Weds: Discussion/quiz. 132 Ex: 18, 19, 20, 21, 22, 24

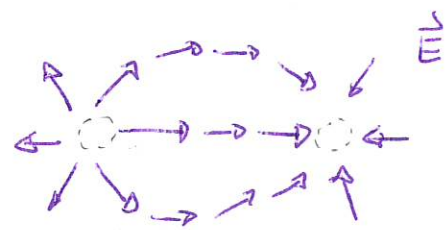
Thurs: Warm Up 2 by 10am

Electric fields

The conceptual scheme behind electric fields is.

Fixed sources with known locations and charges

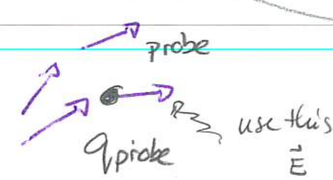
Sources produce an electric field $\vec{E}$ ≡ one electric field vector at each location



Place a different point charge probe in the field. The force exerted on the probe by the field/sources is

$$\vec{F} = q_{probe} \vec{E}$$

where $\vec{E}$ = electric field vector at probe location.



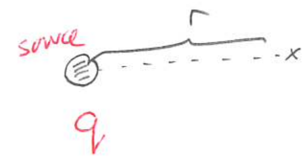
Quiz 1 40% – 50%

Quiz 2 60% –

In order to determine the electric field produced by any charge distribution we need the electric field produced by a point source charge:

The electric field produced by a point source with charge q has

1) magnitude



$$E = \frac{1}{4\pi\epsilon_0} \frac{|q|}{r^2}$$

where r is the distance to the location where we want to compute the field

2) direction $= \begin{cases} \text{radially away} & \text{for positive source} \\ \text{radially toward} & \text{for negative source} \end{cases}$

Then for multiple sources we compute the fields due to individual sources and then add the vectors:

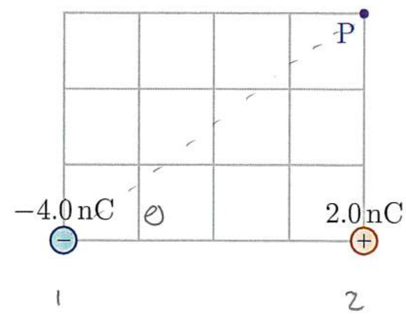
$$\vec{E} = \sum \vec{E}_i$$

where

$$E_i = \frac{1}{4\pi\epsilon_0} \frac{|q_i|}{r_i^2}$$

27 Electric field produced by two point charges

Two charged particles are held fixed as illustrated; the grid units are each 0.010 m. The aim of this exercise will be to determine the field at point P. *(132S22 Class)*

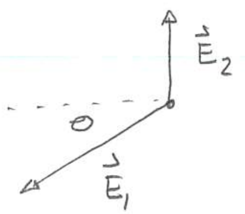


a) Indicate the directions of the electric fields produced by each source charge at point P.

b) Determine the magnitude of the electric field produced by each source charge at point P.

c) Using vector components add the two electric fields. Express the total electric field in terms of standard unit vectors.

Answer: a)



where $\tan\theta = 3/4$

$\Rightarrow \theta = \tan^{-1}(3/4) = 36.9°$

b) $E_1 = \dfrac{1}{4\pi\epsilon_0}\dfrac{|q_1|}{r_1^2}$ $\qquad r_1 = \sqrt{(0.030\text{m})^2 + (0.04\text{cm})^2}$

$= 0.050\text{m}$

$= \dfrac{1}{4\pi \times 8.85\times10^{-12}\, C^2/Nm^2} \dfrac{4.0\times10^{-9}C}{(0.050\text{m})^2}$

$= 14400\ N/C$

$E_2 = \dfrac{1}{4\pi\epsilon_0}\dfrac{|q_2|}{r_2^2} = \dfrac{1}{4\pi\times 8.85\times10^{-12}\, C^2/Nm^2}\dfrac{2.0\times10^{-9}C}{(0.030\text{m})^2}$

$= 20000\ N/C$

c) Clearly $\vec{E}_2 = 0\hat{i} + E_2\hat{j}$

$= 20000 N/c\,\hat{j}$

	x comp	y comp
$\vec{E}_1$	$-11520 N/c$	$-8640 N/c$
$\vec{E}_2$	0	$20000 N/c$

Then $\vec{E}_1 = E_{1x}\hat{i} + E_{1y}\hat{j}$

$E_{1x} = -E_1 \cos\theta$

$= -14400 N/c \cos 36.9°$

$= -11520 N/c$

$E_{1y} = -E_1 \sin\theta$

$= -14400 N/c \sin 36.9°$

$= -8640 N/c$

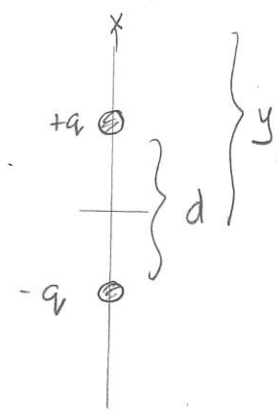
So $\vec{E} = \left[-11520 N/c\,\hat{i} - 8640 N/c\,\hat{j}\right] + 20000 N/c\,\hat{j}$

$\vec{E} = -11520 N/c\,\hat{i} + 11360 N/c\,\hat{j}$

Electric Dipole

An important arrangement of charges is an electric dipole which consists of two exactly opposite point charges.

True point dipoles are not necessarily common. However many systems have a dipole nature. For example the carbon



$$C = O \approx (- \ +)$$

We need to determine the electric fields produced by such a dipole, and eventually how it interacts with other fields.

Consider a point along the dipole axis, at $y > 0$. Then

$$\vec{E} = E_y \hat{j}$$

and $\quad E_y = E_{from +} + E_{from -}$

$$= \frac{1}{4\pi\epsilon_0} \frac{q}{(y - d/2)^2} - \frac{1}{4\pi\epsilon_0} \frac{q}{(y + d/2)^2} = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{(y-d/2)^2} - \frac{1}{(y+d/2)^2}\right]$$

We want to consider y much larger than d $(y \gg d)$. We might imagine that the terms cancel in the limit as $y \to \infty$. Then

$$\frac{1}{(y \pm d/2)^2} = \frac{1}{y^2(1 \pm d/2y)^2}$$

$$\Rightarrow \quad E_y = \frac{q}{4\pi\epsilon_0} \frac{1}{y^2}\left[\frac{1}{(1 - d/2y)^2} - \frac{1}{(1 + d/2y)^2}\right]$$

We now use:

$$\left(1 \pm d/2y\right)^2 = 1 \pm d/y + d^2/4y^2$$

and a Taylor series expansion

$$\frac{1}{1+x} \approx 1 - x + \frac{x^2}{2} + \ldots$$

to get (ignoring any terms higher in order than x^2)

$$E_y \approx \frac{q}{4\pi\epsilon_0 y^2}\left\{\frac{2d}{y}\right\} + \ldots \text{ smaller terms.}$$

So along the y-axis

$$\boxed{E \approx \frac{1}{4\pi\epsilon_0}\frac{2p}{y^3}}$$

where $p = qd$ is the electric dipole moment (units: Cm)

For example, for CO, $p = 4.06 \times 10^{-31}$ Cm

Demo: PhET Charges + fields

- Produce dipole