Grade 12 advance **Physics** **Unit 2: Electric Fields and Gauss's law**

2.1 Definition of an Electric Field 2.3 Electric Field due to Point Charges

Electric Field (E)

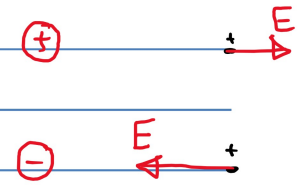
The net electric force on a charge divided by that charge

vector

magnitude — direction

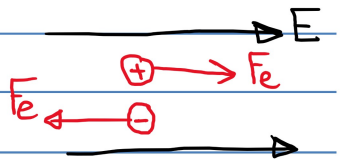
$$E = \frac{F}{q_0}$$

q_0 → test charge
- small
- positive
- does not effect E



$$E = \frac{k|q|}{r^2}$$

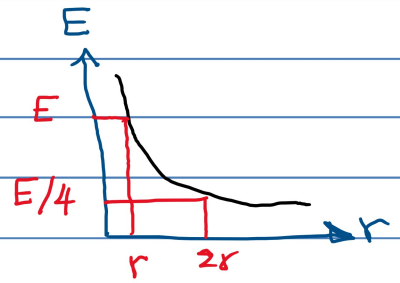
q: electric charge (C)
r: distance (m)
$k = 9 \times 10^9$ N.m²/C²
E: electric field (N/C)

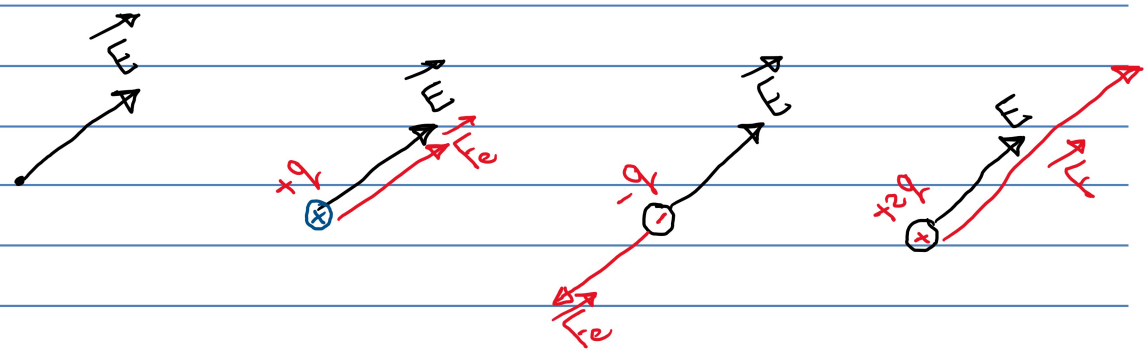


Electric field

- depends on the medium — $k = \frac{1}{4\pi\varepsilon_0}$
- is proportional to the charge (source of E)
- is inversely proportional to the square of distance

$$\frac{E_1}{E_2} = \frac{r_2^2}{r_1^2}$$





same $E = \frac{F}{q}$



Find the electric field :

a- at the position of q_1

$$E = \frac{kq}{r^2} = \frac{(9\times10^9)(3\times10^{-9})}{(0.20)^2} = 675\ N/C$$ to the right

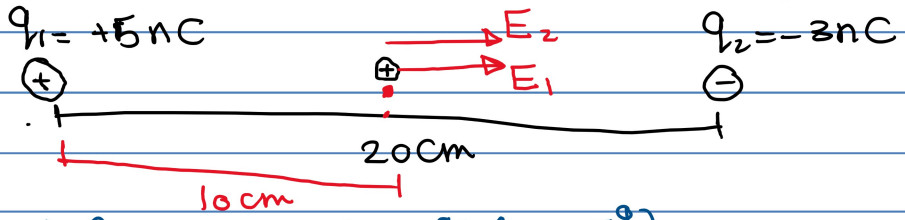


b- at the position of q_2

$$E = \frac{kq}{r^2} = \frac{(9\times10^9)(5\times10^{-9})}{0.20^2} = 1125\ N/C$$ to the right



at the midpoint between the charges



$E_1 = \frac{k q_1}{r_1^2} = \frac{(9\times10^9)(5\times10^{-9})}{0.10^2} =$ N/C right

$E_2 = \frac{k q_2}{r_2^2} = \frac{9\times10^9 \times 3\times10^{-9}}{0.10^2} =$ N/C right

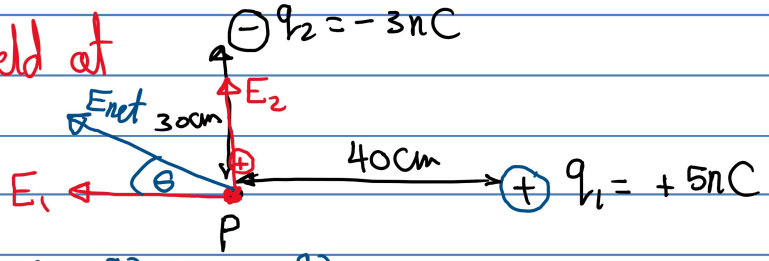
$E_{net} = E_1 + E_2 =$ N/C to the right

If a charge is added at the midpoint, how will be Enet will change?

E_{net} stays the same

Test charge does not effect the electric field

Find the electric field at point P.



$E_1 = \frac{k q_1}{r_1^2} = \frac{(9\times10^9)(5\times10^{-9})}{(0.40)^2} = 281.25$ N/C

$E_2 = \frac{k q_2}{r_2^2} = \frac{(9\times10^9)(3\times10^{-9})}{(0.30)^2} = 300$ N/C

magnitude $E_{net} = \sqrt{(281.25)^2 + (300)^2} = 411$ N/C

direction $\theta = \tan^{-1}\left(\frac{E_y}{E_x}\right) = \tan^{-1}\left(\frac{300}{281.25}\right) = 47^\circ$

$180 - 47 = 133^\circ$

If a q_3 $-2\,nC$ is added at point P.

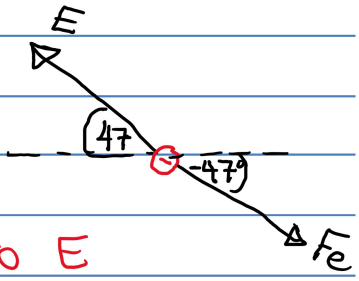
Find the electrostatic force on this charge

$F_{on3} = q_3 E_{net}$

magnitude $F = 2\times10^{-9} \times 411 = 8.2\times10^{-7}\ N$

direction $\theta = -47^\circ$

or $360 - 47$



Fe on ⊖ is opposite to E

$q_1 = +2q$ (+) midprint $q_2 = -q$ (+)

E_2 ← (+) → E_1

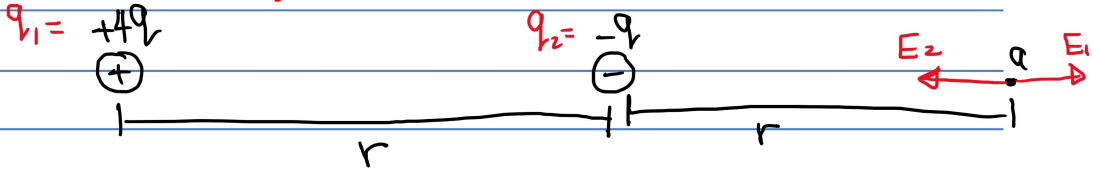
E_{net} →

$q_1 = +q$ (+) $q_2 = -q$ (−)

E_1 →

E_2 ←

E_{net} ←

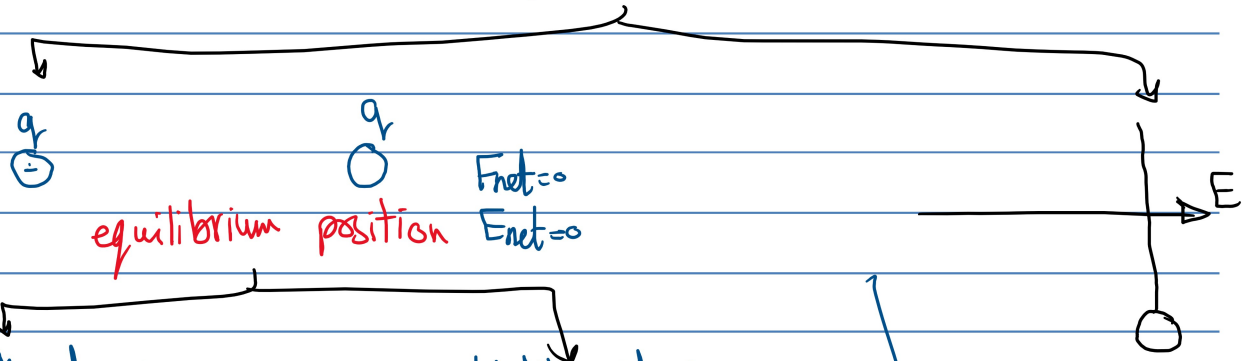


$$E_1 = \frac{k\,4q}{(2r)^2} = \frac{kq}{r^2}$$

$$E_2 = -\frac{kq}{r^2}$$

$E_{net} = 0$

Equilibrium



$F_{net}=0$

$E_{net}=0$

equilibrium position

Like charge

Unlike charges

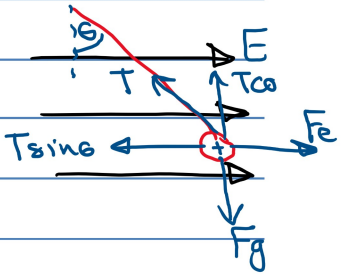
between the charges

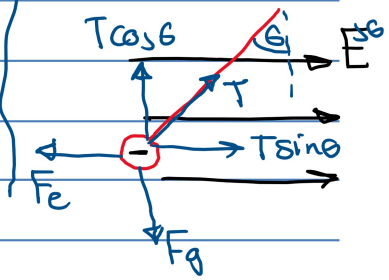
outside from the charges

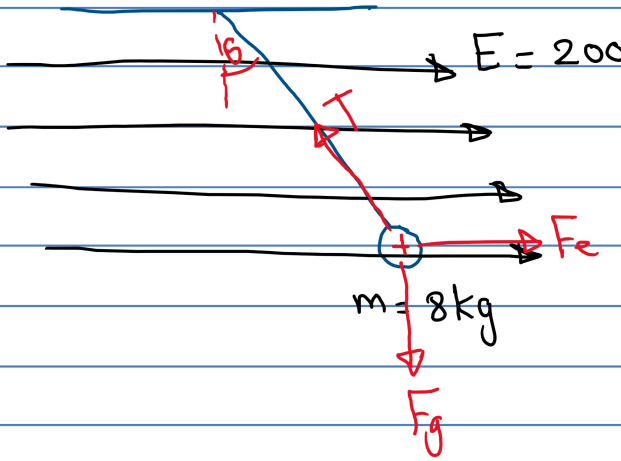
closer to the smallest charge

$$E_1 = E_2$$

$$\frac{\cancel{k}q_1}{r_{13}^2} = \frac{\cancel{k}q_2}{r_{23}^2}$$

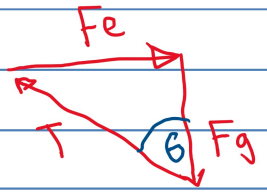






$\theta = 20^\circ$

Find the magnitude and the sign of the ball



$$\tan\theta = \frac{F_e}{F_g}$$

$$\tan\theta = \frac{qE}{mg}$$

$$\tan(20) = \frac{q \times 200}{0.008 \times 9.8}$$

$q = +$ C

↙

moves with E

2.1 Definition of an Electric Field 2.1 تعريف المجال الكهربائي

2.3 Electric Field due to Point Charges 2.3 المجال الكهربائي الناتج عن الشحنات النقطية

1	
What is the unit for the electric field?	ما هي وحدة قياس المجال الكهربائي؟

N/C	J.C	J/C	V.m

2		
The direction of the electric field is the direction of the._____		يكون اتجاه المجال الكهربائي باتجاه .....
	work done moving the test charge	الشغل المبذول على شحنة اختبار
	potential difference	الجهد الكهربائي
	force on the positive test charge	القوة على شحنة اختبار موجبة
	force on the negative test charge	القوة على شحنة اختبار سالبة

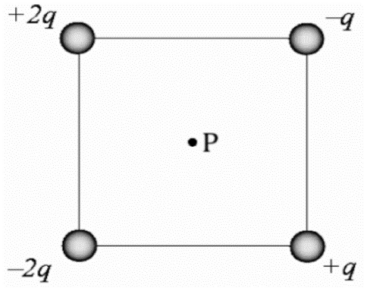
3	
A positive charge of 3.0×10^{-7} C in an electric field with a strength of 27 N/C towards the south. What is the magnitude of the force acting on the charge?	شحنة موجبة 3.0×10^{-7} C في مجال كهربائي شدته 27N/C باتجاه الجنوب . ما مقدار القوة المؤثرة على الشحنة ؟
3.0×10^{-7}N	1.2×10^{6}N
8.1×10^{-6}N	9.0×10^{7}N

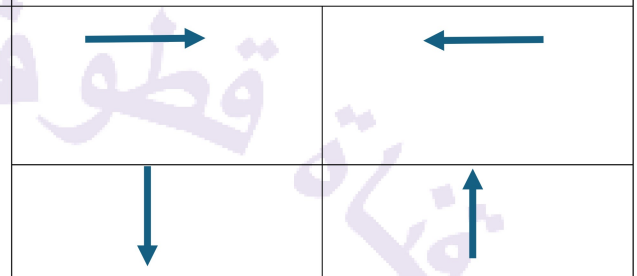
4	
A negative charge of 1.5×10^{-8} C is affected by a force of 0.030 N towards the right in an electric field. What is the magnitude and direction of the electric field?	شحنة سالبة 1.5×10^{-8} C تتاثر بقوة مقدارها 0.030N باتجاه اليمين في مجال كهربائي. ما مقدار واتجاه المجال الكهربائي؟
4.5×10^{-7} N/C to the right	4.5×10^{-7} N/C to the left
2.0×10^{6} N/C to the right	2.0×10^{6} N/C to the left

5

Four charges are located on the corners of a square as shown in the drawing. What is the direction of the net electric field at the point labeled P?

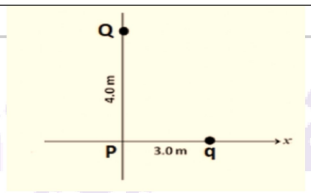
أربعة شحنات كهربائية موجودة على زوايا مربع كما بالشكل
ما اتجاه محصلة المجال الكهربائي عند النقطة P؟



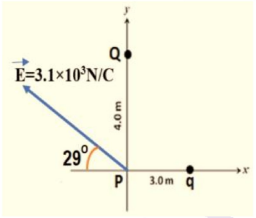


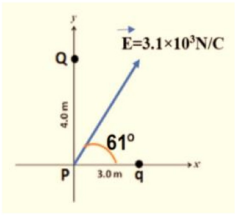
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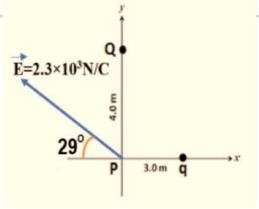
According to the figure if :
$Q = -2\mu C$, $q = +2\mu C$
What is the electric field at point P ?

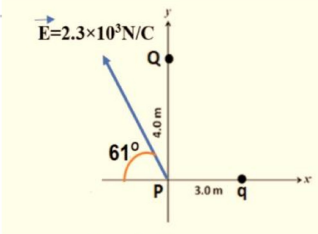


وفقاً للشكل : إذا كان :
$Q = -2\mu C$, $q = +2\mu C$
ما المجال الكهربائي عند النقطة P ؟



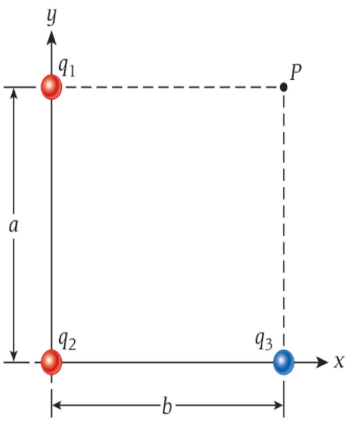




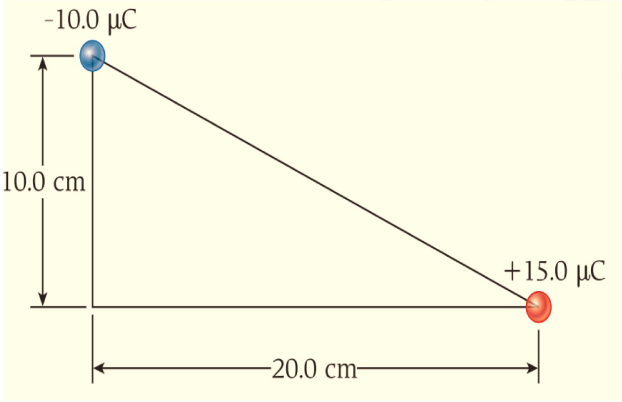


7	
Three -9mC point charges are located at (0,0), (3 m,3 m), and (3 m,-3 m). What is the magnitude of the electric field at (3 m,0)?	تقع ثلاث شحنات مقدار كلا منها $-9mC$ عند النقاط: $(0,0)\ ,(3m\ ,3m)\ ,(3m\ ,-3m)$ ما مقدار المجال الكهربائي عند النقطة $(3m\ ,0)$؟
$0.9x10^7$ N/C	$1.2x10^7$ N/C	$1.8x10^7$ N/C	$2.4x10^7$ N/C

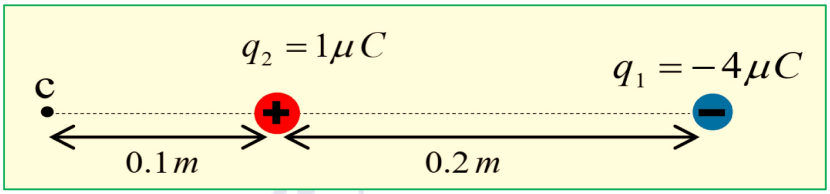
8	
three fixed point charges: $q_1 = +1.50\ \mu C$, $q_2 = +2.50\ \mu C$, and $q_3 = -3.50\ \mu C$. Charge q_1 is located at (0,a), q_2 is located at (0,0), and q_3 is located at (b,0), where a = 8.00 m and b = 6.00 m. What electric field, do these three charges produce at the point P = (b,a)?	ثلاث شحنات نقطية: $q_1 = +1.50\mu C\ , q_2 = +2.50\mu C\ , q_3 = -3.50\mu C$ الشحنة q_1 تقع عند (0,a) والشحنة q_2 تقع عند نقطة الأصل (0,0) والشحنة q_3 تقع عند (b,0). حيث : $a = 8.00m\ , b = 6.00\ m$ ما المجال الكهربائي الذي تنتجه الشحنات الثلاث عند النقطة P=(a,b) ؟



9	
Two point charges are placed at two of the corners of a triangle as shown in the figure. Find the magnitude and the direction of the electric field at the third corner of the triangle.	يتم وضع شحنتين نقطيتين على زاويتين من زوايا المثلث كما هو موضح في الشكل. أوجد مقدار واتجاه المجال الكهربائي عند الزاوية الثالثة للمثلث .

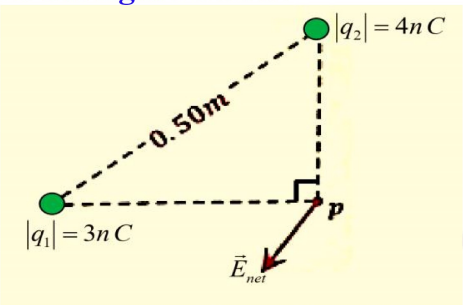


10	
Find the magnitude and direction of the electric field at point C ?	ما مقدار واتجاه المجال الكهربائي عند النقطة C؟



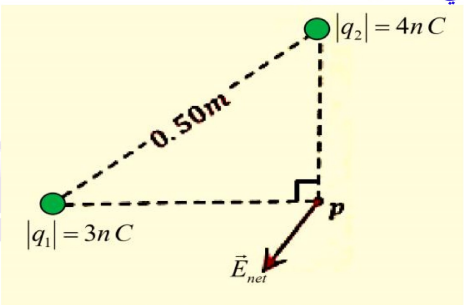
11

In the figure below:



- **What the sign of each charge :**
  - q_1 ... ...
  - q_2 ... ...
- **Find the electric field at the position of charge 2**

في الشكل أدناه:



ما إشارة كل شحنة ؟

.....q_1

..... q_2

أوجد المجال الكهربائي عند موضع الشحنة 2

12

A +5.00 C charge is located at the origin. A -3.00 C charge is placed at x = 1.00 m. At what finite distance(s) along the x-axis will the electric field be equal to zero?

وضعت شحنة 5.00 C+ عند نقطة الأصل و
وضعت الشحنة 3.00 C- عند x=1.00 m
عند أي مسافة (مسافات) محددة على طول محور x
سيكون المجال الكهربائي يساوي صفر؟

13	
Two point charges are placed on the (y) axis, the charge (+q) is at the origin (0, 0) and the other charge (-4q) is located at (y=+r). Where is the resultant electric field equal to zero?	وضعت شحنتان نقطيتان على المحور (y) الشحنة (+q) عند نقطة الأصل (0 , 0) والشحنة الأخرى (-4q) وتقع عند (y=+r) . أين تكون محصلة المجال الكهربائي تساوي صفر؟

قطوف فيزيائية

2.1 Definition of an Electric Field 2.1 تعريف المجال الكهربائي

2.3 Electric Field due to Point Charges 2.3 المجال الكهربائي الناتج عن الشحنات النقطية

1	
What is the unit for the electric field?	ما هي وحدة قياس المجال الكهربائي؟

N/C	J.C	J/C	V.m

$N/C = kg.m/s^2C = V/m$

2	
The direction of the electric field is the direction of the._____	يكون اتجاه المجال الكهربائي باتجاه .....
work done on moving the test charge	الشغل المبذول على شحنة اختبار
potential difference	الجهد الكهربائي
force on the positive test charge	القوة على شحنة اختبار موجبة
force on the negative test charge	القوة على شحنة اختبار سالبة

3	
A positive charge of 3.0×10^{-7} C in an electric field with a strength of 27 N/C towards the south. What is the magnitude of the force acting on the charge?	شحنة موجبة 3.0×10^{-7} C في مجال كهربائي شدته 27N/C باتجاه الجنوب . ما مقدار القوة المؤثرة على الشحنة ؟

3.0×10^{-7}N	1.2×10^{6}N
8.1×10^{-6}N	9.0×10^{7}N

$F = qE$ $F = 3.0 \times 10^{-7} \times 27 = 8.1 \times 10^{-6}$ N South

4	
A negative charge of 1.5×10^{-8} C is affected by a force of 0.030 N towards the right in an electric field. What is the magnitude and direction of the electric field?	شحنة سالبة 1.5×10^{-8} C تتاثر بقوة مقدارها 0.030N باتجاه اليمين في مجال كهربائي. ما مقدار واتجاه المجال الكهربائي؟

4.5×10^{-7} N/C to the right	4.5×10^{-7} N/C to the left
2.0×10^{6} N/C to the right	2.0×10^{6} N/C to the left

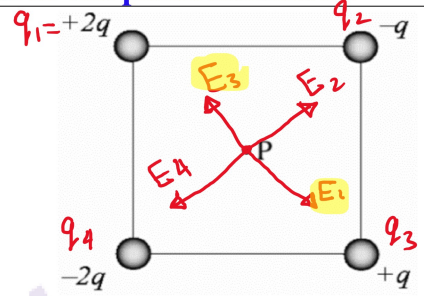
$E = \frac{F}{q}$ $E = \frac{0.030}{1.5 \times 10^{-8}} = 2 \times 10^{6}$ N/C left



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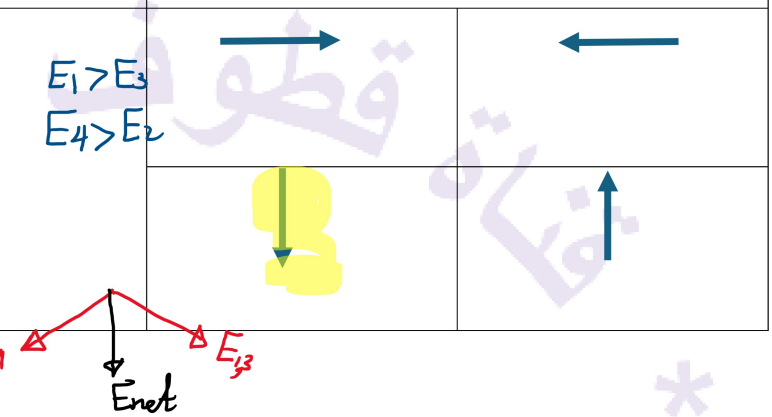
Four charges are located on the corners of a square as shown in the drawing. What is the direction of the net electric field at the point labeled P?

أربعة شحنات كهربائية موجودة على زوايا مربع كما بالشكل
ما اتجاه محصلة المجال الكهربائي عند النقطة P؟



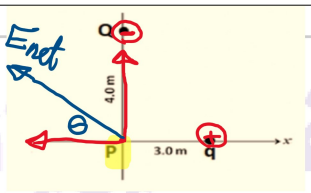
$E_1 > E_3$

$E_4 > E_2$

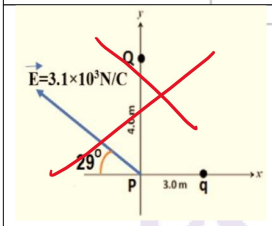


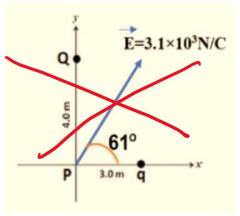
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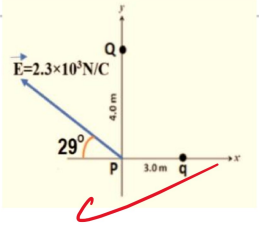
According to the figure if :
$Q = -2\mu C$, $q = +2\mu C$
What is the electric field at point P ?

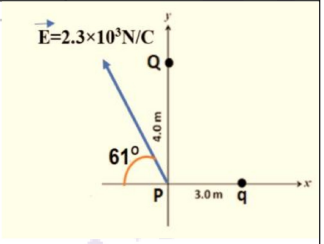


وفقاً للشكل : إذا كان :
$Q = -2\mu C$, $q = +2\mu C$
ما المجال الكهربائي عند النقطة P ؟









$$E_Q = \frac{kQ}{r^2} = \frac{9\times10^9 \times 2\times10^{-6}}{4^2} = 2.0\times10^3 \ N/C$$

$$E_q = \frac{kq}{r^2} = \frac{9\times10^9 \times 2\times10^{-6}}{3^2} = 1.125\times10^3 \ N/C$$

$$E_{net} = \sqrt{(2.0\times10^3)^2 + (1.125\times10^3)^2} = 2.3\times10^3 \ N/C$$

$$\theta = \tan^{-1}\left(\frac{2.0\times10^3}{1.125\times10^3}\right) = 29.4^\circ$$

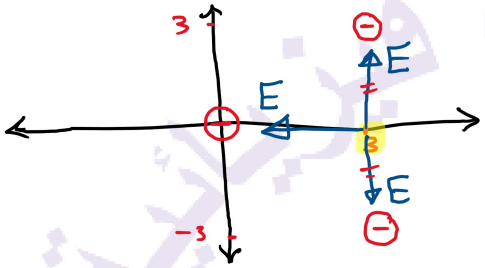
7

Three -9mC point charges are located at (0,0), (3 m,3 m), and (3 m,-3 m). What is the magnitude of the electric field at (3 m,0)?

تقع ثلاث شحنات مقدار كلا منها $-9mC$ عند النقاط: $(0,0)$, $(3m,3m)$, $(3m,-3m)$

ما مقدار المجال الكهربائي عند النقطة $(3m,0)$؟

0.9×10^{7} N/C	1.2×10^{7} N/C	1.8×10^{7} N/C	2.4×10^{7} N/C



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

$$E=\frac{(9\times10^{9})(9\times10^{-3})}{3^2}=9\times10^{6}\ N/C \text{ to the left}$$

$$\vec{E}=-9\times10^{6}\ N/C\ \hat{x}$$

8

three fixed point charges: $q_1 = +1.50\ \mu C$, $q_2 = +2.50\ \mu C$, and $q_3 = -3.50\ \mu C$. Charge q_1 is located at (0,a), q_2 is located at (0,0), and q_3 is located at (b,0), where a = 8.00 m and b = 6.00 m.

What electric field, do these three charges produce at the point P = (b,a)?

ثلاث شحنات نقطية:

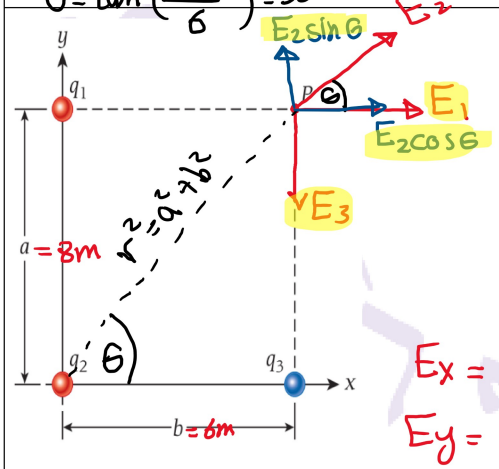
$q_1 = +1.50\mu C$, $q_2 = +2.50\mu C$, $q_3 = -3.50\mu C$

الشحنة q_1 تقع عند $(0,a)$ والشحنة q_2 تقع عند نقطة الأصل $(0,0)$ والشحنة q_3 تقع عند $(b,0)$.

حيث : $a = 8.00m$, $b = 6.00\ m$

ما المجال الكهربائي الذي تنتجه الشحنات الثلاث عند النقطة $P=(a,b)$ ؟

$$\theta=\tan^{-1}\left(\frac{8}{6}\right)=53^{\circ}$$



$$E_1=\frac{(9\times10^{9})(1.50\times10^{-6})}{6^2}=375\ N/C$$

$$E_2=\frac{(9\times10^{9})(2.50\times10^{-6})}{8^2+6^2}=225\ N/C$$

$$E_3=\frac{(9\times10^{9})(3.50\times10^{-6})}{8^2}=492\ N/C$$

$$E_x=E_1+E_2\cos\theta=375+225\cos(53)=510\ N/C$$

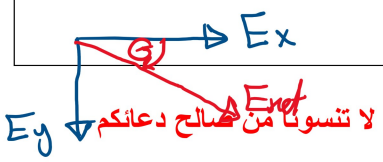
$$E_y=E_2\sin\theta-E_3=225\sin(53)-492=-312\ N/C$$

$$E_{net}=\sqrt{510^2+312^2}=598\ N/C$$

$$\theta=\tan^{-1}\left(\frac{312}{510}\right)=31.5^{\circ}$$

-31.5°

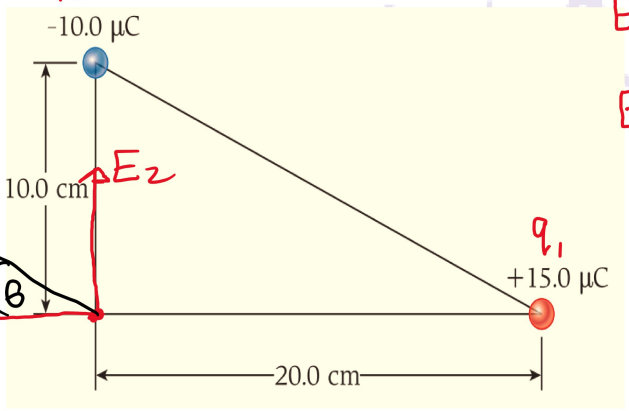
$360-31.5$



9

Two point charges are placed at two of the corners of a triangle as shown in the figure. Find the magnitude and the direction of the electric field at the third corner of the triangle.

يتم وضع شحنتين نقطيتين على زاويتين من زوايا المثلث كما هو موضح في الشكل.
أوجد مقدار واتجاه المجال الكهربائي عند الزاوية الثالثة للمثلث .



q_2 , E_2 , E_{net} , q_1 , E_1

$$E_1 = \frac{(9\times10^9)(15\times10^{-6})}{(0.20)^2} = 3.375\times10^6\ N/C$$

$$E_2 = \frac{(9\times10^9)(10.0\times10^{-6})}{(0.10)^2} = 9\times10^6\ N/C$$

$$E_{net} = \sqrt{(3.375\times10^6)^2 + (9\times10^6)^2}$$

$$E_{net} = 9.61\times10^6\ N/C$$

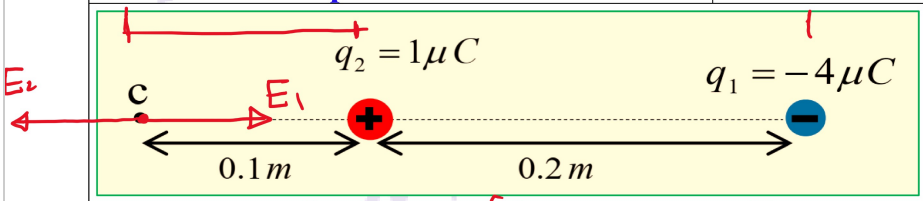
$$\theta = \tan^{-1}\left(\frac{9\times10^6}{3.375\times10^6}\right) = 69.4^\circ$$

$$180 - 69.4 = 110.6^\circ$$

10

Find the magnitude and direction of the electric field at point C ?

ما مقدار واتجاه المجال الكهربائي عند النقطة C؟



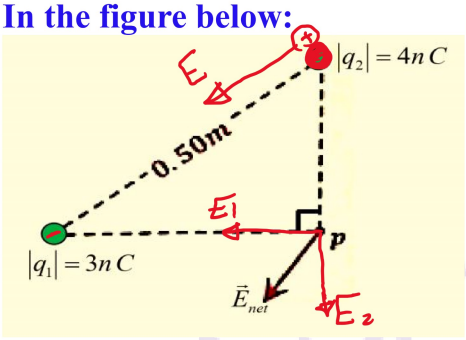
$$E_1 = \frac{(9\times10^9)(4\times10^{-6})}{0.3^2} = 4\times10^5\ N/C$$

$$E_2 = \frac{(9\times10^9)(1\times10^{-6})}{0.1^2} = 9\times10^5\ N/C$$

$$E_{net} = E_2 - E_1 = 9\times10^5 - 4\times10^5 = 5\times10^5\ N/C \text{ to the left}$$

11

In the figure below:

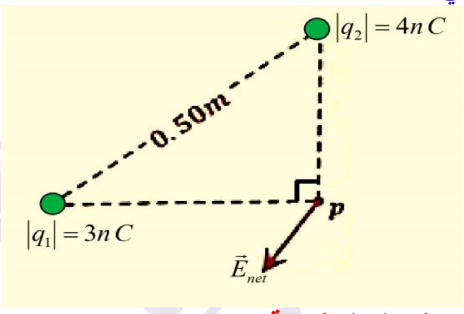


- **What the sign of each charge :**
  - q_1 ... ... negative
  - q_2 ... ... + ... positive
- **Find the electric field at the position of charge 2**

$$E = \frac{(9\times10^{9})(3\times10^{-9})}{(0.50)^2}$$

$$E = 108\ N/C$$

في الشكل أدناه:



ما إشارة كل شحنة ؟

.....q_1

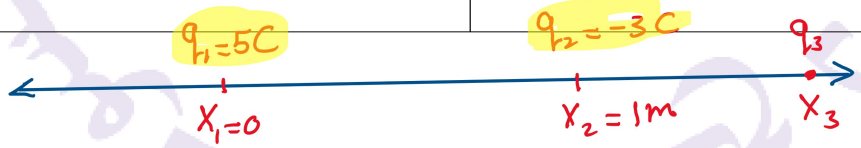
..... q_2

أوجد المجال الكهربائي عند موضع الشحنة 2

12

A +5.00 C charge is located at the origin. A -3.00 C charge is placed at x = 1.00 m. At what finite distance(s) along the x-axis will the electric field be equal to zero?

وضعت شحنة +5.00 C عند نقطة الأصل و
وضعت الشحنة -3.00 C عند x=1.00 m
عند أي مسافة (مسافات) محددة على طول محور x
سيكون المجال الكهربائي يساوي صفر؟



$$E_1 = E_2$$

$$\frac{\cancel{K}q_1}{r_1^2} = \frac{\cancel{K}q_2}{r_2^2}$$

$$\frac{\sqrt{q_1}}{r_{13}} = \frac{\sqrt{q_2}}{r_{23}}$$

$$\frac{\sqrt{5}}{(X_3 - 0)} = \frac{\sqrt{3}}{(X_3 - 1)}$$

$$\sqrt{5}(X-1) = \sqrt{3}\,X$$

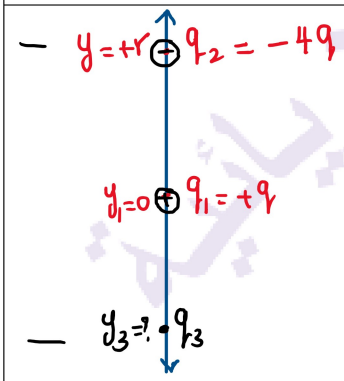
$$\sqrt{5}X - \sqrt{5} = \sqrt{3}\,X$$

$$(\sqrt{5}-\sqrt{3})X = \sqrt{5}$$

$$X = \frac{\sqrt{5}}{\sqrt{5}-\sqrt{3}}$$

$$X = 4.44\ m$$

13	
Two point charges are placed on the (y) axis, the charge (+q) is at the origin (0, 0) and the other charge (-4q) is located at (y=+r). Where is the resultant electric field equal to zero?	وضعت شحنتان نقطيتان على المحور (y) الشحنة (+q) عند نقطة الأصل (0 , 0) والشحنة الأخرى (-4q) وتقع عند (y=+r) . أين تكون محصلة المجال الكهربائي تساوي صفر؟



$$\frac{\sqrt{q_1}}{r_{13}} = \frac{\sqrt{q_2}}{r_{23}}$$

$$\frac{\sqrt{1}}{(0-y)} = \frac{\sqrt{4}}{(r-y)} \qquad \frac{1}{-y} = \frac{2}{r-y}$$

$$-2y = r - y \qquad r = -2y + y = -y$$

$$y = -r$$