A Guide to Electrostatics

Teaching Approach

Lesson 1 revises the concepts from Grade 10 and this lesson need not be used if the learners have these concepts in place.

Grade 10 learners learnt that an object can be:

- Positively charged, as a result of having a shortage of electrons.
- Negatively charged, as a result of having excess electrons.
- Neutral, as it has equal numbers of protons and electrons.

They also learnt that opposite charges attract one another like charges repel one another. This series makes important links with Newton's Third Law, since charges exert equal and opposite forces on each other. Coulomb's law has the same format as the Law of Universal Gravitation, and this is another opportunity to explore forces that act at a distance via a force field.

Learners need to understand that it is only the *magnitude* of the charge that needs to be inserted into the Coulomb's law equation. If the charge is a negative one, the sign is *not* inserted into the equation. However, when the resultant force or electric field strength is to be calculated, the directions of the forces need to be allocated positive and negative signs.

Learners are sometimes under the misconception that electric field diagrams are two-dimensional and not three-dimensional because of the way that the electric field diagrams are drawn. Stress the fact that the electric field is something that exists three-dimensionally around the charge, but that we represent it two-dimensionally when we draw it. The lesson on field patterns provides a good basis before the following series on Electromagnetism.

There are quite a few calculations in this series, many of which are vector-based. This means that before doing this series, learners should be familiar with calculations to find the resultant of two vectors.

Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

1. Revision of Grade 10 Electrostatics

This lesson serves to recap the following Grade 10 principles:

- What makes an object positively or negatively charged
- Principle of conservation of charge
- Charge quantisation

2. Coulomb's Law – Point Charges in One Dimension

In this lesson we cover Coulomb's law in words and mathematically. We also solve problems using Coulomb's law to calculate the force exerted on a charge by one or more charges in 1D.

3. Coulomb's Law in 2D

This video looks at solving problems using Coulomb's law to calculate the force exerted on a charge by one or more charges in 2D.

4. Electric Fields

In this lesson we define electric fields around charged objects. We also draw electric field lines for various configurations of charges.

5. Calculating Electric Field Strength

This video looks at how to calculate the strength of an electric field.

Resource Material

1. Revision of Grade 10 Electrostatics	http://www.physicsclassroom.com/Class/estatics/u8l1c.cfm	This is a resource on static electricity
	http://phet.colorado.edu/en/simulation/balloons	This is a teaching resource on static electricity.
2. Coulomb's Law – Point Charges in One Dimension	http://library.thinkquest.org/10796/ch12/ch12.htm	This website compares gravitational fields and electric fields
	http://www.physicsclassroom.com/Class/estatics/u8l3b.cfm	This is a resource on Coulomb's Law
3. Coulomb's Law in 2D	http://www.studyphysics.ca/30/coulomb.pdf	This website provides everything you need to know about Coulomb's Law
4. Electric Fields	http://www.physicsclassroom.com/Class/estatics/u8l4c.cfm	A resource on Electric Fields
	http://library.thinkquest.org/10796/ch12/ch12.htm	This website compares gravitational fields and electric fields
	http://www.cco.caltech.edu/~phys1/java/phys1/EField/EField.html	This is an Electric Field Applet
	http://www.algebra-class.com/linear-functions.html	This is a study of linear functions
5. Calculating Electric Field Strength	http://www.physicsclassroom.com/Class/estatics/u8l4b.cfm	A resource on Electric Fields

Task

Question 1

Calculate the new charge on each of the spheres in the following diagram after they have touched.

Question 2

A neutral object obtains a charge by gaining 1 800 electrons. What is the charge that the object obtains?

Question 3

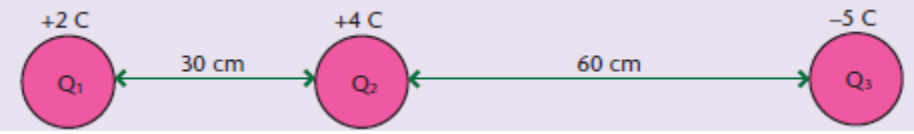
Two perfume particles with charges of 5 µC and 10 µC are placed 0,5 m apart. Calculate the magnitude of the force between them.

Question 4

Two small metal spheres have charges of +2 pC and +5 pC respectively. If the force between the two charges is 9 x 10^{-12} N, calculate the distance between them.

Question 5

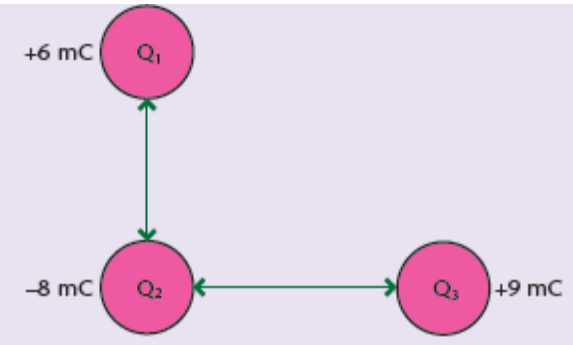
Three point charges are in a straight line. The charges and distances between them are shown.



What is the resultant electrostatic force on Q_2 as a result of the other two charges?

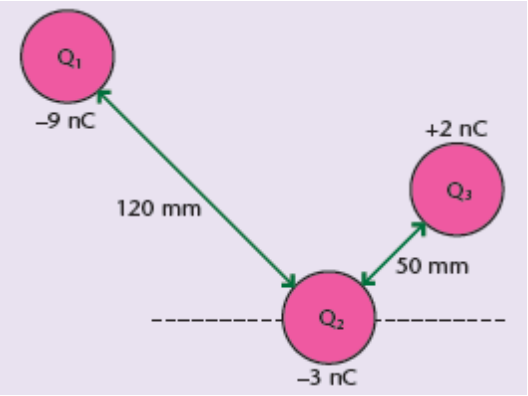
Question 6

Three point charges are placed in close proximity to one another. The charges and distances between them are shown. What is the resultant electrostatic force on Q_2 as a result of the other two charges?



Question 7

Three point charges are placed in close proximity to one another. The charges and distances between them are shown. The angle between the forces on Q_2 is 90°. What is the resultant electrostatic force on Q_2 as a result of the other two charges?



Question 8

Draw the electric field around:

8.1 A positive charge.

8.2 A negative charge.

Question 9

Draw the resulting field pattern between the following pairs of charges:

9.1

9.2

Question 10

A charge of 5 nC experiences a force of 4 x10^{-6} N at a point in an electric field. Calculate the strength of the electric field.

Question 11

Two charges, Q_1 of +6 nC and Q_2 of -7,5 nC are separated by a distance of 150 mm. What is the electric field strength at point X, which is 70 mm from Q_1 and 80 mm from Q_2?

Task Answers

Question 1

$$Q = \frac{Q_1 + Q_2}{2}$$

$$Q = \frac{5 + (-9)}{2}$$

$$Q = -2 \text{ C}$$

Question 2

$$Q = 1800 \times (1,6 \times 10^{-19})$$

$$Q = -2,88 \times 10^{-16} \text{ C}$$

Question 3

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

$$F = \frac{(9 \times 10^9)(5 \times 10^{-6})(10 \times 10^{-6})}{(0,5)^2}$$

$$F = 1,8 \text{ N}$$

Question 4

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

$$9 \times 10^{-12} = \frac{(9 \times 10^9)(2 \times 10^{-12})(5 \times 10^{-12})}{r^2}$$

$$r^2 = \frac{(9 \times 10^9)(2 \times 10^{-12})(5 \times 10^{-12})}{9 \times 10^{-12}}$$

$$r^2 = 0,01$$

$$r = \sqrt{0,01}$$

$$r = 0,1 \text{ m}$$

Question 5

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

$$F = \frac{(9 \times 10^9)(2)(4)}{(0,3)^2} \qquad F = \frac{(9 \times 10^9)(2)(4)}{(0,3)^2}$$

$$F = 8 \times 10^{11} \text{ N} \qquad F = 8 \times 10^{11} \text{ N}$$

$$F_{res} = (1,6 \times 10^{12}) + (5 \times 10^{11}) = 2,1 \times 10^{12} \text{ N right}$$

Question 6

F of Q_1 on Q_2:

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

$$F = \frac{(9\times10^9)(6\times10^{-3})(8\times10^{-3})}{(0,06)^2}$$

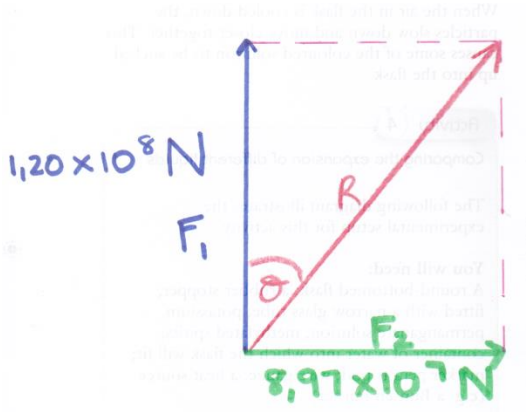
$$F = 1,20\times10^8 \text{ N attraction}$$

F of Q_3 on Q_2:

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

$$F = \frac{(9\times10^9)(8\times10^{-3})(9\times10^{-3})}{(0,085)^2}$$

$$F = 8,97\times10^7 \text{ N attraction}$$



$$F_1^2 + F_2^2 = R^2$$

$$(1,20\times10^8)^2 + (8,97\times10^7)^2 = R^2$$

$$2,24\times10^{16} = R^2$$

$$R = 1,50\times10^8 \text{ N}$$

$$\frac{F_2}{F_1} = \tan\theta$$

$$\frac{8,97\times10^7}{1,20\times10^8} = \tan\theta$$

$$\theta = 36,80^o$$

$R = 1,50\times10^8$ N at $36,80^o$ to the $1,20\times10^8$ N force

Question 7

F of Q_1 on Q_2:

F = $\frac{k\,Q_1\,Q_2}{r^2}$

= $\frac{(9\times10^9)(9\times10^{-9})(3\times10^{-9})}{(0{,}12)^2}$

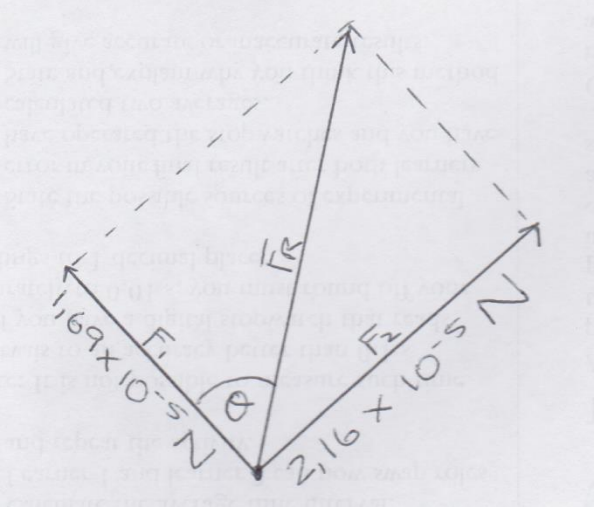
= 1,69 × 10^{-5} N repulsion.

F of Q_3 on Q_2:

F = $\frac{k\,Q_2\,Q_3}{r^2}$

= $\frac{(9\times10^9)(3\times10^{-9})(2\times10^{-9})}{(0{,}05)^2}$

= 2,16 × 10^{-5} N attraction.



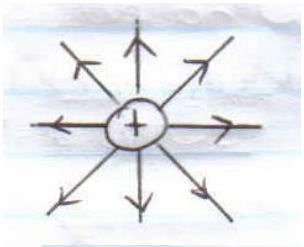
$$F_R^{\,2} = F_1^{\,2} + F_2^{\,2}$$
$$F_R^{\,2} = (1{,}69\times10^{-5})^2 + (2{,}16\times10^{-5})^2$$
$$F_R^{\,2} = 7{,}52\times10^{-10}$$
$$F_R = 2{,}74\times10^{-5}\ \text{N}$$

$$\tan\theta = \frac{2{,}16\times10^{-5}}{1{,}69\times10^{-5}}$$
$$\theta = 51{,}96^o$$

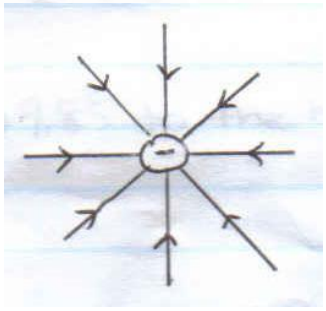
$F_R = 2{,}74\times10^{-5}$ N at $51{,}96^o$ to F_1

Question 8

8.1

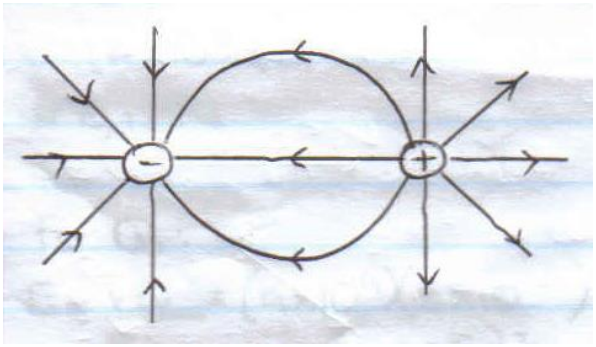


8.2

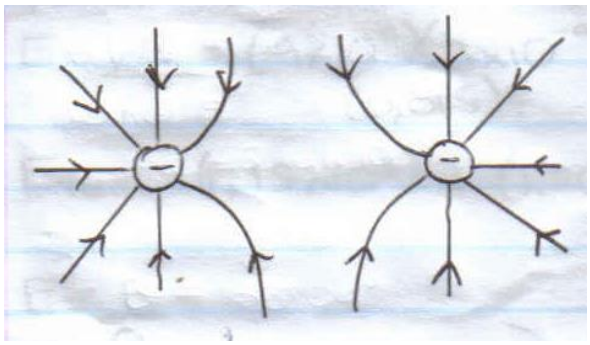


Question 9

9.1



9.2



Question 10

$E = \frac{F}{Q} = \frac{4 \times 10^{-6}}{5 \times 10^{-9}} = 800\ N.C^{-1}$

Question 11

For Q_1:

E = $\frac{kQ}{r^2}$ = $\frac{(9\times10^9)(6\times10^{-9})}{(0,07)^2}$ = 1,10 × 10^4 N.C^{-1} right.

For Q_2:

E = $\frac{kQ}{r^2}$ = $\frac{(9\times10^9)(7,5\times10^9)}{(0,08)^2}$ = 1,05 × 10^4 N.C^{-1} right.

E_{Total} = (1,10 × 10^4) + (1,05 × 10^4) = 2,15 × 10^4 N.C^{-1} right

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