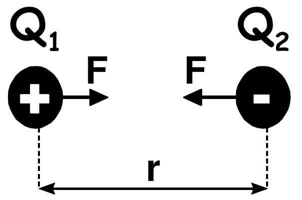
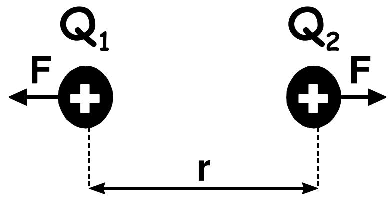
● **Carry out calculations involving Coulomb's Law for the electrostatic force between point charges.**

Opposite charges attract



Like charges repel



The electrostatic force of attraction or repulsion acting between two point charges is given by Coulomb's Law:

Coulomb's Law

1) Two point charges X and Y are separated by a distance of 0.200 m. If the charge on X is +2.00 μC and the charge on Y is -1.00 μC, calculate the magnitude of the electrostatic force of attraction acting between them.

2) Two point charges, both of magnitude +2.50 μC, are separated by a distance of 0.150 m. Calculate the magnitude of the electrostatic force of repulsion acting between them.

3) A -1.50 μC point charge is 0.300 m away from a +2.25 μC point charge. Determine the magnitude of the electrostatic attraction force acting between them.

4) A -1.80 μC point charge and a -2.40 μC point charge are separated by a distance of 0.100 m. Determine the magnitude of the electrostatic repulsion force acting between them.

5) A +3.25 μC point charge is positioned 0.180 m away from another positive point charge of unknown magnitude. A repulsive electrostatic force of 0.625 N acts between the two point charges. Calculate the magnitude of the unknown point charge.

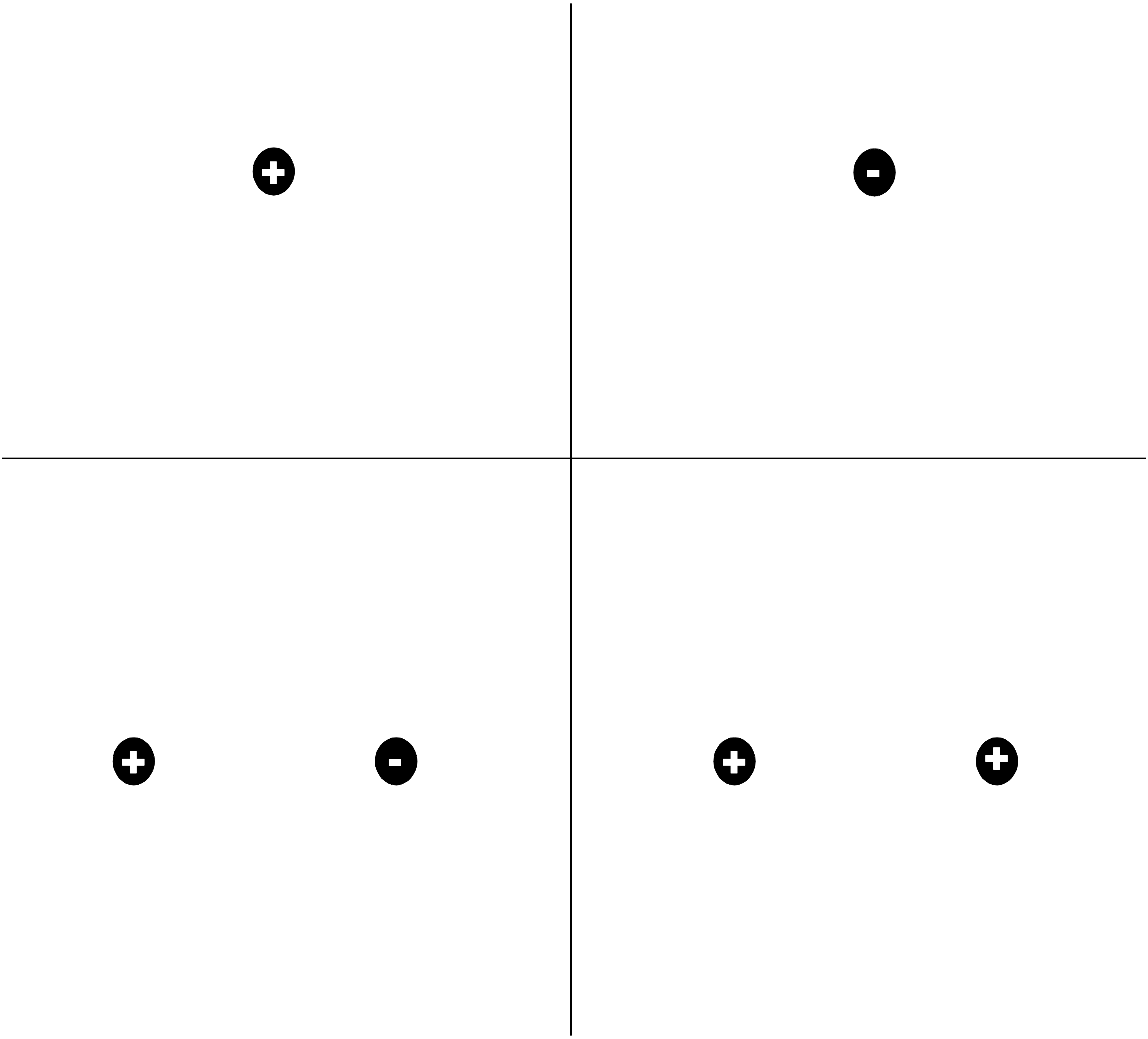
6) A repulsive electrostatic force of 0.500 N exists between two point charges of magnitude -1.50 μC and -1.75 μC. Calculate the straight line distance between the two point charges.

- Describe how the concept of an electric field is used to explain the forces that charged particles at rest exert on each other.

Definition of an Electric Field

We represent electric fields by drawing electric field lines.

The tangent to an electric field line at any point in the electric field gives the direction of the force which would act on a positively charged particle placed at that point in the field.



- **State that the electric field strength at any point in an electric field is the force per unit positive charge placed at that point.**
- **State that the units of electric field strength are newtons per coulomb.**

Definition of Electric Field Strength

7) A +2.50 μC charge experiences a force of 3.50×10^{-15} N when placed at a point in an electric field. Calculate the **electric field strength** at that point.

8) When a proton (charge $+1.60 \times 10^{-19}$ C) is placed at a point in an electric field, the proton experiences a force of 3.20×10^{-15} N. Determine the magnitude of the **electric field strength** at that point.

9) A +2.50 nC charge is placed in a uniform electric field of strength 5.00 N C^{-1}. Calculate the magnitude of the **electric force** which will act on the charge.

10) Determine the magnitude of the electric force which will act on an electron which is placed in a uniform electric field of strength 50.0 N C^{-1}.

11) When placed in a uniform electric field of strength 25.0 N C^{-1}, a positive charge experiences an electric force of 5.00×10^{-15} N. Calculate the magnitude of the **electric charge**.

12) A positive charge experiences a force of 2.50×10^{-15} N when placed in a uniform electric field of strength 15.0 N C^{-1}. Determine the magnitude of the **electric charge**.

- **Carry out calculations involving the electric fields due to point charges.**

Electric Field Strength (E) Due to a Point Charge

The electric field strength about a point charge is spherically symmetric.

This formula allows us to calculate the electric field strength (E) at a distance r from a point charge with charge Q:

13) Calculate the **electric field strength** due to a +1.50 μC point charge at a distance of 2.00×10^{-6} m from the charge.

14) Determine the **electric field strength** at a distance of 1 μm from an alpha particle (charge $+3.20 \times 10^{-19}$ C).

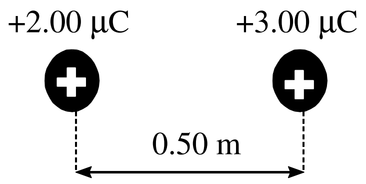
15) At a distance of 2.50×10^{-6} m from a positive point charge, the electric field strength is 3 000 N C^{-1}. Calculate the magnitude of the **point charge**.

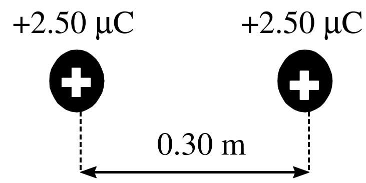
16) The electric field strength at a distance of 4.00×10^{-19} m from a point charge is 3 500 N C^{-1}. Determine the magnitude of the **point charge**.

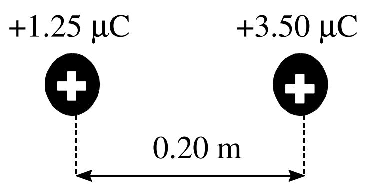
17) At what **distance** from a +1.25 μC point charge will the electric field strength have a value of 1 200 N C^{-1}?

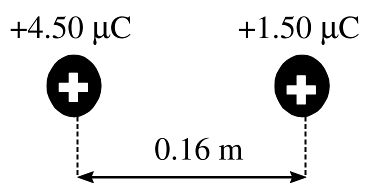
18) The electric field strength at a distance from a proton (charge $+1.60 \times 10^{-19}$ C) is 3 200 N C^{-1}. Calculate the **distance**.

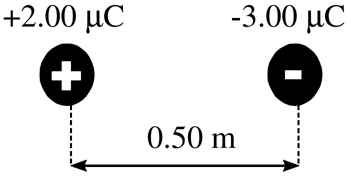
19) In each case, determine the **total electric field strength** at the point *midway* *between* the two point charges:

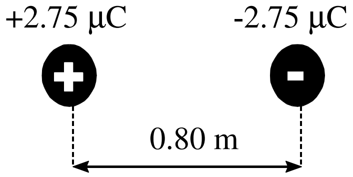


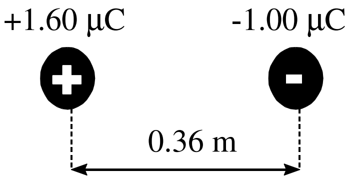


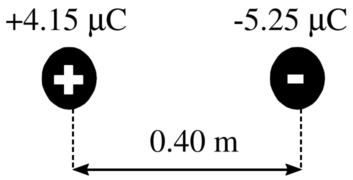




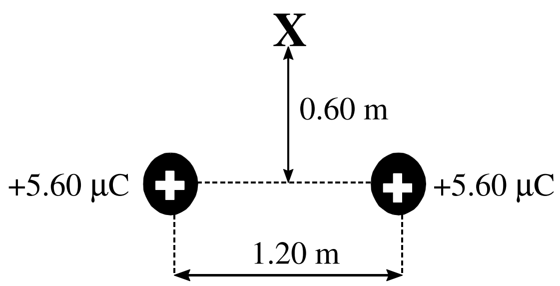

+2.00 μC
-3.00 μC
0.50 m

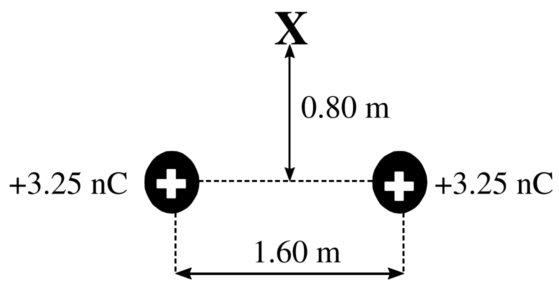

+2.75 μC
-2.75 μC
0.80 m

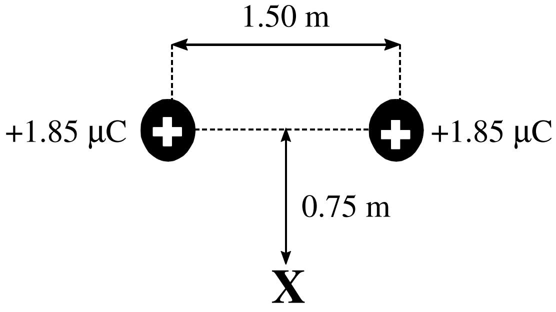

+1.60 μC
-1.00 μC
0.36 m

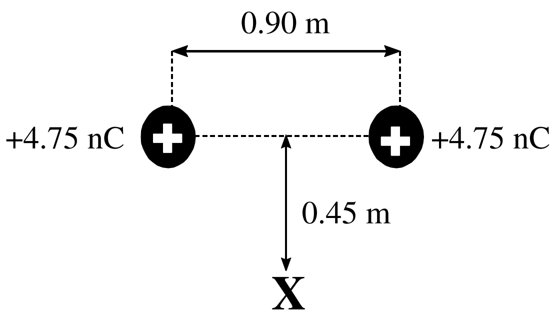

+4.15 μC
-5.25 μC
0.40 m

20) In each case, determine the magnitue and direction of the **electric field strength** at point X, on the line *midway between* the two point charges:





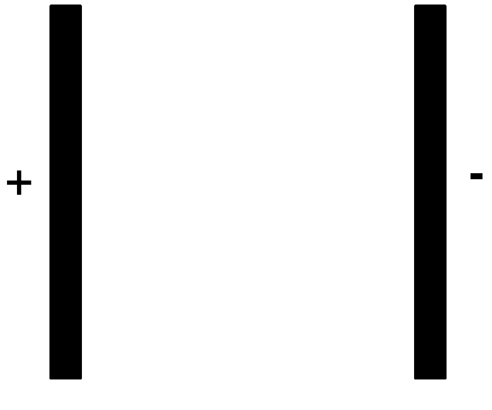

1.50 m
+1.85 μC
+1.85 μC
0.75 m
X


0.90 m
+4.75 nC
+4.75 nC
0.45 m
X

● **Derive the expression $V = Ed$ for a uniform electric field.**

● **Carry out calculations involving uniform electric fields.**

21) (a) Sketch the uniform electric field pattern between the positive and negative plates.



(b) The potential difference between the two charged plates is 12.0 V. The plates are separated by a distance of 200 μm.

Calculate the **electric field strength** of the uniform electric field between the plates.

22) The potential difference between two charged parallel metal plates is 24.0 V.

Calculate the magnitude of the **electric field strength** between the plates if they are 120 mm apart.

23) Calculate the magnitude of the **electric field strength** between the charged parallel plates of a capacitor if they are 15 µm apart and the potential difference between them is 7.5 V.

24) Two charged metal plates are set up parallel to each other, separated by a distance of 0.115 m. The potential difference between the plates is 230 V.

Calculate the magnitude of the uniform **electric field strength** between the plates.

25) The electric field strength between the two charged plates of a parallel-plate capacitor is 4 000 N C^{-1}. The plates are 2.0 mm apart.

Calculate the **potential difference** between the plates.

26) The electric field strength between two charged parallel copper plates, separated by a distance of 0.05 m, is 2 500 V m^{-1}.

Calculate the **potential difference** between the plates.

27) Calculate the **potential difference** between the parallel plates of a capacitor if the uniform electric field between them has a strength of 1 800 V m^{-1} and the plate separation is 90 µm.

28) The electric field strength between two charged parallel metal plates is 500 N C^{-1}. If the potential difference between the plates is 125 V, calculate the **distance** between them.

29) Calculate the **distance** between two parallel capacitor plates which have 230 V across them if the uniform electric field between them has a strength of 525 V m^{-1}.

30) The potential difference across a uniform electric field, strength 1.0×10^6 V m^{-1}, is 20 000 V. The field exists between two parallel metal plates.

Determine the **separation** of the metal plates.

- **Describe what happens during the process of charging by induction.**

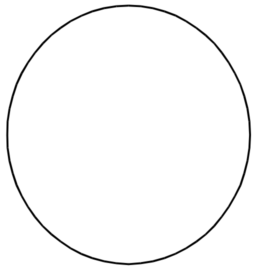
1)

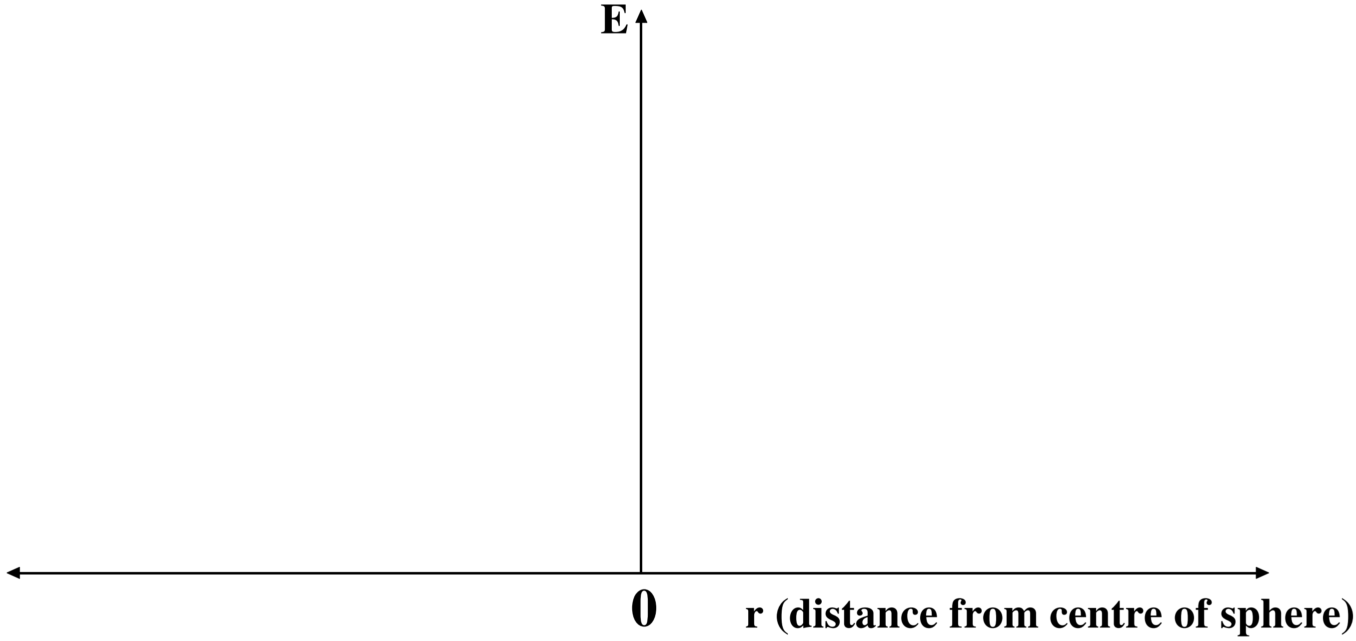
2)

3)

4)

- **Describe the effect of placing a conducting shape in an electric field: the induced charge resides on the surface of the conductor, inside the shape the electric field is zero, and outside the shape the electric field is perpendicular to the surface of the conductor.**





<u>Electrostatic Screening Inside a Hollow Conductor Placed in an Electric Field</u>

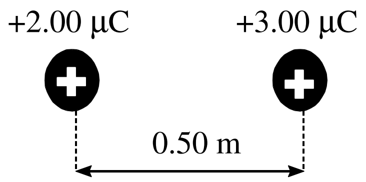
- **State that the electrostatic potential at a point is the work done by external forces in bringing unit positive charge from infinity to that point.**
- **State the expression for the electrostatic potential V at a distance r from a point charge Q.**

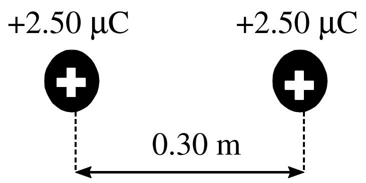
- **Carry out calculations involving potentials due to point charges.**

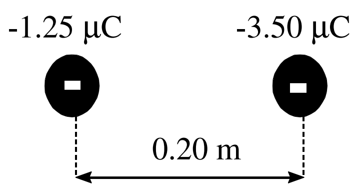
31) In each case, calculate the value for the electrostatic potential (V) at the stated distance (r) from each point charge (Q):

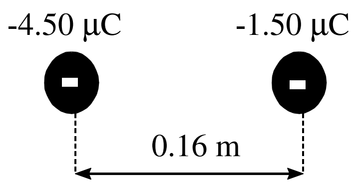
distance = 5.00 cm point charge = +1.50 μC	distance = 1.25 cm point charge = +1.75 μC	distance = 2.50 cm point charge = +3.25 μC
distance = 0.15 cm point charge = -2.25 μC	distance = 0.75 cm point charge = -1.40 μC	distance = 1.30 cm point charge = -4.25 μC

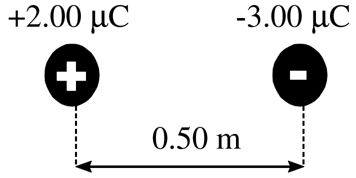
32) In each case, determine the **electrostatic potential** at the *midway point* between the two point charges:

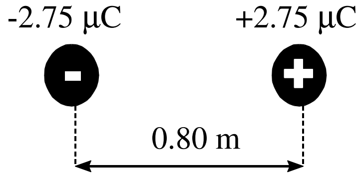


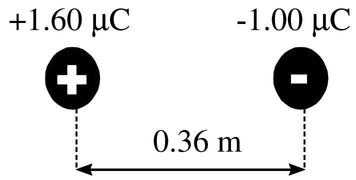


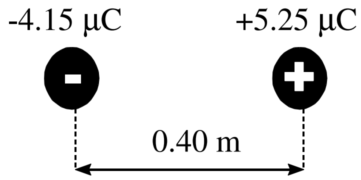




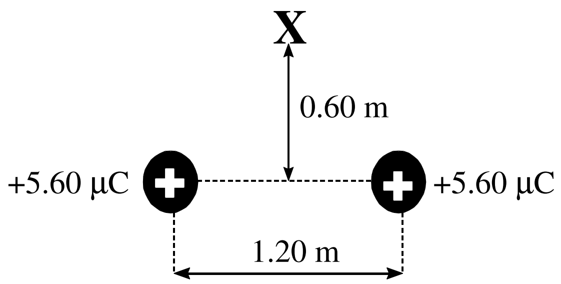

+2.00 μC
-3.00 μC
0.50 m

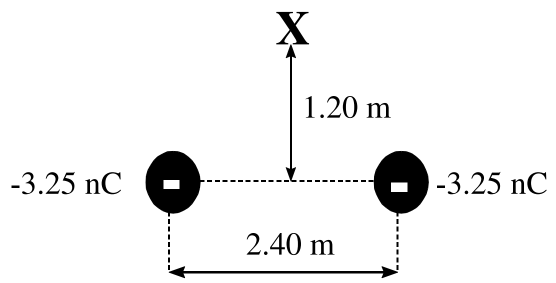

-2.75 μC
+2.75 μC
0.80 m

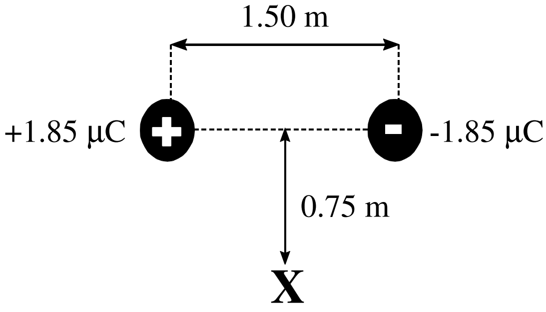

+1.60 μC
-1.00 μC
0.36 m

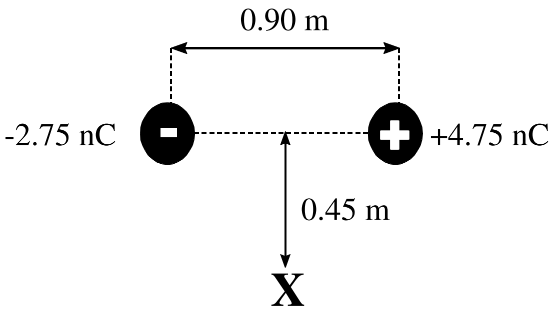

-4.15 μC
+5.25 μC
0.40 m

33) In each case, determine the **electrostatic potential** at point X, on the line *midway between* the two point charges:



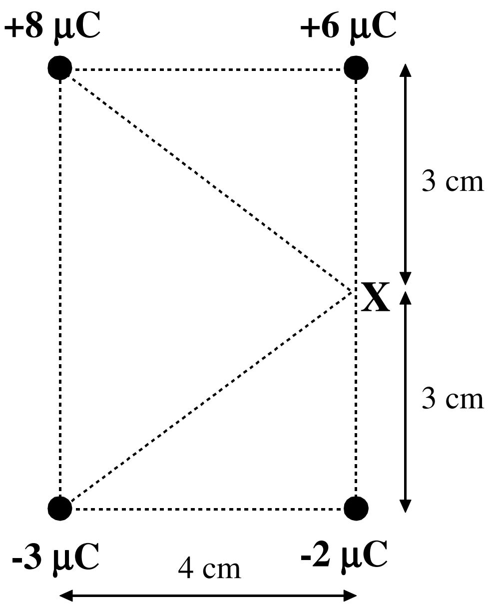



1.50 m
+1.85 μC
-1.85 μC
0.75 m
X


0.90 m
-2.75 nC
+4.75 nC
0.45 m
X

34) The diagram represents four point charges positioned at the corners of a rectangle.

Determine the **electrostatic potential** at point X.



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35) Four point charges, +6 mC, +6 mC, -8 mC and -8 mC, are positioned at the corners of a square, side length 4 cm.

(a) Sketch this situation.

(b) Determine the **electrostatic potential** at the ***midpoint*** of the square.

- **Describe the energy transformations associated with the movement of a charge in an electric field.**

36) An electron, initially at rest, is accelerated between two parallel metal plates. The potential difference between the plates is 100 V.

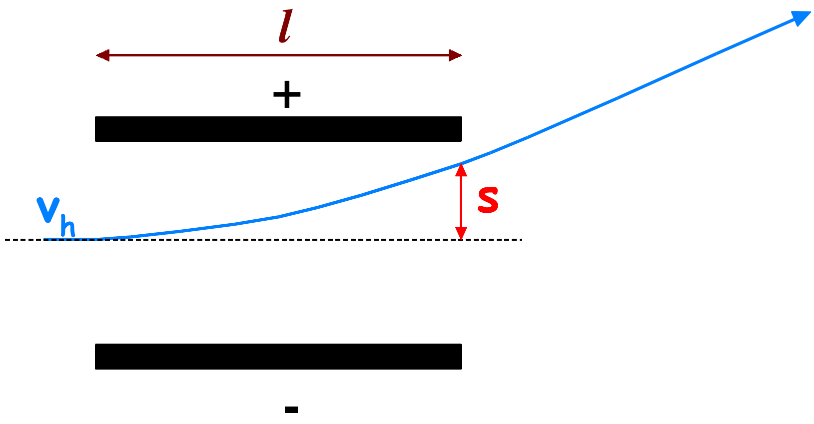
Calculate the **final speed** of the electron.

37) An electron is accelerated from rest to a speed of 4.19×10^6 m s^{-1} through the electric field set up between two parallel metal plates.

Calculate the **potential difference** between the plates.

● **Describe the motion of charged particles in uniform electric fields.**

The diagram shows the path of an electron which enters an electric field with a horizontal speed v_h at a point midway between the two charged parallel plates of length l.



● *Assuming gravitational effects to be negligible compared to the electrostatic force exerted on the electron, describe and explain the path of the electron:*

(a) While it is travelling between the two charged plates.

(b) After it has passed between and left the two charged plates.

● How can we calculate the **acceleration** of the electron as it passes **between the plates**?

● How can we calculate the **time** it takes the electron to pass **between the plates**?

● How can we calculate the **deflection of the electron from the centre line** (**s**) as the electron **leaves the plates**?

● **Carry out calculations concerning the motion of charged particles in uniform electric fields.**

38) Two parallel horizontal metal plates are charged so that a uniform electric field of strength 200 N C^{-1} acts between them. The top plate is positively charged. An electron, travelling horizontally from left to right at 4.00 x 10^{6} m s^{-1}, enters the plates at the midpoint between them.

(a) Sketch this situation.

(b) Calculate the **acceleration** of the electron as it travels between the two plates.

(c) Calculate the **time** it takes the electron to travel between the two plates.

(d) Calculate the **deflection of the electron from the centre line** at the instant the electron leaves the two plates.

44) In an oscilloscope, an electron enters an electric field between two horizontal charged metal plates at a point midway between the plates in a direction parallel to them. The speed of the electron on entering the electric field is 6.00×10^6 m s^{-1} and the electric field strength between the plates is 400 V m^{-1}.
The plates are both 5.00 cm long and the screen of the oscilloscope is a further 20.0 cm beyond the plates.

(a) Sketch this situation.

(b) Calculate the **time** it takes the electron to pass between the two plates.

(c) Calculate the **vertical displacement** of the electron as it leaves the plates.

(d) Calculate the **final direction** of the electron as it leaves the plates.

(e) Determine the **total vertical displacement** of the electron as it hits the oscilloscope screen.

- **State that relativistic effects must be considered when the velocity of a charged particle is more than 10 % of the velocity of light.**

- **Carry out calculations involving the head-on collision of a charged particle with a fixed nucleus.**