What is the force between them?

3. (a) The force between two identical charges P and Q is 6.0×10^{-6} N attraction. If the charges are 5 mm apart, what is their magnitude?

(b) Are the charges positive or negative? Explain your answer.

4. Charge X is four times the magnitude of charge Y. X and Y are 7 mm apart and repel each other with a force of 3.6×10^{-6} N. What is the magnitude and sign of each charge?

5. X and Y are two charged spheres distance *d* m apart. Each sphere carries a charge of $-q$. The force between the spheres is 4.5×10^{-6} N repulsion.



What will be the force between the charges in each of the following cases?

(a) $+2q$ is added to sphere X.

(b) Instead, the distance between X and Y is doubled.

(c) Instead, an additional $+3q$ is added to sphere Y.

(d) Instead, the distance between X and Y is reduced to one third its original value.

(e) Instead, the charge on X is reduced to $-0.5q$, the charge on Y is increased to $-2.5q$ and the distance between them is halved.

6. X and Y are 7.5 m apart. X has a net charge of $0.3q$, and Y has a net charge of $0.4q$. The ratio of the magnitude of the electric force on X to that on Y is:

(A) 1 : 1

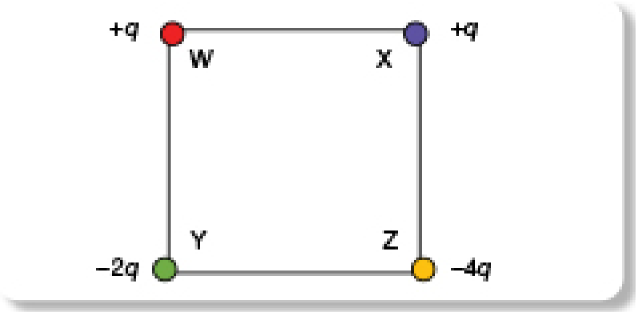
(B) 2 : 1

(C) 1 : 2

(D) 1 : 4

Use this information for the next TWO questions

Consider the system below that consists of four charges placed at the corners of a square. The force charge X puts on charge W is *F* newtons.



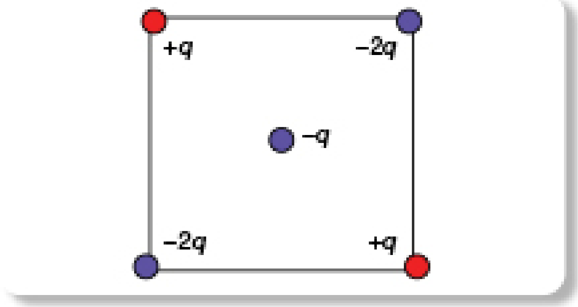
7. In terms of *F*, what is the force of Y on W?

(A) *F* (B) −*F* (C) 2*F* (D) −2*F*

8. What is the force Y places on Z in terms of *F*?

(A) 2*F* (B) 4*F* (C) −8*F* (D) +8*F*

9. Four charges, are set up forming a square as shown.



Charge $-q$ is placed in the centre.

Which statement about the force acting on the charge at the centre is correct?

(A) It is zero.

(B) It is directed to the right.

(C) It is directed down the page.

(D) It is directed into the page.

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