Electric Fields 1

Exercise A

$\varepsilon_0 = 8.85 \times 10^{-12}\,\text{F m}^{-1}$,

$e = 1.6 \times 10^{-19}\,\text{C}$

1 Calculate the force between an electron and

a a proton at a distance of 2.5×10^{-9} m,

b a nucleus of a nitrogen atom (charge $+7e$) at a distance of 2.5×10^{-9} m

2 **a** Two point charges $Q_1 = +6.3$ nC and $Q_2 = -2.7$ nC exert a force of 3.2×10^{-5} N on each other when they are at a certain distance, d, apart. Calculate:

i the distance d between the two charges,

ii the force between the two charges if they are moved to distance $3d$ apart.

b A charge of +4.0 nC is added to each charge in part **a**. Calculate the force between Q_1 and Q_2 when they are at separation d.

3 A +30 nC point charge is at a fixed distance of 6.2 mm from a point charge Q. The charges attract each other with a force of 4.3×10^{-2} N.

a Calculate the magnitude of charge Q and state whether Q is a positive or a negative charge.

b The two charges are moved 2.5 mm further part. Calculate the force between them in this new position.

4 Two point objects, X and Y, carry equal and opposite amounts of charge at a fixed separation of 3.6×10^{-2} m. The two objects exert a force on each other of 5.1×10^{-5} N.

a Calculate the magnitude, Q, of each charge, and state whether the charges attract or repel each other.

b The charge of each object is increased by adding a positive charge of $+2Q$ to each object. Calculate the separation at which the two objects would exert a force of 5.1×10^{-5} N on each other, and state whether the objects attract or repel each other.

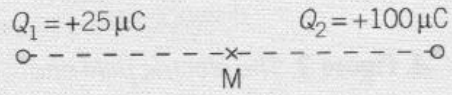
Exercise B

$\varepsilon_0 = 8.85 \times 10^{-12}\,\text{F m}^{-1}$

1 **a** Calculate the electric field strength at a distance of 3.2 mm from a +6.0 nC point charge.

b Calculate the distance from the point charge in **a** at which the electric field strength is $5.4 \times 10^5\,\text{V m}^{-1}$.

2 A +25 μC point charge Q_1 is at a distance of 60 mm from a +100 μC charge Q_2.



▲ **Figure 4**

a A +15 pC charge q is placed at M, 25 mm from Q_1 and 35 mm from Q_2. Calculate:

i the resultant electric field strength at M,

ii the magnitude and direction of the force on q.

b Show that the electric field strength due to Q_1 and Q_2 is zero at the point which is 20 mm from Q_1 and 40 mm from Q_2.

3 A +15 μC point charge Q_1 is at a distance of 20 mm from a +10 μC charge Q_2.

a Calculate the resultant electric field strength:

i at M, the midpoint between the two charges,

ii at the point P along the line between Q_1 and Q_2 which is 25 mm from Q_1 and 45 mm from Q_2

b **i** Explain why there is a point along the line between the two charges at which the electric field strength is zero.

ii Calculate the distance from this point to Q_1 and to Q_2.

4 A +15 μC point charge Q_1 is at a distance of 30 mm from a −30 μC charge Q_2.

a Calculate electric potential at the midpoint of the two charges.

b **i** Show that the electric potential is zero at a point between the two charges which is 10 mm from Q_1 and 20 mm from Q_2.

ii Calculate the electric field strength at this position and state its direction.

Exercise C

$e = 1.6 \times 10^{-19}$ C

1 A +40 nC point charge Q_1 is placed in an electric field.

a Calculate the magnitude of the force on Q_1 if the electric field strength where Q_1 is placed is 3.5×10^4 V m^{-1}.

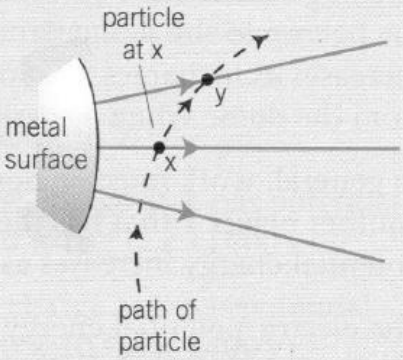
b Q_1 is moved to a different position in the electric field. The force on Q_1 at this position is 1.6×10^{-3} N. Calculate the magnitude of the electric field strength at this position.

2 Figure 6 shows the path of a charged dust particle in an electric field.

a The electric field strength at X is 65 kV m^{-1}. The force due to the field on the particle when it is at X is 8.2×10^{-3} N towards the metal surface.

i Describe the type of charge carried by X.

ii Calculate the charge carried by the particle.



▲ Figure 6

b **i** Calculate the magnitude of the force on the particle when it is at Y where the electric field strength is 58 kV m^{-1}.

ii State the direction of the force on the particle when it is at Y.

3 A high-voltage supply unit is connected across a pair of parallel plates which are at a separation of 50 mm.

a The voltage is adjusted to 4.5 kV. Calculate:

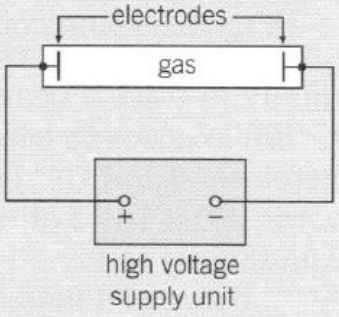
i the electric field strength between the plates,

ii the electrostatic force on a droplet in the field that carries a charge of 8.0×10^{-19} C.

b The separation between the plates is altered without changing the pd between the plates. The droplet in **a** is now acted on by a force of 4.5×10^{-14} N. Calculate the new separation between the plates.

4 A certain gas in a tube is subjected to an electric field of increasing strength. The gas becomes conducting when the electric field reaches a strength of 35 kV m^{-1}.

a The electrodes in the tube are at a spacing of 84 mm. Assuming the field between the electrodes is uniform before the gas conducts, calculate the potential difference between the electrodes that is necessary to produce an electric field of strength 35 kV m^{-1} in the tube.



▲ Figure 7

b i Calculate the force on an electron in the tube when the electric field strength is 35 kV m^{-1}.

ii Explain why the gas becomes conducting only when the electric field strength in the tube reaches a certain value.

Exercise D

$e = 1.6 \times 10^{-19}$ C

1 An electron in a beam is accelerated from a potential of −50 V to a potential of +450 V. Calculate:

a the potential energy of the electron at

i −50 V,

ii +450 V,

b the change of potential energy of the electron.

2 In Figure 3, a test charge q is moved from X to Z. Calculate the change of potential energy of the test charge

a if $q = +3.0\,\mu C$,

b if $q = -2.0\,\mu C$.

3 An oil droplet carrying a charge of $+2e$ is in air between two parallel metal plates separated by a distance of 20 mm. The pd between the plates is 5.0 V.

a Calculate:

i the potential gradient between the two plates,

ii the force on the droplet.

b Calculate the change of electric potential energy of the oil droplet if it moves from the midpoint of the plates to the negative plate.

4 a Define electric potential and state its unit.

b Two parallel horizontal metal plates are placed one above the other at a separation of 20 mm. A potential difference of +60 V is applied between the plates with the top plate positive.

i Calculate the electric field strength between the plates.

ii Sketch a graph to show how the electric potential V between the plates varies with height h above the lower plate.
