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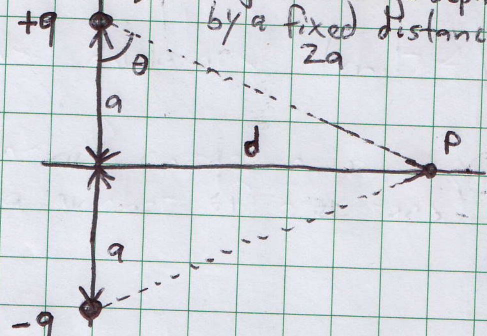
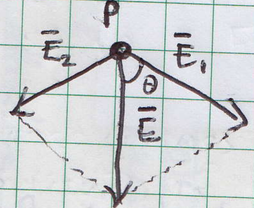
ex For an electric dipole, find E at point P

dipole has a positive and negative charge separated by a fixed distance of $2a$



- Consider that since $\bar{E} = \frac{\bar{F}}{q}$ (i.e. $\bar{E}$ and $\bar{F}$ point in the same direction for a point charge) the electric field at P will be a vector sum as:



where E_1 is due to $+q$ and E_2 due to $-q$; put another way

$$\bar{E} = \bar{E}_1 + \bar{E}_2$$

- $|E_1| = |E_2| = \frac{1}{4\pi\epsilon_0}\frac{q}{a^2+d^2} = |E|$

- as vectors: $\bar{E}_1 = E_{1x}\hat{x} + E_{1y}\hat{y}$

where $E_{1x} = |E_1|\sin\theta$, $E_{1y} = -|E_1|\cos\theta$ (since it points downwards)

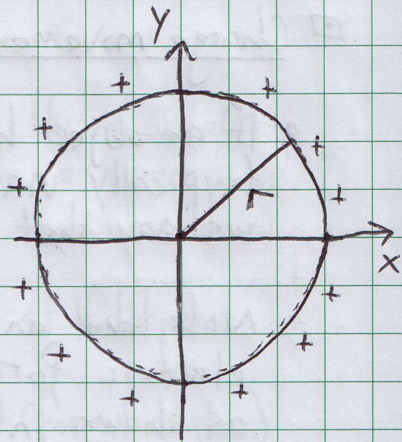
similarly $\bar{E}_2 = -|E|\sin\theta\,\hat{x} - |E|\cos\theta\,\hat{y}$

$$\rightsquigarrow \bar{E} = -2|E|\cos\theta\,\hat{y} = -2|E|\frac{a}{\sqrt{a^2+d^2}}\hat{y}$$

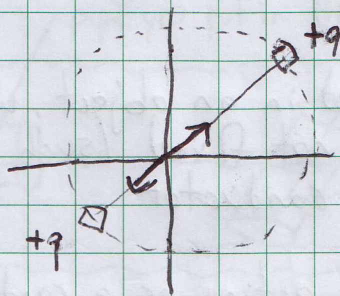
$$= -\frac{2qa}{4\pi\epsilon_0}\frac{1}{(a^2+d^2)^{3/2}}\hat{y}$$

→ Note that when $d \gg a$, $|E| \simeq \frac{1}{4\pi\epsilon_0}\frac{2aq}{d^3}$ (i.e. E falls off as $1/r^3$!); sometimes the product $2aq$ is referred to ~~to~~ as the dipole moment ex (Giordano 17.40)

A circular ring of uniform charge has radius 25 cm and a total charge of 50 μC. What is $\bar{E}$ at the origin?



- consider two infintesimal oppositely located piezes a shown below:



→ in each case, the contribution $\bar{E}_n$ point radially away from the origin and thus the two cancel one another out

→ thereby due to symmetry, the total electric field at the origin is zero

- Note that if you move off the origin, $\bar{E}$ is non-zero (e.g. consider putting a positive charge at an arbitrary location inside the circle, or similarly, a negative charge)

- Also note that if the charge were not uniform, symmetry would not be present to cause cancellation

- Lastly, consider drawing the 'lines of force' to show what the electric field looks like here

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Charge movement: Conductors vs. Insulators (ch. 17.4)

- If an object has an excess amount of charge on it (typically via the loss/gain of a number of electrons) we say that it is charged

- Note that an object can be neutral and still cause electric forces (e.g. a dipole, or water molecules as shown in Fig. 17.24)

- If free charges (i.e. electrons) are fixed in an object, we call it an insulator; if they are not fixed (such as in a metal), we say the object is a conductor

- This notion of an object acting as a conductor is an important we will return to in ch. 19 as it relates to electric **current** and impedance/resistivity

- If charge has an 'outlet' it can flow to, we call that a **ground** (another important aspect we will consider later in the context of electric circuits)

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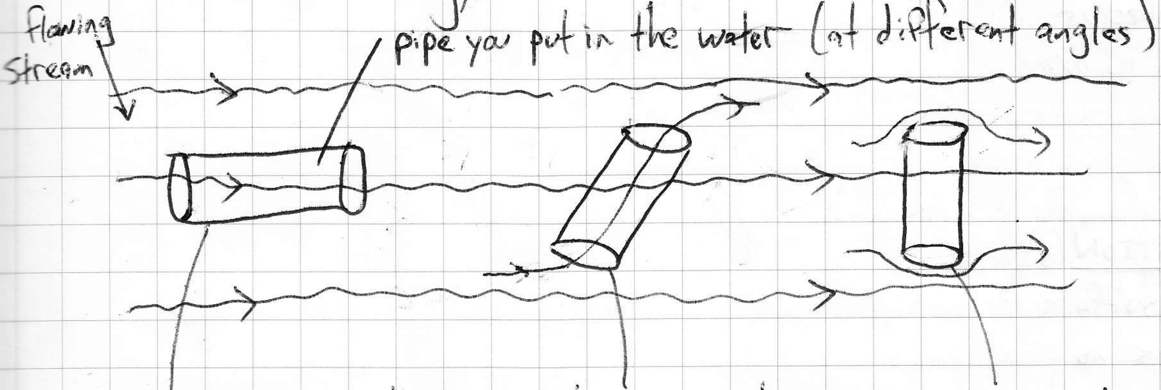
Electric Flux

- Flux is a scalar quantity that is defined by an electric field (a vector quantity) passing through a specified surface (also a vector quantity)

- This latter aspect can be a bit confusing at first, so consider an analogy:



put the pipe in parallel to the stream's flow and water freely flows through it

put it at an angle and you'll reduce the flow through the pipe

put it perpendicular to the stream's direction and you won't get any flow

  - so the direction of the pipe (the analog to the vector of the surface) matters quite a bit in determining the flow through the pipe (the analog to the flux)

  - the flow of the stream is the analog to the electric field

- We define the flux as follows:

flux through surface element $\bar{A}$ $\longrightarrow$ $$\Phi_E \simeq \sum_i \bar{E}_i \cdot \bar{A}_i$$ $\longleftarrow$ surface element you are calculating the flux through

sum over all possible charges/elements

electric field due to a given charge

NOTE
vector 'dot product'
$\bar{A} \cdot \bar{B} = |A||B| \cos\theta$
where θ is the angle between $\bar{A}$ and $\bar{B}$

- Note that the 'surface' here has been discretized into 'surface elements', each with its own surface area vector (which is normal to it)

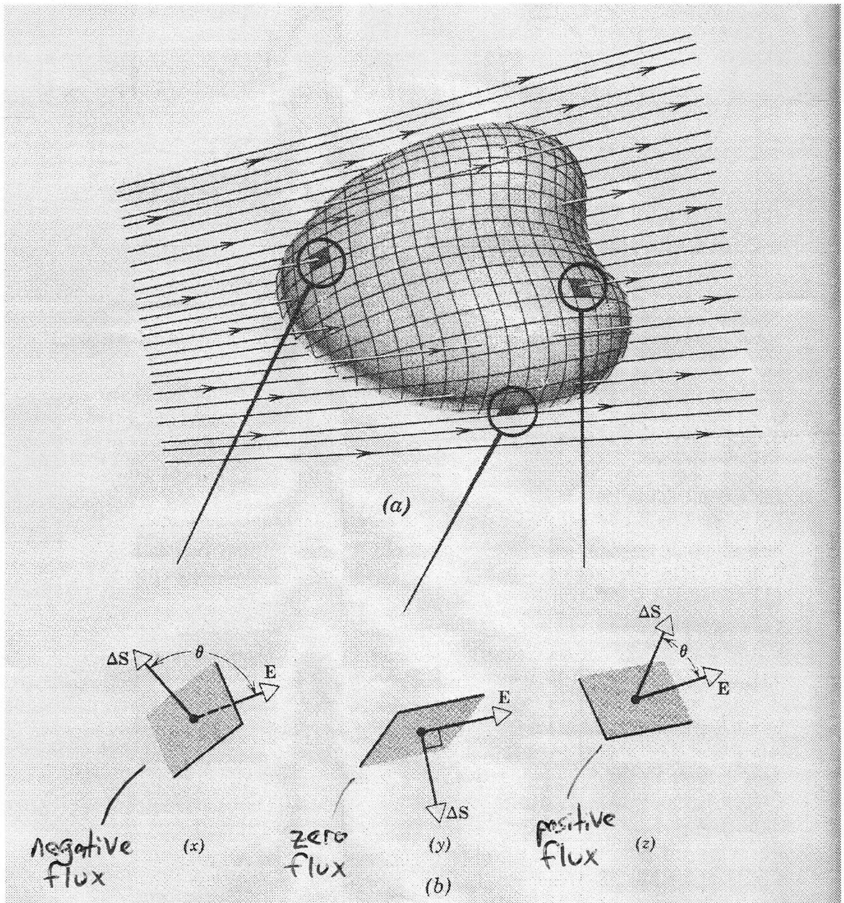


Fig. 28–2 (*a*) A hypothetical surface immersed in an electric field. (*b*) Three elements of area on this surface, shown enlarged.

- <u>QUESTION</u>(s) if the surface contains no charges in it, is the total flux negative, positive, or zero? How would your answer change if you re-oriented the surface? Or changed its shape?
  [we'll come back to these questions shortly]

<u>NOTE</u>: the figure above shows what we call a **closed surface** (see wikipedia page for 'surface' for more info on how we describe surfaces)

<u>Dot Product Rules</u>

$\hat{x} \cdot \hat{x} = 1$ (similary $\hat{y} \cdot \hat{y} = 1$)

$\hat{x} \cdot -\hat{x} = -1$

$\hat{x} \cdot \hat{y} = \hat{y} \cdot \hat{x} = 0$