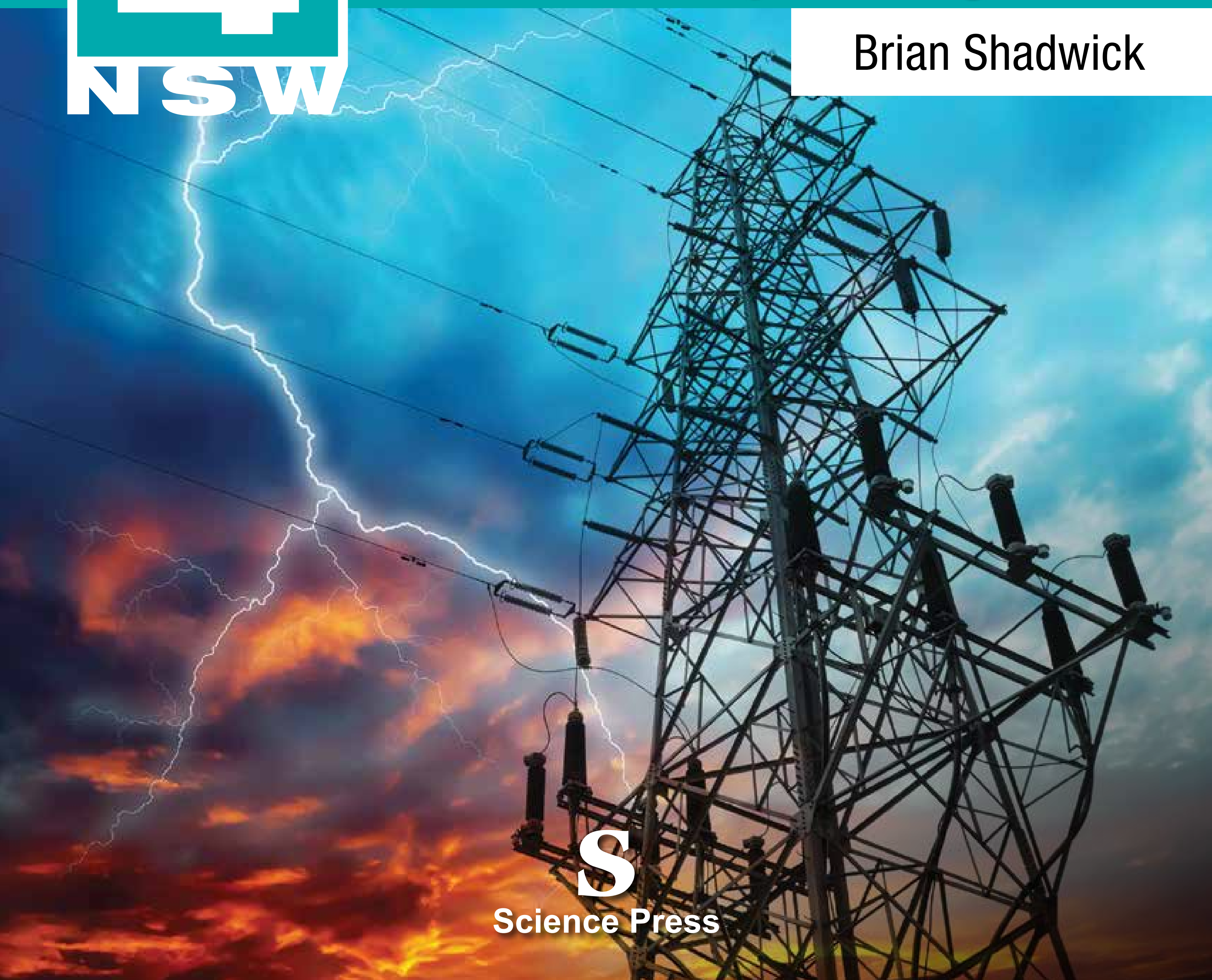
Mastering Physics

MODULE 4
NSW

Electricity and Magnetism

Brian Shadwick



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Contents

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Words to Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

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Electrostatics

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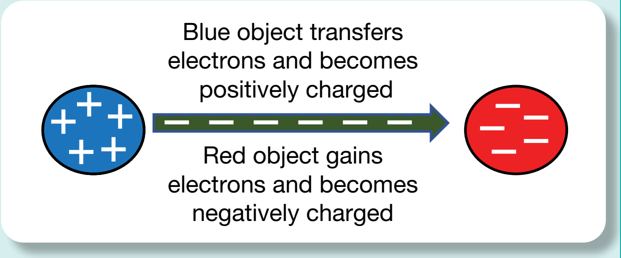
4.1 Electrostatic Charges

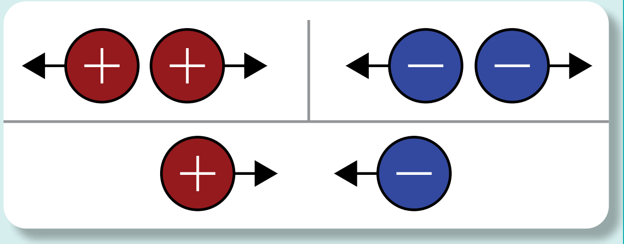
Conduct investigations to describe and analyse qualitatively and quantitatively the processes by which objects become electrically charged.

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*

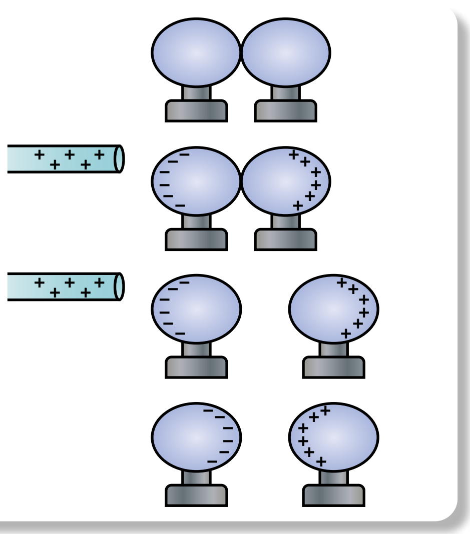
1. Some objects – such as your plastic ruler – can be electrostatically charged by rubbing them with a cloth. Others cannot be charged this way. Explain why some can and some cannot be charged this way.

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?

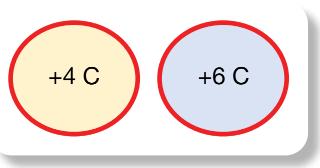
(a) Object which has a deficiency of 6.0×10^{10} electrons.

(b) Object which has an excess of 7.5×10^{16} 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.

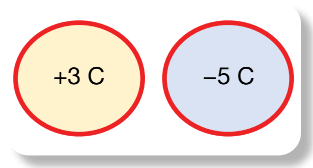


(a) What happens if these spheres are touched together?

(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.

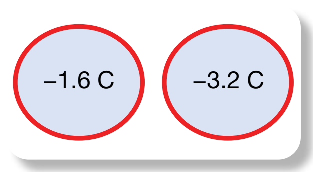


(a) What happens if these spheres are touched together?

(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.

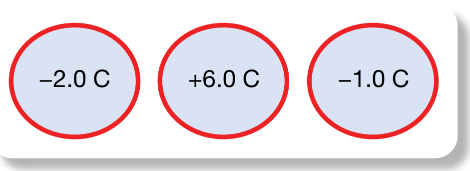


(a) What happens if these spheres are touched together?

(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 $F = \frac{1}{4\pi\varepsilon_0} \times \frac{q_1 q_2}{r^2}$.

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**.

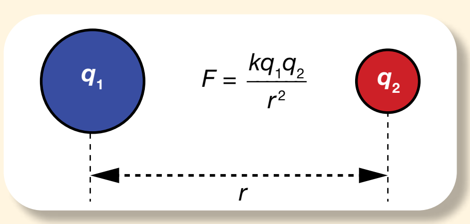
Coulomb's law

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



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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?

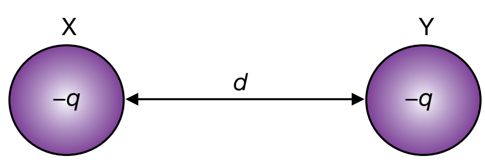
2. Two charges, A, 4.0×10^{-8} C, and B, 2.5×10^{-8} C are 6 mm apart. What is the force between them?

3. (a) The force between two identical charges P and Q is 6.0×10^{-8} 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^{-8} 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

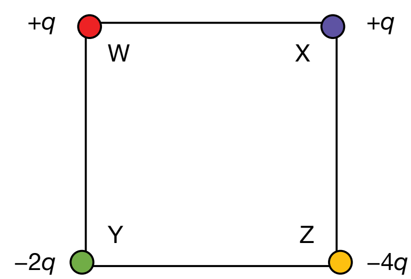
(B) 2 : 1

(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.



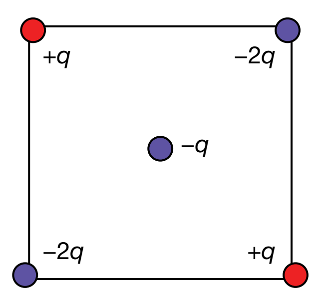
7. In terms of F, what is the force of Y on W?

(A) F (B) $-F$ (C) $2F$ (D) $-2F$

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

(A) $2F$ (B) $4F$ (C) $-8F$ (D) $+8F$

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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4.5 Electric Fields

Use electric field lines to model qualitatively the direction and strength of electric fields produced by simple point charges, pairs of charges, dipoles and parallel charged plates.

Electric fields

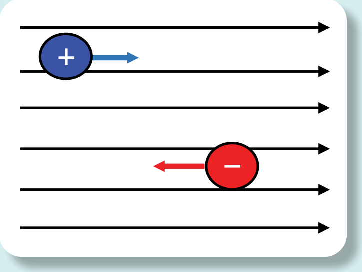
Fields

- A **field** is a region in which some quantity in physics has a value at every point in the region.
- Fields in which certain objects experience a force are known as **force fields**.
- Fields are found around objects similar to the ones they affect.
- Gravitational fields are found around all masses.
- Magnetic fields are associated with magnets, and electric fields are found around electrostatic charges, or between charged electric plates.

Electric fields

- An electric field exists at a point if a charge placed at that point experiences a force.
- As a result of these forces, if the charges are free to move, they will accelerate in the direction of the force on them (Newton's second law of motion).

- Positive charges experience forces in the direction of the field.
- Positive charges experience forces from higher to lower potential.

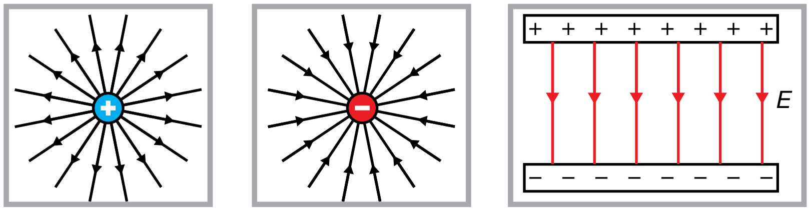


- Negative charges experience forces in the opposite direction to the field.
- Negative charges experience forces from lower to higher potential.

- The direction of the electric field at a point is the direction of the force experienced by a positive charge placed in the field at that point, or
- Electric field is directed from positive towards negative, or
- Electric field is directed from *high potential* to *low potential*.

Field vectors

- Electric field is a **vector** quantity, and can therefore be represented by vector arrows.
- The **direction of the arrow represents the direction of the field** (from positive to negative, or, from high to low potential), and
- The **closeness of the arrows indicates** the magnitude of the field at each point in the field.
- Field is directed away from positive charge.
- Field is direct towards negative charge.
- Field between parallel plates is uniform.



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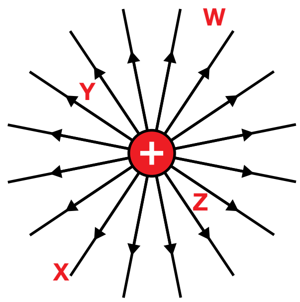
Sample Questions

1. Consider the four points within the electric field around the charge shown. Imagine identical positive charges placed at each point.

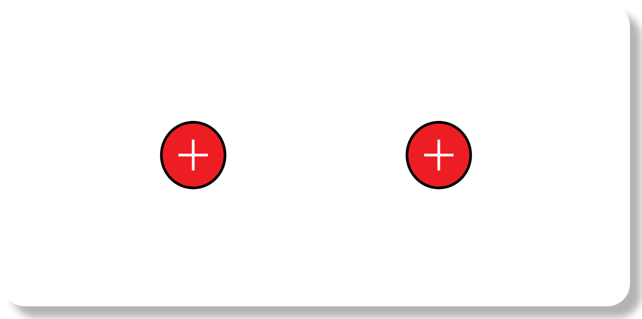


(a) On which of the four charges would there be the largest force? Justify your answer.

(b) On which two charges would the forces be approximately equal? Justify your answer.

(c) How would your answers to each of (a) and (b) above be different if the charges were negative rather than positive?

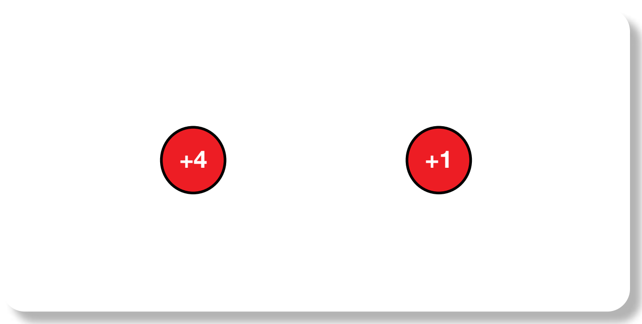
2. (a) Draw the shape of the electric field around and between the two positive charges in the box provided.



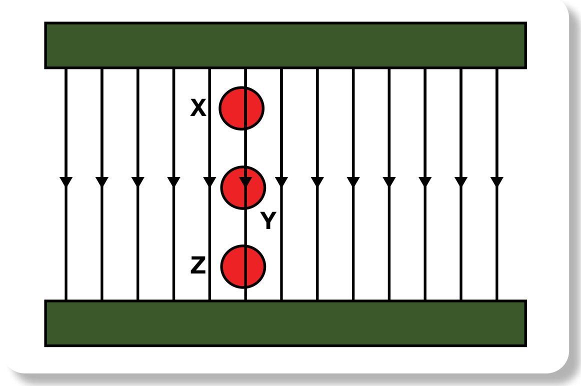
(b) The point exactly in the midpoint between the two charges is a special point. What is it called and what does it signify?

(c) How would the shape of the field be different if both the charges were negative rather than positive?

3. Draw the shape of the electric field around and between the +4*q* and the +1*q* charges in the box.



4. Consider the electric field between the parallel plates shown.



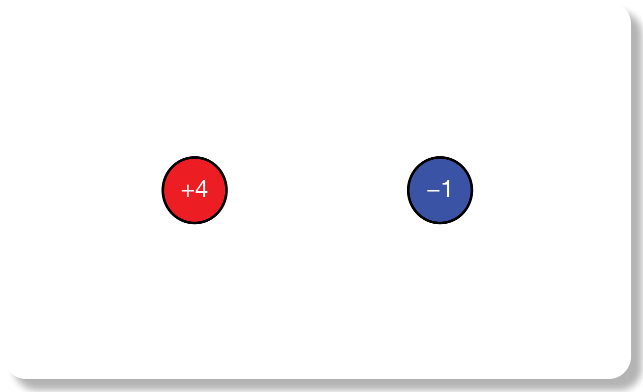
(a) Which plate is the positive plate? Justify your answer.

(b) What evidence is there in the diagram to indicate that the electric field between the plates is uniform in strength?

(c) Imagine identical charges at X, Y and Z. Y is exactly halfway between the plates, and X and Z are equidistant from Y. What is the ratio of the force on these charges? Justify your answer.

5. (a) Draw the shape of the electric field around and between the positive and negative charges in the box shown.

(b) How would the shape of the field be different if the positions of both the charges was swapped?



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4.6 Electric Field Strength

Apply the electric field model to account for and quantitatively analyse interactions between charged objects using $E = \frac{F}{q} = \frac{kq}{r^2}$.

Electric field strength

The electric field strength at a distance d from a point charge q_2 can be found in the following way:

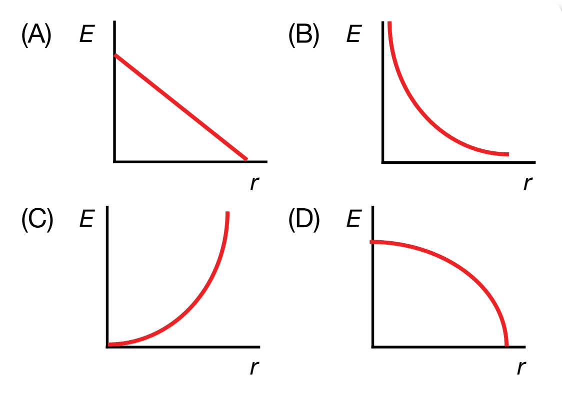
From $F = Eq_1 = \frac{kq_1q_2}{r^2}$

Where F = force on charge q_1 due to field produced by charge q_2 (N)
E = strength of electric field around charge q_2 (C)
r = distance of charge q_1 from charge q_2 (m)
k = constant = 9×10^9 (N m^2 C^{-2})

We get $E = \frac{F}{q_1} = \frac{kq_2}{r^2}$ = field strength at distance d from charge q_2

Sample Questions

1. A solid, small point sphere has radius r and carries positive charge q. Which of the following graphs represents the electric field E as a function of the distance r from the centre of the sphere?



2. Calculate the electric field strength 15 cm from a charge of -4.6×10^{-9} C.

3. The field strength 20 cm from a charge is 8×10^3 N C^{-1} directed towards the charge. What is the value of the charge?

4. At P, some distance from a charge of 6.4×10^{-6} C, the field strength is 0.8×10^4 N C^{-1} directed away from the charge.

(a) How far is point P from the charge?

(b) What sign is the charge? Justify your answer.

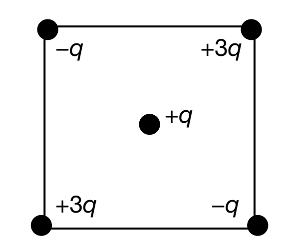
5. Calculate the electric field strength 25 cm from a charge of 6.0×10^{-8} C.

6. The field strength 9 cm from a charge is 7.5×10^6 N C^{-1} directed away from the charge. What is the value of the charge?

Use this to answer the next TWO questions.

Four charges are placed at the corners of a square. A charge of $+q$ is placed in the centre.

The field at the centre due to the $-q$ charge at the top left corner of the square is E.



7. What is the field at the centre due to the charge at the bottom left of the square?

8. What is the field at the centre due to all four corner charges?

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Force on a charge in an electric field

The strength of an electric field can be defined as the force per unit charge at that point.

Mathematically, $$E = \frac{F}{q}$$

Where F = force on charge placed in the field in newtons (N)
q = charge in coulombs (C)
E = electric field in newtons per coulomb ($N\ C^{-1}$)

Sample Questions

1. What is the force on –3.6 μC in an electric field of 5.0×10^{-4} $N\ C^{-1}$ west?
(A) 1.8×10^{-9} N west
(B) 1.8×10^{-9} N east
(C) 139 N west
(D) 139 N east

2. A charge of -6.0×10^{-8} C experiences a force of 1.5×10^{-4} N east at point P. What is the electric field at P?
(A) 2.5×10^{3} $N\ C^{-1}$ east
(B) 2.5×10^{3} $N\ C^{-1}$ west
(C) 4×10^{-4} $N\ C^{-1}$ east
(D) 4×10^{-4} $N\ C^{-1}$ west

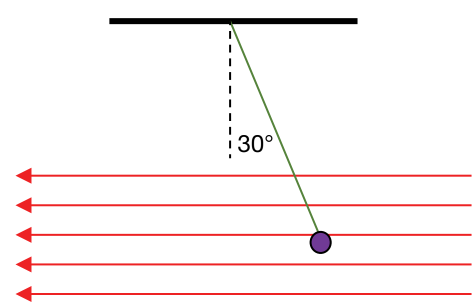
3. What is the force on +8.0 nC in a field of strength 7.5×10^{-3} $N\ C^{-1}$ west?
(A) 6×10^{-11} N west
(B) 6×10^{-11} N east
(C) 1.1×10^{-6} N west
(D) 1.1×10^{-6} N east

4. A force of 2.4×10^{-4} N east acts on a charge in an electric field of strength 6.0×10^{-4} $N\ C^{-1}$ east. What is the charge?
(A) + 0.4 C
(B) + 1.44×10^{-7} C
(C) –0.4 C
(D) + 1.44×10^{-7} C

5. What is the acceleration of an electron in a field of strength 2.5×10^{-6} $N\ C^{-1}$ east? Its mass is 9.1×10^{-31} kg.
(A) 2.3×10^{-6} $m\ s^{-2}$ west
(B) 2.3×10^{-6} $m\ s^{-2}$ east
(C) 4.4×10^{6} $m\ s^{-2}$ west
(D) 4.4×10^{6} $m\ s^{-2}$ east

6. The charge on a proton is $+1.6 \times 10^{-19}$ C and its mass is 1.67×10^{-27} kg. What is the acceleration of a proton in an electric field of strength 2.4×10^{-9} $N\ C^{-1}$ west?
(A) 0.23 $m\ s^{-2}$ west
(B) 0.23 $m\ s^{-2}$ east
(C) 4.35 $m\ s^{-2}$ west
(D) 4.35 $m\ s^{-2}$ east

7. A uniform electric field points to the left. A small metal ball charged to –2.0 mC hangs at a 30° angle from a string of negligible mass attached to the ceiling as shown.



The tension in the string is 0.1 N. What is the magnitude of the electric field?
(A) 0.49 $N\ C^{-1}$
(B) 24.5 $N\ C^{-1}$
(C) 245 $N\ C^{-1}$
(D) 490 $N\ C^{-1}$

8. A charge of –3.0 μC experiences a force of 4.2×10^{-3} N south at point P. Calculate the strength of the electric field at P.

9. A charge of +4.0 μC is an electric field of strength 1.5×10^{-3} $N\ C^{-1}$ north at point P. Calculate the force on the charge.

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4.7 Electric Field Strength Between Parallel Plates

Apply the electric field model to account for and quantitatively analyse interaction between charged objects using $E = \frac{V}{d}$.

Electric field strength between parallel plates

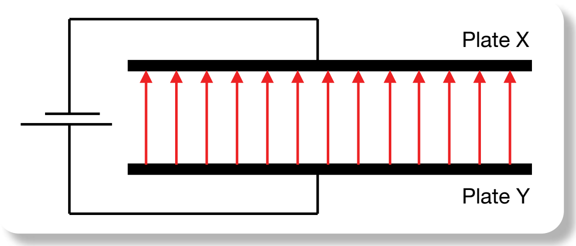
The electric field between parallel plates is uniform in strength and given by the following.

Mathematically, $$\boldsymbol{E = \frac{V}{d}}$$

Where V = electrical potential difference between plates (V)
d = distance between plates (m)
E = electric field in volts per metre (V m^{-1})

Sample Questions

1. The diagram shows electric field lines representing the electric field between two parallel plates X and Y.



(a) Describe the nature of the field between the plates.
(b) Which plate is the high potential plate?
(c) Which plate is the positively charged plate?

2. Two parallel plates have a potential of V volts across them. They are 8.0 cm apart. At point P, midway between the two plates, the strength of the electric field is E N C^{-1}.
(a) What will be the strength of the electric field at point X, 2.0 cm from the positive plate?
(b) What will be the strength of the electric field at point X, 2.0 cm from the negative plate?
(c) Find the strength of the electric field at point Y if the voltage across the plates is halved?
(d) Find the strength of the field at point Y if the distance between the plates is doubled?
(e) Find the strength of the electric field at point Y if a charge of 9.0×10^{-8} C is placed at Y?
(f) Find the ratio of the forces acting on charges of 9.0×10^{-8} C placed at Y and at X?

3. The electric field between two parallel plates is E V m^{-1}. Predict the new field if:
(a) The distance between the plates is increased by a factor of 5.
(b) The voltage across the plates is tripled.
(c) The distance between the plates is doubled and the voltage across them is tripled.
(d) The charge on a particle placed between the plates is halved.
(e) The area of each plate is doubled.
(f) The distance between the plates is doubled *and* the potential difference is doubled.

4. A positively charged particle with a mass of 6.0×10^{-3} kg is placed between two parallel plates, 5.0 mm apart. When the voltage across the plates is 1250 V, the particle is suspended between them.
(a) What is the magnitude of the charge on the particle?
(b) Which plate of the two is the positive plate? Justify your answer.

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Answers

4.1 Electrostatic Charges

Electrostatic charges

1. This does not happen with all substances because the strength of the forces holding the electrons to their atoms is an important factor in whether or not the electrostatic charges can occur this way. If the forces are strong, then friction will not cause the electrostatic charge.

2. Protons are within the nucleus of atoms and nuclear forces are required to release them.

3. (a) The diagrams are showing charging by induction. Two uncharged spheres are in contact and when the positively charged rod is brought near, electrons are attracted to it and flow from the right sphere onto the left sphere. This makes the left sphere negative and the right sphere positive. If they are separated while the rod is still there, then when the rod is removed, because the charges are isolated on the spheres, the spheres carry opposite charges.

(b) If, in the situation shown, before the rod is removed, the right hand sphere is connected to earth, then electrons will flow from earth onto the sphere to neutralise the positive charge. When the rod is removed, the left hand sphere will be negative and the right hand neutral. If the spheres are now touched together, the electrons will spread evenly across both spheres. Separating them again we have two negatively charged spheres.

(c) If a negatively charged rod is brought near the spheres, the electrons on the left sphere are repelled to the right sphere. Earthing the right sphere causes these electrons to flow to earth. This leaves the left sphere positively charged and the right sphere neutral. Removing the rod, and touching the spheres together will cause electrons to flow from the right sphere to the left sphere until the positive charge is distributed evenly across both spheres.

The electrostatic charge

1. (a) $+4.0\text{ mC} = 4.0 \times 10^{-3} \times 6.25 \times 10^{18}$
$= 2.5 \times 10^{16}$ electrons removed

(b) $-2.5\ \mu\text{C} = 2.5 \times 10^{-6} \times 6.25 \times 10^{18}$
$= 1.56 \times 10^{13}$ electrons added

(c) $+6.0 \times 10^{-8}\text{ C} = 6 \times 10^{-8} \times 6.25 \times 10^{18}$
$= 3.75 \times 10^{11}$ electrons removed

(d) $-7.2\text{ nC} = 7.2 \times 10^{-9} \times 6.25 \times 10^{18}$
$= 4.5 \times 10^{10}$ electrons added

2. (a) From charge $= \dfrac{\text{number of electrons}}{6.25 \times 10^{18}} = \dfrac{6 \times 10^{9}}{6.25 \times 10^{18}}$
$= +\ 0.96\text{ nC}$

(b) From charge $= \dfrac{\text{number of electrons}}{6.25 \times 10^{18}} = \dfrac{7.5 \times 10^{16}}{6.25 \times 10^{18}}$
$= -12\text{ mC}$

(c) From charge $= \dfrac{\text{number of electrons}}{6.25 \times 10^{18}} = \dfrac{4.8 \times 10^{9}}{6.25 \times 10^{18}}$
$= +\ 768\text{ nC}$

(d) From charge $= \dfrac{\text{number of electrons}}{6.25 \times 10^{18}} = \dfrac{3.4 \times 10^{9}}{6.25 \times 10^{18}}$
$= -0.054\text{ C}$

3. (a) Electrons will flow so that net charge is shared
(b) +5 C
(c) One coulomb of electrons flow from the +4 C ball to the +6 C ball

4. (a) Electrons will flow so that net charge is shared
(b) −1.0 C
(c) 4 coulombs of electrons flow from the −5 C ball to the +3 C ball

5. (a) Electrons will flow so that net charge is shared
(b) −2.4 C
(c) 0.8 coulombs of electrons flow from the −3.2 C ball to the −1.6 C ball

6. The net charge +3 C will be shared equally by the three spheres, so each will end up with a charge of +1 C. 3.0 C of electrons will flow from the −2.0 C sphere to the middle sphere and +2.0 C of electrons will flow from the right hand sphere to the middle sphere to achieve this.

4.2 Electrostatics Research Assignment

A Friction between the clothes will result in electrons being rubbed off some materials and onto others. The different materials will gain opposite electrostatic charges and attract each other – they stick together.

B Friction between the clothes and your skin will result in electrons being transferred so that your skin and the silk will gain opposite electrostatic charges and attract each other – the silk sticks to your body.

C Friction between the two balloons and your skin will result in electrons being transferred from one to the other so that they gain opposite electrostatic charges and attract each other.

D Friction between the moving liquids and the walls of the pipes or hoses will result in electrons being transferred from one to the other so that they gain opposite electrostatic charges. Given the low ignition temperature and high volatility of these liquids, this presents a danger because an accidental electrostatic discharge could ignite the vapours.

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