Your Comments

“What is the quantity ε_0 exactly?” “What does it meannnnnnnnn????? How was it derived from the equations presented in the prelecture?”

IT’S JUST A CONSTANT

$$\vec{E} = k\frac{q}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\hat{r} = \frac{1}{4\pi r^2}\frac{q}{\varepsilon_o}\hat{r}$$

$$k \equiv \frac{1}{4\pi\varepsilon_o}$$

$k = 9 \text{ x } 10^9 \text{ N m}^2 / \text{C}^2$

$\varepsilon_o = 8.85 \; x \; 10^{-12} \text{ C}^2 / \text{N}\cdot\text{m}^2$

I'm completely confused(or at least I think I am), I hope lecture tomorrow helps

Please go over the flux and how to find it, there were a lot of equations thrown at once.

The application of flux, eg. why do we have these concept?

This to me was a difficult prelecture. Can we go over electric field lines and using spheres.

Gary Gladding + classical music >>>>> Gary Gladding without classical music

And how does this prelecture connect to the flux capacitor in Back the Future??

Electricity & Magnetism
Lecture 3

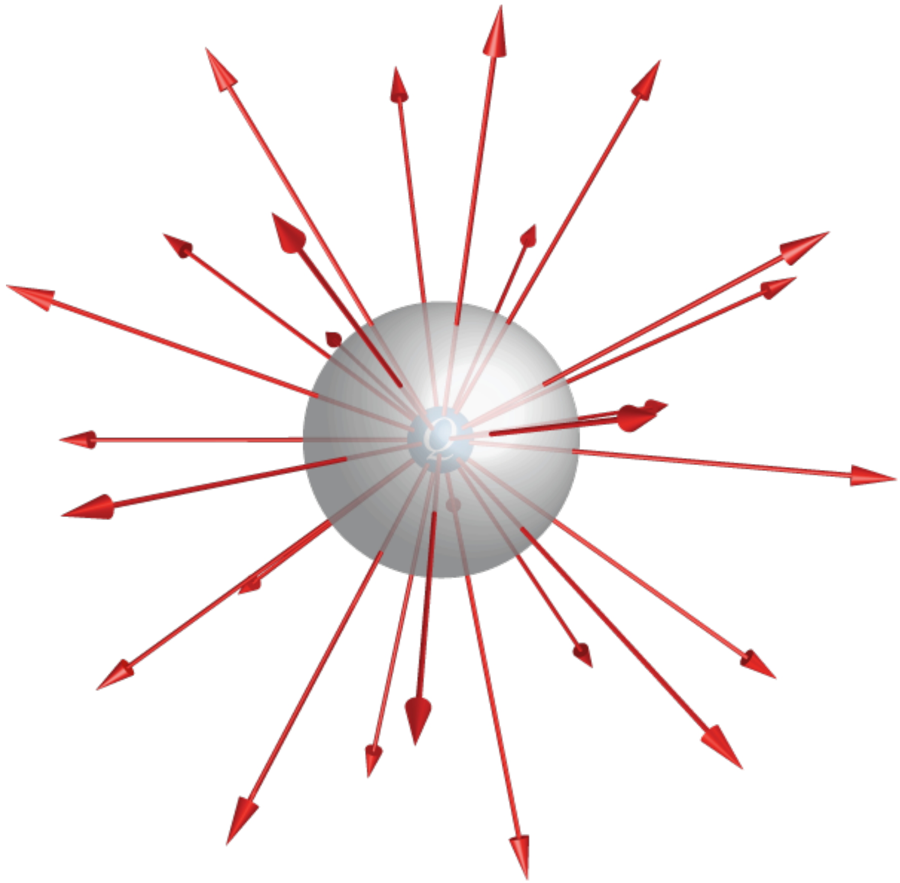
Today's Concepts:

A) Electric Flux

B) Field Lines

→ Gauss' Law

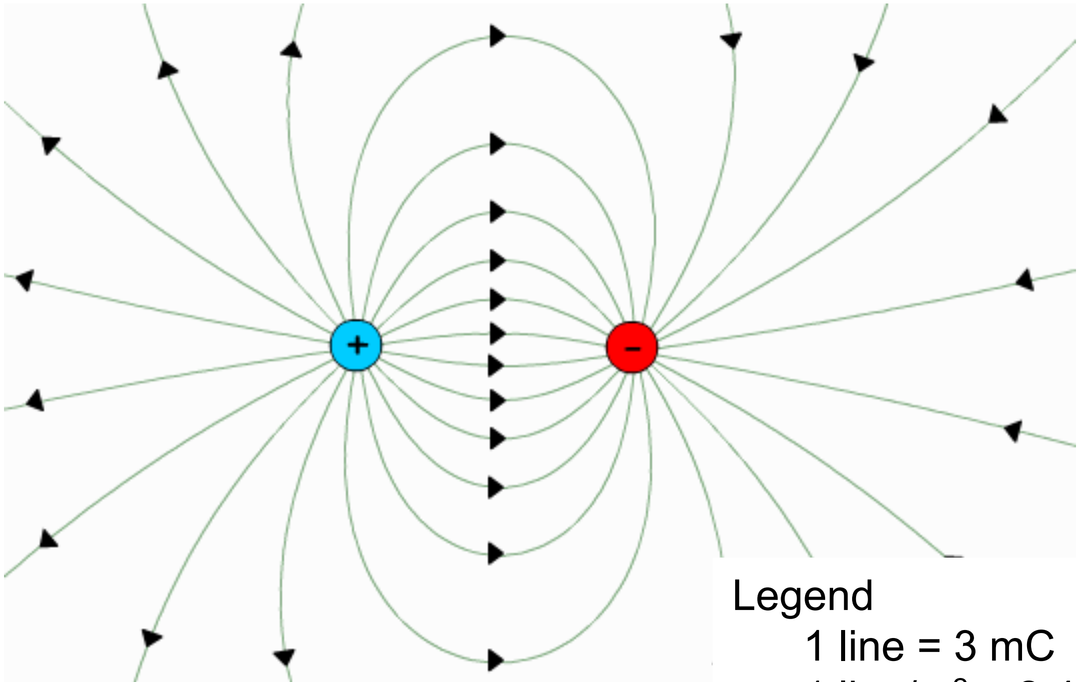
Electric Field Lines



Direction & Density of Lines
represent
Direction & Magnitude of E

Point Charge:
 Direction is radial
 Density $\propto 1/R^2$

Electric Field Lines



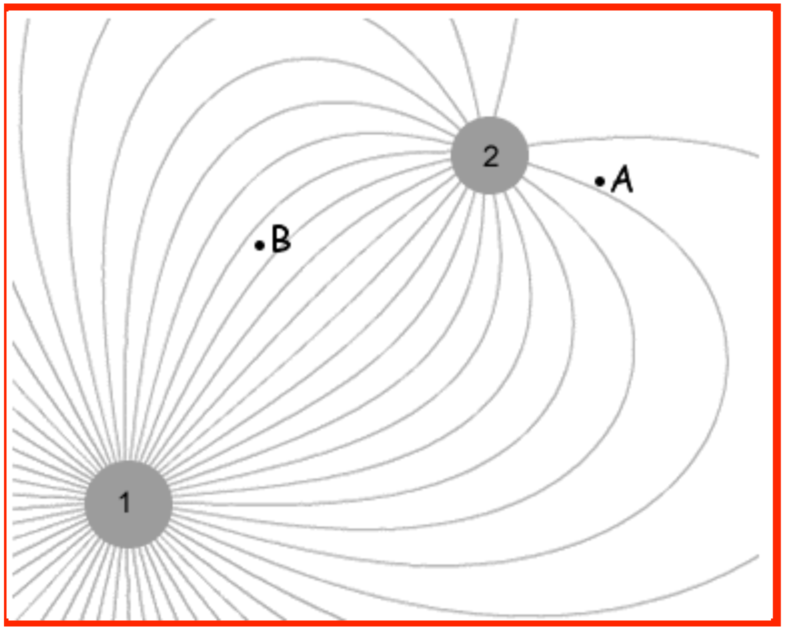
Legend
1 line = 3 mC
1 line/m^2 = 2.4 x 10^{11} N/C

Dipole Charge Distribution:
Direction & Density
much more interesting.

Simulation

I don't quite understand the concept of charge being proportional to number of electric field lines. Isn't there an electric field at all points surrounding a charge? If that is the case, shouldn't there always be an infinite number of electric field lines surrounding a charge?

CheckPoint 3.1

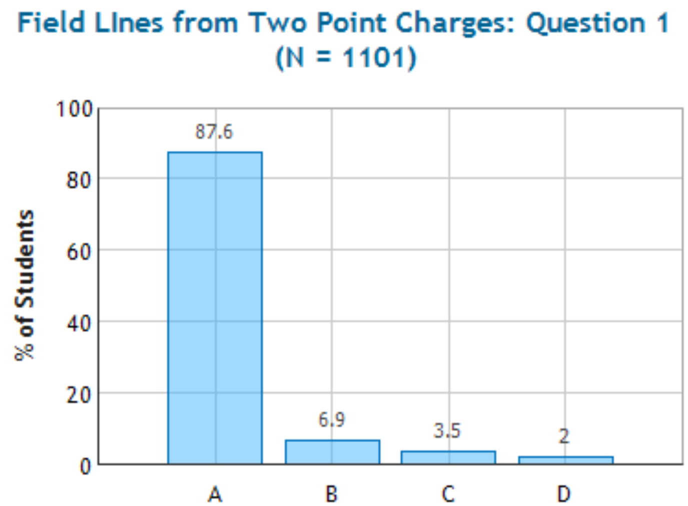


A. $|Q_1| > |Q_2|$

B. $|Q_1| = |Q_2|$

C. $|Q_1| < |Q_2|$

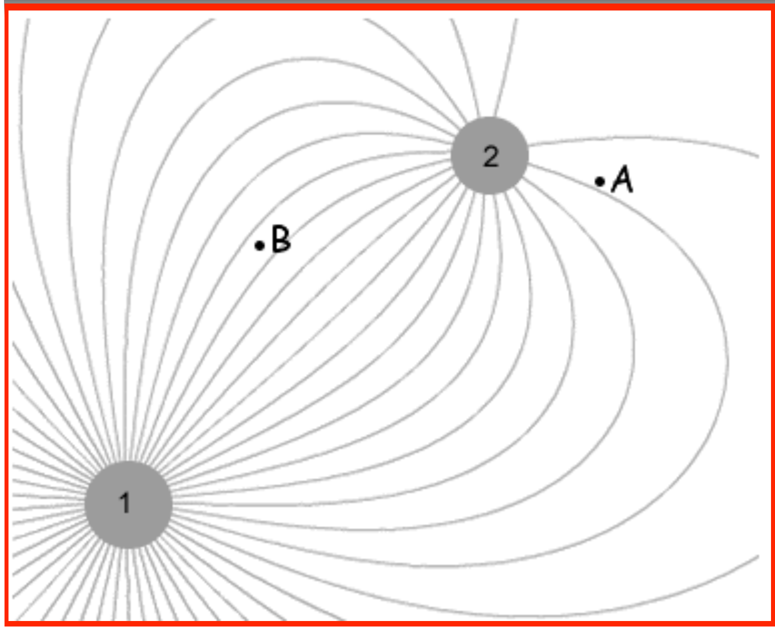
D. Not enough info



"more lines = higher magnitude of charge"

Simulation

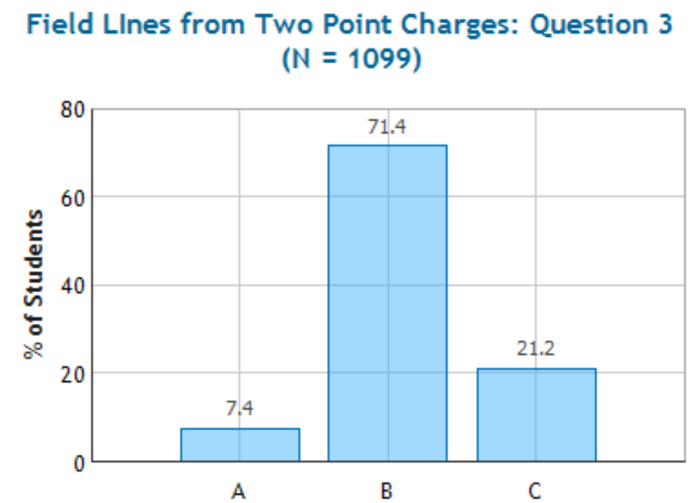
CheckPoint 3.3



A. Q_1 and Q_2 have the same sign

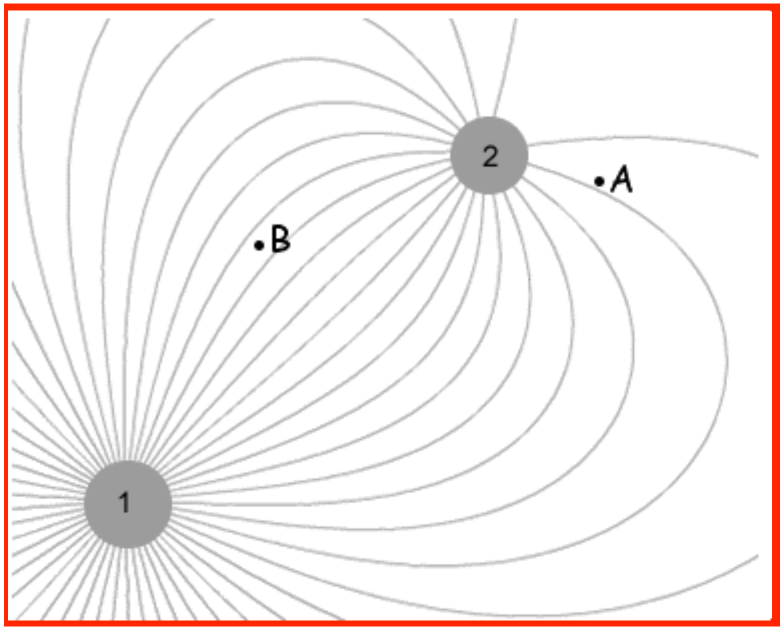
B. Q_1 and Q_2 have opposite signs

C. Not enough info



"Because they go from one to the other."

CheckPoint 3.5

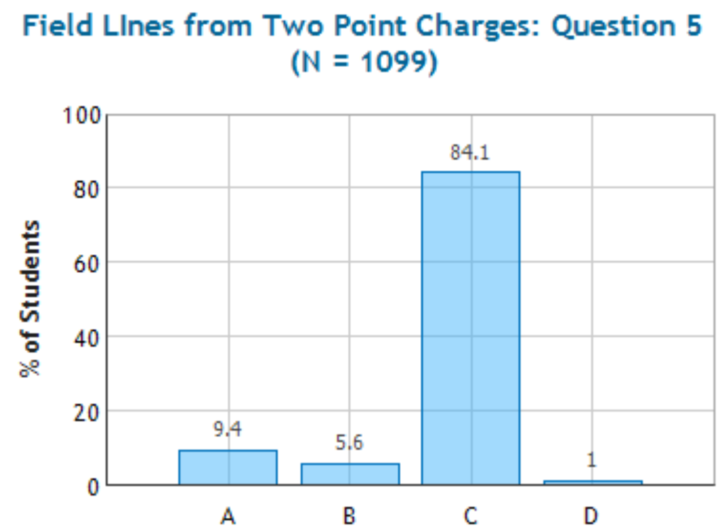


$A.\ |E_A| > |E_B|$

$B.\ |E_A| = |E_B|$

$C.\ |E_A| < |E_B|$

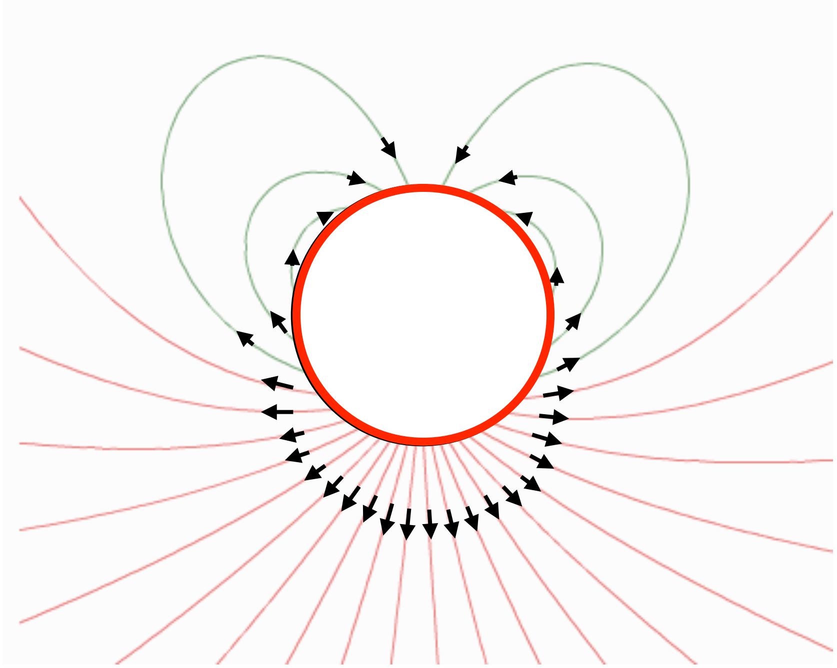
D. Not enough info



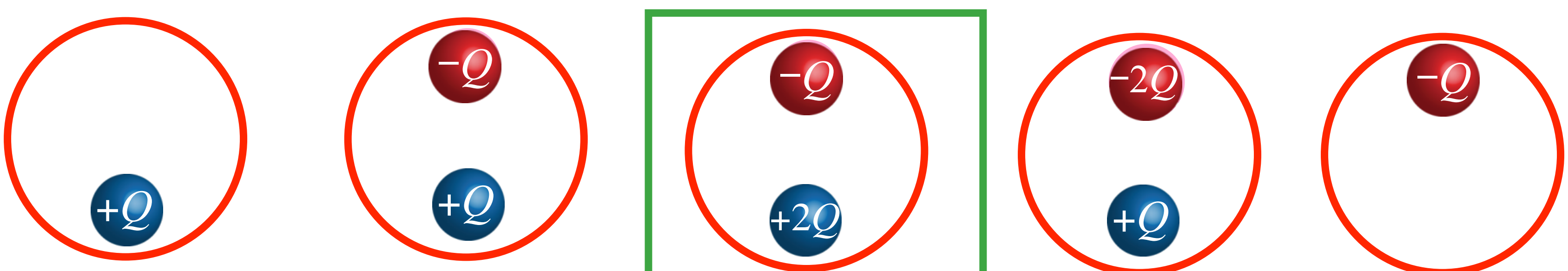
"the lines are closer together at B, meaning electric field is stronger"

Point Charges

"Telling the difference between positive and negative charges while looking at field lines. Does field line density from a certain charge give information about the sign of the charge?"



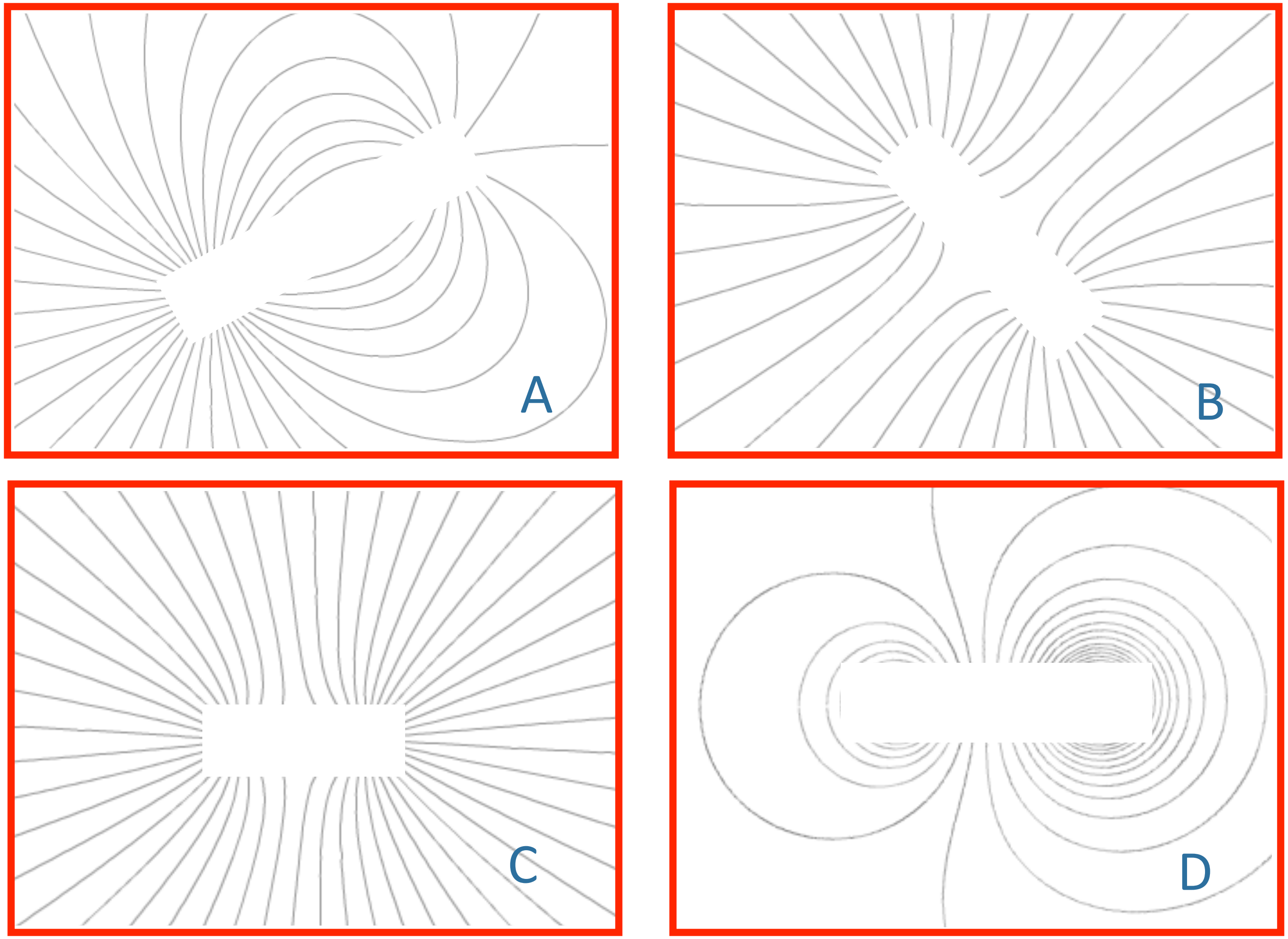
What charges are inside the red circle?



A B C D E

Electric Field lines

Which of the following field line pictures best represents the electric field from two charges that have the same sign but different magnitudes?



Simulation

Electric Flux "Counts Field Lines"

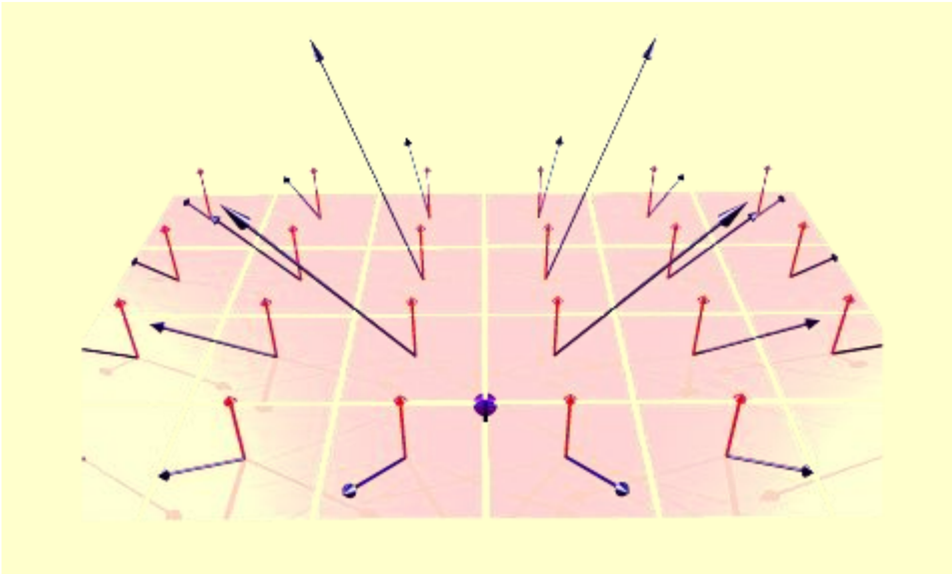
Can you give us a clear, simple definition of what flux is?

$$\Phi_S = \underbrace{\int_S \vec{E} \cdot d\vec{A}}$$

Flux through surface S

Integral of $\vec{E} \cdot d\vec{A}$ on surface S

Representing the area of a surface as a vector in order to take the dot product.

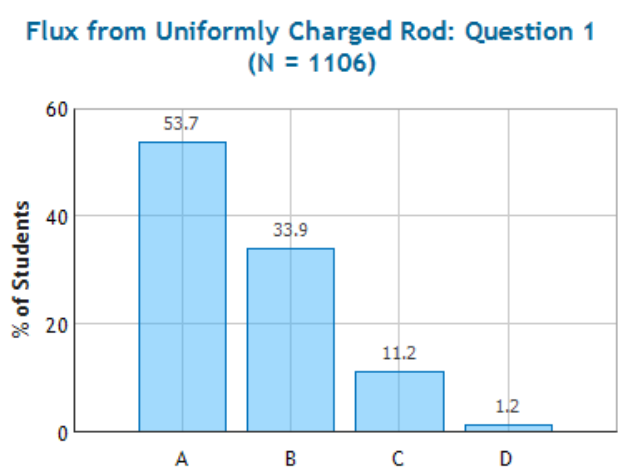


CheckPoint 1

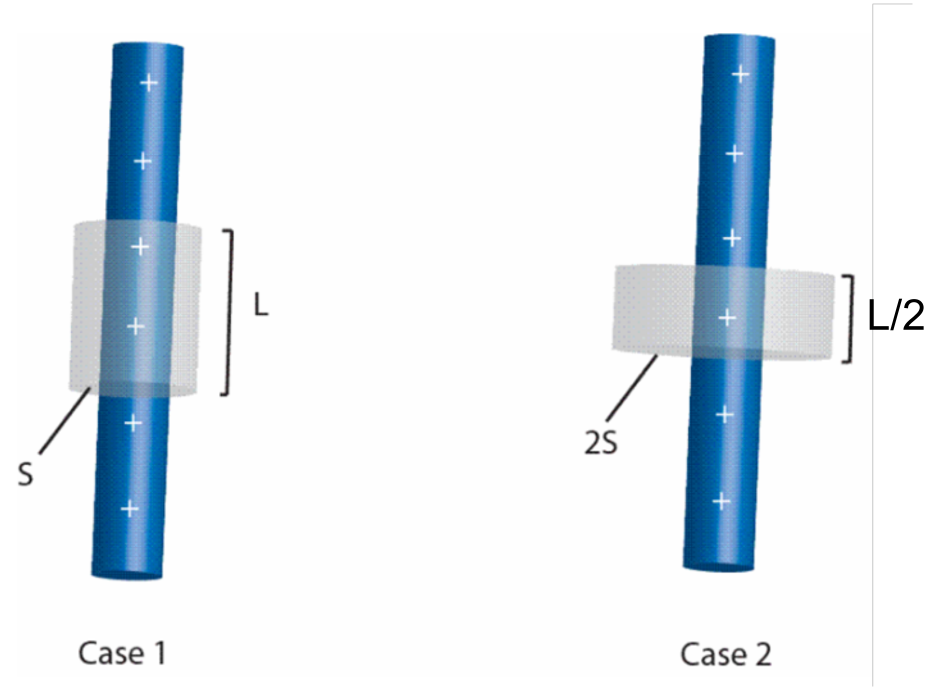
"Because the charge is proportional to length of the cylinder enclosing the charge, and the flux is proportional to the charge, this means that the flux is proportional to the length and an increase in length of 2l yields in an increase in flux of 2omega."

"The flux is just E*A, and the area is 2(pi)RL, so in both cases the flux is (lambda)(s)(L)/(epsilon). The fluxes are the same."

"The first cylinder has double the area, and double the charge so the flux should be quadrupled."



An infinitely long charged rod has uniform charge density λ and passes through a cylinder (gray). The cylinder in Case 2 has twice the radius and half the length compared with the cylinder in Case 1.



(A)	(B)	(C)	(D)
$\Phi_1 = 2\Phi_2$	$\Phi_1 = \Phi_2$	$\Phi_1 = 1/2\Phi_2$	none

CheckPoint 2

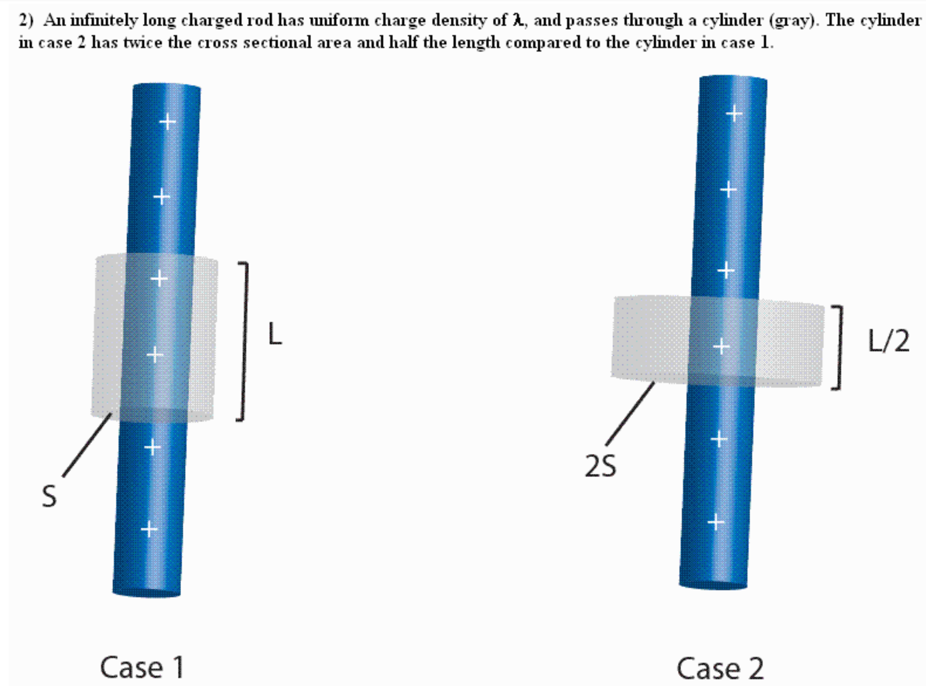
Definition of Flux:

$$\Phi \equiv \int_{surface} \vec{E} \cdot d\vec{A}$$

E constant on barrel of cylinder
E perpendicular to barrel surface
(E parallel to dA)

$$\Phi = E \int_{barrel} d\vec{A}$$

$$= EA_{barrel}$$



$\boxed{\Phi_1 = 2\Phi_2 \text{ (A)}}$ $\Phi_1 = \Phi_2$ (B) $\Phi_1 = 1/2\Phi_2$ (C) none (D)

RESULT: GAUSS' LAW
Φ proportional to charge enclosed !

Case 1

$$A_{barrel} = 2\pi s L$$

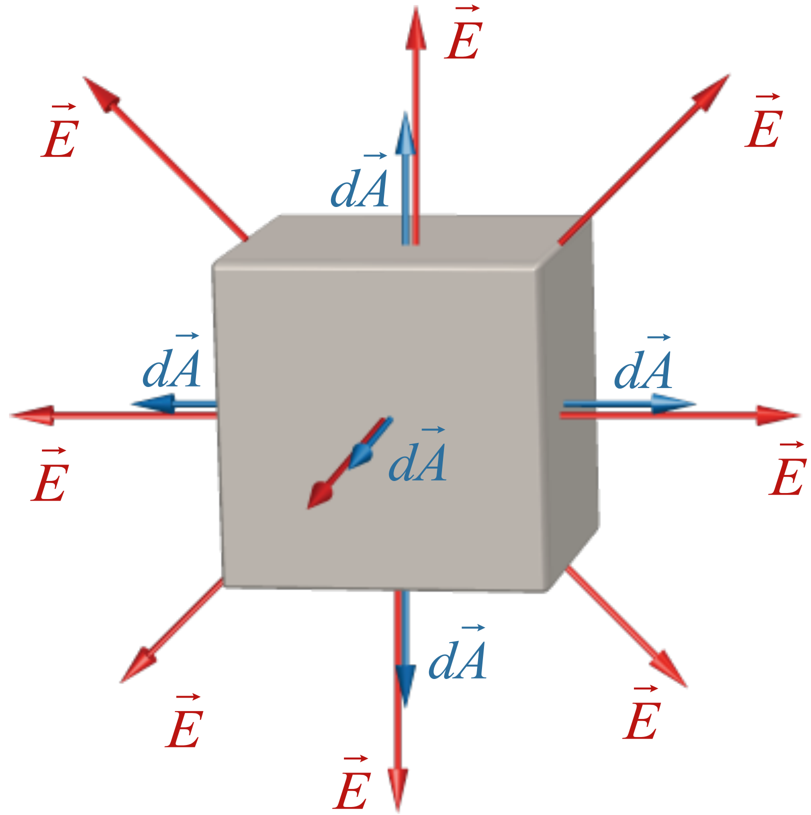
$$E_1 = \frac{\lambda}{2\pi\varepsilon_0 s} \rightarrow \boxed{\Phi_1 = \frac{\lambda L}{\varepsilon_0}}$$

Case 2

$$A_2 = (2\pi(2s))L/2 = 2\pi s L$$

$$E_2 = \frac{\lambda}{2\pi\varepsilon_0 (2s)} \rightarrow \boxed{\Phi_2 = \frac{\lambda (L/2)}{\varepsilon_0}}$$

Direction Matters:

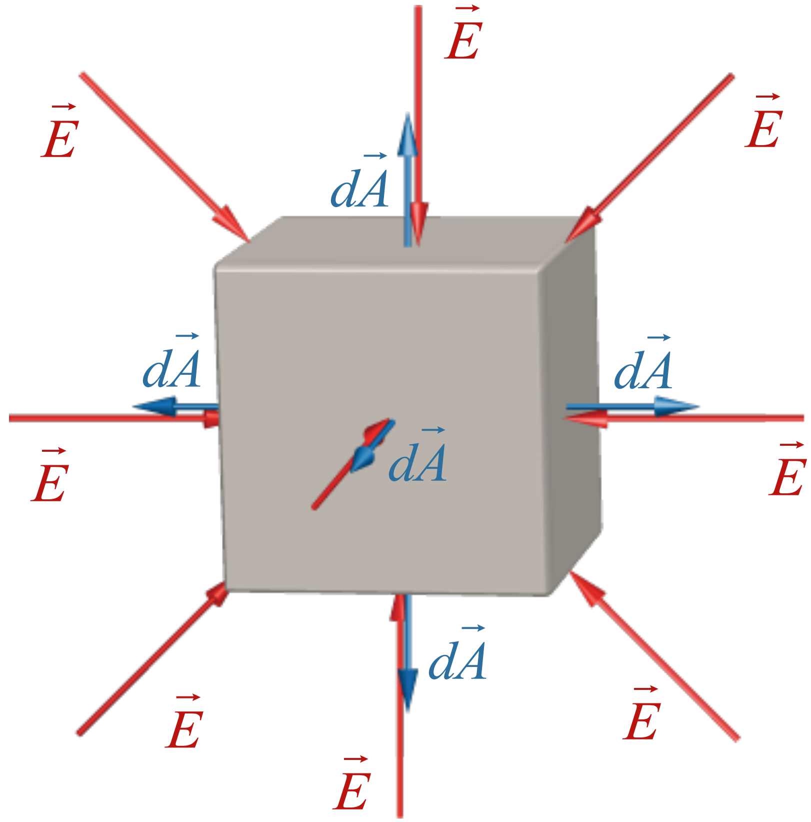


For a closed surface, $d\vec{A}$ points outward

$$\Phi_S = \int_S \vec{E} \cdot d\vec{A} > 0$$

Direction Matters:

Can flux through a flat plane be negative? What would that represent?



For a closed surface, $d\vec{A}$ points outward

$$\Phi_S = \int_S \vec{E} \cdot d\vec{A} < 0$$

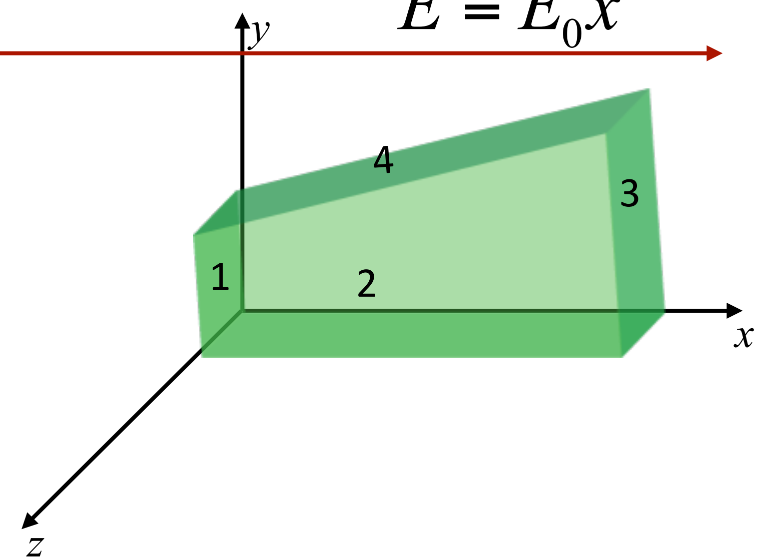
Trapezoid in Constant Field

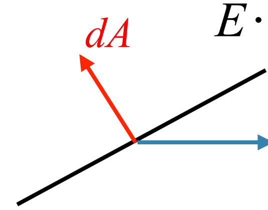
$$\vec{E} = E_0\hat{x}$$

Label faces:

1: $x = 0$
2: $z = +a$
3: $x = +a$
4: slanted

Define Φ_n = Flux through Face n





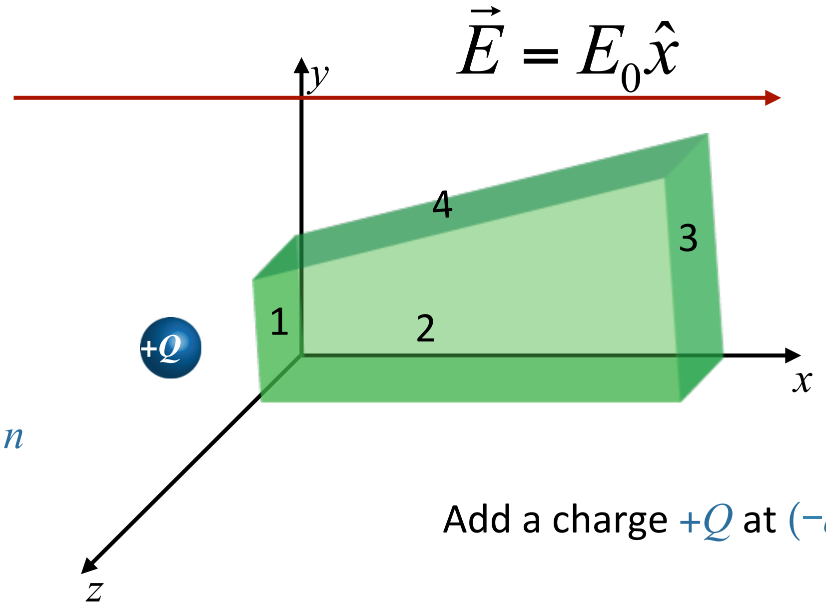
$\boxed{\text{A) } \Phi_1 < 0}$	A) $\Phi_2 < 0$	A) $\Phi_3 < 0$	$\boxed{\text{A) } \Phi_4 < 0}$
B) $\Phi_1 = 0$	$\boxed{\text{B) } \Phi_2 = 0}$	B) $\Phi_3 = 0$	B) $\Phi_4 = 0$
C) $\Phi_1 > 0$	C) $\Phi_2 > 0$	$\boxed{\text{C) } \Phi_3 > 0}$	C) $\Phi_4 > 0$

Trapezoid in Constant Field + Q

Label faces:

1: $x = 0$
2: $z = +a$
3: $x = +a$
4: slanted

Define Φ_n = Flux through Face n
Φ = Flux through Trapezoid



Add a charge $+Q$ at $(-a, a/2, a/2)$

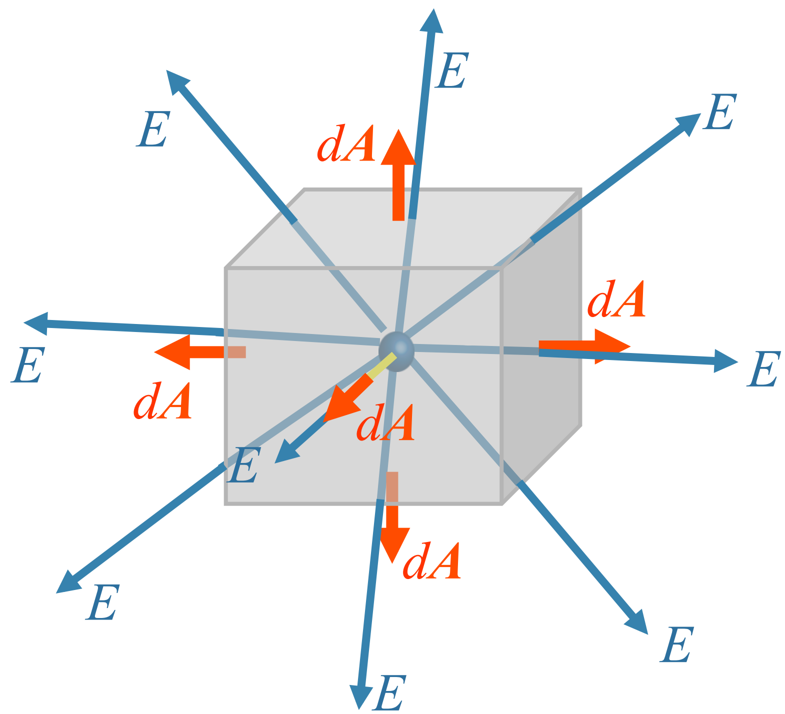
How does Flux change?
Note (-6 < -4) sign matters

A) Φ_1 increases
B) Φ_1 decreases
C) Φ_1 remains same

A) Φ_3 increases
B) Φ_3 decreases
C) Φ_3 remains same

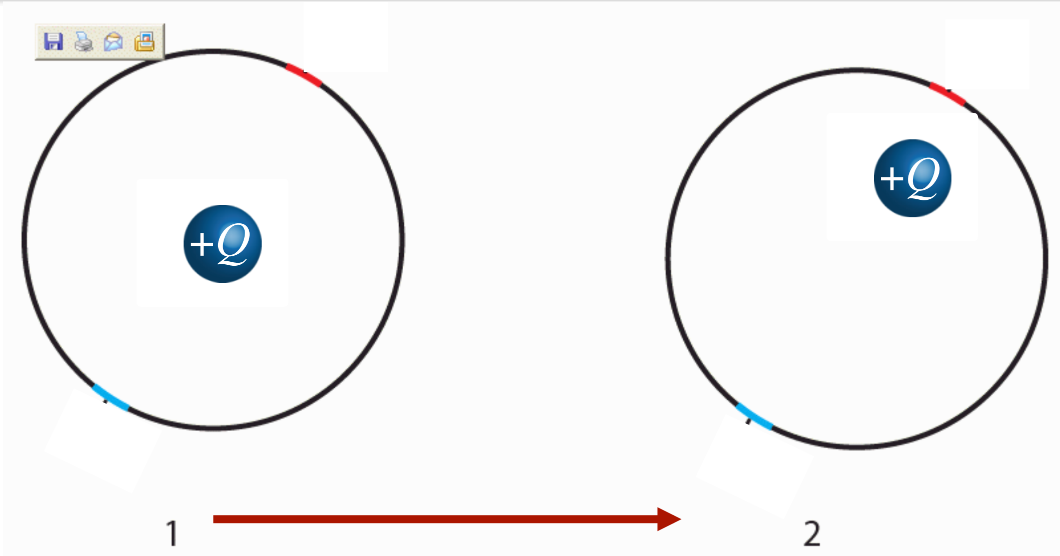
A) Φ increases
B) Φ decreases
C) Φ remains same

Gauss Law



$$\int_{\substack{closed\\surface}} \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

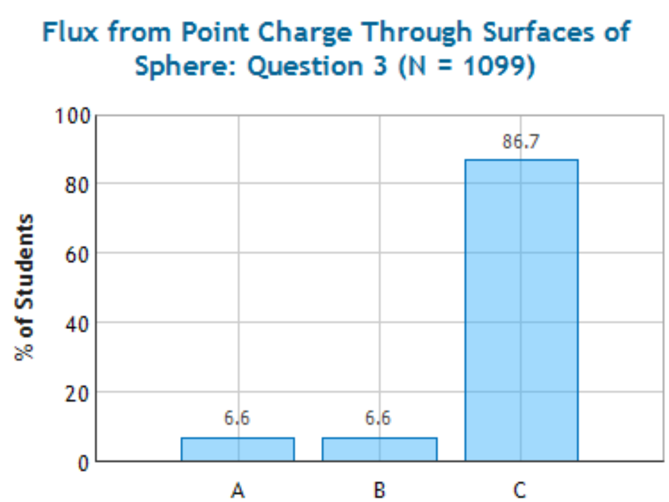
CheckPoint 2.3



A
Φ_E increases

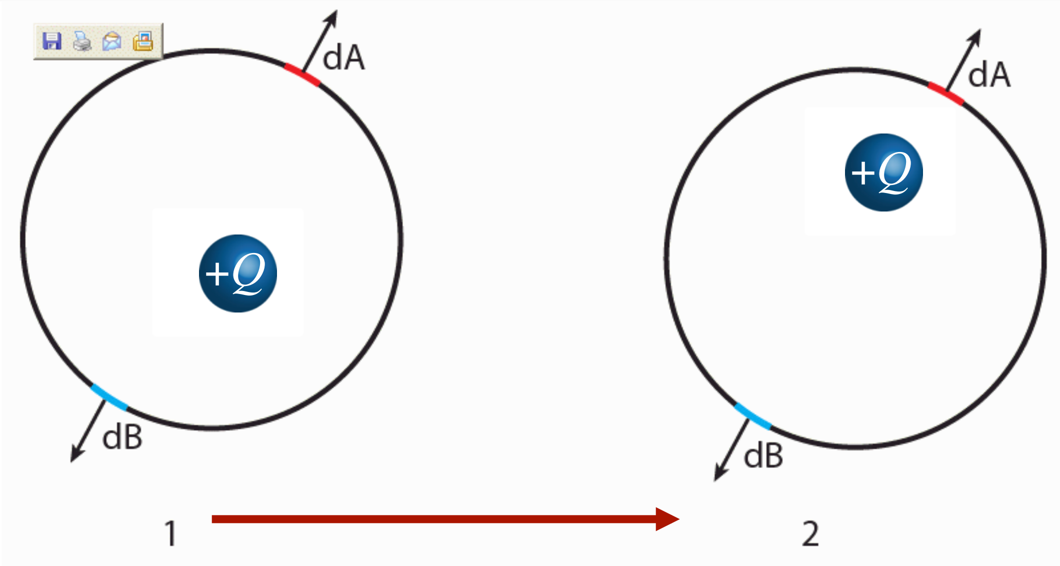
B
Φ_E decreases

C
Φ_E stays same

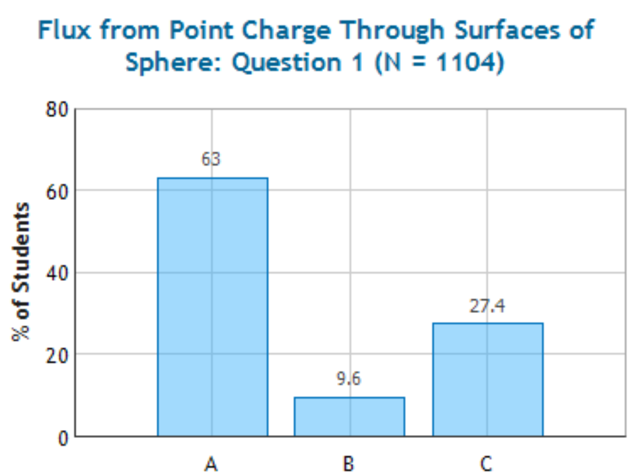


"Because +Q is still in the shell, no matter where it is, the total flux is the same."

CheckPoint 2.1

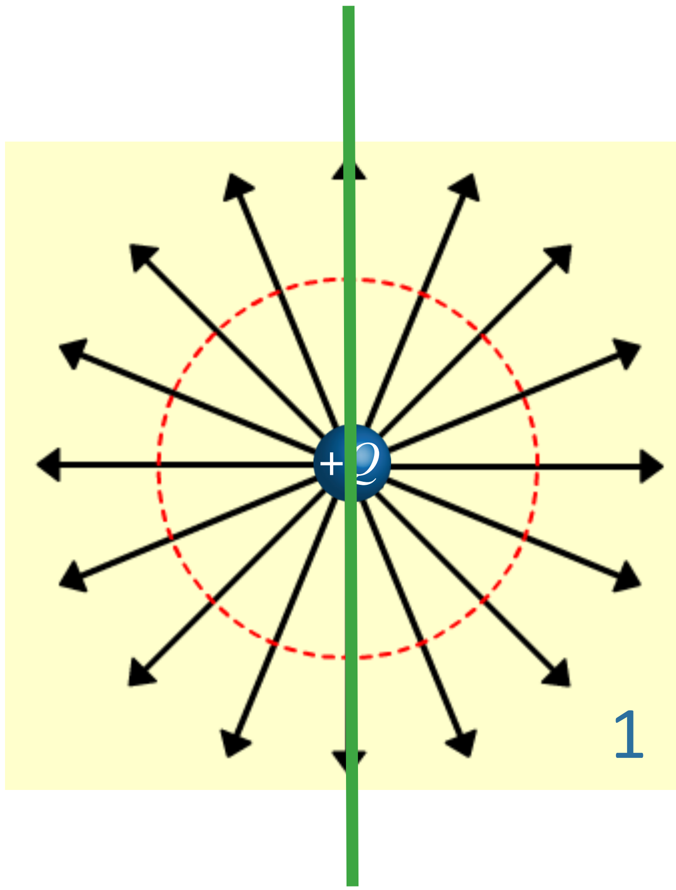


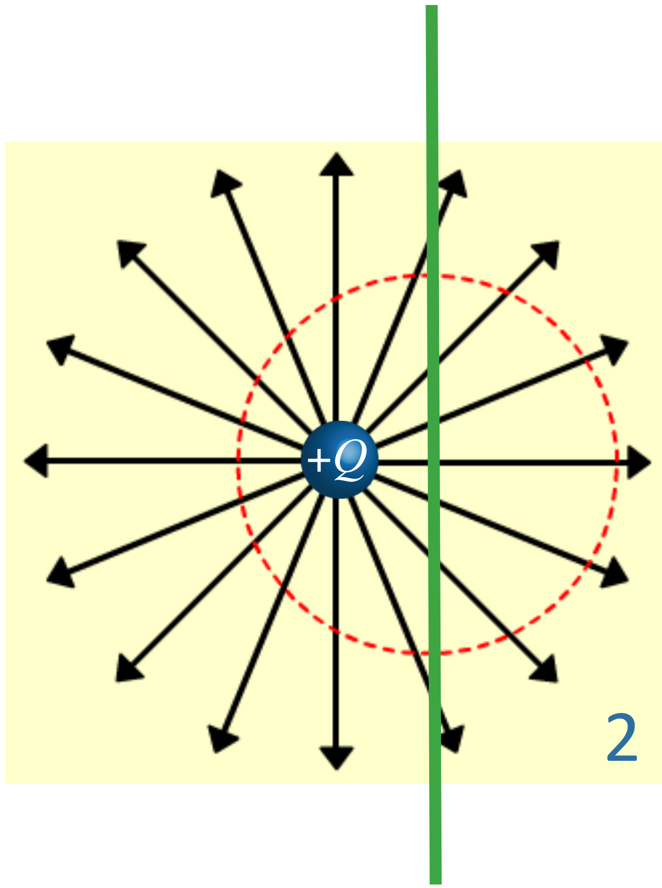
A	B	C
$d\Phi_A$ increases	$d\Phi_A$ decreases	$d\Phi_A$ stays same
$d\Phi_B$ decreases	$d\Phi_B$ increases	$d\Phi_B$ stays same



"Electric field is now stronger at point A. More field line passing through means a greater value for electric flux"

Think of it this way:

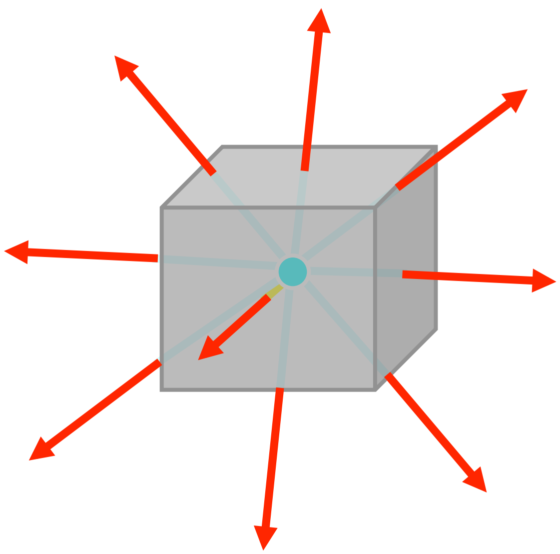




The total flux is the same in both cases (just the total number of lines)

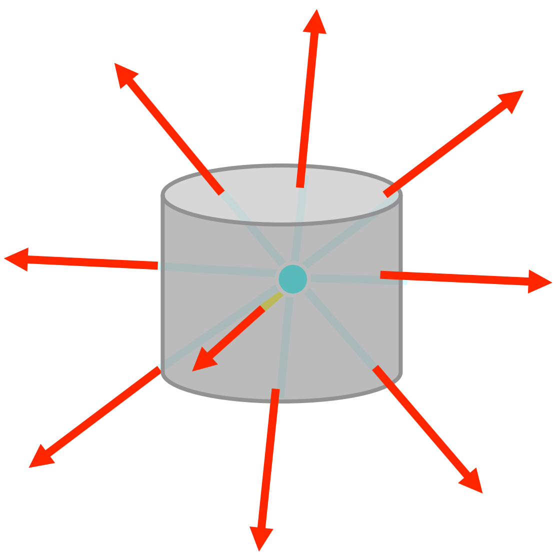
The flux through the right (left) hemisphere is smaller (bigger) for case 2.

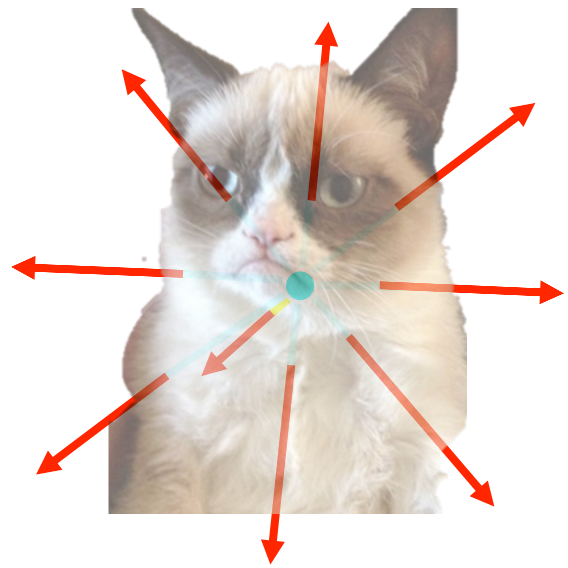
Things to notice about Gauss Law



$$\Phi_S = \int_{\substack{closed \\ surface}} \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

If $Q_{enclosed}$ is the same, the flux has to be the same, which means that the integral must yield the same result for any surface.





Things to notice about Gauss Law

$$\int \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

In cases of high symmetry it may be possible to bring E outside the integral. In these cases we can solve Gauss Law for E

$$E \int dA = \frac{Q_{enclosed}}{\varepsilon_0}$$

$$E = \frac{Q_{enclosed}}{A \varepsilon_0}$$

So - if we can figure out $Q_{enclosed}$ and the area of the surface A, then we know E!

This is the topic of the next lecture.