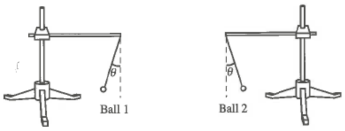
We'll start with some group work to finish ch5, then start on ch6.

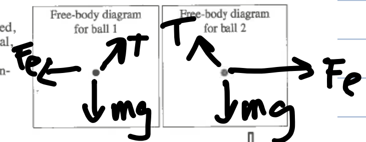
CHARGE — Name ______ EM HW-75

Two identical metal balls are suspended by insulating threads. Both balls have the same net charge. In this problem, do not assume the balls are point charges.




a. Draw a separate free-body diagram for each ball. Label the forces to indicate:

- the object exerting the force,
- the object on which the force is exerted,
- the type of force (gravitational, normal, etc.), and
- whether the force is a contact or a non-contact force.



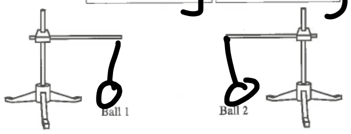

$$F_{1 on 2} = \frac{kq_2q_1}{r^2}$$

$$\theta_{ball\,1} = \theta_{ball\,2}$$

$$F_{2 on 1} = \frac{kq_1q_2}{r^2}$$

b. Suppose the charge on the second ball is reduced slightly, so that it is less than that on the first ball.

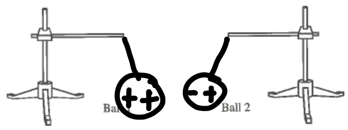
Predict whether the angle that ball 1 makes with the vertical will be *greater than, less than,* or *equal to* the angle that ball 2 makes with the vertical. Explain. Sketch your answer above.




How does the free-body diagram for each ball in this case compare to the corresponding free-body diagram that you drew in part a? If the magnitudes or directions of any of the forces change, describe how they change.

$\theta_b < \theta_a$

c. Predict what will happen if the net charge on ball 2 is reduced to zero. Make a sketch to illustrate your answer.




induced polarization

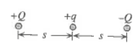






2. *Coulomb's law* allows us to find the force between two *point* charges.

Three point charges are held fixed in place as shown.




Consider the following comment about this situation:

*"There will be zero net electric force on the charge in the middle due to the other charges. Using Coulomb's law, the force due to the +Q charge is positive, and the force due to the -Q charge is negative. The forces cancel."*

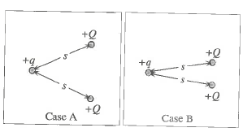
a. Do you agree with this statement? Explain.

b. How does Coulomb's law apply to situations in which there are more than two point charges?

3. Each of the following parts involves a comparison of the net electric force exerted on a positive charge $+q$ in two different cases.

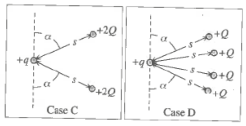
a. In cases A and B shown at right there are two positive point charges $+Q$ each a distance $s$ away from a third positive point charge $+q$.

Is the net electric force on the $+q$ charge in case A *greater than, less than,* or *equal to* the net electric force on the $+q$ charge in case B? Explain.




b. In case C, two positive point charges $+2Q$ are each a distance $s$ away from a third positive point charge $+q$. In case D, four positive point charges $+Q$ are each a distance $s$ away from a fifth positive point charge $+q$. (The angle $\alpha$ shown is the same in both cases.)

Is the net electric force on the $+q$ charge in case C *greater than, less than,* or *equal to* the net electric force on the $+q$ charge in case D? Explain.




see solutions posted online

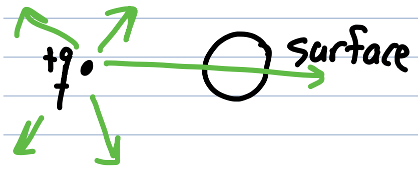
## chapter 6

[see zoom recordings on course website for when I'll be gone next week! Lab 3 on Monday! ]

We toyed with a Gaussian surface and electric flux sim

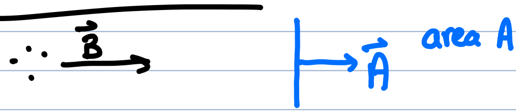
double charge → double flux

change sign of charge → change sign of flux

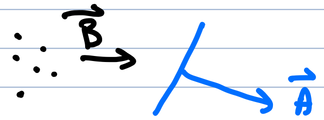



flux = 0 [habanero hypothesis]

**killer Bee flux** see slide 1 ch 6



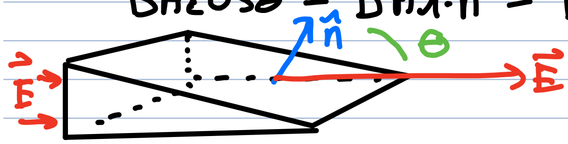

lots of bees pass




fewer bees pass

killer bee flux $\propto$ cosine angle between $\vec{B}$ and $\vec{A}$

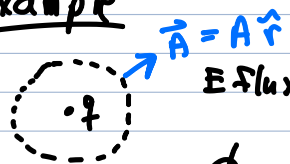
$$BA\cos\theta = BA\hat{n}\cdot\hat{n} = \vec{B}\cdot\vec{A}$$




E flux through top surface is is $\phi = EA\cos\theta = \vec{E}\cdot\vec{A}$

top surface has area $A$, and $\vec{A} = A\hat{n}$

**example**




E flux through a sphere $\vec{E}(r) = \frac{kq}{r^2}\hat{r}$

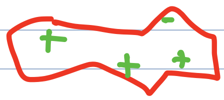
$$\phi = \int d\phi = \int \vec{E}\cdot d\vec{A} = \int E\,dA\,\hat{r}\cdot\hat{r} = \int E\,dA\cos 0°$$

$$= \int E\,dA = E\int dA = EA = E4\pi r^2$$

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

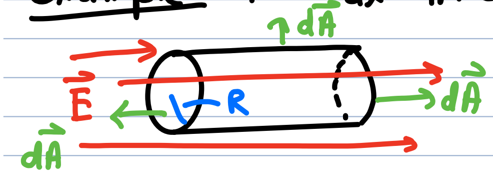
Gauss' Law: $\phi = q_{enclosed}/\epsilon_0$

imagine some bizarre geometry and ch. distribution




$\phi = q_{enc}/\epsilon_0$ math is easier!

<u>example</u> E flux through a Gaussian cylinder.




$\phi_{net} = \phi_{left} + \phi_{right} + \phi_{tube}$

$$\phi_{net} = \int_{left} \vec{E}\cdot d\vec{A} + \int_{right} \vec{E}\cdot d\vec{A} + \int_{tube} \vec{E}\cdot d\vec{A}$$

$$= \int E\,dA \cos 180° + \int E\,dA \cos 0° + \int E\,dA \cos 90°$$

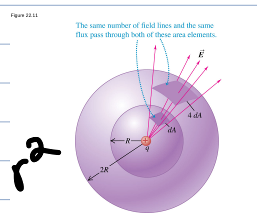
$$= -E\pi R^2 + E\pi R^2 + 0 = 0$$ which is what Gauss' Law predicted

ch6 concept Q #1

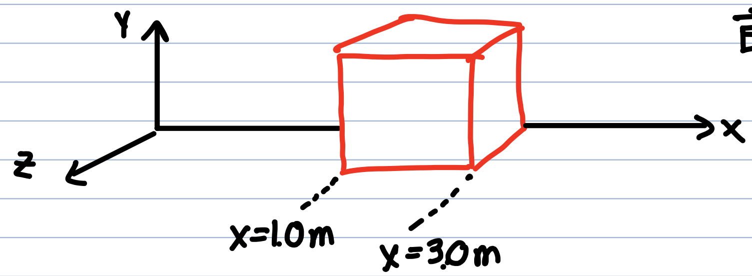
(B)

$\phi = EA = \frac{kq}{r^2} 4\pi r^2$

$\phi' = E'A' = \frac{kq}{(2r)^2} 4\pi (2r)^2 = \phi$




<u>example</u>




$\vec{E} = (3.0x\hat{i} + 4.0\hat{j})\frac{N}{C}$

right face $\vec{dA} = dA\,\hat{\imath}$

$$\phi_{right} = \int \vec{E} \cdot \vec{dA} = \int (3.0x\,\hat{\imath} + 4.0\,\hat{\jmath}) \cdot dA\,\hat{\imath}$$

$$= \int (3.0x\,dA\,\hat{\imath}\cdot\hat{\imath} + 4.0\,dA\,\hat{\jmath}\cdot\hat{\imath}) = \int (3.0x\,dA + 0) = 3.0\int x\,dA$$

$$= 3.0 \cdot 3.0 \int dA = 9.0\,\frac{N}{C}\,A = 36\,\frac{Nm^2}{C}$$

$\phi_{left} = -\frac{1}{3}\,\phi_{right}$ since $\vec{dA} = -dA\,\hat{\imath}$ and $x = 1.0\,m$

$= -12\,\frac{Nm^2}{C}$

top face $\vec{dA} = dA\,\hat{\jmath}$

$$\phi_{top} = \int (3.0x\,\hat{\imath} + 4.0\,\hat{\jmath})\,dA\,\hat{\jmath} = \int (3.0x\,dA\,\hat{\imath}\cdot\hat{\jmath}) + 4.0\,dA\,\hat{\jmath}\cdot\hat{\jmath} = \int (0 + 4.0\,dA)$$

$= 16\,Nm^2/C$

$\phi_{bottom} = -\phi_{top}$ since $\vec{dA} = dA\,(-\hat{\jmath})$

$\phi_{front} = \phi_{back} = 0$