Lecture-3

Field intensity, flux lines

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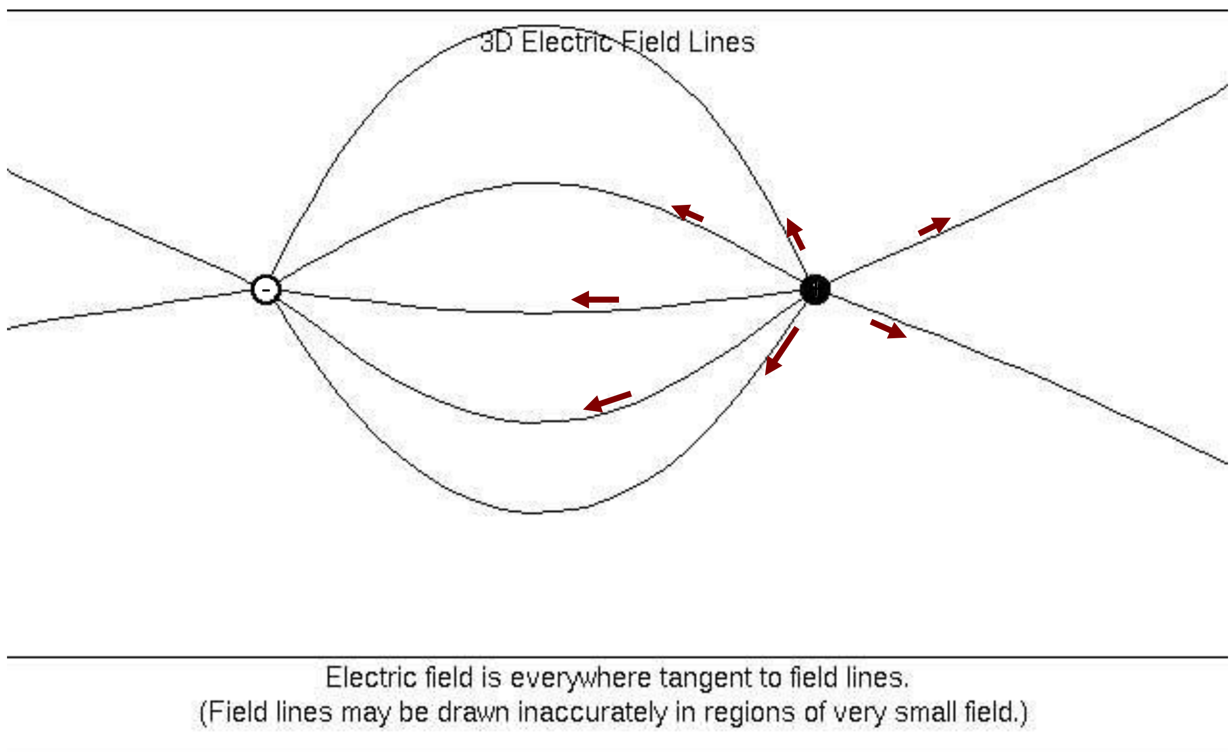
Electric Field Lines

Electric field lines help us visualize the electric field and predict how charged particles would respond the field.



Here's how electric field lines are related to the field:

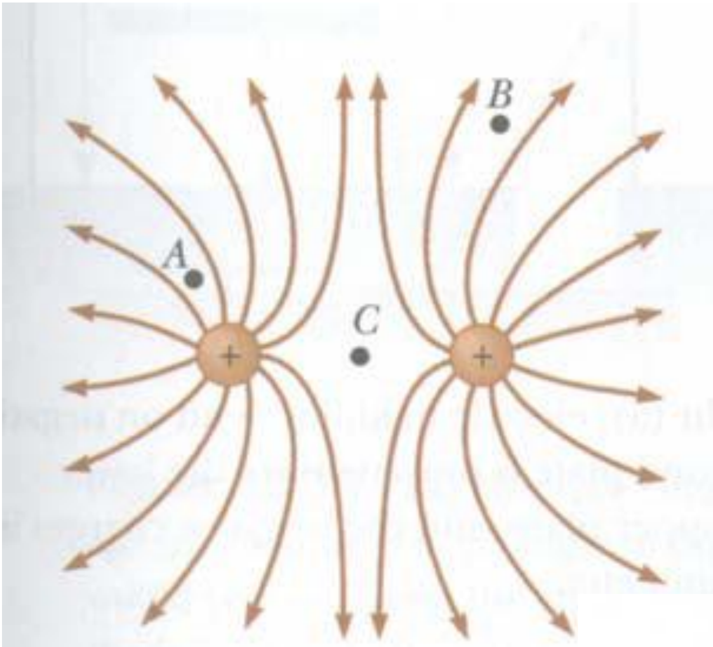
- The electric field vector $\vec{E}$ is tangent to the field lines.

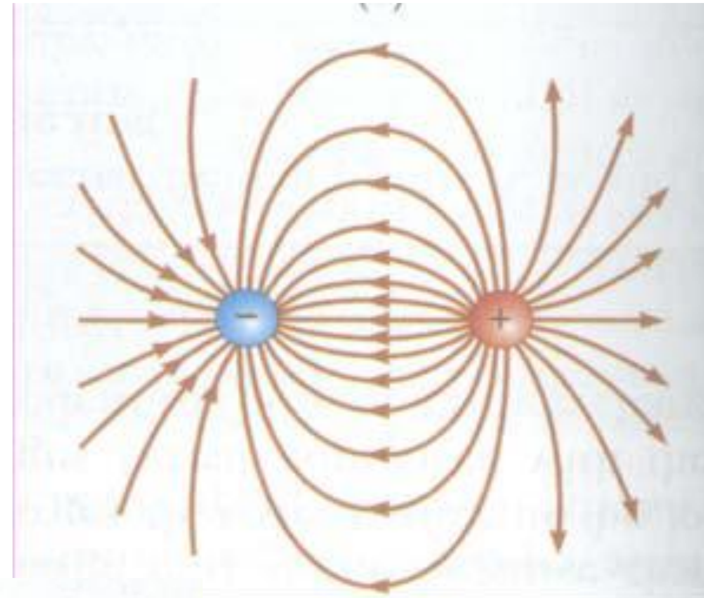
- The number of lines per unit area through a surface perpendicular to the lines is proportional to the electric field strength in that region

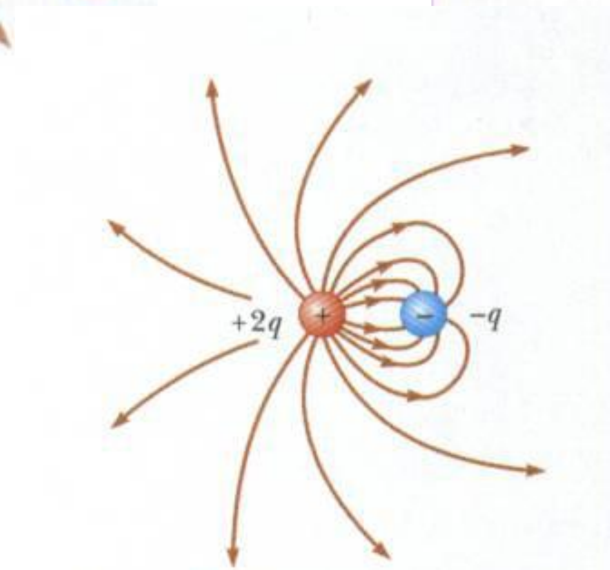
- The field lines begin on positive charges and end on negative charges.

- The number of lines leaving a positive charge or approaching a negative charge is proportional to the magnitude of the charge.

- No two field lines can cross.


A
B
C
+
+


−
+

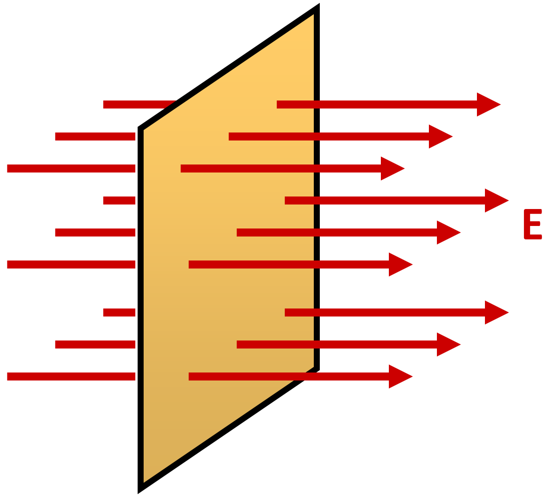

+2q
+
−
−q

Gauss' Law

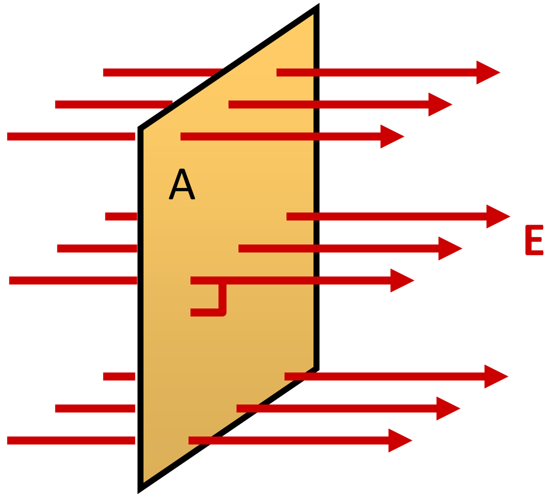
Electric Flux

We have used electric field lines to visualize electric fields and indicate their strength.

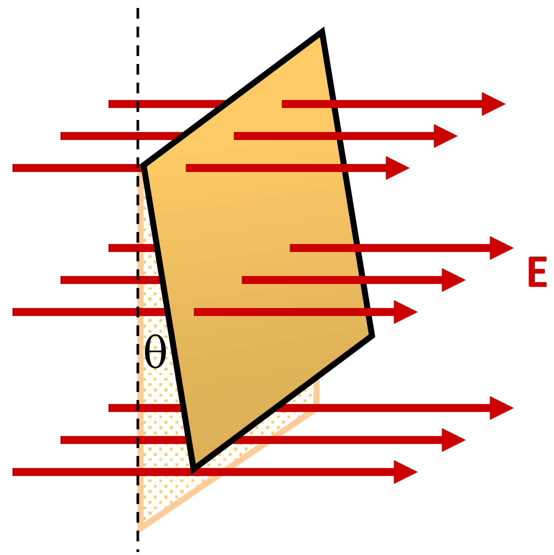
We are now going to count the number of electric field lines passing through a surface, and use this count to determine the electric field.



The **electric flux** passing through a surface is the number of electric field lines that pass through it.

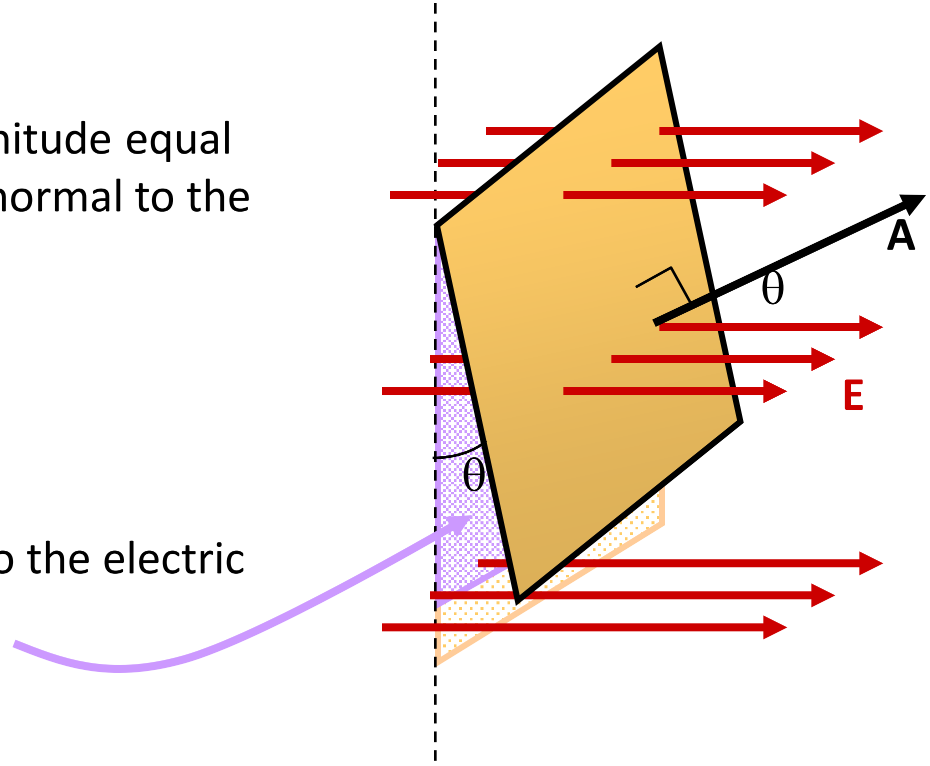


Because electric field lines are drawn arbitrarily, we **quantify** electric flux like this: Φ_E=EA, except that…



If the surface is tilted, fewer lines cut the surface.

We define $\vec{A}$ to be a vector having a magnitude equal to the area of the surface, in a direction normal to the surface.



The "amount of surface" perpendicular to the electric field is $A\cos\theta$.

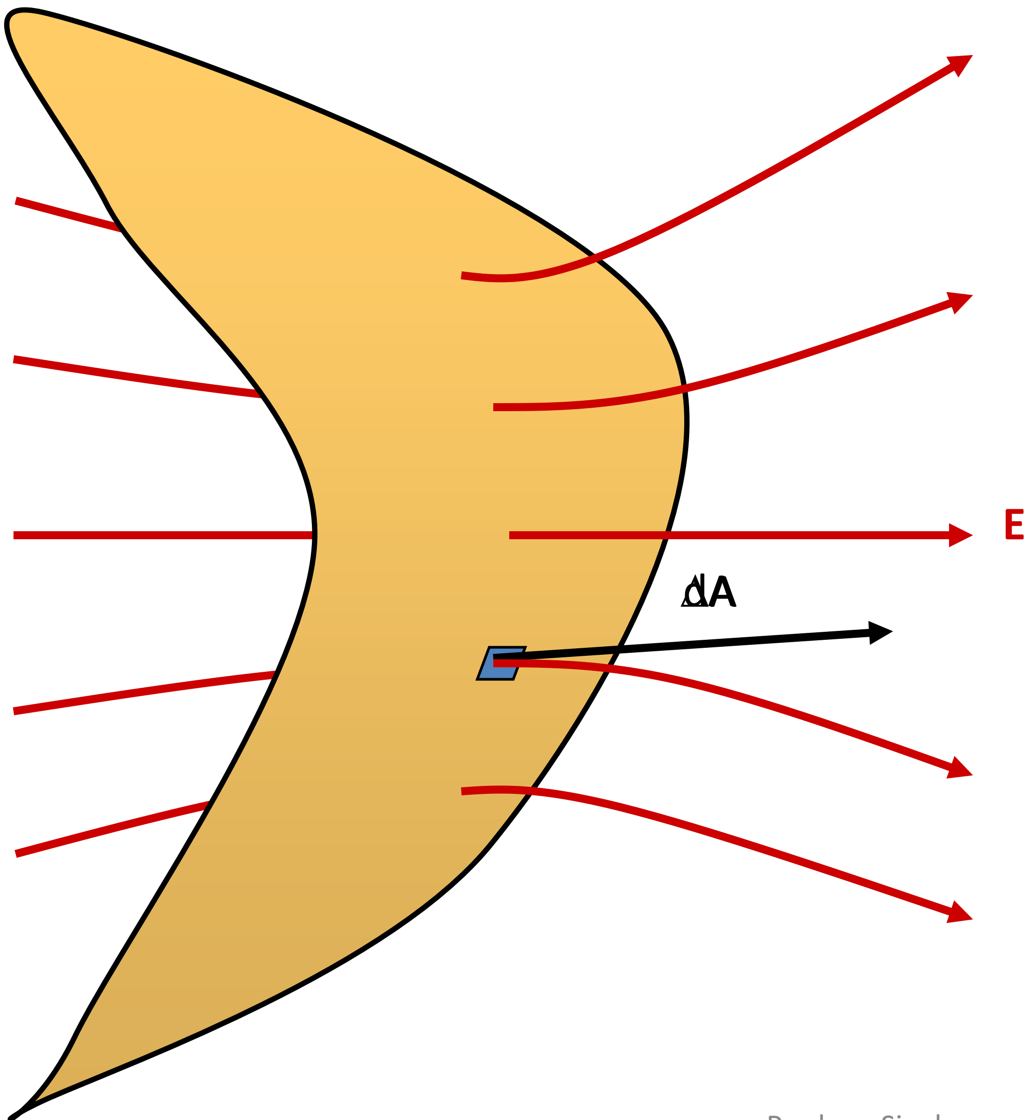
Because $\vec{A}$ is perpendicular to the surface, the amount of $\vec{A}$ parallel to the electric field is $A\cos\theta$.

$$A_{||} = A\cos\theta \quad \text{so} \quad \Phi_E = EA_{||} = EA\cos\theta.$$

Remember the dot product?

$$\Phi_E = \vec{E}\cdot\vec{A}$$

If the electric field is not uniform, or the surface is not flat…

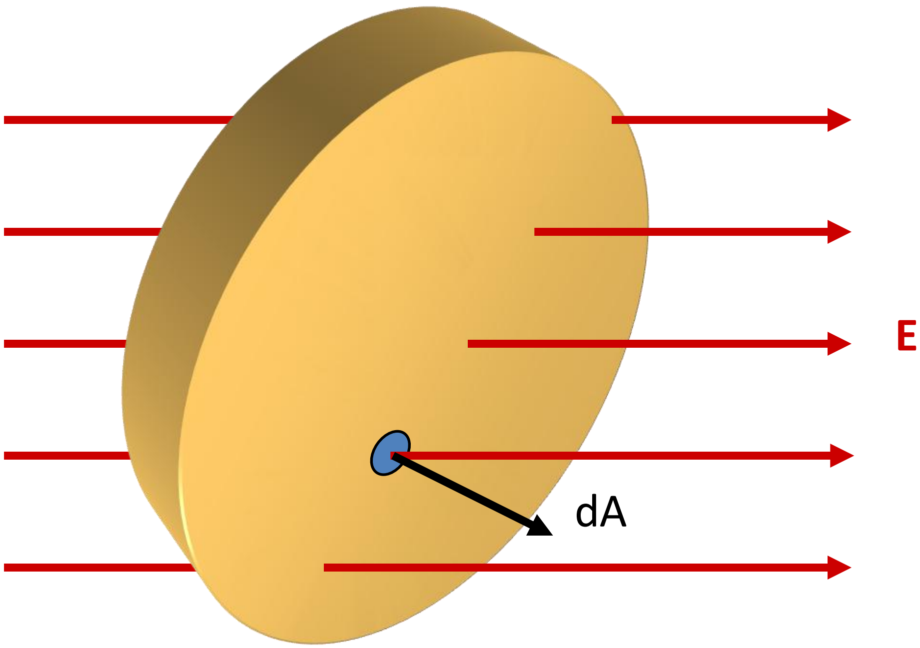


divide the surface into infinitesimal surface elements and add the flux through each…

$$\Phi_E = \lim_{\Delta A_i \to 0} \sum_i \vec{E}_i \cdot \Delta \vec{A}_i$$

$$\Phi_E = \int \vec{E} \cdot d\vec{A}$$

If the surface is closed (completely encloses a volume)…



…we count* lines going out as positive and lines going in as negative…

$$\Phi_E = \oint \vec{E} \cdot d\vec{A}$$

a surface integral, therefore a double integral $\iint$