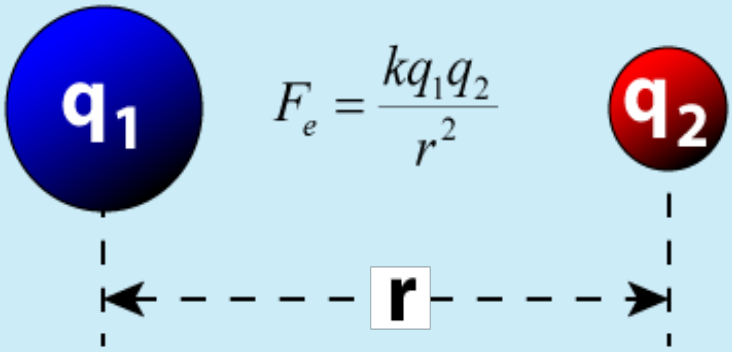
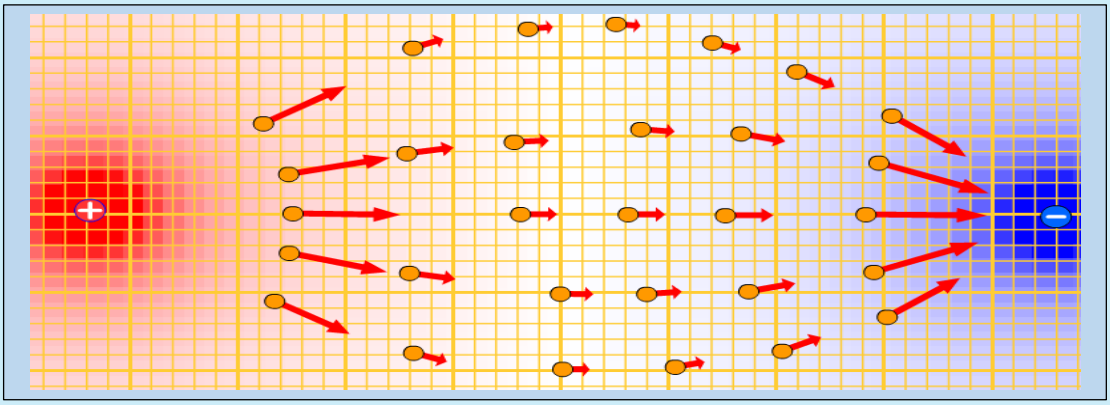
NORTHERN CAPE DEPARTMENT OF EDUCATION

PHISICAL SCIENCES
PHYSICS





GRADE 12 REVISION

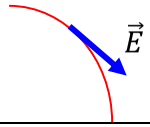
ELECTROSTATICS

COMPILED BY:
G. IZQUIERDO RODRIGUEZ

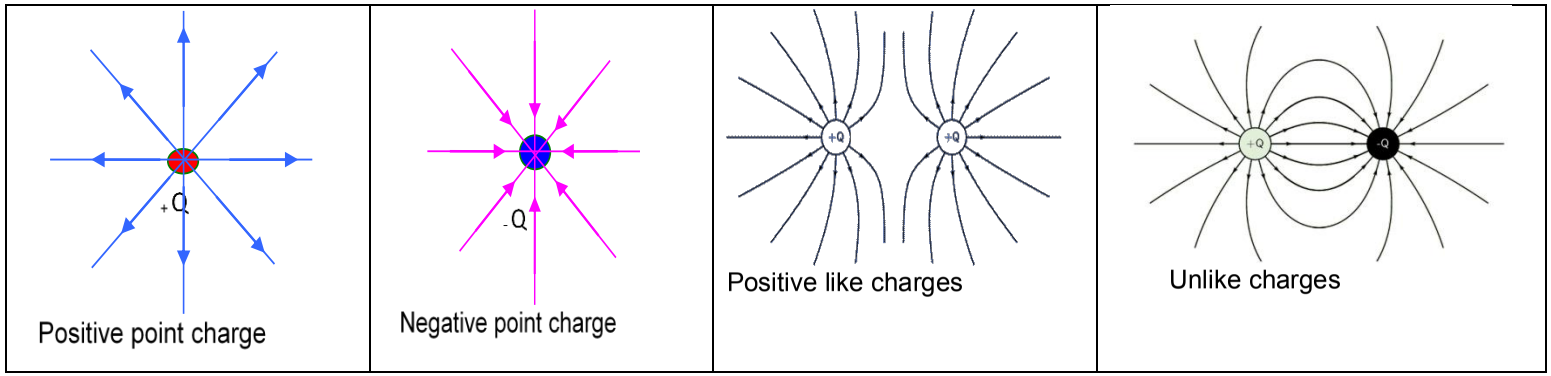
2020

PHYSICS

ELECTROSTATICS

ELECTROSTATICS					
Electrostatics Force	Electric field	Electric field at a point	Lines	Principle of superposition of forces	Principle of superposition of fields
Coulomb`s law The magnitude of the electrostatic force exerted by one point charge (Q_1) on another point charge (Q_2) is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them: $F = \frac{KqQ}{r^2}$	***Electric field* is an area of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction in which a positive test charge would move if placed at that point.**	**The electric field at a point is the electrostatic force experienced per unit positive charge placed at that point.** $\vec{E} = \frac{\vec{F}}{q}$ **For a point charge:** $E = \frac{KQ}{r^2}$	Electric field lines are IMAGINARY LINES along which a small POSITIVE **test charge** would move. The force experienced by the positive **test charge** is always in the **direction** of the **tangent** to the field line They start on a positive **charge** and end on a negative **charge**. 	**The force that a system of point charges exerts on another point charge is equal to the vector addition of all the forces each one exerts on it.** $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + ... + \vec{F}_n$	**The electric field strength at a point due to a system of point charges is equal to the vector addition of all the electric field strengths of each one at a specific point.** $\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 + ... + \vec{E}_n$

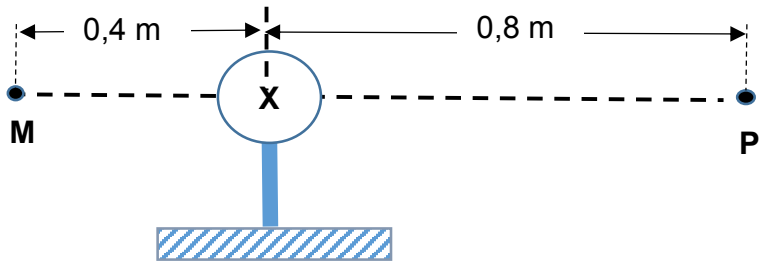
Electric field pattern



EXAMPLE

QUESTION 1

The diagram below shows a metal sphere **X** of negligible mass on an insulated stand in a vacuum. 3,125 x 10^{10} electrons have been removed from the sphere.



1.1 Draw the electric field pattern associated with sphere **X**. (2)

1.2 Describe an *electric field*. (2)

1.3 Calculate the net charge on the sphere. (3)

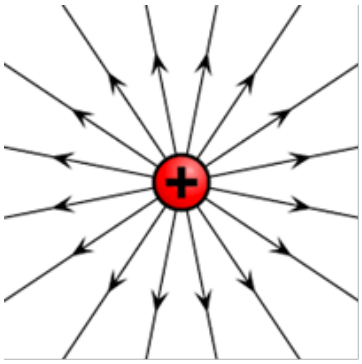
1.4 Calculate the electric field at point **P**. (3)

1.5 How does the magnitude of the electric field at point **M** compare with the value calculated in QUESTION 7.4? Write down only GREATER THAN, EQUAL TO or SMALLER THAN. Give a reason for the answer. (2)

1.6 A metal sphere **Y,** on an insulated stand carrying a charge of -4 nC, is now placed at point **M**. Show by calculations where a positive point charge **Q** should be placed so that it is in equilibrium. (4)
[16]

SOLUTION

1.1



Shape (radial)✓

Correct direction ✓

(2)

1.2 An *electric field* is a region of space in which an electric charge experiences a force✓. The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.✓ (2)

1.3 $Q=ne$✓

$Q=(3{,}125\times10^{10})(1{,}6\times10^{-19})$✓

$Q=+5\times10^{-9}C$✓ (3)

1.4 **POSITIVE MARKING FROM 1.3**

$E=\frac{kQ}{r^2}$✓

$E=\frac{(9{,}0\times10^{9})(5\times10^{-9})}{(0{,}8)^2}$✓

$E=70{,}31\ N\cdot C^{-1}$away from the charge✓ (3)

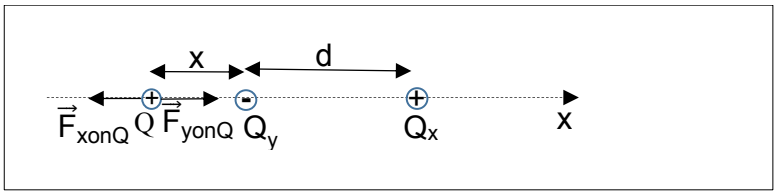
1.5 GREATER THAN ✓

The <u>electric field</u> at a point due to a point charge is <u>inversely proportional to the square of the distance</u> between the point and the charge/($E \propto \frac{1}{r^2}$) ✓

OR

The distance from <u>the charge to point **M** is smaller than the distance from the charge to point **P**</u>. ✓ (2)

1.6



OPTION 1

$\vec{F}_{x\text{ on }Q}+\vec{F}_{y\text{ on }Q}=\vec{0}$ **OR** $-F_{x\text{ on }Q}+F_{y\text{ on }Q}=0$ **OR** $F_{x\text{ on }Q}=F_{y\text{ on }Q}$

$k\frac{Q_xQ}{(d+x)^2}=k\frac{Q_yQ}{x^2}$ **OR** $\sqrt{\frac{Q_x}{(d+x)^2}}=\sqrt{\frac{Q_y}{x^2}}$ **OR** $\frac{\sqrt{Q_x}}{d+x}=\frac{\sqrt{Q_y}}{x}$

✓Any one

$\frac{\sqrt{(5\times10^{-9})}}{0,4+x}$ ✓ $=\frac{\sqrt{(4\times10^{-9})}}{x}$ ✓

x=3,39 m✓

OPTION 2

$\vec{F}_{x\text{ on }Q}+\vec{F}_{y\text{ on }Q}=\vec{0}$ ✓ **OR** $-F_{x\text{ on }Q}+F_{y\text{ on }Q}=0$ **OR** $F_{x\text{ on }Q}=F_{yon\ Q}$

$k\frac{Q_xQ}{(d+x)^2}=k\frac{Q_yQ}{x^2}$ **OR** $Q_xx^2=Q_y(d+x)^2$

OR

$Q_xx^2=Q_yd^2+2Q_ydx+Q_yx^2$

OR

$Q_xx^2-Q_yd^2-2Q_ydx-Q_yx^2=0$

OR

$(Q_x-Q_y)x^2-2Q_ydx-Q_yd^2=0$

✓Any one/

$(5\times10^{-9}-4\times10^{-9})x^2$✓ $-2(4\times10^{-9})(0,4)x-4\times10^{-9}(0,4)^2=0$✓

OR

$(10^{-9})x^2$ ✓ $-(3,2\times10^{-9})x+0,64\times10^{-9}=0$✓

OR/*OF*

x^2✓$-3,2x-0,64=0$✓

OR

$x=\frac{3,2\pm\sqrt{(3,2)^2-4(1)(-0,64)}}{2}$ ✓✓ **OR** $x=\frac{3,2\pm\sqrt{(3,2)^2+4(1)(0,64)}}{2}$

x = 3,39 m✓

OPTION 3

$\vec{F}_{net}=\vec{0}$

$\vec{F}_{x\text{ on }Q}+\vec{F}_{y\text{ on }Q}=\vec{0}$ **OR** $-F_{x\text{ on }Q}+F_{y\text{ on }Q}=0$ **OR** $F_{x\text{ on }Q}=F_{y\text{ on }Q}$

✓Any one/

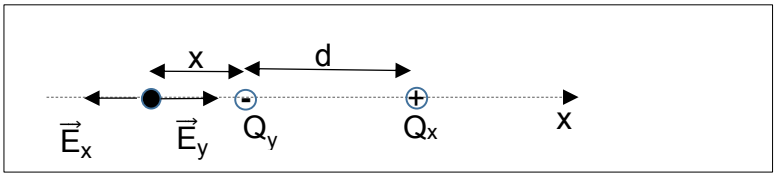
$Q\vec{E}_x+Q\vec{E}_y=\vec{0}$ **OR** $-QE_x+QE_y=0$ **OR** $QE_x=QE_y$

$k\frac{Q_x}{(d+x)^2}=k\frac{Q_y}{x^2}$ **OR** $\sqrt{\frac{Q_x}{(d+x)^2}}=\sqrt{\frac{Q_y}{x^2}}$ **OR** $\frac{\sqrt{Q_x}}{d+x}=\frac{\sqrt{Q_y}}{x}$

$\frac{\sqrt{(5\times10^{-9})}}{0,4+x}$ ✓$=\frac{\sqrt{(4\times10^{-9})}}{x}$ ✓

x=3,39 m✓

OPTION 4



$\vec{F}_{net}=\vec{0}$

$\vec{F}_{net}=q\vec{E}_{net}=0$

Therefore

$\vec{E}_{net}=\vec{0}$

$\vec{E}_x+\vec{E}_y=\vec{0}$ **OR** $-E_x+E_y=0$ **OR** $E_x=E_y$

$k\frac{Q_x}{(d+x)^2}=k\frac{Q_y}{x^2}$ **OR** $\sqrt{\frac{Q_x}{(d+x)^2}}=\sqrt{\frac{Q_y}{x^2}}$ **OR** $\frac{\sqrt{Q_x}}{d+x}=\frac{\sqrt{Q_y}}{x}$

$\frac{\sqrt{(5\times10^{-9})}}{0,4+x}$ ✓$=\frac{\sqrt{(4\times10^{-9})}}{x}$ ✓

x=3,39 m✓

(4)

[16]

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 Two charged spheres of magnitudes 2Q and Q respectively are placed a distance r apart on insulating stands.

If the sphere of charge Q experiences a force **F** to the east, then the sphere of charge 2Q will experience a force …

A **F** to the west.

B **F** to the east.

C 2**F** to the west.

D 2**F** to the east. (2)

1.2 P, Q and R are three charged spheres. When P and Q are brought near each other, they experience an attractive force. When Q and R are brought near each other, they experience a repulsive force.

Which ONE of the following is TRUE?

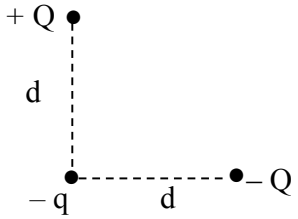
A P and R have charges with the same sign.

B P and R have charges with opposite signs.

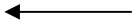
C P, Q and R have charges with the same sign.

D P, Q and R have equal charges. (2)

1.3 Two charges, + Q and – Q, are placed a distance d from a negative charge – q. The charges, + Q and – Q, are located along lines that are perpendicular to each other as shown in the diagram below.



Which ONE of the following arrows CORRECTLY shows the direction of the net force acting on charge – q due to the presence of charges + Q and – Q?

A	
B	
C	
D	

(2)

1.4 Two identical conducting spheres are charged such that sphere 1 has a charge of 4 C and sphere 2 has a charge of −4 C. A third identical sphere is initially uncharged. If sphere 3 touches sphere 1 and separates, then touches sphere 2 and separates. The final charge on sphere 3 is…

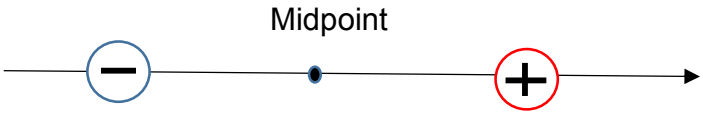
A -1 C

B + 1C

C - 2 C

D + 2 C (2)

1.5 The sketch below shows a negative and a positive point charge. The magnitude of the positive charge is greater than that of the negative charge.



Where on the line that passes through the charges is the total electric field zero?

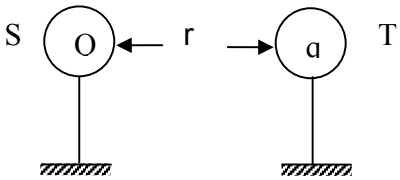
A To the right of the positive charge.

B To the left of the negative charge.

C Between the charges, to the left of the midpoint.

D Between the charges, to the right of the midpoint. (2)

1.6 Two spheres **S** and **T** on isolated stands carry charges **Q** and **q** respectively and their centres are a distance **r** apart.



The magnitude of the electrostatic force exerted by **S** on **T** is **F**. If the distance between them is doubled the new electrostatic force is:

A 2 F

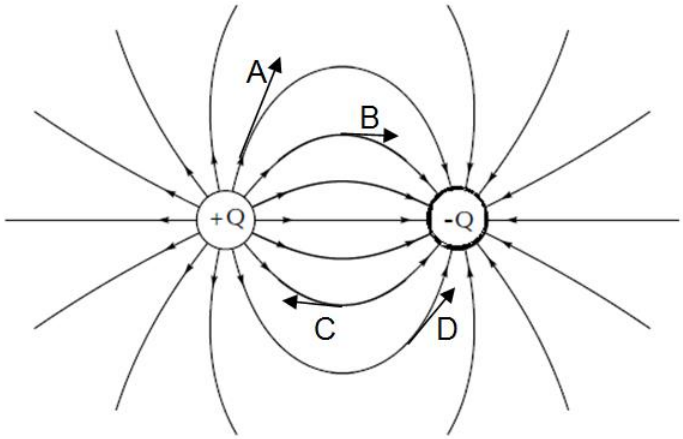
B 1/2 F

C 1/4 F

D 4 F

(2)

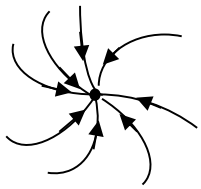
1.7 A learner drew a diagram shown below to show the electric field pattern due to two point charges and the electric field strength at different points.



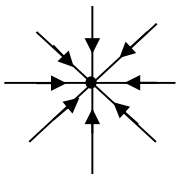
Which ONE of the vectors that show the electric field strength at a point was represented incorrectly? (2)

1.8 Which ONE of the sketches below correctly represents the electric field lines of a positive point charge?

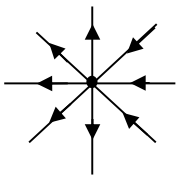
A



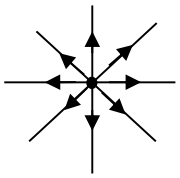
B



C

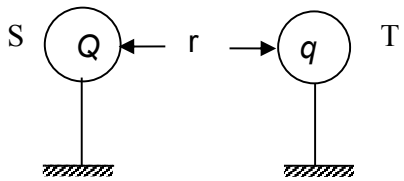


D



(2)

1.9 Two spheres **S** and **T** on isolated stands carry charges Q and q respectively and their centres are a distance r apart. The magnitude of the electrostatic force exerted by **S** on **T** is F.



If the distance between them is tripled the new electrostatic force is …

A $\frac{1}{9}F$

B $\frac{1}{3}F$

C F

D $9F$

(2)

1.10 Which ONE of the following combinations is CORRECT regarding the properties of electric field lines?

	Direction	Strength of field
A	Positive to negative	Strongest where the lines are the most dense
B	Negative to positive	Weakest where the lines are the least dense
C	North to south	Strongest where the lines are the most dense
D	North to south	Weakest where the lines are the least dense

(2)

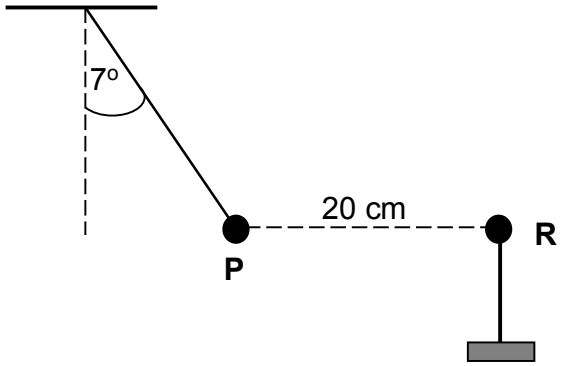
[20]

QUESTION 2 (DBE/November 2015)

A very small graphite-coated sphere **P** is rubbed with a cloth. It is found that the sphere acquires a charge of + 0,5 µC.

2.1 Calculate the number of electrons removed from sphere **P** during the charging process. (3)

Now the charged sphere **P** is suspended from a light, inextensible string. Another sphere, **R**, with a charge of – 0,9 µC, on an insulated stand, is brought close to sphere **P**. As a result sphere **P** moves to a position where it is 20 cm from sphere **R**, as shown below. The system is in equilibrium and the angle between the string and the vertical is 7^o.



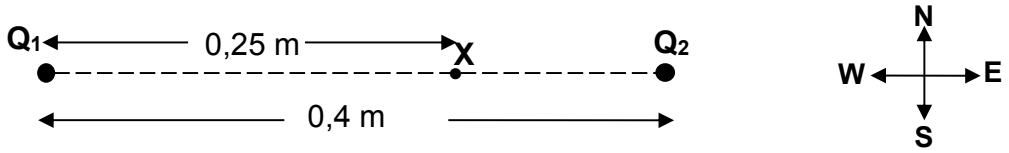
2.2 Draw a labelled free-body diagram showing ALL the forces acting on sphere **P**. (3)

2.3 State Coulomb's law in words. (2)

2.4 Calculate the magnitude of the tension in the string. (5)
[13]

QUESTION 3 (DBE/November 2015)

Two charged particles, Q_1 and Q_2, are placed 0,4 m apart along a straight line. The charge on Q_1 is + 2 x 10^{-5} C, and the charge on Q_2 is – 8 x 10^{-6} C. Point **X** is 0,25 m **east** of Q_1, as shown in the diagram below.



Calculate the:

3.1 Net electric field at point **X** due to the two charges (6)

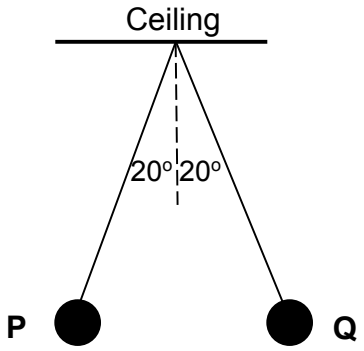
3.2 Electrostatic force that a – 2 x 10^{-9} C charge will experience at point **X** (4)

The – 2 x 10^{-9} C charge is replaced with a charge of – 4 x 10^{-9} C at point **X**.

3.3 **Without any further calculation**, determine the magnitude of the force that the – 4 x 10^{-9} C charge will experience at point **X**. (1)
[11]

QUESTION 4 DBE/Feb.–Mar. 2016)

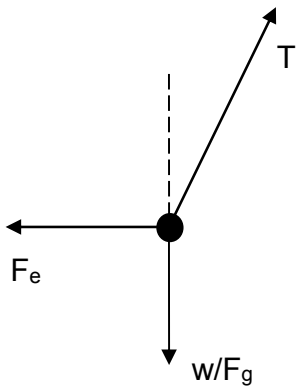
Two identical spherical balls, **P** and **Q**, each of mass 100 g, are suspended at the same point from a ceiling by means of identical light, inextensible insulating strings. Each ball carries a charge of +250 nC. The balls come to rest in the positions shown in the diagram below.



4.1 In the diagram, the angles between each string and the vertical are the same. Give a reason why the angles are the same. (1)

4.2 State Coulomb's law in words. (2)

4.3 The free-body diagram, not drawn to scale, of the forces acting on ball **P** is shown below.



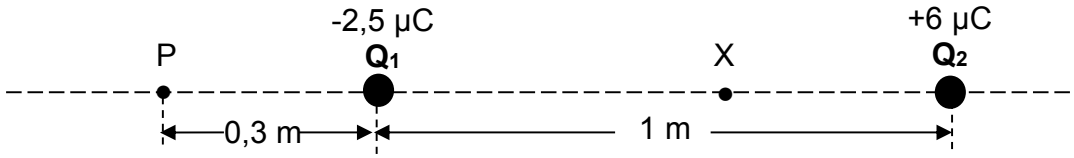
Calculate the:

4.3.1 Magnitude of the tension (T) in the string (3)

4.3.2 Distance between balls **P** and **Q** (5)
[11]

QUESTION 5 (DBE/Feb.–Mar. 2016)

A sphere Q_1, with a charge of -2,5 µC, is placed 1 m away from a second sphere Q_2, with a charge +6 µC. The spheres lie along a straight line, as shown in the diagram below. Point **P** is located a distance of 0,3 m to the left of sphere Q_1, while point **X** is located between Q_1 and Q_2 . The diagram is not drawn to scale.



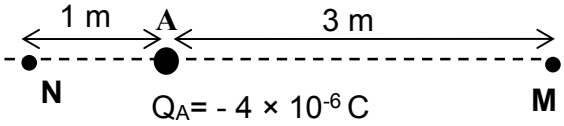
5.1 Show, with the aid of a VECTOR DIAGRAM, why the net electric field at point **X** *cannot be zero.* (4)

5.2 Calculate the net electric field at point **P**, due to the two charged spheres Q_1 and Q_2. (6)

[10]

QUESTION 6

The diagram below shows a point charge **A** with a charge of - 4 × 10^{-6} C and two points **M** and **N.**



6.1 Define *electric field at a point* in words (2)

6.2 Draw the electric field pattern due to point charge **A.** (2)

6.3 At what point,**M** or **N,** is the magnitude of the electric field due to the point charge **A** greater? Explain the answer. (3)

6.4 A positive point charge **B** with charge + 8 x 10^{-6} C is placed at point **M.** Point charges **A** and **B** exerts forces on each other.

6.4.1 State *Coulomb's law* in words. (2)

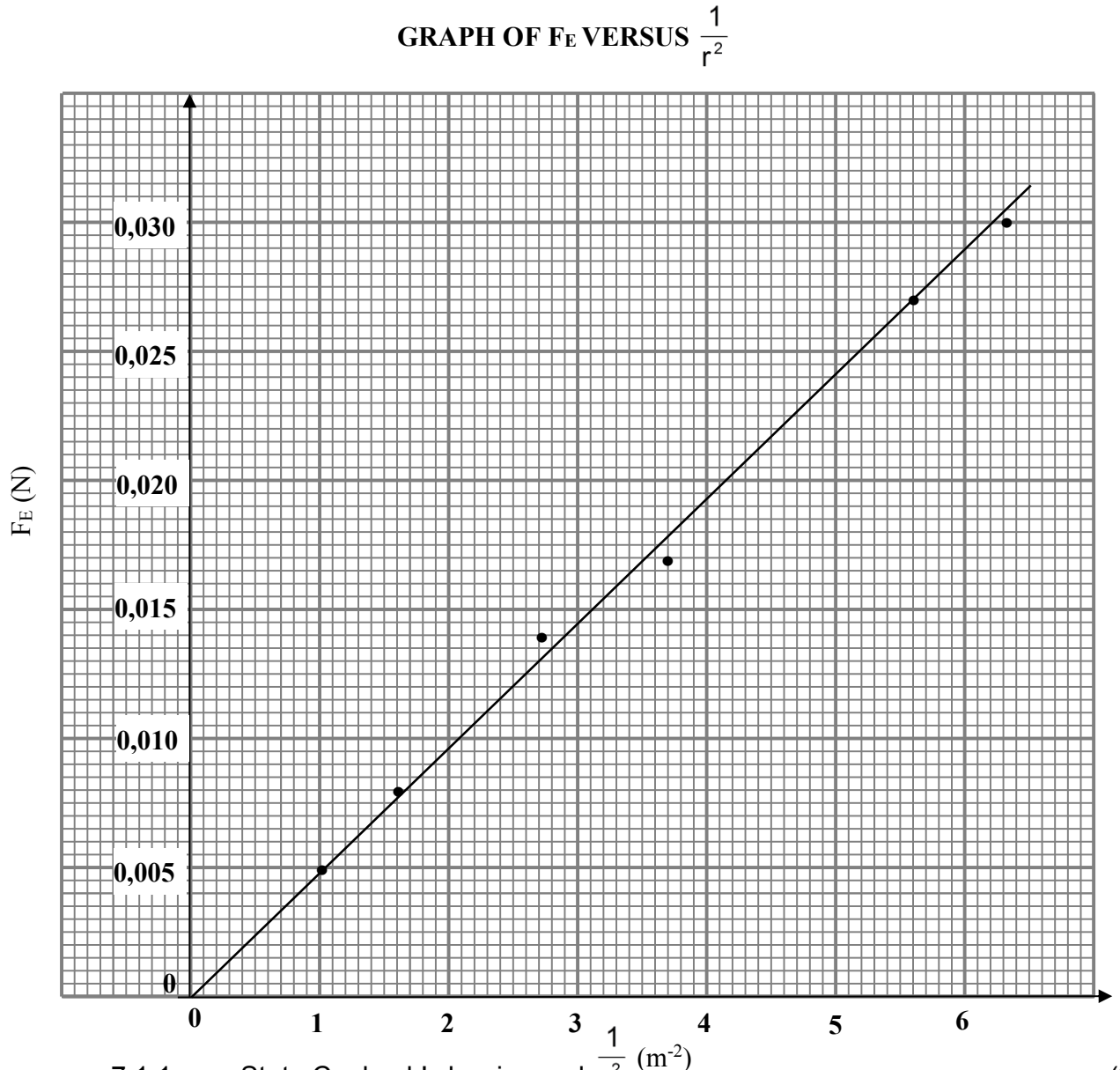
6.4.2 Calculate the electrostatic force exerted by charge **A** on charge **B.** (4)

6.4.3 Calculate the net electric field at point N. (5)

[18]

QUESTION 7 (DBE/November 2016))

7.1 In an experiment to verify the relationship between the electrostatic force, F_E, and distance, r, between two **identical**, positively charged spheres, the graph below was obtained.



7.1.1 State Coulomb's law in words (2)

7.1.2 Write down the dependent variable of the experiment. (1)

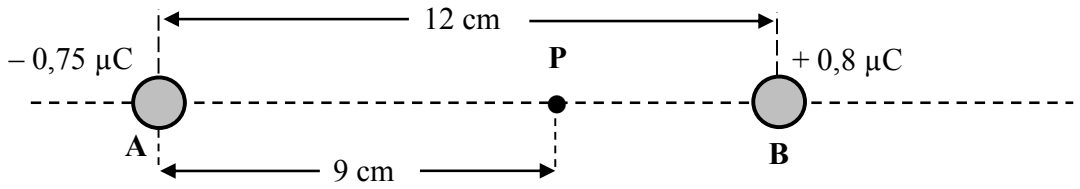
7.1.3 What relationship between the electrostatic force F_E and the square of the distance, r^2, between the charged spheres can be deduced from the graph? (1)

7.1.4 Use the information in the graph to calculate the charge on each sphere. (6)

7.2 A charged sphere, **A**, carries a charge of – 0,75 µC.

7.2.1 Draw a diagram showing the electric field lines surrounding sphere **A**. (2)

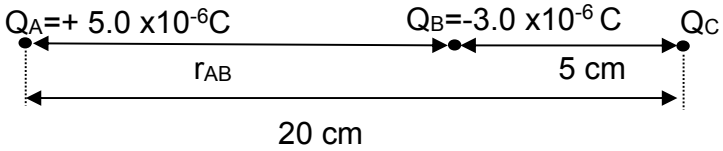
Sphere **A** is placed 12 cm away from another charged sphere, **B**, along a straight line in a vacuum, as shown below. Sphere **B** carries a charge of +0,8 µC. Point **P** is located 9 cm to the right of sphere **A**.



7.2.2 Calculate the magnitude of the net electric field at point **P**. (5)
[17]

QUESTION 8

Three point charges Q_A, Q_B and Q_C are placed in vacuum as shown in the sketch below. The distance between point charges Q_A and Q_C is 20 cm while that between Q_B and Q_C is 5 cm.



8.1 State Coulomb's Law in words. (2)

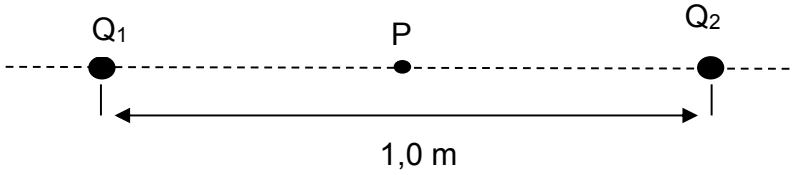
8.2 How does the magnitude of the electrostatic force exerted by point charge Q_A on point charge Q_B compare with the magnitude of the electrostatic force exerted by point charge Q_B on point charge Q_A ? Write down only GREATER THAN, SMALLER THAN or EQUAL TO. (1)

8.3 Determine the nature (positive or negative) and calculate the number of protons or electrons in charge Q_c so that the net electrostatic force on Q_B is zero. (8)

[11]

QUESTION 9

Two point charges Q_1= +5,0 µC and Q_2= -3,0 µC 1 m apart, are placed in vacuum as shown in the sketch below .



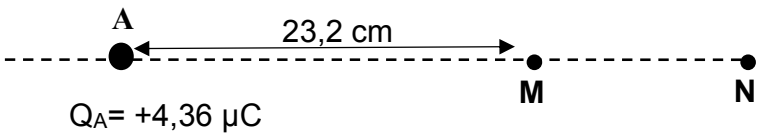
9.1 Define the term *electric field* at a point. (2)

9.2 Calculate the net electric field at point P located at the middle of the distance between the point charges Q_1 and Q_2. (6)

[8]

QUESTION 10

The diagram below shows a point charge **A** with a charge +4,36 µC and two points **M** and **N.**



10.1 Define *electric field at a point* in words (2)

10.2 Draw the electric field pattern due to point charge **A.** (2)

10.3 At what point, **M** or **N,** is the magnitude of the electric field due to the point charge **A** greater? Explain the answer. (3)

10.4 A negative point charge **B** with charge – 7 x 10^{-6} C is placed at point **M.** Point charges **A** and **B** exerts forces on each other.

10.4.1 State *Coulomb's law* in words. (2)

10.4.2 Calculate the magnitude of the electrostatic force exerted by charge **A** on charge **B.** (4)

10.4.3 Calculate the distance from charge sphere **A** along the line that passes through the point charges where the net electric field is zero. (5)

[18]