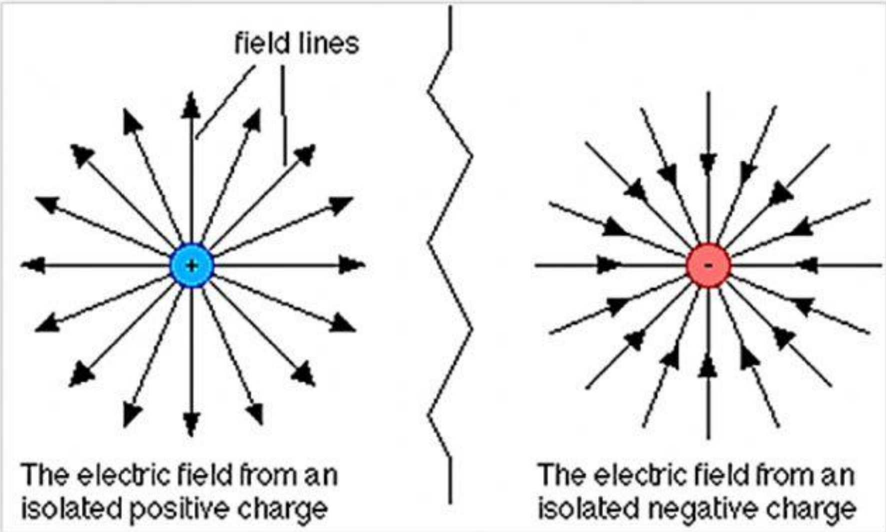
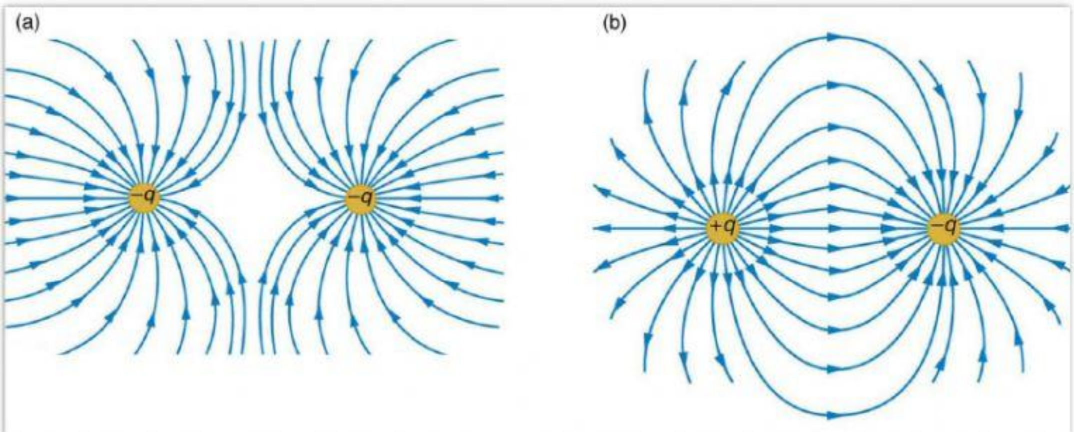
Electrostatics 2

Electric field: A region of space in which an electric charge experiences a force.

The shape of an electric field is determined by the charge which causes the field. Use is made of field lines to form a picture of a field. Field lines are imaginary lines which indicate the direction of the field at each point around the charge. The direction of the field is the same as the direction in which a small **positive** test charge would move when placed in the field.



http://physics.bu.edu/~duffy/PY106/Electricfield.html



https://courses.lumenlearning.com/austincc-physics2/chapter/18-5-electric-field-lines-multiple-charges/

- Arrows on the field lines indicate the direction of the field, i.e. the direction in which a positive test charge would move if placed in the field.
- Electric field lines point away from positive charges (like charges repel) and towards negative charges (unlike charges attract).
- Field lines are drawn closer together where the field is stronger.
- Field lines do not touch or cross each other.
- Field lines are drawn perpendicular to a charge or charged surface.
- The greater the magnitude of the charge, the stronger its electric field. We represent this by drawing more field lines around the greater charge than for charges with smaller magnitudes.

Calculating electric field strength:

Electric field at a point: The electrostatic force experienced by a unit positive charge placed at that point.

The magnitude of an Electric field is the force **per** unit charge *(remember - per means divide, in other words force divided by charge)*

$$\boxed{E = \frac{F}{Q}}$$

F is force measured in Newtons

Q is charge measured in Coulombs

E is measured in $N.C^{-1}$

Question 1

A charge of 6 nC experiences a force of 0,009 N at a certain point in an electric field. Calculate the magnitude of the electric field at that point.

$$E = \frac{F}{Q} \quad = \frac{\_\_\_\_\_\_}{\times 10} \quad = \quad \times 10 \quad N.C^{-1}$$

Another equation that can be used to calculate E:

$$E = \frac{kQ}{r^2}$$

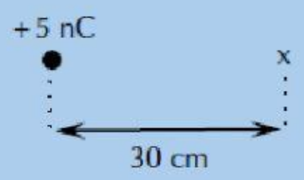
k is Coulomb's constant = 9×10^9

Q is charge measured in Coulombs

r is distance measured in metres

Question 2

Calculate the electric field strength 30 cm from a 5 nC charge.



$$\begin{aligned} E &= \frac{kQ}{r^2} \\ &= \frac{(9{,}0 \times 10^9)(\quad \times 10^{\quad})}{(\quad)^2} \\ &= \qquad \text{N}\cdot\text{C}^{-1} \end{aligned}$$

Question 3

Calculate the electric field strength 52 cm from a −6 nC charge. Give your answer correct to 2 decimal places.

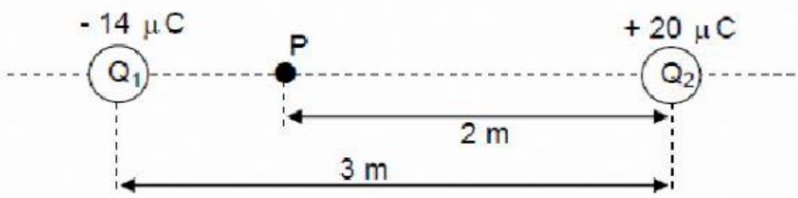
$$\begin{aligned} E &= \frac{kQ}{r^2} \\ &= \frac{(\quad \times 10^9)(\quad \times 10^{\quad})}{\left(\frac{\quad}{100}\right)^2} \\ &= \frac{(\quad \times 10^9)(\quad \times 10^{\quad})}{(\quad)^2} \\ &= \qquad \text{N}\cdot\text{C}^{-1} \end{aligned}$$

Electric field strength is always positive so NO SIGNS on charges are used for E calculations!

Then you should be able to calculate the electric field at a point due to a number of point charges. Calculate the individual values for E due to each charge, and then add them together to get E_{net}. Remember that the DIRECTION of the field will be the direction at the point that would be experienced by a POSITIVE charge. If the calculated E for the point is in different directions for the different charges, then assign one direction positive and the other negative when you calculate E_{net}.

Question 4 – Work through this example to ensure you understand.

Two point charges, Q_1 and Q_2, a distance 3 m apart, are shown below. The charge on Q_1 is - 14 μC and the charge on Q_2 is + 20 μC.



Calculate the net electric field at point P situated 2 m from Q_2.

Electric field at P due to Q_1:

$$E = \frac{kQ}{r^2} \checkmark = \frac{9\times10^{9}\times14\times10^{-6}}{1^2} \checkmark = 1{,}26 \times 10^{5}\ \text{N}\cdot\text{C}^{-1} \text{ to the left}$$

Electric field at P due to Q_2.

$$E = \frac{kQ}{r^2} = \frac{9\times10^{9}\times20\times10^{-6}}{2^2} \checkmark = 4{,}5 \times 10^{4}\ \text{N}\cdot\text{C}^{-1} \text{ to the left}$$

$$E_{net} = 1{,}26 \times 10^{5} + 4{,}5 \times 10^{4}\ \text{N}\cdot\text{C}^{-1} \checkmark = 1{,}71 \times 10^{5}\ \text{N}\cdot\text{C}^{-1} \text{ to the left}$$

Question 5

Two charges of $Q_1 = +3\text{nC}$ and $Q_2 = -4\text{nC}$ are separated by a distance of 50 cm. What is the electric field strength at a point X

We first solve for Q_1:

$$E = \frac{kQ}{r^2}$$
$$= \frac{(\square \times 10^9)(\square \times 10^{\square})}{\square^2}$$
$$= \square \ \text{N·C}^{-1}$$ left / right

Then for Q_2:

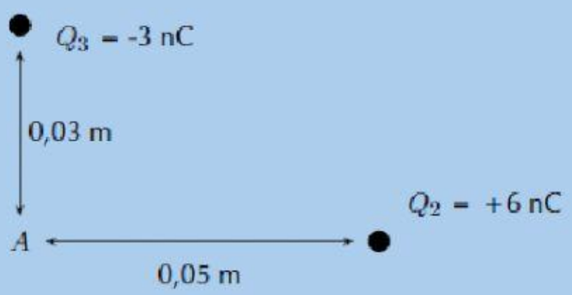
$$E = \frac{kQ}{r^2}$$
$$= \frac{(\square \times 10^9)(\square \times 10^{\square})}{\square^2}$$
$$= \square \ \text{N·C}^{-1}$$ left / right

We need to add the two electric fields because both are in the same direction. The field is away from Q_1 and towards Q_2. Therefore, $E_{\text{total}} = \square + \square = \square$ N·C^{-1}

Calculating electric field strength in 2-D

Question 1

Two point charges form a right-angled triangle with the point A at the origin. Their charges are $Q_2 = 6 \times 10^{-9}$ C $= 6$ nC and $Q_3 = -3 \times 10^{-9}$ C $= -3$ nC. The distance between A and Q_2 is 5×10^{-2} m and the distance between A and Q_3 is 3×10^{-2} m. What is the net electric field measured at A from the two charges if they are arranged as shown?



$$E_2 = k\frac{Q_2}{r^2}$$
$$= (9{,}0 \times 10^9)\frac{(\quad \times 10^{\quad})}{(\qquad)^2}$$
$$= \qquad \text{N.C}^{-1}$$

The magnitude of the electric field from Q_3 at A, which we will call E_3, is:

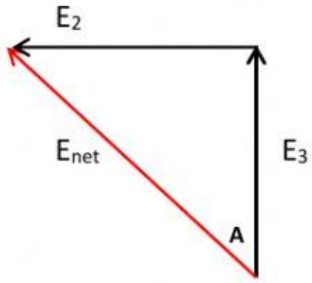
$$E_3 = k\frac{Q_3}{r^2}$$
$$= (9{,}0 \times 10^9)\frac{(\quad \times 10^{\quad})}{(\qquad)^2}$$
$$= \qquad \text{N.C}^{-1}$$

The magnitude of the resultant force acting on Q_1 can be calculated from the forces using Pythagoras' theorem because there are only two forces and they act in the x- and y-directions:

$$E_R^2 = E_2^2 + E_3^2 \text{ Pythagoras' theorem}$$
$$E_R = \sqrt{(\qquad)^2 + (\qquad)^2}$$
$$E_R = \qquad \text{N·C}^{-1}$$

Calculate the direction of E_{net} as a bearing using Trig:

A positive charge at A would move up (towards Q3) and left (away from Q2). Drawing the vectors for E_2 and E_3 head-to-tail, we can calculate the angle A of the electric field direction.



$\tan A = \frac{\text{opposite}}{\text{adjacent}}$

$= \frac{E_2}{E_3}$

= ________

=

$A = \tan^{-1}$

A = °

Convert this angle to a BEARING:

Bearing = 360 - A = °

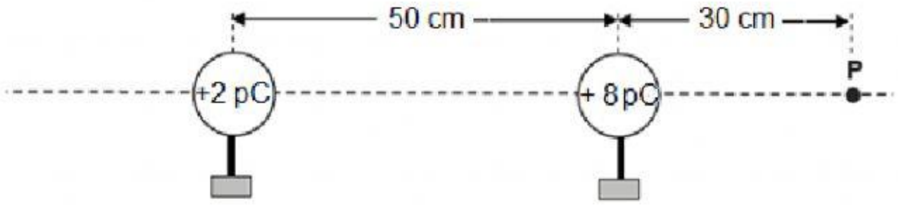
Final answer:

E_{net} = N.C^{-1} on a bearing of °

Electrostatics worksheet

Complete the following exercise in your books and submit on MS Teams.

Question 1

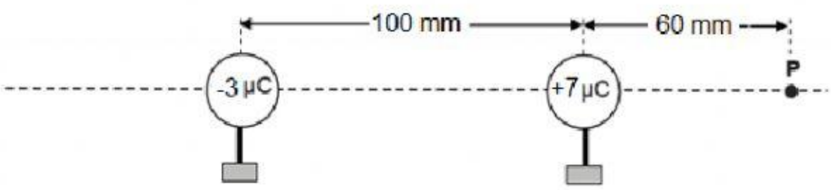


1.1 Sketch the electric field pattern for the two objects.

1.2 Calculate the magnitude of the force the two charges exert on each other.

1.3 Are these forces attractive or repulsive?

Question 2



2.1 Sketch the electric field pattern for the two objects.

2.2 Calculate the magnitude of the force the two charges exert on each other.

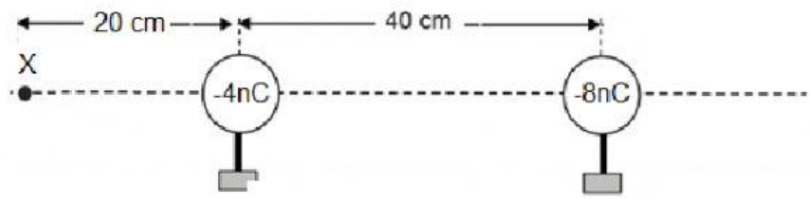
2.3 Calculate the net electric field op point P

2.4 If the charges are free to move explain how they would move

2.5 Calculate the charge on each sphere after they have touched

2.6 Determine how many electrons were transferred after the spheres touched

Question 3



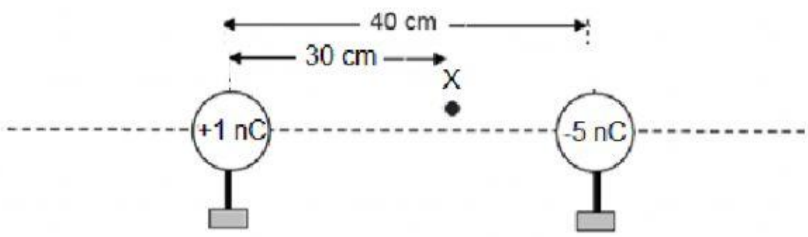
3.1 Sketch the electric field pattern for the two objects.

3.2 Calculate the magnitude of the force the two charges exert on each other.

3.3 Calculate the net electric field op point X

3.4 If the charges are free to move explain how they would move

Question 4



4.1 Sketch the electric field pattern for the two objects.

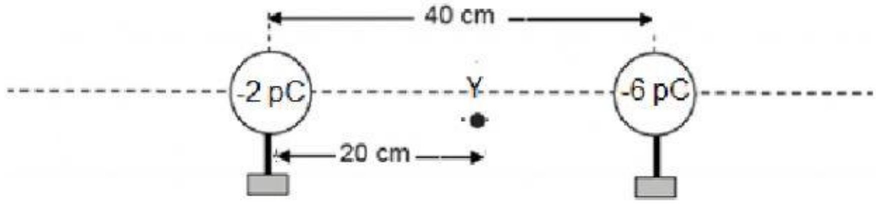
4.2 Calculate the magnitude of the force the two charges exert on each other.

4.3 Calculate the net electric field op point X

4.4 Calculate the charge on each sphere after they have touched

4.5 Determine how many electrons were transferred after the spheres touched

Question 5



5.1 Sketch the electric field pattern for the two objects.

5.2 Calculate the magnitude of the force the two charges exert on each other.

5.3 Calculate the net electric field at point X.

5.4 Two objects exert an electrostatic force of F on each other. By what factor would the force change if:

5.4.1 One of the charge is doubled

5.4.2 Both charges are doubled

5.4.3 One of the charges is halved

5.4.4 Both charges are halved

5.4.5 The distance between the charged objects is halved

5.4.6 The distance between the charged objects is doubled

5.4.7 Both charges are doubled and the distance is halved

5.4.8 One charge is halved and the distance is trebled

5.4.9 One charge is doubled and the other halved and the distance doubled

Question 6

Calculate the strength of the electric field at a distance of 40 mm from a charge of 4 μC.