Electric Flux, Surface Integrals, and Gauss's Law

If we know the locations of all electric charges, we can calculate the Electric Field at any point in space through:

\[
\vec{E} = \sum_i \frac{1}{4\pi\varepsilon_0} \frac{q_i}{r_i^2} \hat{r}_i
\]

\[
\vec{E} = \int_{\text{all}} \frac{1}{4\pi\varepsilon_0} \frac{\rho(\hat{r})}{r^2} \hat{r} \, dv
\]

In practice, except for very simple geometries, this is very difficult!

We will avoid this difficulty by using a very clever relationship called Gauss’s Law.

This requires the introduction of 2 critically important concepts:

1. Flux

2. Surface Integrals
Flux is the "Amount of Stuff" going through an Area
Flux Depends on the orientation of the “Area”

\[ A_\perp = A \cos \phi \]
Electric Flux

\[ E = \frac{\Phi}{A} \cos \phi \]

\[ \Phi = \vec{E} \cdot \vec{A} \]

Direction of \( \vec{A} \) is \perp \) to the surface

Magnitude of \( \vec{A} \) is equal to area of surface

\[ \vec{A} = A \hat{n} \]

Total Flux \[ \Phi = \int E \cos \phi \, dA = \int \vec{E}_\perp \, dA = \int \vec{E} \cdot d\vec{A} \]

IMPORTANT: Nothing is really "flowing"
Total Flux From a Point Charge Through a Sphere
\[ \Phi = \oint d\Phi \]

\( \Phi \) \text{ is the total flux through the entire spherical surface}

\[ d\Phi = \vec{E} \cdot d\vec{A} \]

\text{IMPORTANT NOTE: } \Phi \text{ & } d\Phi \text{ are SCALARS}

\( \vec{E} \text{ & } d\vec{A} \text{ are VECTORS} \)

\[ \Phi = \oint_{\text{surface}} \vec{E} \cdot d\vec{A} \]

\[ \vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r} \]

\[ d\vec{A} = \hat{r} dA \]

\[ \Phi = \oint_{\text{surface}} \left( \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \right) \hat{r} \cdot \hat{r} dA \]

\( \hat{r} \) \text{ is a unit vector so } \hat{r} \cdot \hat{r} = (1)(1) \cos(0) = 1

\[ \int dA = A = 4\pi r^2 \text{ is the surface area of a sphere} \]

\[ \Phi = \frac{q}{4\pi\varepsilon_0 r^2} \]

\[ \Phi = \frac{q}{\varepsilon_0} \]
**Strategy for the evaluation of surface integrals**

1. Carefully set up the problem

\[ \Phi = \oint_{\text{surface}} d\Phi \]

\( \Phi \) is the total flux through the entire spherical surface

\( d\Phi \) is the differential flux through the infinitesimal area

\[ d\Phi = \vec{E} \cdot d\vec{A} \]

**IMPORTANT NOTE:** \( \Phi \) & \( d\Phi \) are SCALARS

\( \vec{E} \) & \( d\vec{A} \) are VECTORS

\[ \Phi = \oint_{\text{surface}} \left( \frac{1}{4\pi \varepsilon_0} \frac{q}{r^2} \right) \hat{r} \cdot d\vec{A} \]

\( \hat{r} \) is a unit vector so \( \hat{r} \cdot \hat{r} = (1)(1)\cos(0) = 1 \)

\[ \oint_{\text{surface}} d\vec{A} = A = 4\pi r^2 \]

is the surface area of a sphere

\[ \Phi = \frac{q}{4\pi \varepsilon_0} \]

\[ \int_{\text{surface}} \vec{E} \cdot d\vec{A} = \frac{1}{4\pi \varepsilon_0} \frac{q}{r^2} \hat{r} \cdot d\vec{A} \]

\[ \Phi = \oint_{\text{surface}} d\Phi \]

\( \Phi \) is the total flux through the entire spherical surface

\[ d\Phi = \vec{E} \cdot d\vec{A} \]
Strategy for the evaluation of surface integrals

1. Carefully set up the problem

2. Write down expressions for the vector quantities

\[ \Phi = \int_{\text{surface}} d\Phi \]

\( \Phi \) is the total flux through the entire spherical surface

\( d\Phi \) is the differential flux through the infinitesimal area

\[ d\Phi = \vec{E} \cdot d\vec{A} \]

**IMPORTANT NOTE:** \( \Phi \) & \( d\Phi \) are SCALARS

\( \vec{E} \) & \( d\vec{A} \) are VECTORS

\[ \Phi = \int_{\text{surface}} \left( \frac{1}{4\pi \varepsilon_0 \ r^2} \right) \hat{r} \cdot \hat{r} dA \]

\( \hat{r} \) is a unit vector so \( \hat{r} \cdot \hat{r} = (1)(1) \cos(0) = 1 \)

\[ \Phi = \frac{q}{4\pi \varepsilon_0 \ r^2} \int_{\text{surface}} dA \]

\[ \int_{\text{surface}} dA = A = 4\pi r^2 \] is the surface area of a sphere

\[ \Phi = \frac{q}{\varepsilon_0} \]
**Strategy for the evaluation of surface integrals**

1. Carefully set up the problem

2. Write down expressions for the vector quantities

3. Make substitution

\[ \Phi = \iint_{\text{surface}} d\Phi \]

\( \Phi \) is the total flux through the entire spherical surface

\( d\Phi \) is the differential flux through the infinitesimal area

\[ d\Phi = \vec{E} \cdot d\vec{A} \]

**IMPORTANT NOTE:** \( \Phi \) & \( d\Phi \) are SCALARS

\( \vec{E} \) & \( d\vec{A} \) are VECTORS

\[ \Phi = \iiint_{\text{surface}} \left( \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \right) \hat{r} \cdot \hat{r} dA \]

\( \hat{r} \) is a unit vector so \( \hat{r} \cdot \hat{r} = 1 \)

\[ \vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r} \]

\[ d\vec{A} = \hat{r} dA \]

\[ \int dA = A = 4\pi r^2 \]

is the surface area of a sphere

\[ \Phi = \int \frac{q}{4\pi\varepsilon_0} \frac{1}{r^2} 4\pi r^2 \]

\[ \Phi = \frac{q}{\varepsilon_0} \]
Strategy for the evaluation of surface integrals

1. Carefully set up the problem

2. Write down expressions for the vector quantities

3. Make substitution

4. Use symmetry to simplify

Φ is the total flux through the entire spherical surface

\( d\Phi = \vec{E} \cdot d\vec{A} \)

**IMPORTANT NOTE:** Φ & \( d\Phi \) are SCALARS

\( \vec{E} \) & \( d\vec{A} \) are VECTORS

Φ is the total flux through the entire spherical surface

\( \Phi = \int \vec{E} \cdot d\vec{A} \)

\( \Phi = \int_{\text{surface}} \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r} \cdot \hat{r} dA \)

\( \Phi = \frac{q}{4\pi\varepsilon_0} \frac{1}{r^2} 4\pi r^2 \)

\( \Phi = \frac{q}{\varepsilon_0} \)

\( \hat{r} \) is a unit vector so \( \hat{r} \cdot \hat{r} = (1)(1)\cos(0) = 1 \)

\( \int dA = A = 4\pi r^2 \) is the surface area of a sphere
Using Symmetry

Both the Electric Field AND the spherical surface have the same symmetry, that is they both look the same following a rotation about any axis that goes through the center of the sphere.

Because they both have the same symmetry, it is possible to easily convert the potentially surface integral to an easy to evaluate simple integral.

This use of symmetry will be critical when we evaluate surface integrals in real problems.
Strategy for the evaluation of surface integrals

1. Carefully set up the problem

2. Write down expressions for the vector quantities

3. Make substitution

4. Use symmetry to simplify

5. Evaluate integral, do algebra

\[
\Phi = \int \mathbf{E} \cdot d\mathbf{A} \\
\Phi \text{ is the total flux through the entire spherical surface} \\
d\Phi \text{ is the differential flux through the infinitesimal area} \\
\Phi = \mathbf{E} \cdot d\mathbf{A} \\
\]

IMPORTANT NOTE: \( \Phi \) & \( d\Phi \) are SCALARS \\
\( \mathbf{E} \) & \( d\mathbf{A} \) are VECTORS

\[
\Phi = \int \mathbf{E} \cdot d\mathbf{A} \\
\Phi = \int \left( \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \right) \hat{r} \cdot d\mathbf{A} \\
\Phi = \left( \frac{q}{4\pi\varepsilon_0} \frac{1}{r^2} \right) \int d\mathbf{A} \\
\Phi = \left( \frac{q}{4\pi\varepsilon_0} \right) \frac{1}{r^2} 4\pi r^2 \\
\Phi = \frac{q}{4\pi\varepsilon_0} \\
\]

\[
\int d\mathbf{A} = A = 4\pi r^2 \quad \text{is the surface area of a sphere} \\
\int \mathbf{E} \cdot d\mathbf{A} = \Phi = \frac{q}{\varepsilon_0} \\
\]

\( \hat{r} \) is a unit vector so \( \hat{r} \cdot \hat{r} = (1)(1)\cos(0) = 1 \)
Total Flux is Independent of the Radius of the Sphere

\[ \Phi = \frac{q}{\varepsilon_0} \]

Electric field decreases as \(1/r^2\) but
Area increases as \(r^2\)
Total Flux is Independent of the "Shape" of the "Sphere"

Electric field decreases as $1/r^2$
but area increases as $r^2$

AND

Area of $dA$ increases with $\phi$
But $\cos \phi$ decreases with $\phi$
There is NO total flux for a charge outside the closed surface.

Any Electric Field line that enters, must leave somewhere else!
There is no TOTAL Flux for a Charge OUTSIDE a closed surface

Every Electric Field Line That Enters, Must Leave Somewhere Else!
The same arguments hold for positive and negative charges.

(a) Gaussian surface around positive charge: positive (outward) flux

(b) Gaussian surface around negative charge: negative (inward) flux
GAUSS’S LAW

\[ \Phi_E = \oint_{\text{closed surface}} \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enclosed}}}{\varepsilon_0} \]

The total electric flux through a closed Surface is equal to \(1/\varepsilon_0\) times the total (net) electric charge inside the surface.
Using Gauss’s Law to Determine the Electric Field of a Charged Plane

A cylindrical Gaussian surface is used to find the field of an infinite plane sheet of charge.
Using Gauss’s Law to Determine the Electric Field of a Charged Plane

\[ E_\perp = E \]

Gaussian surface
Plane of Charge has surface charge density

$\sigma = \frac{\text{charge}}{\text{unit area}}$

Symmetry implies that the field is everywhere perpendicular to the plane

$$\Phi = \oint \vec{E} \cdot d\vec{A} = \oint E_\perp dA = \frac{Q_{\text{enclosed}}}{\varepsilon_0}$$

$$\Phi = \oint E_\perp dA = \oint E_\perp dA + \oint E_\perp dA = \frac{Q_{\text{enclosed}}}{\varepsilon_0}$$

$$\Phi = 2E \oint dA + 0 = \frac{\sigma A}{\varepsilon_0}$$

$$2EA = \frac{\sigma A}{\varepsilon_0}$$

$$E = \frac{\sigma}{2\varepsilon_0}$$

Magnitude of $E$ is independent of position

$E_\perp = E$

$E$ is uniform over end cap

$\vec{E} \cdot d\vec{A} = 0$ over the cylinder

$\int dA = A$
Example: Conducting Parallel Plates (See Y&F Example 22.8)

Two large parallel conducting plates are given charges of equal magnitude and opposite sign; the charge per unit area is $+\sigma$ for one and $-\sigma$ for the other. Determine where the charges are located and what the fields everywhere.

NOTE: It is important to note that the actual electric field will have a complicated shape at the edges of the plates.

We will ordinarily disregard these “Fringing Fields” when we do electric field calculations. Sometimes we assume the plates are “infinite” or we assume the size of the plate is much, much bigger than the separation.
Strategy for Solution of Gauss’s Law Problems:

Use a succession of Gaussian Surfaces. Start with fields or charges you know. Use this information to “bootstrap” your way along to learn about the fields or charges you don’t know.

**Important Note:** The symmetry of the problem implies that the component of the electric field perpendicular to the plates must be zero.

\[
\oint E \cdot dA = \frac{Q_{\text{enclosed}}}{\varepsilon_0}
\]
**Question #1: What is the Electric Field Outside the Plates?**

**Observation:** Because the charge densities are equal and opposite, the total charge will be zero if the surface encloses equal area of both plates

Pick Surface #1 to enclose both plates

Contribution from “c” is zero because field must be parallel to surface and dot product is zero

Total charge inside is zero because of cancellation of + and – charges.

\[ \oint_{\text{surface #1}} \vec{E} \cdot d\vec{A} = E_{\text{outside left}} A_a + E_{\text{outside right}} A_b + 0 = 0 \]

\[ E_{\text{outside left}} + E_{\text{outside right}} = 0 \]

Area \( a \) equals area \( b \)

Symmetry of system tells us the magnitudes of the fields outside are equal.

\[ E_{\text{outside left}} = E_{\text{outside right}} = 0 \]
**Question #2: What is the Charge on the Outside Surface of the Plates?**

**Observation:** We know that the field outside the plates is zero from previous step. We know the field inside the conductor is zero.

**Pick Surface #1 to pass through regions where we know E=0**

Contribution from “c” is zero because field must be parallel to surface and dot product is zero

\[
\oint_{\text{surface#1}} \vec{E} \cdot d\vec{A} = E_{\text{outside \ left}} A_a + E_{\text{inside \ conductor}} A_b + 0 = \frac{Q_{\text{enclosed}}}{\varepsilon_0}
\]

\[
E_{\text{outside \ left}} + E_{\text{inside \ conductor}} = 0 = Q_{\text{enclosed}} \quad \text{Area a equals area b}
\]

\[
Q_{\text{enclosed}} = 0
\]

**Conclusion: No charge on outside surfaces of Conductors**

**ALL CHARGE IS ON INSIDE SURFACE OF CONDUCTORS!**
**Question #3: What is the Electric Field Between the Plates?**

Pick Surface #3 to have surface $b$ in the region between the plates and surface $a$ in a region of zero field.

\[
\oint_{\text{surface #1}} \vec{E} \cdot d\vec{A} = E_{\text{inside conductor}} A_a + E_{\text{between plates}} A_b = \frac{Q_{\text{enclosed}}}{\varepsilon_0}
\]

Total charge is equal to area times areal density.

\[
E_{\text{between plates}} = \frac{\sigma}{\varepsilon_0}
\]
Field Inside a Conductor

Add Charge $Q$

Evaluate $\int \mathbf{E} \cdot d\mathbf{A}$ over an arbitrary Gaussian Surface

Remember — Electric Field Inside a Conductor is zero

$\int \mathbf{E} \cdot d\mathbf{A} = 0 = \frac{Q_{\text{enclosed}}}{\varepsilon_0}$

$Q_{\text{enclosed}} = 0$ inside ANY Conductor!

Where did the Charge go?

IT'S ALL ON THE SURFACE!!
Sample Problem

Conductor Originally Neutral

What is the Field?
Where are the Charges?

Conductor

Gaussian Surface

STEP 1 -

\[ \oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q_1}{\varepsilon_0} \]

By symmetry, \( E_z = E = \text{constant} \)

\[ \mathbf{E} \cdot d\mathbf{A} = \frac{Q_1}{2\pi r} \]

Area of surface

\[ E = \frac{Q_1}{4\pi \varepsilon_0 r^2} \quad \text{For } r \gg a \]
**Step 2**

**Gaussian Surface**

\[ \sigma < r < b \]

\[ \oint E \cdot dA = \frac{Q_{\text{total}}}{\varepsilon_0} \]

\[ E \cdot 4\pi r^2 = \frac{Q_{\text{total}}}{\varepsilon_0} \]

**But** \( E = 0 \) **inside a conductor**!

\[ 0 = \frac{Q_{\text{total}}}{\varepsilon_0} = Q_{\text{total}} = 0 \]

**But** \( Q_{\text{total}} = Q_1 + \sum \text{charge on inside surface of conductor} \)

\[ Q_{\text{inside surface}} = -Q_1 \]

\[ \int_{\text{inside surface}} = \frac{Q_{\text{inside surface}}}{\text{Area (inside surface)}} = -\frac{Q_1}{4\pi a^2} \]

\[ J = \frac{-Q_1}{4\pi a^2} \]
**Step 3**

**Gaussian Surface**

$\mathbf{b < r}$

**TOTAL CHARGE** = $Q_1 + \text{Total Charge on Conductor}$

**Field Outside** is

$$E = \frac{Q_1}{4\pi\varepsilon_0 r^2}$$

**Surface charge density on outside** is

$$\sigma = \frac{Q_1}{4\pi b^2}$$
A solid metal sphere of radius $a = 1.30 \, \text{cm}$ is surrounded by a concentric spherical metal shell of inner radius $b = 1.90 \, \text{cm}$ and outer radius $c = 2.40 \, \text{cm}$. The inner sphere has net charge $Q_1 = 3.80 \, \text{microCoulombs}$, and the outer spherical shell has net charge $Q_2 = -7.10 \, \text{microCoulombs}$.

What is the radial component of the electric field $E_r$ at a point located at radius $r = 1.60 \, \text{cm}$, i.e. between the two conductors? ($E_r$ is positive if $E$ points outward, negative if $E$ points inward.)

\[ \int_{\text{sphere}} E \cdot d\mathbf{r} = \frac{Q}{\varepsilon_0} \]

\[ 4\pi r^2 E(r) = \frac{Q_{\text{inner sphere}}}{\varepsilon_0} \]

\[ E(r) = \frac{Q_{\text{inner sphere}}}{4\pi \varepsilon_0 r^2} \]
A solid metal sphere of radius \( a = 1.30 \text{ cm} \) is surrounded by a concentric spherical metal shell of inner radius \( b = 1.90 \text{ cm} \) and outer radius \( c = 2.40 \text{ cm} \). The inner sphere has net charge \( Q_1 = 3.80 \text{ microCoulombs} \), and the outer spherical shell has net charge \( Q_2 = -7.10 \text{ microCoulombs} \).

9. [1pt] What is the surface charge density, \( \sigma_b \), on the inner surface of the outer spherical conductor?

\[
Q(\text{surface } b) + Q_1 = 0
\]

\[
\sigma = \frac{-Q_1}{4\pi b^2}
\]

This surface is inside a conductor so \( E = 0 \) so \( \int E \cdot d\mathbf{A} = 0 \)

So \( Q_{\text{inside}} = 0 \)

All charge must be on surface
A solid metal sphere of radius \( a = 1.30 \text{ cm} \) is surrounded by a concentric spherical metal shell of inner radius \( b = 1.90 \text{ cm} \) and outer radius \( c = 2.40 \text{ cm} \). The inner sphere has net charge \( Q_1 = 3.80 \text{ microCoulombs} \), and the outer spherical shell has net charge \( Q_2 = -7.10 \text{ microCoulombs} \).

10. [1pt]

What is the surface charge density, \( \sigma_c \), on the outer surface of the outer spherical conductor?

\[
\text{Total Charge on outer sphere is } Q_2 \\
\text{Charge on inner surface is } -Q_1 \\
\text{Charge on outer surface is } Q_2 - (-Q_1) = Q_2 + Q_1 \\
\text{Surface Density is } \frac{Q_2 + Q_1}{4\pi c^2}
\]
Using Gauss's Law to determine the Electric Field from a line Charge

\[ E_\perp = E \]

Gaussian surface

\[ E_\perp = 0 \]
Plane of Charge has surface charge density

\[ \lambda = \frac{\text{charge}}{\text{unit length}} \]

Symmetry implies that the field is everywhere perpendicular to the line charge

\[ \Phi = \oint \vec{E} \cdot d\vec{A} = \int E_\perp dA = \frac{Q_{\text{enclosed}}}{\varepsilon_0} \]

\[ \Phi = \int_{\text{caps}} E_\perp dA + \int_{\text{cylinder}} E_\perp dA = \frac{Q_{\text{enclosed}}}{\varepsilon_0} \]

\[ \Phi = 0 + E(r) \int_{\text{cylinder}} dA = \frac{\lambda l}{\varepsilon_0} \]

\[ E(r) \cdot 2\pi r \cdot l = \frac{\lambda l}{\varepsilon_0} \]

\[ E(r) = \frac{1}{2\pi \varepsilon_0} \frac{\lambda}{r} \]

For cylindrical geometry, \( E \) falls off as \( 1/r \)
Go back to our sphere problem.

Put charge $\infty$ into a sphere.

Net effect is to change the OUTSIDE of the SPHERE!
How to Build up a "Big" Charge

1) Rub comb against hair to get a charge

2) Touch comb against inside of metal sphere — All charge goes to outside

3) Repeat
Fig. 11. The giant Van de Graaff high-voltage generator in its airship-dock laboratory near New Bedford, Massachusetts. (Courtesy of Professor Van de Graaff.)
5. [1pt]
Consider a spherical CONDUCTING shell with NO NET CHARGE, with a point charge, \( +Q \), placed at its center. (For each statement select T True, F False).

A) The electric field at \( c \) is zero.
B) The electric field at \( e \) is zero.
C) The inner surface of the shell carries a charge \( -Q \).
D) The electric field at \( a \) is zero.
A) C is inside a conductor → Electric Field is zero

B) Imagine a Gaussian Sphere that goes through point e. The net charge inside that sphere will be +Q (Conducting sphenical shell has no net change)

\[ \int_{\text{sphere}} \vec{E} \cdot d\vec{a} = \frac{Q}{\epsilon_0} \neq 0 \quad E_e \neq 0 \]

C) A Gaussian sphere of radius just inside the conductor, \( E = 0 \) so total Q inside of sphere is zero. So charge on inside of shell must be equal and opposite to charge Q. Inner surface has change -Q

D) Gaussian sphere around a encloses charge Q

\[ E_a \neq 0 \]
Chapter 22 Summary

Electric flux is a measure of the “flow” of electric field through a surface. It is equal to the product of an area element and the perpendicular component of $\vec{E}$, integrated over a surface.
(See Examples 22.1 through 22.3)

\[
\Phi_E = \int E \cos \phi \, dA
= \int E_{\perp} \, dA = \int \vec{E} \cdot d\vec{A}
\]  
(22.5)

Gauss’s law states that the total electric flux through a closed surface, which can be written as the surface integral of the component of $\vec{E}$ normal to the surface, equals a constant times the total charge $Q_{\text{encl}}$ enclosed by the surface.
Gauss’s law is logically equivalent to Coulomb’s law, but its use greatly simplifies problems with a high degree of symmetry.
(See Examples 22.4 through 22.10)

\[
\Phi_E = \oint E \cos \phi \, dA
= \oint E_{\perp} \, dA = \oint \vec{E} \cdot d\vec{A}
= \frac{Q_{\text{encl}}}{\varepsilon_0}
\]  
(22.8), (22.9)
When excess charge is placed on a conductor and is at rest, it resides entirely on the surface, and $\vec{E} = 0$ everywhere in the material of the conductor. (See Examples 22.11 through 22.13)

The following table lists electric fields caused by several symmetric charge distributions. In the table, $q$, $Q$, $\lambda$, and $\sigma$ refer to the magnitudes of the quantities.

<table>
<thead>
<tr>
<th>Charge Distribution</th>
<th>Point in Electric Field</th>
<th>Electric Field Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single point charge $q$</td>
<td>Distance $r$ from $q$</td>
<td>$E = \frac{1}{4\pi \varepsilon_0} \frac{q}{r^2}$</td>
</tr>
<tr>
<td>Charge $q$ on surface of conducting sphere with radius $R$</td>
<td>Outside sphere, $r &gt; R$</td>
<td>$E = \frac{1}{4\pi \varepsilon_0} \frac{q}{r^2}$</td>
</tr>
<tr>
<td></td>
<td>Inside sphere, $r &lt; R$</td>
<td>$E = 0$</td>
</tr>
<tr>
<td>Infinite wire, charge per unit length $\lambda$</td>
<td>Distance $r$ from wire</td>
<td>$E = \frac{1}{2\pi \varepsilon_0} \frac{\lambda}{r}$</td>
</tr>
</tbody>
</table>
End of Chapter 22

You are responsible for the material covered in T&F Sections 22.1-22.5

You are expected to:

• Understand the following:
  Electric Flux, Vector Area, Gauss’s Law

• Be able to perform surface integrals in simple geometries (planes, spheres, cylinders, lines, etc..)

• Be able to apply Gauss’s Law for simple geometries using surfaces with appropriate symmetry.

• Be able to apply Gauss’s Law in cases where charged and uncharged conductors and insulators are involved.

• Be able to reconstruct the reasoning used in examples 22.3 through 22.10

Recommended F&Y Exercises chapter 22:
1, 16, 23, 25, 29