Electrostatics

Course- PHY 2105 / PHY 105

Lecture 14

Md Shafqat Amin Inan

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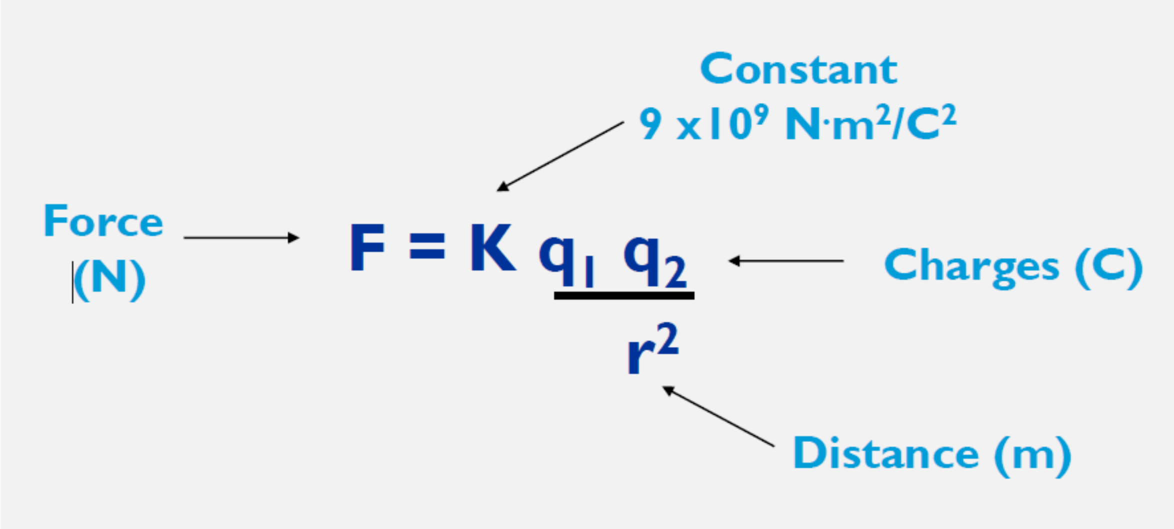
Coulomb’s Law

The electrostatic force between two charged object is directly proportional to the product of the amount of charges and inversely proportional to the square of the distance between them



$$k = \frac{1}{4\pi\varepsilon_0}$$

- *Experimental law*
- *Valid for point charges only*
- *Obeys Inverse Square Law*
- *Valid for only charges at rest*

$$Electrostatic\ constant, k = 9 \times 10^9 \frac{Nm^2}{C^2}$$

$$Permittivity\ constant, \varepsilon_0 = 8.854 \times 10^{-12} \frac{C^2}{Nm^2}$$

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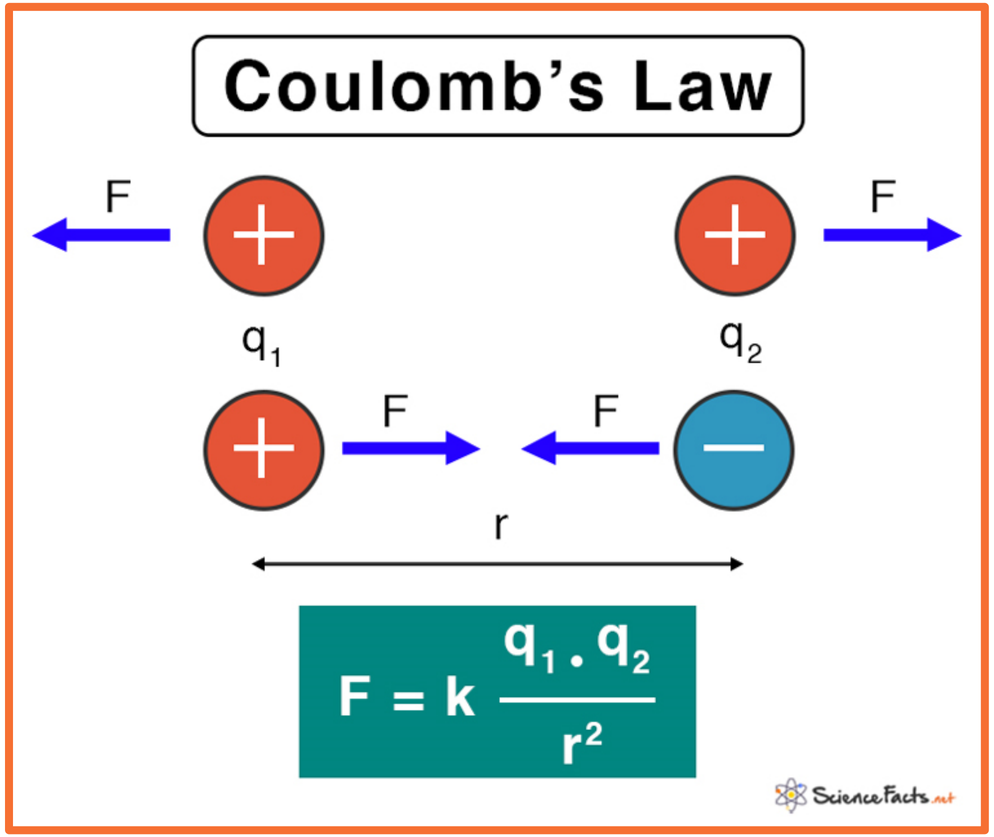
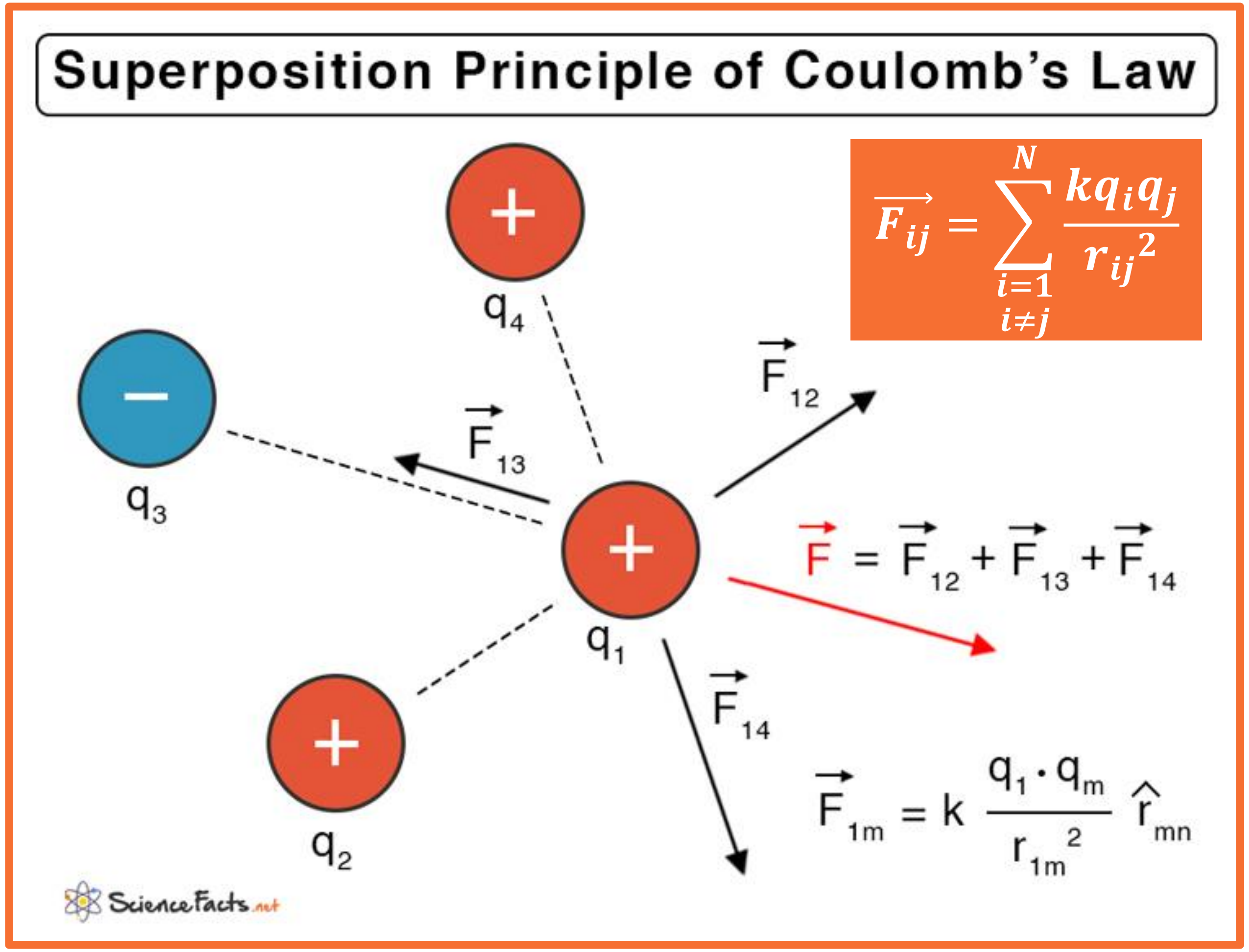
Coulomb's Law: Superposition





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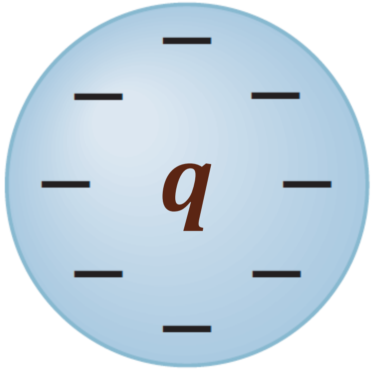
Electric Field

$$\boxed{F = q_0 E}$$

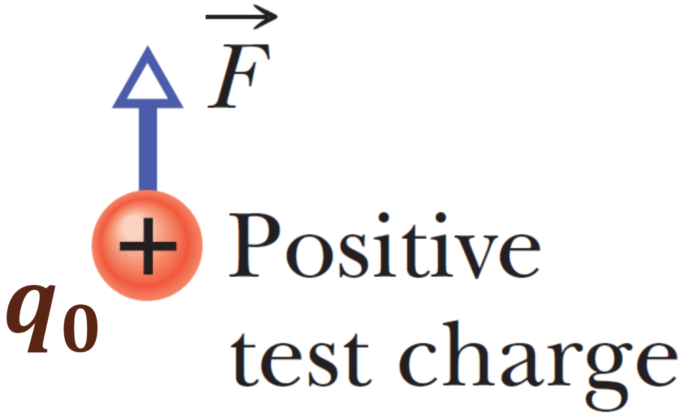
A charge has an effect on its surroundings. The area where it has an effect is generally called an *Electric field.* If any other charge enters that area, it feels an electrostatic Coulomb force.



$$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\,\hat{r}}$$

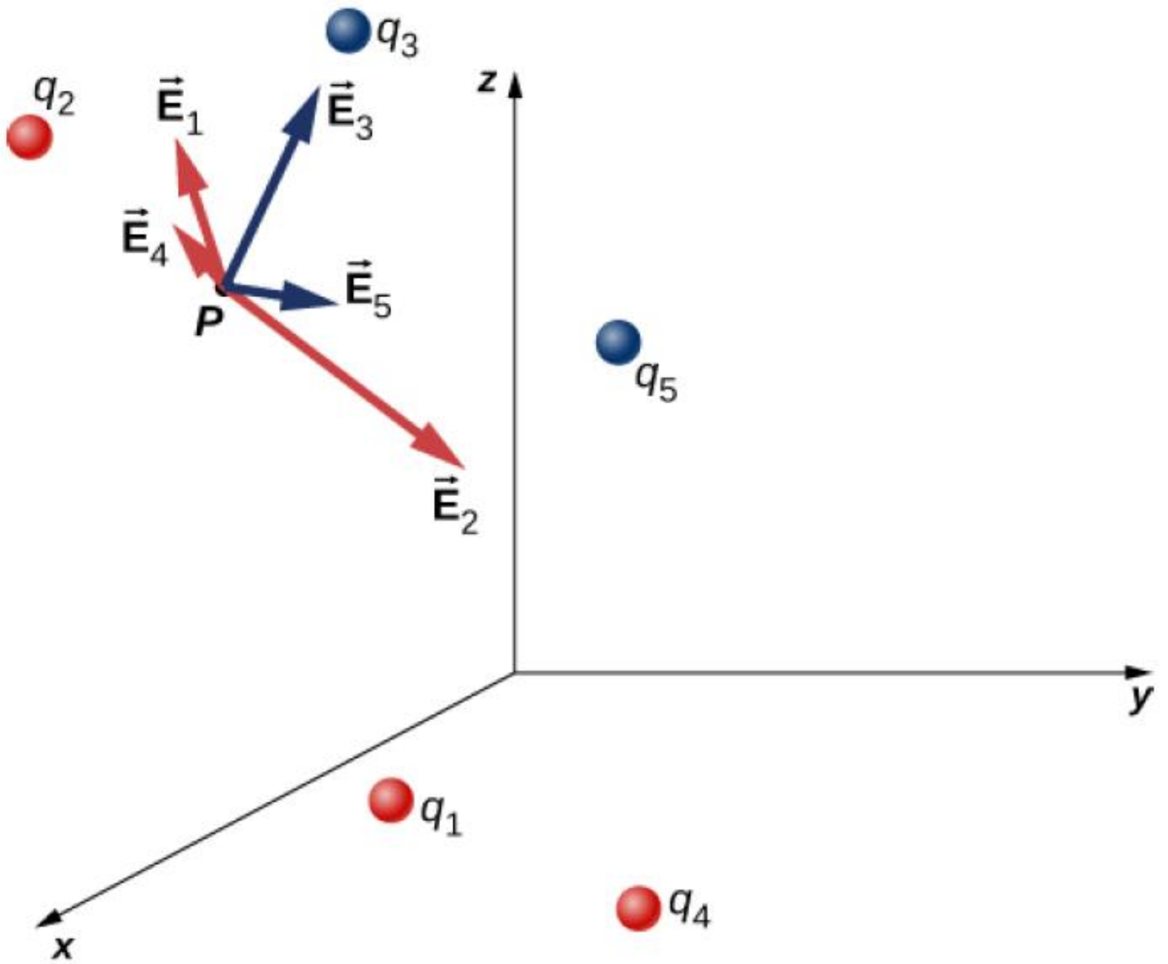
for point test charges only

The electric force on a charged body is exerted by the electric field created by *other* charged bodies.



Superposition of Electric field

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{q_i}{r_i^2}\,\hat{r}$$



- ❑ Treat electric field as a vector quantity
- ❑ q is source charge
- ❑ The test charge is positive

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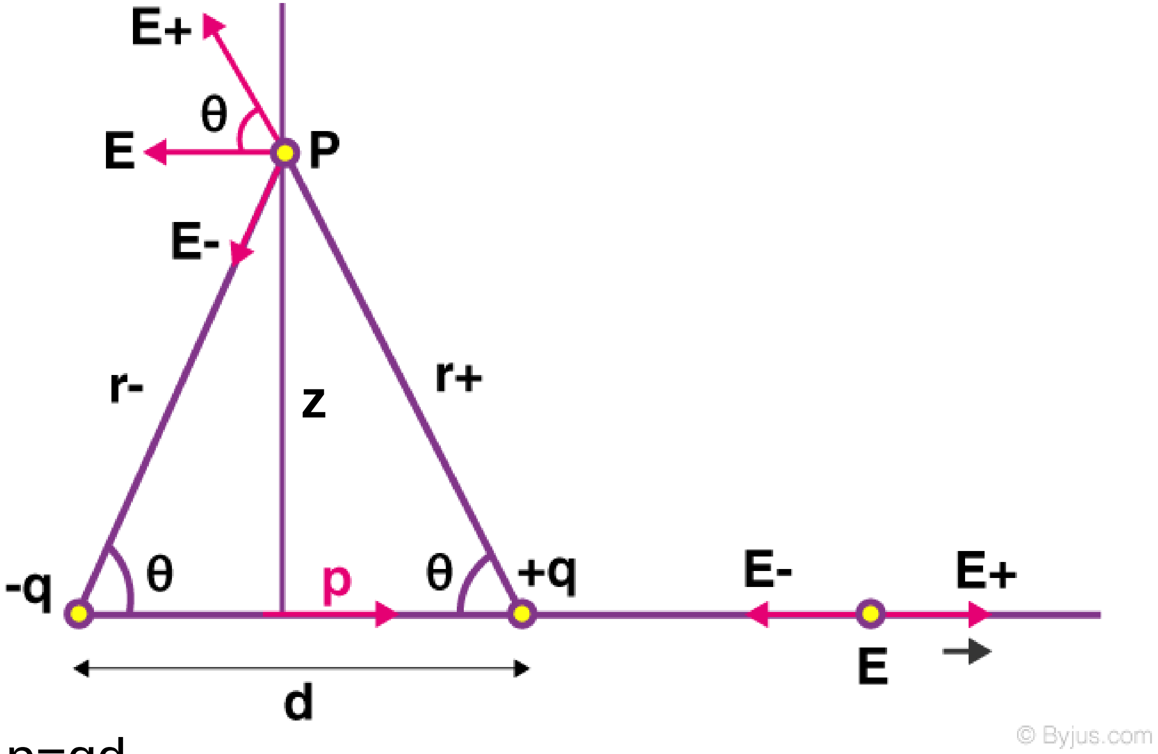
Electric field due to a dipole

Pairs of point charges with equal magnitude and opposite sign are called *electric dipoles*

At any point $$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{p}{z^3}}$$

Along the dipole axis

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{z^3}}$$



Where, dipole moment, p=qd

Example 14.1

21.22 •• Two point charges are placed on the x-axis as follows: Charge $q_1 = +4.00$ nC is located at $x = 0.200$ m, and charge $q_2 = +5.00$ nC is at $x = -0.300$ m. What are the magnitude and direction of the total force exerted by these two charges on a negative point charge $q_3 = -6.00$ nC that is placed at the origin?

Example 14.2

21.14 • A negative charge of $-0.550\ \mu C$ exerts an upward 0.200-N force on an unknown charge 0.300 m directly below it. (a) What is the unknown charge (magnitude and sign)? (b) What are the magnitude and direction of the force that the unknown charge exerts on the $-0.550\text{-}\mu C$ charge?

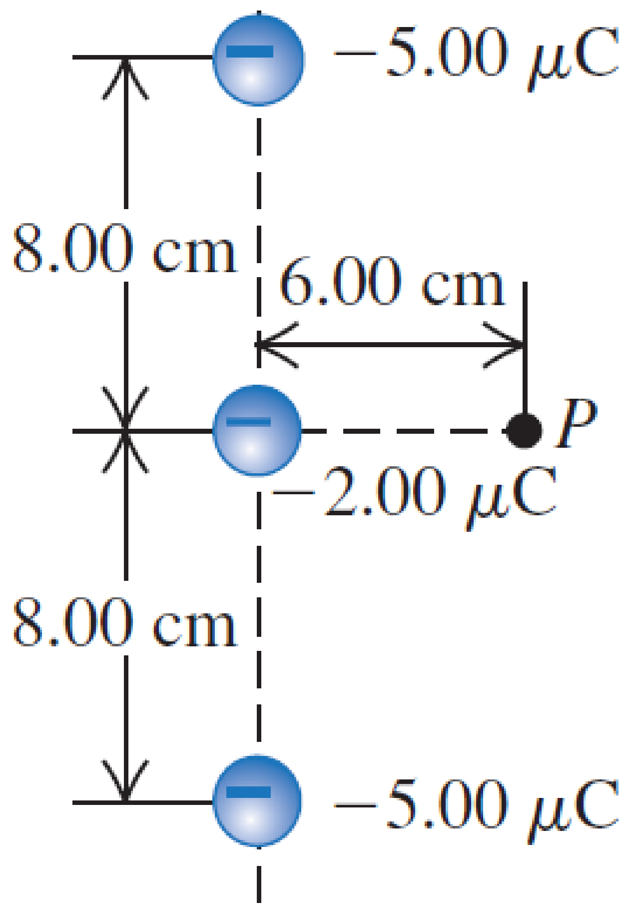
Example 14.3

21.15 •• Three point charges are arranged on a line. Charge $q_3 = +5.00$ nC and is at the origin. Charge $q_2 = -3.00$ nC and is at $x = +4.00$ cm. Charge q_1 is at $x = +2.00$ cm. What is q_1 (magnitude and sign) if the net force on q_3 is zero?

Example 14.4

21.47 • Three negative point charges lie along a line as shown in Fig. E21.47. Find the magnitude and direction of the electric field this combination of charges produces at point *P*, which lies 6.00 cm from the -2.00-μC charge measured perpendicular to the line connecting the three charges.

Figure **E21.47**



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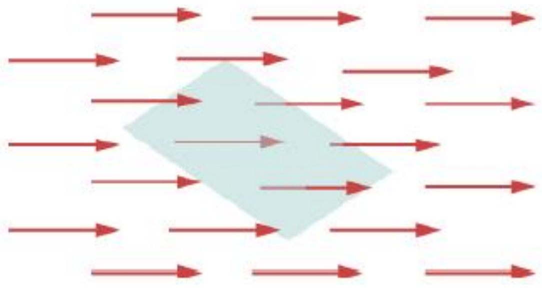
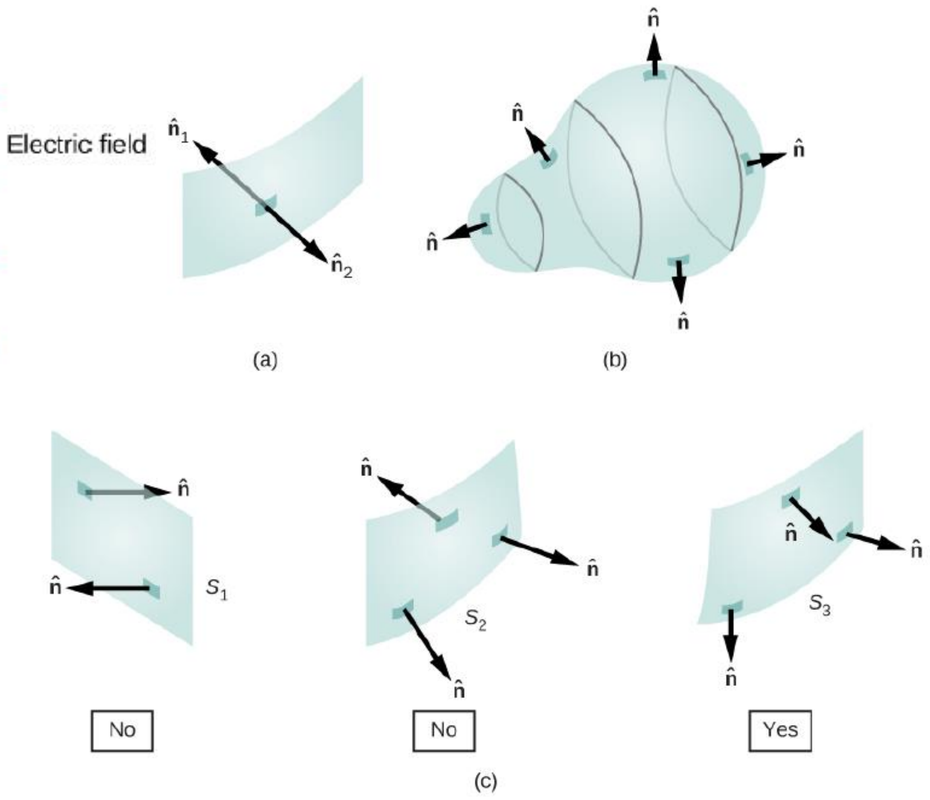
Electric Flux

The concept of **flux** describes how much of something goes through a given area.

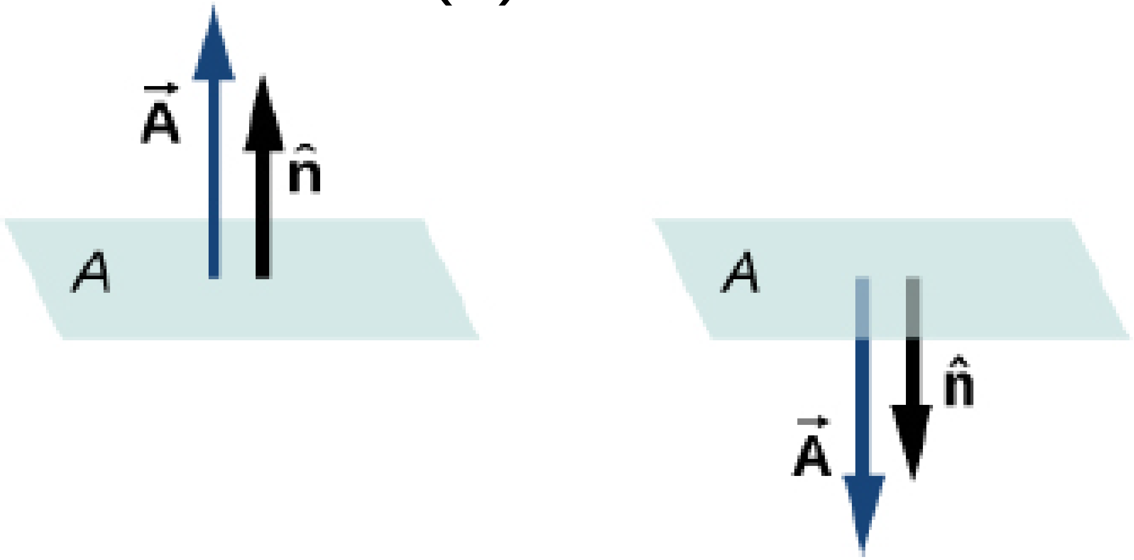
The flux of an electric field as a measure of the number of electric field lines passing through an area





The **area vector** of a flat surface of area A has the following magnitude and direction:

- ❑ Magnitude is equal to area (A)
- ❑ Direction is along the normal to the surface ($\hat{n}$); that is, **perpendicular** to the surface



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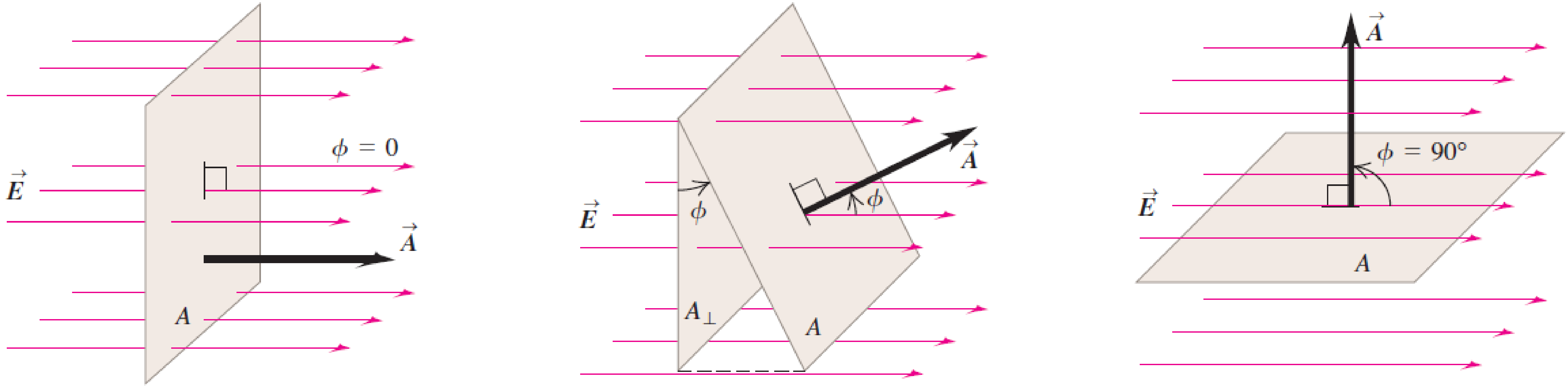
(a) Surface is face-on to electric field:
- $\vec{E}$ and $\vec{A}$ are parallel (the angle between $\vec{E}$ and $\vec{A}$ is $\phi = 0$).
- The flux $\Phi_E = \vec{E} \cdot \vec{A} = EA$.

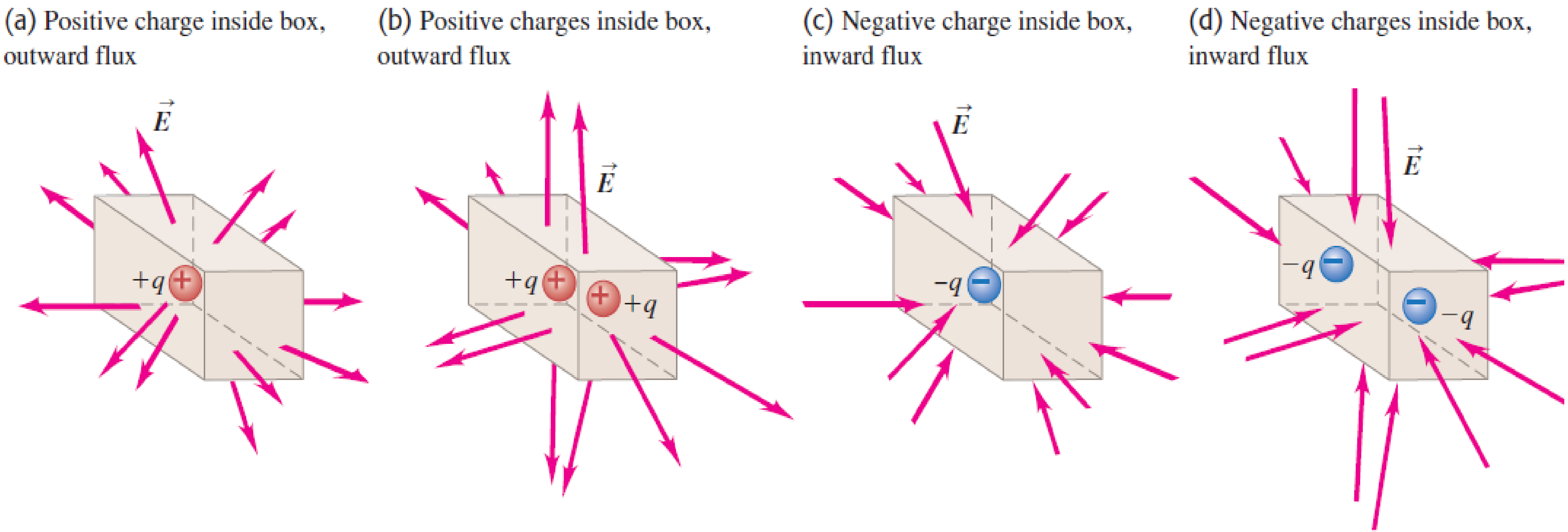
(b) Surface is tilted from a face-on orientation by an angle ϕ:
- The angle between $\vec{E}$ and $\vec{A}$ is ϕ.
- The flux $\Phi_E = \vec{E} \cdot \vec{A} = EA \cos \phi$.

(c) Surface is edge-on to electric field:
- $\vec{E}$ and $\vec{A}$ are perpendicular (the angle between $\vec{E}$ and $\vec{A}$ is $\phi = 90°$).
- The flux $\Phi_E = \vec{E} \cdot \vec{A} = EA \cos 90° = 0$.

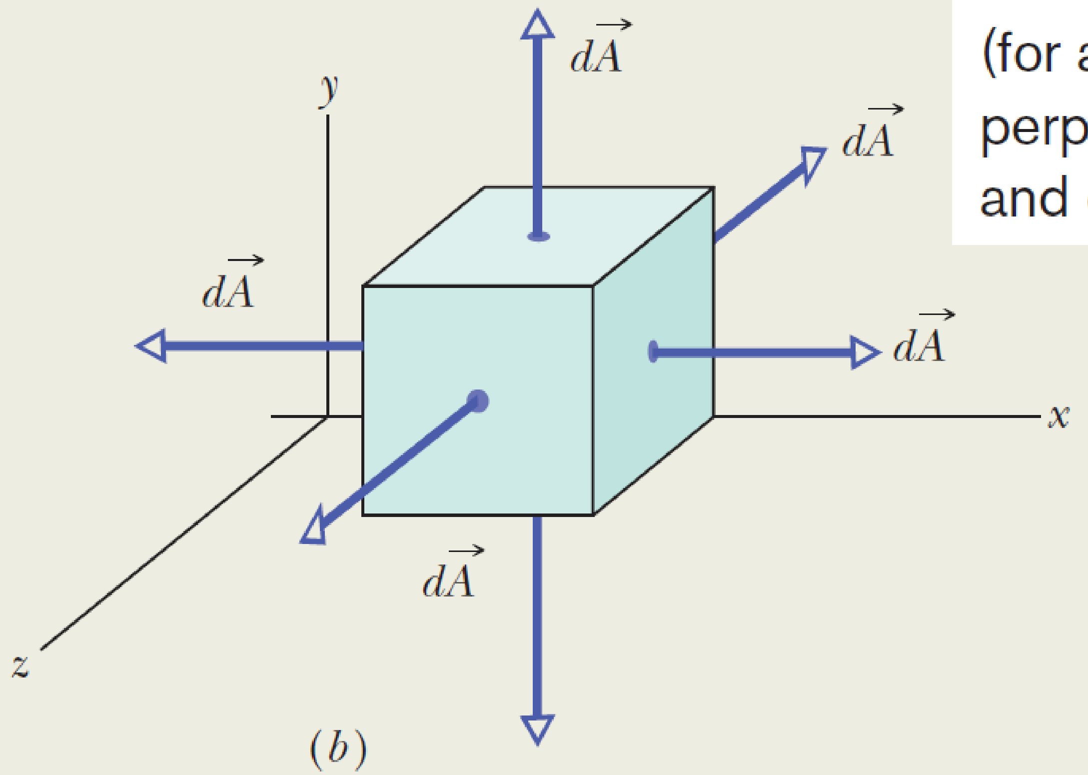


$$\varphi = \vec{E}.\hat{n}A = EA\, cos\varphi$$

Flux in an enclosed space

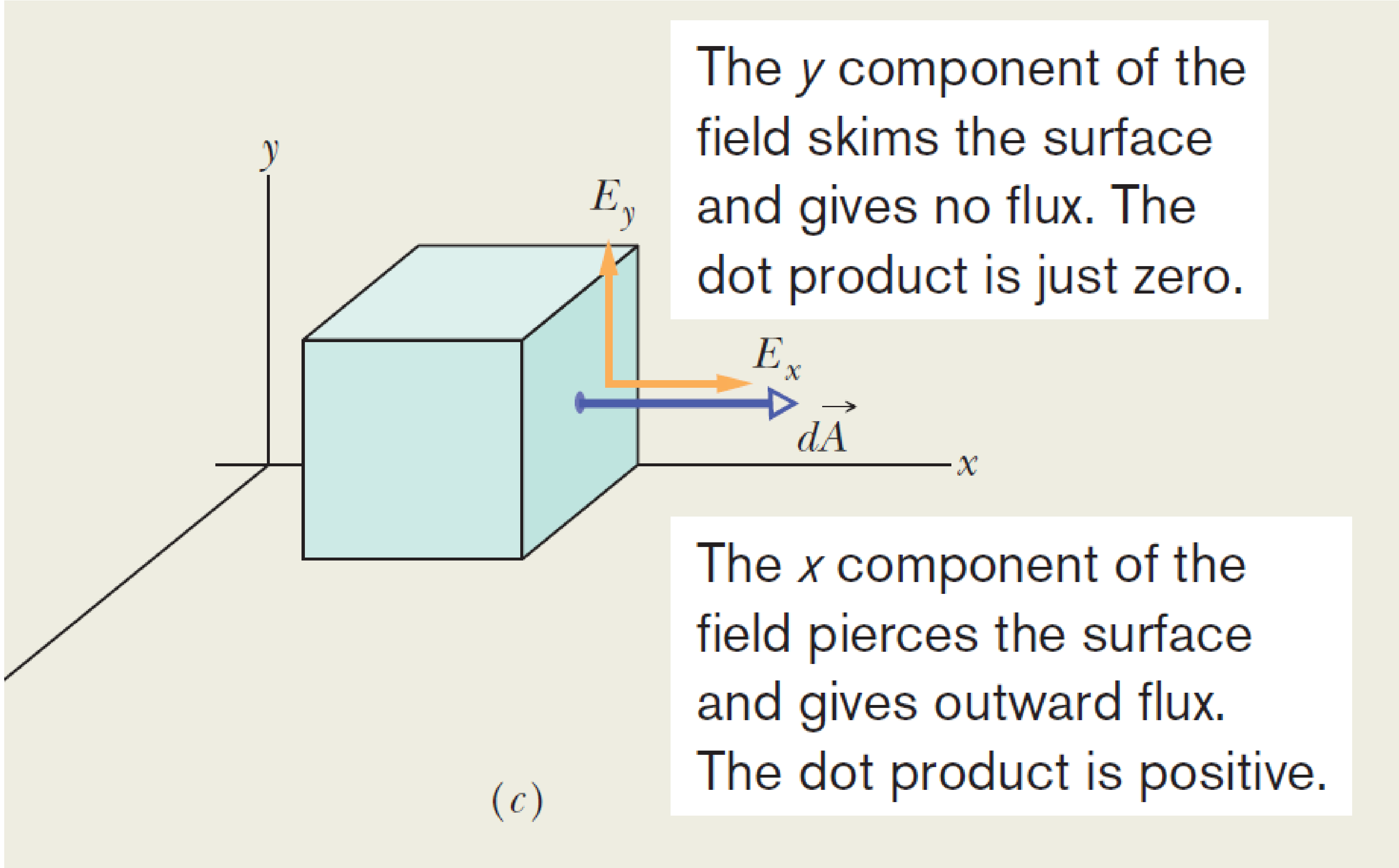


Electric Flux through a Cube

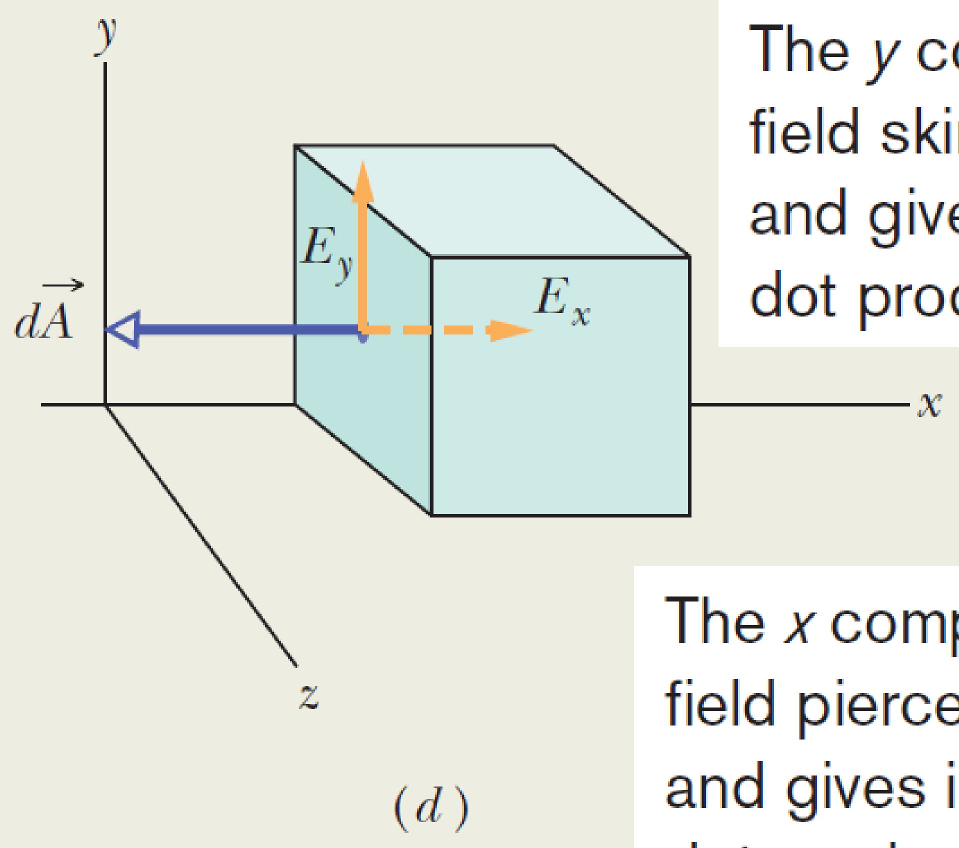


The element area vector (for a patch element) is perpendicular to the surface and outward.

Electric Flux through a Cube



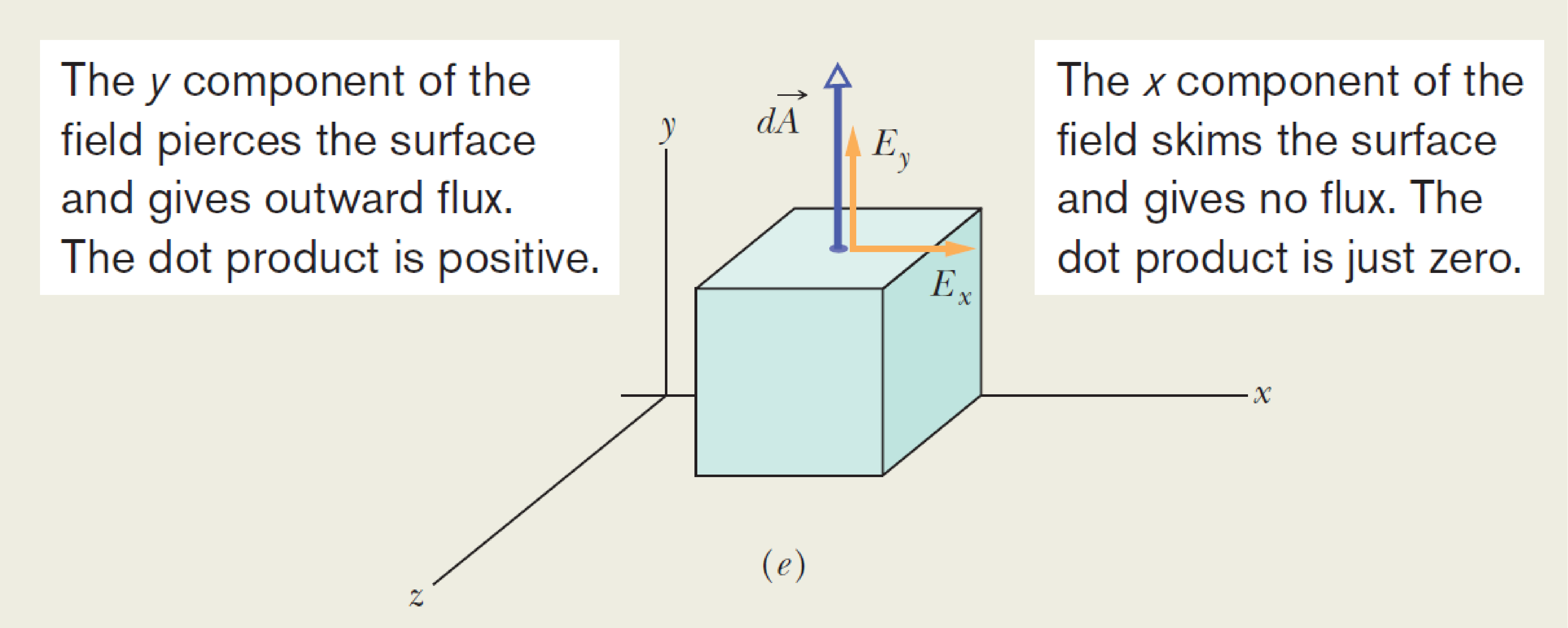
Electric Flux through a Cube



The *y* component of the field skims the surface and gives no flux. The dot product is just zero.

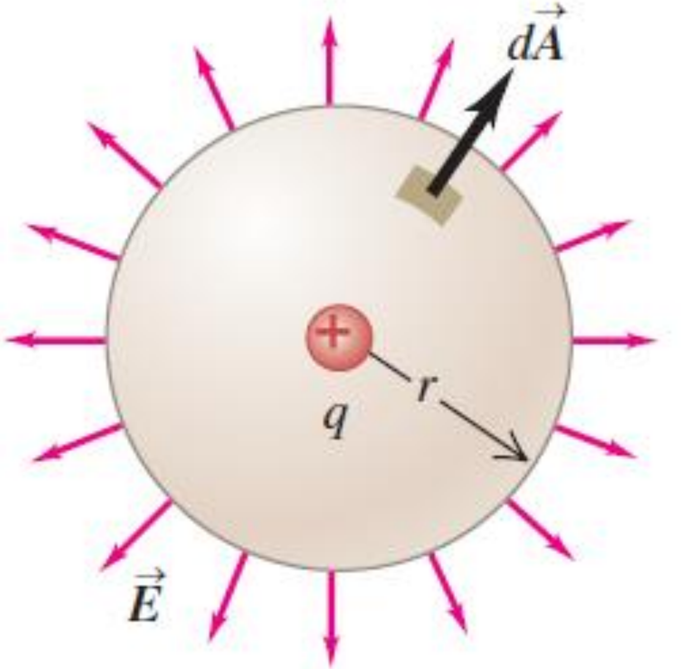
The *x* component of the field pierces the surface and gives inward flux. The dot product is negative.

Electric Flux through a Cube



Example 14.5

A point charge q= +3μC is surrounded by an imaginary sphere of radius r= 0.2m centered on the charge. Find the resulting electric flux through the sphere.



$$\Phi_E = EA = \frac{q}{4\pi\epsilon_0 r^2} 4\pi r^2 = \frac{q}{\epsilon_0}$$

$$= \frac{3.0 \times 10^{-6}\ \mathrm{C}}{8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}} = 3.4 \times 10^5\ \mathrm{N \cdot m^2/C}$$

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