UNIT 4
ELECTRIC FLUX AND GAUSS' LAW

Objectives

- to understand that the area of a flat surface can be represented by a vector

- to understand the concept of electric flux qualitatively and quantitatively

- to understand Gauss' Law qualitatively

Equipment:
        1 sheet of graph paper
        1 index card
        1 box
        2 electric field line models
        1 square loop of wire
        1 protractor
        Excel software

1.1

a. Obtain a sheet of graph paper and an index card.

Determine the area of the graph paper and the index card. Is there a unique way to represent the area of a flat surface by a vector? Which direction would it point? How long would it be? Explain.

b. Obtain a box. Is it possible to represent each surface of the box unambiguously by a vector? Explain your reasoning. Is it possible to represent a flat surface unambiguously by a vector? Explain.

c. Write a rule for representing the area of a surface by a vector.

Discuss your rule with an instructor.

d. Roll the graph paper into a cylinder. Is it now possible to represent the area of the surface by a vector? Explain your reasoning.

e. Could you represent the area of a small box on the graph paper by a vector when it is rolled into a cylinder? Explain.

The area of a flat surface can be represented by a single vector perpendicular to the plane of the surface. The length of the vector is proportional to the area.

1.2 It is useful to define a quantity called electric flux. *Electric flux* is defined as a measure of the number of electric field lines passing through a surface.

a. We can use an arrangement of nails to represent the electric field lines in the center of a parallel plate capacitor. We will represent a surface as the area surrounded by a loop. Obtain two pieces of plywood, with different arrangements of nails and a square loop of wire. The different arrangements of nails represent two different magnitudes of an electric field. Which arrangement represents a stronger electric field? Explain.

b. Place the "surface" of the square loop in the electric field. What does the number of field lines passing through the surface depend on? Explain.

c. Place the surface at different orientations in each of the "fields". Which orientation has the least number of field lines through it? What is the direction of the vector that represents the area of the surface in this case? How does it compare to the direction of the electric field? Which orientation has the greatest number of field lines through it? What is the direction of the vector that represents the area of the surface in this case? How does it compare to the direction of the electric field?

d. For orientations in between those that have the maximum and minimum number of field lines passing through the loop, qualitatively, how does the number of field lines passing through the loop depend on the angle between the vector that represents the area of the surface and the direction of the electric field? Explain.

e. Use the model of the electric field represented by 100 field lines. Use a protractor to measure the angle between the area vector of the surface and the direction of the electric field for the number of field lines in the table below. Record the number of field lines as negative for angles greater than 90°, as in the table. Use Excel to plot the number of field lines vs. the angle in radians. What does the curve look like?

Degrees θ	Radians θ	Number of field lines
		100
		90
		80
		70
		60
		50
		40
		30
		20
		10
		0
		-10
		-20

			-30
			-40
			-50
			-60
			-70
			-80
			-90
			-100

f. Summarize what the number of field lines passing through a surface depends on.

The electric flux through a surface is defined as the magnitude of the electric field times the area of the surface times the cosine of the angle between the direction of the electric field and the area vector of surface

$$\Phi = EA\cos\theta$$

The units of flux are Nm^2/C. Qualitatively, flux is the number of field lines passing through a surface. When the angle between the area vector of the surface and the direction of the electric field is greater than 90°, the flux is negative.

Equipment:
     None

2.1

a. Consider the situations shown below. Each picture contains some charge and an imaginary box. In each case, determine if there is net flux through the box. The total electric flux through the imaginary box is the sum of the electric flux through each surface of the box. Remember that when the angle between the area vector of the surface and the direction of the electric field is greater than 90°, the flux is negative.
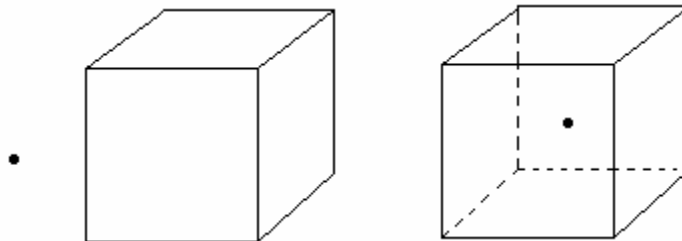
b. Qualitatively, what does the flux through the box depend on? When is there more flux and when is there less flux? When is there zero flux?

Explain your reasoning to an instructor.

Gauss' Law states that the net flux through an enclosed surface is proportional to the amount of charge enclosed by the surface. The constant of proportionality is ε_0. The value of ε_0 is 8.85×10^{-12} $C^2/$ N m^2. This can be written as

$$\Phi_{net} = \frac{q_{enclosed}}{\varepsilon_0}$$

SUMMARY

You should understand that the area of a flat surface can be represented by a vector. You should understand the concept of electric flux qualitatively and quantitatively and understand Gauss' Law qualitatively.