Electrostatics (Gr 11) – 1

Once you have completed the Grade 10 revision worksheets you will have familiarized yourselves with the Law of Conservation of Charge and Coulomb's Law and you should be comfortable in working with the following formulae:

1) $Q_{new} = \frac{Q_1 + Q_2}{2}$

2) $Q_{transferred} = Q_{final} - Q_{initial}$

Signs are IMPORTANT for these two!

3) $n = \frac{Q}{e}$

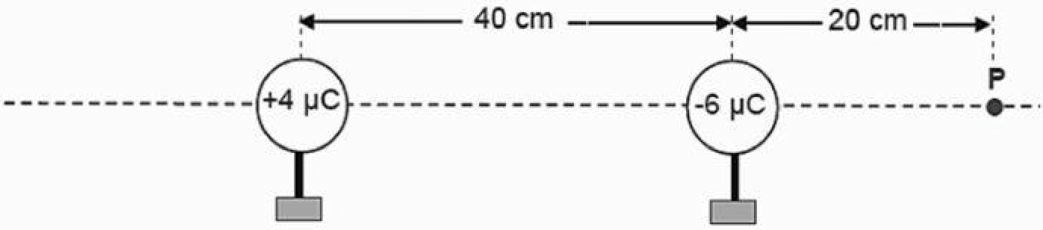
4) $F = \frac{kQ_1Q_2}{r^2}$

Don't use signs for final answers of these two! (For (4) sign indicates direction)

Let's practice some examples:

Question 1

Two metal spheres on insulated stands carry charges of +4 µC and -6 µC respectively. The spheres are arranged with their centres 40 cm apart, as shown below.



10.1 Calculate the magnitude of the force exerted by each sphere on the other.

$F = \frac{kQ_1Q_2}{r^2} = \frac{(\quad \times 10 \quad)(\quad \times 10 \quad)(\quad \times 10 \quad)}{\quad^2}$

$=$ N attraction / repulsion

Question 2

Two point-like charges carrying charges of 8×10^{-9} C and 9×10^{-9} C are 10 m apart. Determine the magnitude of the force between them.

$$F = \frac{kQ_1Q_2}{r^2} = \frac{(\quad \times 10^{\quad})(\quad \times 10^{\quad})(\quad \times 10^{\quad})}{\quad^2}$$

$$= \quad \times 10^{\quad} \text{ N} \quad \text{attraction / repulsion}$$

Question 3

Calculate the distance between two charges of 8 nC and 8 nC if the electrostatic force between them is 0,03 N. Give your answer correct to 2 decimal places.

$$F = \frac{kQ_1Q_2}{r^2}$$

$$r^2 = \frac{\quad}{\quad}$$

Rearrange the formula

$$= \frac{(9 \times 10^9)(\quad \times 10^{\quad})(\quad \times 10^{\quad})}{\quad}$$

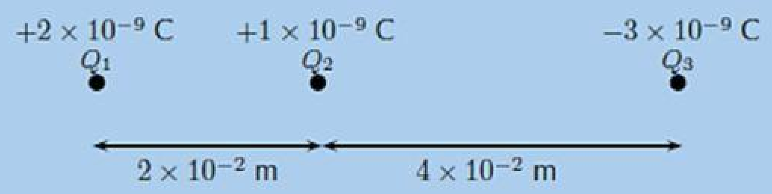
$$= \quad \times 10^{\quad}$$

$$\text{Therefore } r = \quad \times 10^{-} \text{ m}$$

Question 4

Now we will look at the interaction between 3 charges. Remember you need to identify which charge is the one we are focusing on. Then you calculate the force exerted on this force by <u>each</u> of the other charges (2 separate sums) and then you add the forces together to get a NET force.

Three point charges are in a straight line. Their charges are $Q_1 = +2 \times 10^{-9}$ C, $Q_2 = +1 \times 10^{-9}$ C and $Q_3 = -3 \times 10^{-9}$ C. The distance between Q_1 and Q_2 is 2×10^{-2} m and the distance between Q_2 and Q_3 is 4×10^{-2} m. What is the net electrostatic force on Q_2 due to the other two charges?



Step 1: force of Q1 on Q2:

$$F_1 = k\frac{Q_1 Q_2}{r^2}$$
$$= (9{,}0 \times 10^9)\frac{(\square \times 10^{-9})(\square \times 10^{-9})}{(\square \times 10^{-2})^2}$$
$$= (9{,}0 \times 10^9)\frac{(2 \times 10^{-9})(1 \times 10^{-9})}{(4 \times 10^{-4})}$$
$$= \square \times 10^{\square}\ \text{N}$$ right / left.

Step 2: force of Q3 on Q2:

$$F_3 = k\frac{Q_2 Q_3}{r^2}$$
$$= (9{,}0 \times 10^9)\frac{(\square \times 10^{-9})(\square \times 10^{-9})}{(\square \times 10^{-2})^2}$$
$$= (9{,}0 \times 10^9)\frac{(1 \times 10^{-9})(3 \times 10^{-9})}{(16 \times 10^{-4})}$$
$$= \square \times 10^{\square}\ \text{N}$$ right / left.

Step 3: Net force on Q2

Therefore,

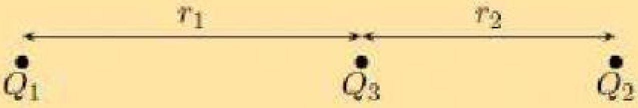
$$F_R = \square \times 10^{\square}\ \text{N} + \square \times 10^{\square}\ \text{N}$$
$$= \square \times 10^{\square}\ \text{N}$$

The resultant force acting on Q_2 is $\square \times 10^{\square}$ N to the right / left.

Question 5

For the charge configuration shown, calculate the charge on Q_3 if the resultant force on Q_2 is $6,3 \times 10^{-1}$ N to the right and:

- $Q_1 = 4,36 \times 10^{-6}$ C
- $Q_2 = -7 \times 10^{-7}$ C
- $r_1 = 1,85 \times 10^{-1}$ m
- $r_2 = 4,7 \times 10^{-2}$ m



$F_{1on2} = \dfrac{kQ_1Q_2}{r^2} = \dfrac{(\quad \times 10 \quad)(\quad \times 10 \quad)(\quad \times 10 \quad)}{(0,185 + 0,047)^2} = \quad \times 10 \quad$ N left / right

$F_{net} = F_{1on2} + F_{3on2} = 6,3 \times 10^{-1}$ N right

$\quad \times 10 \quad + F_{3on2} = 6,3 \times 10^{-1}$ N

So: $F_{3on2} = \quad$ N right / left

Hint: make right positive and left negative since final answer is right

$F_{3on2} = \dfrac{kQ_2Q_3}{r^2} = \dfrac{(\quad \times 10 \quad)(\quad \times 10 \quad)\,\mathbf{Q_3}}{0,047^2} = \quad$ N

Q_3 = x 10 C

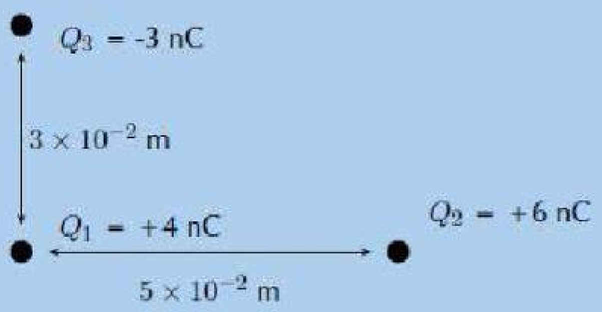
Coulomb's law calculations in 2-D

Now instead of the 3 charges being all in a straight line, we will look at the charges in a right-angled triangle.

Remember that F_{net} is the resultant of 2 forces when you draw them Head – to – Tail.

QUESTION

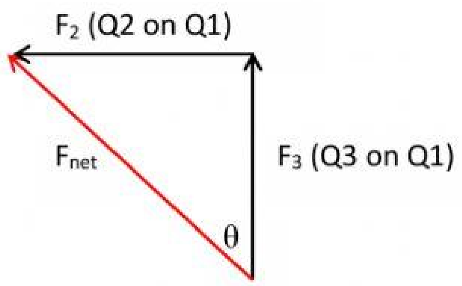
Three point charges form a right-angled triangle. Their charges are $Q_1 = 4 \times 10^{-9}$ C $=$ 4 nC, $Q_2 = 6 \times 10^{-9}$ C $=$ 6 nC and $Q_3 = -3 \times 10^{-9}$ C $= -3$ nC. The distance between Q_1 and Q_2 is 5×10^{-2} m and the distance between Q_1 and Q_3 is 3×10^{-2} m. What is the net electrostatic force on Q_1 due to the other two charges if they are arranged as shown?



The question asks for the net force on Q1, so we need to calculate the force of Q3 on Q1 (attractive), and then the force of Q2 on Q1 (repulsive), and then calculate the resultant of those 2 forces. Remember that Fnet also needs a direction, which you will calculate from the angles of the force triangle.

Step 1:

Start by drawing the forces head-to-tail, creating the triangle and identifying the angle of interest, θ:



Step 2:

Calculate the two individual forces:

$$
\begin{aligned}
F_2 &= k\frac{Q_1Q_2}{r^2} \\
&= (9{,}0 \times 10^9)\frac{(\square \times 10^{-9})(\square \times 10^{-9})}{(\square \times 10^{-2})^2} \\
&= (9{,}0 \times 10^9)\frac{(\square \times 10^{-9})(\square \times 10^{-9})}{(\square \times 10^{-4})} \\
&= \square \times 10^{-5}\ \text{N} \quad \text{left / right}
\end{aligned}
$$

The magnitude of the force exerted by Q_3 on Q_1, which we will call F_3, is:

$$
\begin{aligned}
F_3 &= k\frac{Q_1Q_3}{r^2} \\
&= (9{,}0 \times 10^9)\frac{(\square \times 10^{-9})(\square \times 10^{-9})}{(\square \times 10^{-2})^2} \\
&= (9{,}0 \times 10^9)\frac{(\square \times 10^{-9})(\square \times 10^{-9})}{(\square \times 10^{-4})} \\
&= \square \times 10^{-4}\ \text{N} \quad \text{up / down}
\end{aligned}
$$

Step 3:

Calculate the F_{net} using Pythagorus:

$$
\begin{aligned}
F_R^2 &= F_2^2 + F_3^2 \text{ by Pythagoras' theorem} \\
F_R &= \sqrt{(8{,}630 \times 10^{-5})^2 + (1{,}199 \times 10^{-4})^2} \\
F_R &= \square \times 10^{-4}\ \text{N}
\end{aligned}
$$

Step 4:

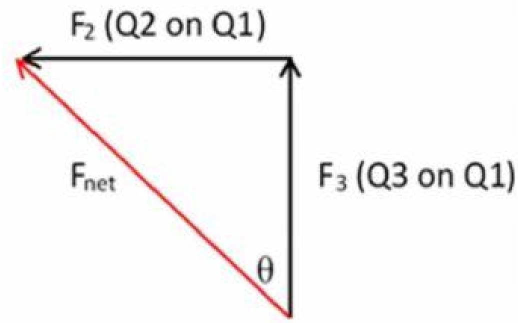
Calculate the direction of F_{net} as a bearing using Trig:

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

$= \frac{F_2}{F_3}$

$= \frac{\quad \times 10}{\quad \times 10}$

$=$



$\theta = \tan^{-1}$

$\theta =$ ° (2 decimal places)

Convert this angle to a BEARING:

Bearing = 360 - θ = °

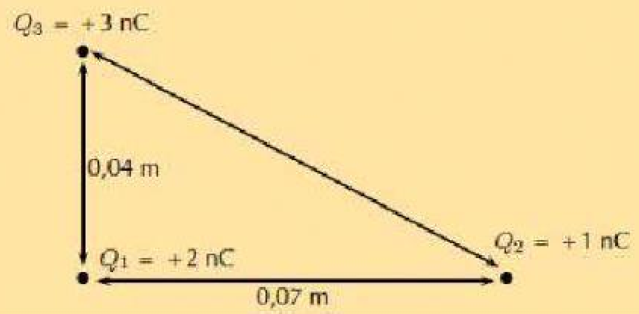
Final answer:

F_{net} = x 10^{-4} N on a bearing of °

Do the following calculations in your books, following the same method as shown above:

Question 2

Calculate the resultant force on Q_1 given this charge configuration:



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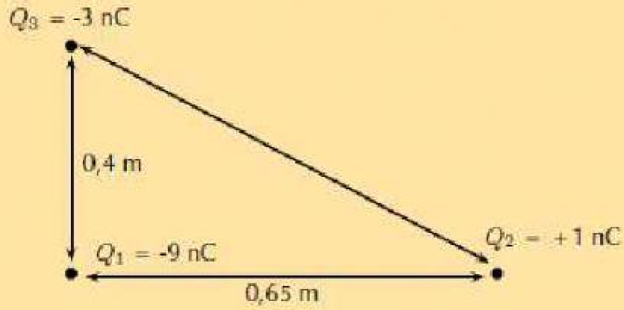

Question 4

Calculate the resultant force on Q_2 given this charge configuration: