# Course Updates

http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

Reminders:

1) Quiz today

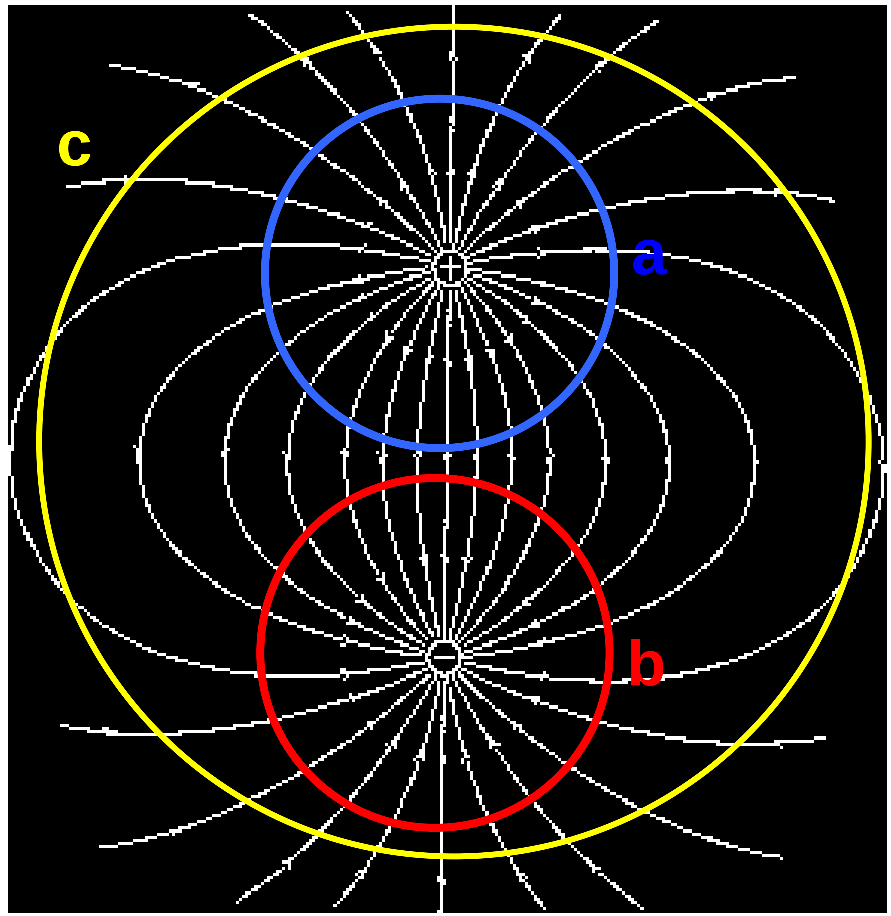
2) Written problems: 21.96, 22.6, 22.58, 22.30

3) Complete Chapter 22
   (all this information on web page)

# Gauss's Law and Electric Flux

## Preview

Gauss's Law relates number of E field lines entering and leaving a surface to the net charge inside the surface.




Consider imaginary spheres centered on:

a.) +q (blue)
b.) -q (red)
c.) midpoint (yellow)

Number of lines exiting:
a.) (blue) 24
b.) -q (red) -24
c.) midpoint (yellow) 0

More on Gauss's Law later.

# Electric Flux

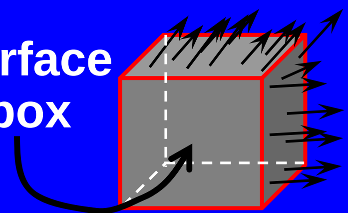
- Flux:

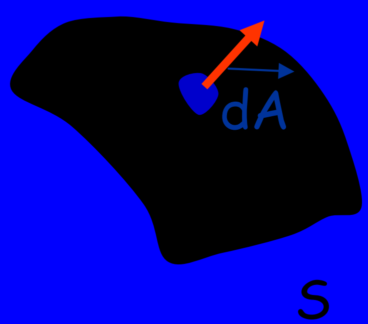
  Let's quantify previous discussion about field-line "counting"

  Define: electric flux $\Phi_E$ through the closed surface $S$

$$\Phi_E \equiv \oint_S \vec{E} \bullet d\vec{A}$$

"$S$" is surface of the box





# Electric Flux

$$\Phi_E \equiv \oint_S \vec{E} \bullet d\vec{A}$$

- What does this new quantity mean?
  - The integral is over a CLOSED SURFACE
  - Since $\vec{E} \bullet d\vec{A}$ is a SCALAR product, the electric flux is a SCALAR quantity
  - The integration vector $d\vec{A}$ is normal to the surface and points OUT of the surface. $\vec{E} \bullet d\vec{A}$ is interpreted as the component of $\boldsymbol{E}$ which is NORMAL to the SURFACE
  - Therefore, the electric flux through a closed surface is the sum of the normal components of the electric field all over the surface.
  - The sign matters!!
    Pay attention to the direction of the normal component as it penetrates the surface… is it "out of" or "into" the surface?
  - "Out of" is "+" "into" is "-"

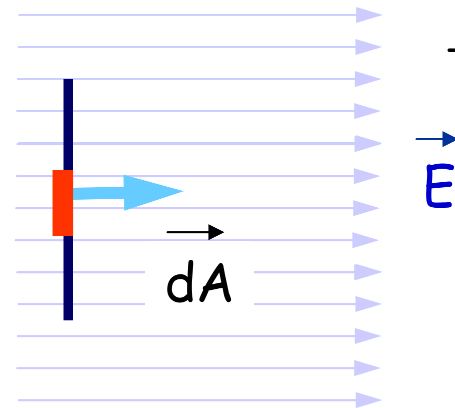
# Electric Flux

Special case: uniform $\vec{E}$ perpendicular to plane surface A.

$$\Phi_E \equiv \oint_S \vec{E} \bullet d\vec{A} = \oint_S E\, dA\ \cos\theta = E\oint_S dA = \boxed{EA}$$

constant

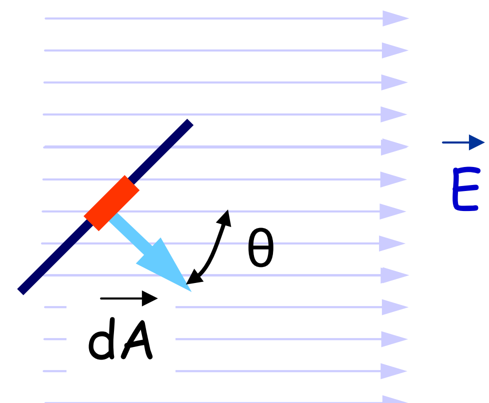
=1




Another: uniform E at angle to plane surface A.

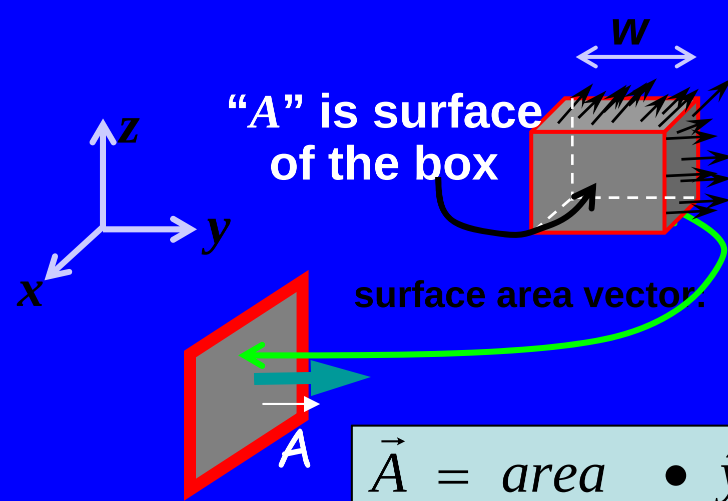
constants

$$\Phi_E \equiv \oint_S \vec{E} \bullet d\vec{A} = \oint_S E\, dA\ \cos\theta = E\ \cos\theta\oint_S dA = \boxed{EA\cos\theta}$$



# How to think about flux

- We will be interested in net flux in or out of a closed surface like this box

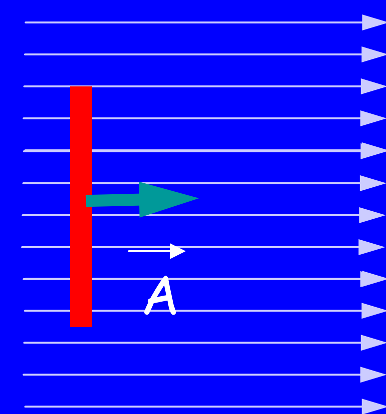



- This is the sum of the flux through each side of the box
  - consider each side separately

$$\vec{A} = area \bullet \hat{y}$$
$$= w^2 \hat{y}$$

- Let *E*-field point in *y*-direction
  - then $\vec{E}$ and $\vec{A}$ are parallel and $\vec{E} \bullet \vec{A} = |\vec{E}|\, w^2$

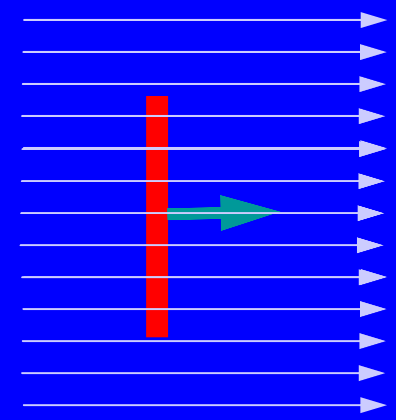
- Look at this from on top
  - down the *z*-axis



# How to think about flux

- **Consider flux through two surfaces that "intercept different numbers of field lines"**
  - first surface is side of box from previous slide
  - Second surface rotated by an angle $\theta$

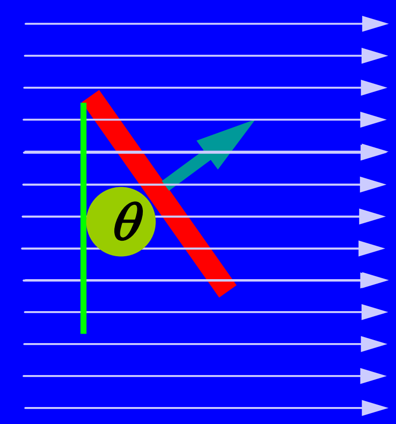
case 1



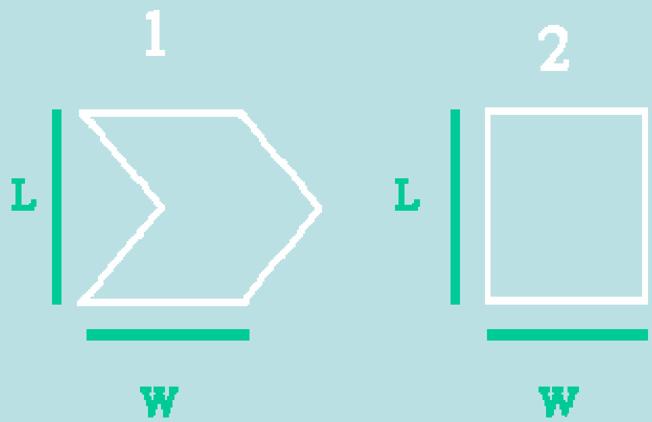
| | $E$-field | surface area | Flux: $\vec{E} \bullet \vec{A}$ |
|---|---|---|---|
| case 1 | $\vec{E} = E_o \hat{x}$ | $w^2$ | $E_o w^2$ |
| case 2 | $\vec{E} = E_o \hat{x}$ | $w^2$ | $E_o w^2 \cdot \cos\theta$ |

Case 2 is smaller!

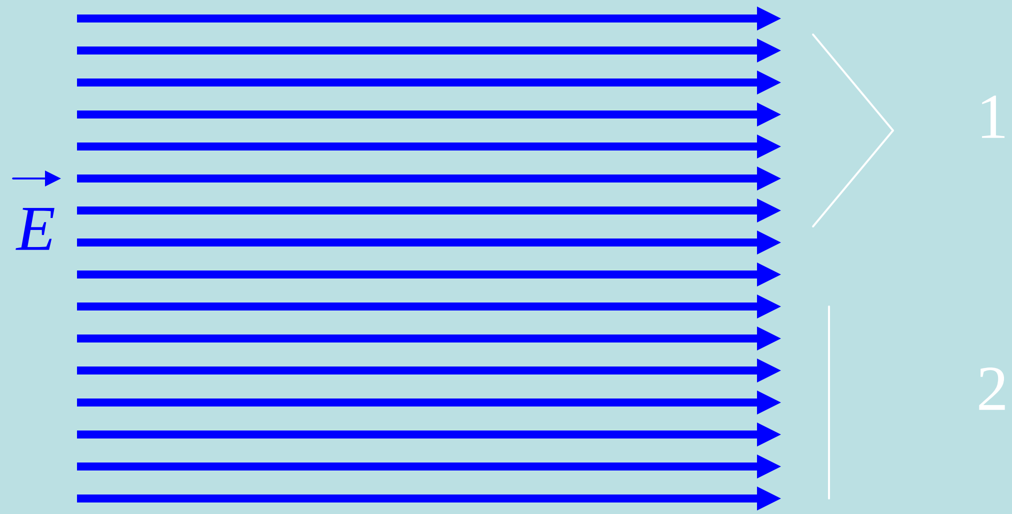
case 2



Example 1:




Wire loops (1) and (2) have the same length and width, but differences in shape.

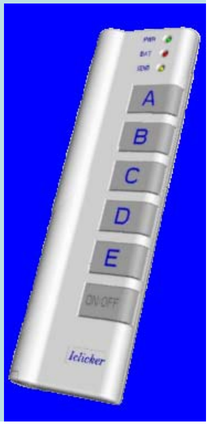



5) Wire loops (1) and (2) are placed in a uniform electric field as shown. Compare the flux through the two surfaces.

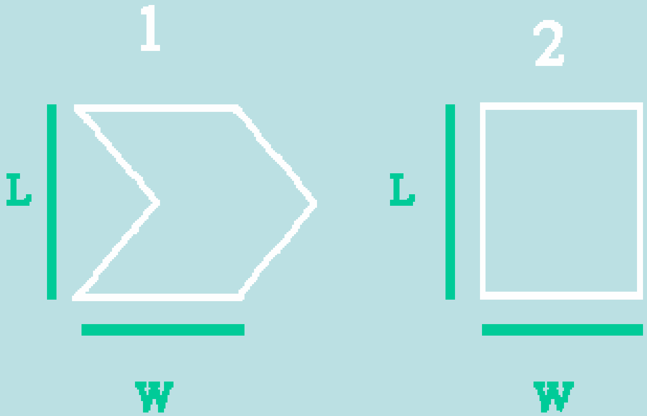
a) $\Phi_1 > \Phi_2$

b) $\Phi_1 = \Phi_2$

c) $\Phi_1 < \Phi_2$



## Example 1:

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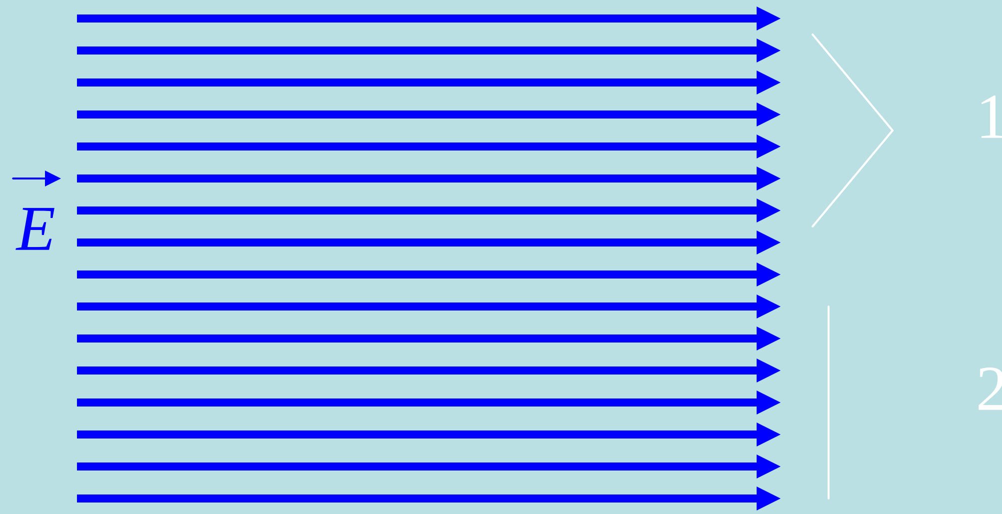


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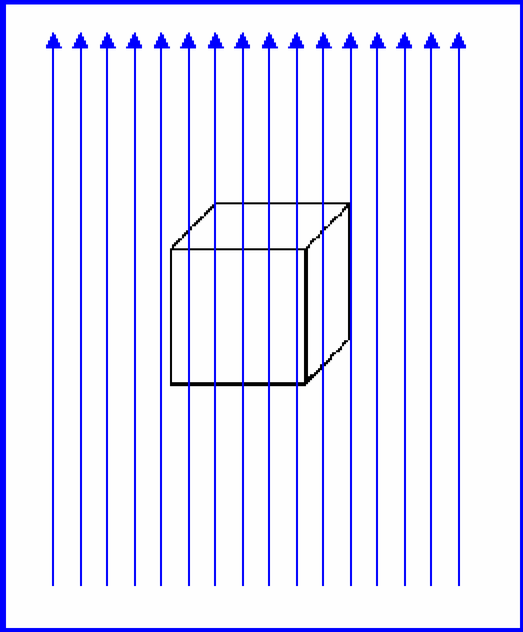
## Example 2:

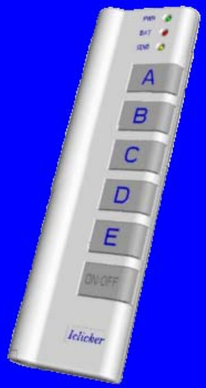
A cube is placed in a uniform electric field. Find the flux through the bottom surface of the cube.



a) $\Phi_{bottom} < 0$

b) $\Phi_{bottom} = 0$

c) $\Phi_{bottom} > 0$



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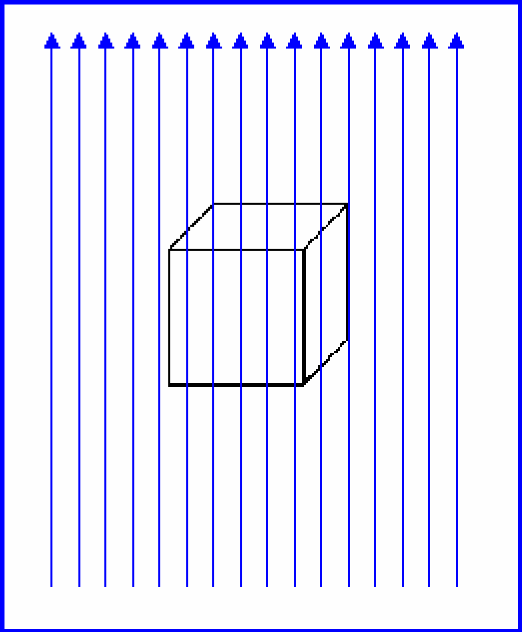


a) $\Phi_{bottom} < 0$

b) $\Phi_{bottom} = 0$

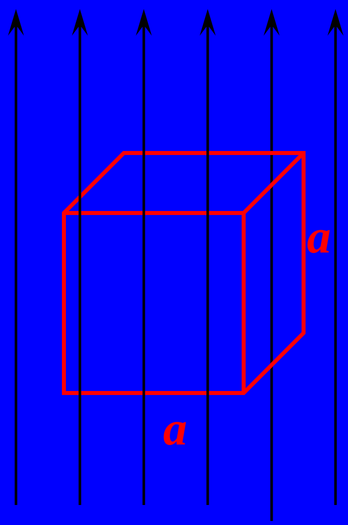
c) $\Phi_{bottom} > 0$

Key here is flux through the bottom (coming into box bottom = -ve [<0] flux outward from bottom)

Through top surface flux $\Phi_{top} > 0$

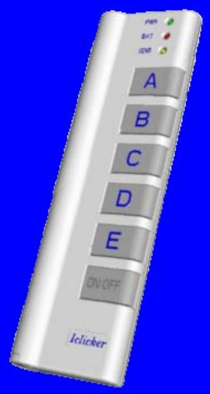
# Exercise 3

- Imagine a cube of side $a$ positioned in a region of constant electric field as shown




  - Which of the following statements about the net electric flux $\Phi_E$ through the surface of this cube is true?

(a) $\Phi_E = 0$ (b) $\Phi_E \propto 2a^2$ (c) $\Phi_E \propto 6a^2$



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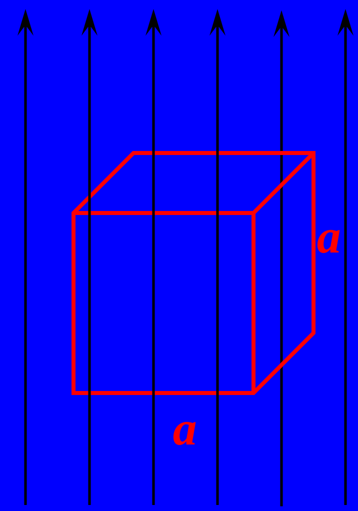


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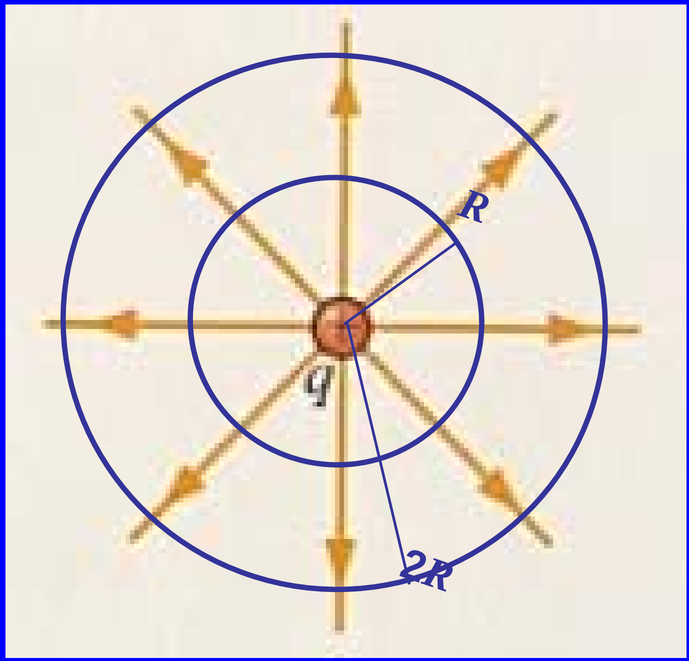
$\boxed{\text{(a) } \Phi_E = 0}$ (b) $\Phi_E \propto 2a^2$ (c) $\Phi_E \propto 6a^2$

- The electric flux through the surface is defined by: $\Phi \equiv \oint \vec{E} \bullet d\vec{A}$
- $\oint \vec{E} \bullet d\vec{A}$ is ZERO on the four sides that are parallel to the electric field.
- $\oint \vec{E} \bullet d\vec{A}$ on the bottom face is negative. ($dA$ is out; $E$ is in)
- $\oint \vec{E} \bullet d\vec{A}$ on the top face is positive. ($dA$ is out; $E$ is out)
- Therefore, the total flux through the cube is:

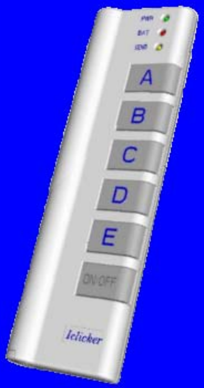
$$\Phi \equiv \tilde{}\ \vec{E} \bullet \vec{A} = \Phi_{sides} + \Phi_{bottom} + \Phi_{top} = 0 - Ea^2 + Ea^2 = 0$$

# Exercise 4




- **Consider 2 spheres (of radius $R$ and $2R$) drawn around a single charge as shown.**
  - **Which of the following statements about the net electric flux through the 2 surfaces ($\Phi_{2R}$ and $\Phi_R$) is true?**

**(a) $\Phi_R < \Phi_{2R}$** **(b) $\Phi_R = \Phi_{2R}$** **(c) $\Phi_R > \Phi_{2R}$**



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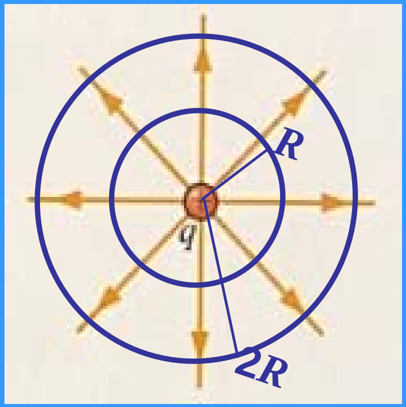


(a) $\Phi_R < \Phi_{2R}$ (b) $\boxed{\Phi_R = \Phi_{2R}}$ (c) $\Phi_R > \Phi_{2R}$

- **Look at the lines going out through each circle -- each circle has the same number of lines.**
- **The electric field is different at the two surfaces, because $E$ is proportional to 1 / $r^2$, but the surface areas are also different. The surface area of a sphere is proportional to $r^2$.**
- **Since flux = $\oint_S \vec{E} \bullet d\vec{A}$, the $r^2$ and 1/$r^2$ terms will cancel, and the two circles have the same flux!**
- **There is an easier way. Gauss' Law states the net flux is proportional to the NET enclosed charge. The NET charge is the SAME in both cases.**
- ***But, what is Gauss' Law ???*** ***--You'll find out next lecture!***

# More weekend fun?

- HW #2 → some parts don't need Gauss' Law
- Office Hours immediately after this class (9:30 – 10:00) in WAT214 (? 1-1:30 MWF)
- Don't fall behind – first Quiz Now!