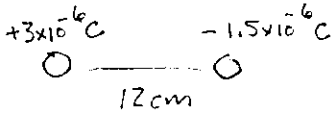
21-5

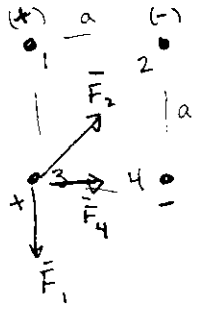


$$|\vec{F}| = \left| k \frac{qQ}{r^2} \right| = (9\times10^9)\frac{(3\times-6)(1.5\times-6)}{(0.12)^2}$$

$$= 2.81 \text{ Newtons}$$

the <u>magnitude</u> is a positive number

21-11



$a = 5$ cm

$Q_1 = 100$ nC

$Q_2 = -100$ nC

$Q_3 = 200$ nC

$Q_4 = -200$ nC

diagonal dist $= 5\sqrt{2}$ cm

$$F_1 = k\frac{q_3 Q_1}{a^2} = (9\times9)\frac{(200\times9)(100\text{nC})}{(0.05)^2} = 7.2\times10^{-2} \text{ Newton}$$

so $\vec{F}_1 = 0\ \hat{i} - 0.072\ \hat{j}$

$$F_4 = k\frac{q_3 Q_4}{a^2} = (9\times9)\frac{(200\times9)(200\times9)}{(0.05)^2} = 1.44\times10^{-1} \text{ Newton}$$

so $\vec{F}_4 = 0.144\ \hat{i} + 0\ \hat{j}$

(CONT)

$$F_2 = k\frac{q_3 Q_2}{r^2} = (9\times9)\frac{(200\times9)(100\times9)}{(0.05\sqrt{2})^2} = 3.6\times10^{-2}$$

so $\vec{F}_2 = 0.036\cos45^\circ\ \hat{i} + 0.036\sin45^\circ\ \hat{j}$

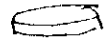
$0.025\ \hat{i} + 0.025\ \hat{j}$

To get the total force, add the components

$$\vec{F}_{TOT} = \vec{F}_1 + \vec{F}_4 + \vec{F}_2$$

$$\vec{F}_{TOT} = 0.169\ \hat{i} + -0.047\ \hat{j} \text{ Newtons}$$

21-25

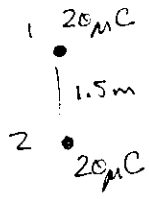


How many electrons are in -1.0×10^{-7} C?

Each electron has charge -1.602×10^{-19} Coul

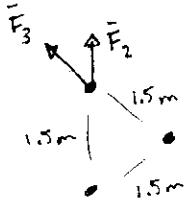
so $\dfrac{1.0\times10^{-7}}{1.602\times10^{-19}} = 6.24\times10^{11}$ electrons

21-17



$$F_{\substack{on\,1\\by\,2}} = k\frac{q_1 Q_2}{r^2} = (9\times 9)\frac{(20\text{-}6)(20\text{-}6)}{(1.5)^2}$$

$$= 1.6 \text{ Newtons}$$

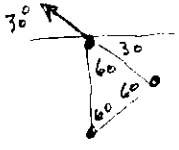


The magnitudes are

$F_2 = 1.6$ Newtons

$F_3 = 1.6$ Newtons (since same charges & distance)

Now must write these as vectors in order to add



$$\bar{F}_2 = 0\,\hat{i} + 1.6\,\hat{j}$$

$$\bar{F}_3 = \underbrace{-1.6\cos 30^\circ}_{-1.386}\,\hat{i} + \underbrace{1.6\sin 30^\circ}_{0.8}\,\hat{j}$$

$$\bar{F}_{TOT} = \bar{F}_2 + \bar{F}_3$$

$$= -1.386\,\hat{i} + 2.4\,\hat{j}$$

then

$$|\bar{F}_{TOT}| = \sqrt{(-1.386)^2 + (2.4)^2} = 2.77 \text{ Newtons}$$

21-28

$\xrightarrow{0.3 \text{ Amp}}$ 2 min

Total charge = (Charge/time)(time)

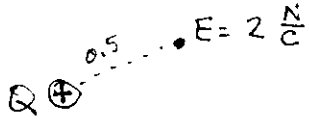
$= (0.3\,\frac{C}{sec})(120 \text{ sec})$

$= 36$ Coulombs

charges in 36 Coulombs

$$\frac{36\text{ C}}{1.602\times10^{-19}\text{ C}} = 2.247\times10^{20} \text{ charges}$$

22-5

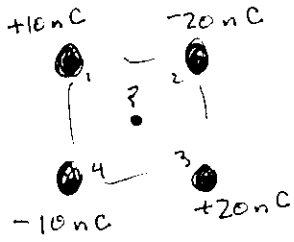


point charge formula $E = k\frac{Q}{r^2}$

$$2 = (9+9)\frac{Q}{(0.5)^2}$$

$$Q = 5.56\times10^{-11} \text{ Coulomb}$$

22-7

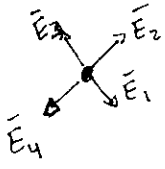


a = 5 cm

Want to know Efield in the center of the square.

The distance from the center to a corner is $2.5\sqrt{2}$ cm

Note that all these vectors point opposite & perpendicular.



A clever way to work this problem is to rotate the coord system by 45°. But we'll do it the hard way

Note

$\cos 45° = 0.707$

$\sin 45° = 0.707$

Now collect the vectors one at a time

$$E_1 = k\frac{Q_1}{r^2} = (9+9)\frac{(10-9)}{(0.025\sqrt{2})^2} = 7.2\times10^4 \text{ N/C}$$

so the vector is

$\bar{E}_1$

$$\bar{E}_1 = 5.09\times10^4\,\hat{i} - 5.09\times10^4\,\hat{j}$$

$$E_2 = k\frac{Q_2}{r^2} = (9+9)\frac{20-9}{(0.025\sqrt{2})^2} = 14.4\times10^4 \text{ N/C}$$

so the vector is

$\bar{E}_2$

$$\bar{E}_2 = 1.018\times10^5\,\hat{i} + 1.018\times10^5\,\hat{j}$$

$$= 10.18\times10^4\,\hat{i} + 10.18\times10^4\,\hat{j}$$

$$E_3 = k\frac{Q_3}{r^2} = (9+9)\frac{(20-9)}{(0.025\sqrt{2})^2} = 14.4\times10^4$$

so the vector is

$\bar{E}_3$

$$\vec{E}_3 = -10.18\times10^4\,\hat{i} + 10.18\times10^4\,\hat{j}$$

$$E_4 = k\frac{Q_4}{r^2} = (9+9)\frac{(10-9)}{(0.025\sqrt{2})^2} = 7.2\times10^4 \text{ N/C}$$

so the vector is

$\bar{E}_4$

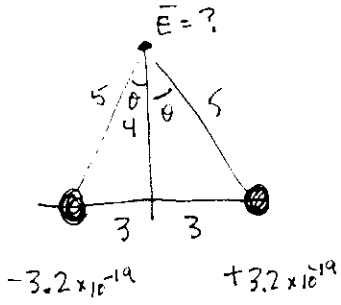
$$\vec{E}_4 = -5.09\times10^4\,\hat{i} - 5.09\times10^4\,\hat{j}$$

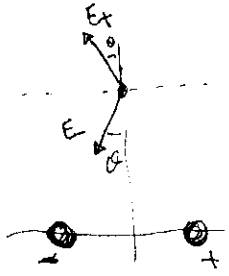
Then add 'em up

$$\bar{E}_{TOT} = \bar{E}_1 + \bar{E}_2 + \bar{E}_3 + \bar{E}_4$$

$$= 0\,\hat{i} + 10.18\times10^4\,\hat{j} \text{ N/C}$$

22-9





$\cos\theta = \frac{4}{5}$

$\sin\theta = \frac{3}{5}$

Note that the vertical components will cancel.

$$E_+ = k\frac{Q_+}{r^2} = (9\times9)\frac{(3.2\times19)}{5^2} = 1.152\times10^{-10} \quad N/C$$

the x-comp is

$$-(1.152\times10^{-10})\sin\theta = -6.912\times10^{-11} \quad N/C$$

$$E_- = k\frac{Q_-}{r^2} = (9\times9)\frac{(3.2\times19)}{5^2} = 1.152\times10^{-10} \quad N/C$$

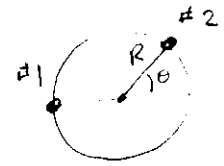
the x-comp is

$$-(1.152\times10^{-10})\sin\theta = -6.912\times10^{-11} \quad N/C$$

the $\bar{E}_{TOT} = \vec{E}_+ + \bar{E}_-$

$$= -1.382\times10^{-10}\,\hat{i} + 0\,\hat{j} \quad N/C$$

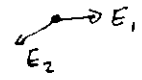
22-16



$R = 50\text{ cm} = 0.5\text{ m}$

$Q_1 = +2\,\mu C$

$Q_2 = +6\,\mu C$



$$E_1 = k\frac{Q_1}{R^2}$$

$$\vec{E}_1 = k\frac{Q_1}{R^2}\,\hat{i} + 0\,\hat{j}$$

$$E_2 = k\frac{Q_2}{R}$$

$$\vec{E}_2 = -\frac{kQ_2}{R^2}\cos\theta\,\hat{i} - \frac{kQ_2}{R^2}\sin\theta\,\hat{j}$$

The net $\vec{E}$-field is

$$\bar{E}_{TOT} = \left[k\frac{Q_1}{R^2} - k\frac{Q_2}{R^2}\cos\theta\right]\hat{i} + \left[-\frac{kQ_2}{R^2}\sin\theta\right]\hat{j}$$

The magnitude is

$$E_{TOT}^2 = \left[k\frac{Q_1}{R^2} - k\frac{Q_2}{R^2}\cos\theta\right]^2 + \left[-\frac{kQ_2}{R^2}\sin\theta\right]^2$$

$$E_{TOT}^2 = \frac{k^2}{R^4}\left\{(Q_1 - Q_2\cos\theta)^2 + (Q_2\sin\theta)^2\right\}$$

given desired $E_{TOT} = 2\times10^5$ N/C

$$\frac{E_{TOT}}{k/R^2} = \frac{(2\times10^5)^2}{9\times10^9/(0.5)^2} = \ldots \quad 5.56\times10^{-6}$$

$$(5.56\times10^{-6})^2 = (Q_1 - Q_2\cos\theta)^2 + (Q_2\sin\theta)^2$$

$$\theta = +67.6 \text{ and } -67.6$$

EtotR^2/k	3.09E-11
Q1	2.00E-06
Q2	6.00E-06

theta (deg)	theta (rad)	Q1-Q2cos "x-term"	Q2sin "y-term"	(x-term)^2+(y-term)^2-EtotR^2/k	
0	0	-4.00E-06	0.00E+00	-1.49E-11	
10	0.174533	-3.91E-06	1.04E-06	-1.45E-11	
20	0.349066	-3.64E-06	2.05E-06	-1.34E-11	
30	0.523598	-3.20E-06	3.00E-06	-1.16E-11	
40	0.698131	-2.60E-06	3.86E-06	-9.25E-12	
50	0.872664	-1.86E-06	4.60E-06	-6.29E-12	
60	1.047197	-1.00E-06	5.20E-06	-2.86E-12	the solution is between 60 and 70 deg
70	1.221729	-5.21E-08	5.64E-06	9.28E-13	
80	1.396262	9.58E-07	5.91E-06	4.97E-12	
60	1.047197	-1.00E-06	5.20E-06	-2.86E-12	
62	1.082103	-8.17E-07	5.30E-06	-2.13E-12	
64	1.11701	-6.30E-07	5.39E-06	-1.38E-12	
66	1.151916	-4.40E-07	5.48E-06	-6.25E-13	the solution is between 66 and 68 deg
68	1.186823	-2.48E-07	5.56E-06	1.46E-13	
70	1.221729	-5.21E-08	5.64E-06	9.28E-13	
66	1.151916	-4.40E-07	5.48E-06	-6.25E-13	
67	1.16937	-3.44E-07	5.52E-06	-2.41E-13	
67.5	1.178096	-2.96E-07	5.54E-06	-4.80E-14	
67.6	1.179842	-2.86E-07	5.55E-06	-9.29E-15	the solution is between 67.6 and 67.7 deg
67.7	1.181587	-2.77E-07	5.55E-06	2.94E-14	
67.8	1.183332	-2.67E-07	5.56E-06	6.82E-14	
68	1.186823	-2.48E-07	5.56E-06	1.46E-13	