

Topic 2 - Electric Fields

2.1.4	Apply the relationship between the electric field E, the electric force F and the charge q in numerical problems. $\vec{E} = \vec{F}/q$
2.2.2	Explain electric field lines, including where they originate and terminate and what their spacing represents.
2.2.5	Identify the direction of the electric force vector $\vec{F}$ resulting from placing a positive or negative charged particle in an electric field or other charged particles
2.2.6	Sketch an electric-field diagram of a single point charge, a dipole, or a collection of static point charges
2.3.1	For a given point in the electric field of a charged particle, apply the relationship between the field magnitude E , the charge magnitude q , and the distance r between the point and the particle ($E = kq/r^2$)
2.3.3	Solve problems related to the electric field due to a charged particle.
2.4.2	Calculate the total charge contained in lines, surfaces, or volumes when given a linear-charge density, a surface-charge density, or a volume-charge density of the charge configuration. (Identify the equations)
2.5.1	Apply the relationship ($F = qE$) to find the electric force on a charged particle of charge q , placed in an external electric field (a field due to other charged objects), and identify the relative directions of the force and the field when the particle is positively charged and negatively charged

2.5.2	Solve problems related to a point charge in an electric field
2.6.1	Define electric flux ϕ as the amount of electric field piercing a surface (not skimming along the surface) of area A.
2.6.4	For a closed surface, explain the algebraic signs associated with inward flux and outward flux.
2.6.5	Calculate the net flux ϕ through a surface by integrating the dot product of the electric field vector $\vec{E}$ and the area vector $d\vec{A}$ (for patch elements) over the surface
2.7.2	Apply Gauss' law to relate the net flux ϕ through a closed surface (real or imaginary) to the net charge q_{enc} enclosed by the surface.
2.7.3	Show how the algebraic sign of the net enclosed charge corresponds to the direction (inward or outward) of the net flux through a Gaussian surface.
2.7.4	Explain why a charge outside a Gaussian surface makes no contribution to the net flux through the closed surface.
2.7.8	Explain electrostatic shielding (from external fields) by conductors.
2.7.9	Identify that the electrostatic field inside any isolated conductor is always zero.
2.7.10	Explain how cavities inside conductors are shielded from electric fields- electrostatic shielding
2.8.14	Apply Gauss's law to find the electric field inside and outside a uniformly charged solid insulating and solid conducting sphere.
2.8.15	Identify that the electric field inside a closed conductor is zero.
2.8.16	Identify that the electric field outside a spherical distribution of charge is the same as the field of a point charge with the same total charge located at the sphere's center
2.8.17	Determine the charge on the cavity wall and on the external surface for a conductor with a cavity that contains a charged object.

2.1.4	Apply the relationship between the electric field E , the electric force F and the charge q in numerical problems. $\vec{E} = \vec{F}/q$
2.2.2	Explain electric field lines , including where they originate and terminate and what their spacing represents .

originate : begin
terminate : end

2.1.4

The electric field (E) created by a point charge q is given by:

$$E = F/Q$$

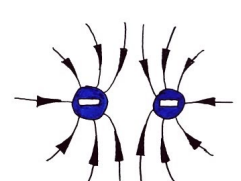
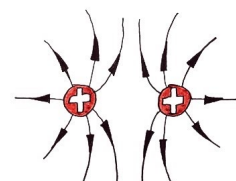
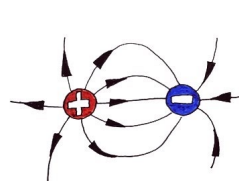
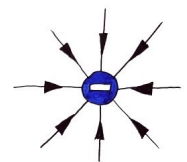
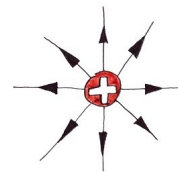
Where:

- E = magnitude of the electric field
- F = magnitude of the force exerted by the charge
- q = magnitude of the charge creating the electric field

2.2.2

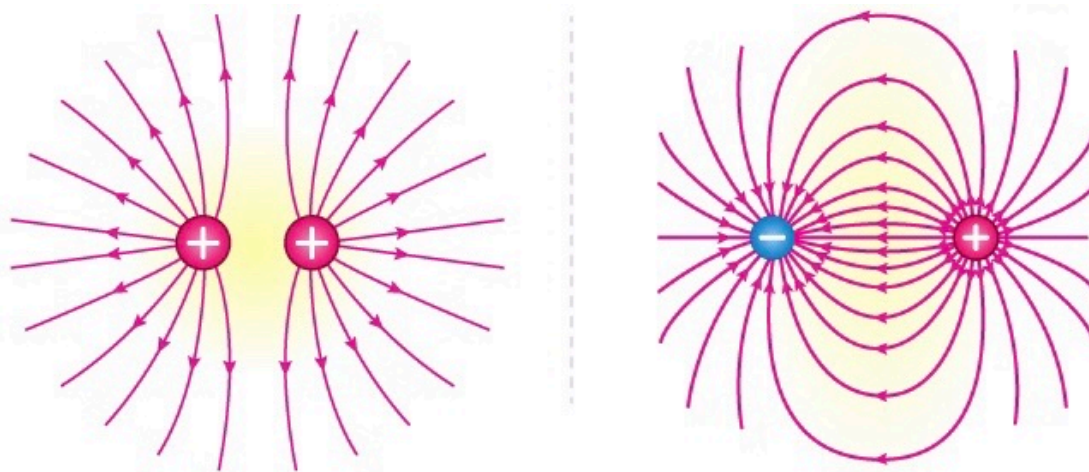
①

Electric field lines are a **visual representation** used to illustrate the direction and strength of an electric field around charged objects. They describe the force that a positive test charge would experience if placed at any point in the field.



②

Electric field lines **originate from positive charges** and **terminate at negative charges**. They emerge radially outward from positive charges and converge radially inward toward negative charges.



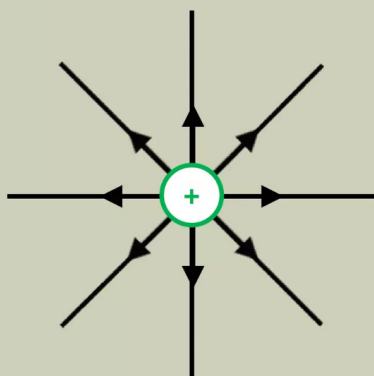
The direction of the electric field at any point is tangent to the field line at that point. Field lines point away from positive charges and toward negative charges.

③

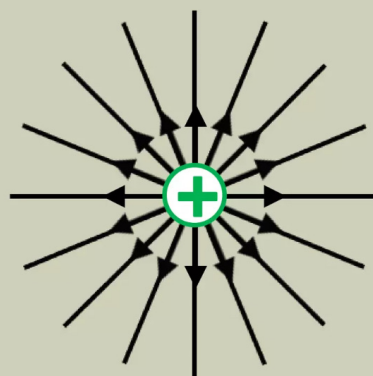
The spacing of the electric field lines represents the strength of the electric field.

Where the lines are closer together, the field is stronger, and where they are farther apart, the field is weaker.

- The **spacing** between the lines indicate the **strength** of the field.
- A **stronger field** would have more **closely spaced** lines.



Weaker Field

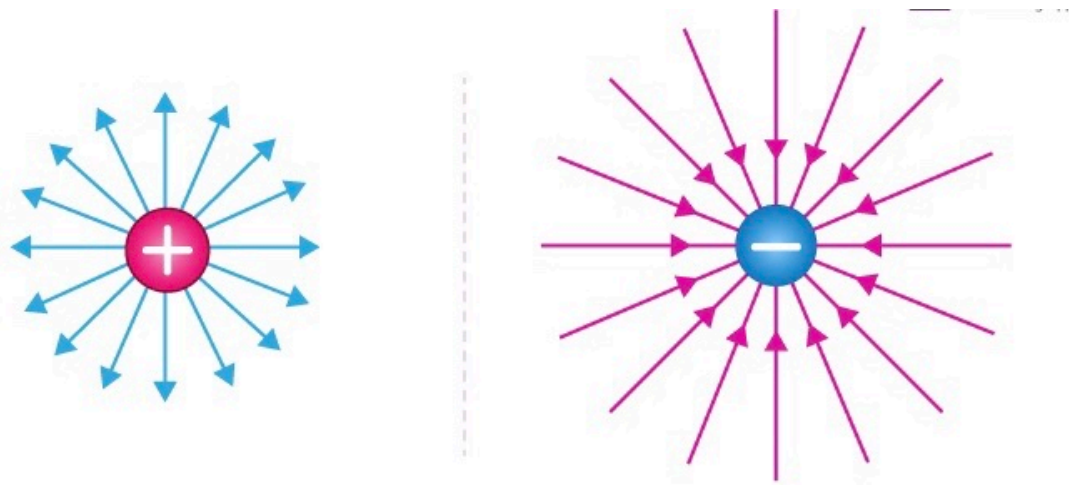


Stronger Field

2.2.5	Identify the direction of the electric force vector $\vec{F}$ resulting from placing a positive or negative charged particle in an electric field or other charged particles
2.2.6	Sketch an electric-field diagram of a single point charge, a dipole, or a collection of static point charges

2.2.5

For positive charges, the force vector aligns with the direction of the electric field, while for negative charges, the force vector opposes the direction of the electric field.



2.5.6

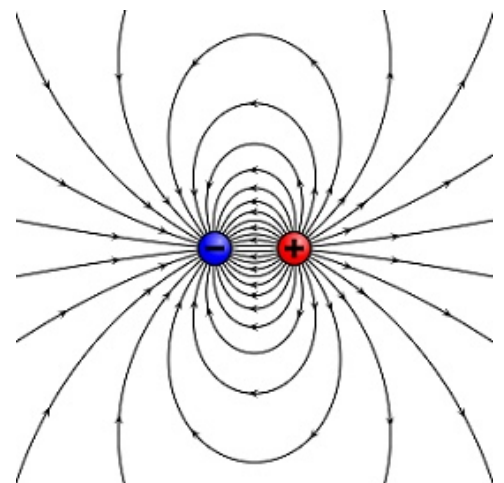
Single Point Charge:

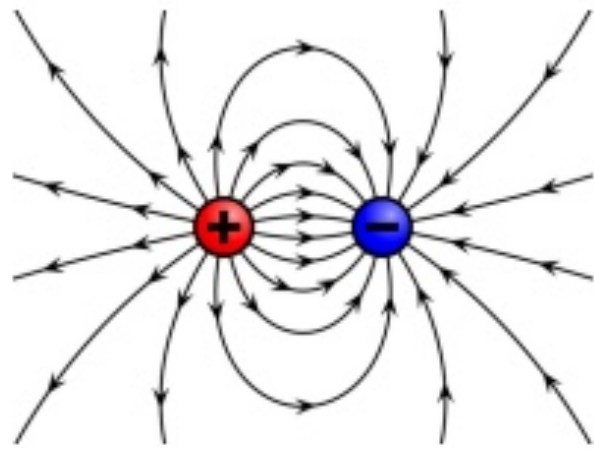
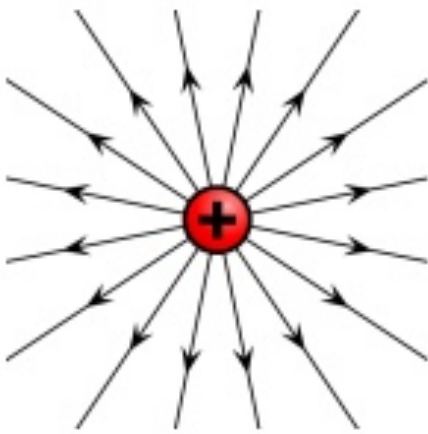
For a single point charge (q) the electric field lines radiate outward in all directions if it's positive or inward if it's negative, following a radial pattern.

Electric Dipole:

An electric dipole consists of two equal and opposite charges $+q$ and $-q$ separated by a small distance d

The electric field lines start at the positive charge and terminate at the negative charge, following curved lines that gradually become parallel to each other.





2.3.1	For a given point in the electric field of a charged particle, apply the relationship between the field magnitude E , the charge magnitude q , and the distance r between the point and the particle ($E = kq/r^2$)
2.3.3	Solve problems related to the electric field due to a charged particle.

2.3.1

Coulomb's law states that the magnitude of the electric field created by a point charge is directly proportional to the magnitude of the charge and inversely proportional to the square of the distance from the charge.

LESSON SUMMARY

Electric field strength
in newtons per
coulomb (N/C)

E

Electrostatic constant (9×10^9)

k

Size of charge
creating the field
in coulombs (C)

q

(r^2)

d^2

Distance to the charge
creating the field, in meters

$=$

$\frac{kq}{d^2}$

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2.4.2	Calculate the total charge contained in lines, surfaces, or volumes when given a linear-charge density , a surface-charge density , or a volume-charge density of the charge configuration. (Identify the equations)
2.5.1	Apply the relationship ($F = qE$) to find the electric force on a charged particle of charge q , placed in an external electric field (a field due to other charged objects), and identify the relative directions of the force and the field when the particle is positively charged and negatively charged

2.4.2

- **For Linear Charge Density (λ) along a Line:**

The total charge Q contained in a length L with linear charge density λ is calculated as:

$$Q = \lambda \cdot L$$

- **For Surface Charge Density (σ) on a Surface:**

The total charge Q contained on a surface area A with surface charge density σ is calculated as:

$$Q = \sigma \cdot A$$

- **For Volume Charge Density (ρ) within a Volume:**

The total charge Q contained in a volume V with volume charge density ρ is calculated as:

$$Q = \rho \cdot V$$

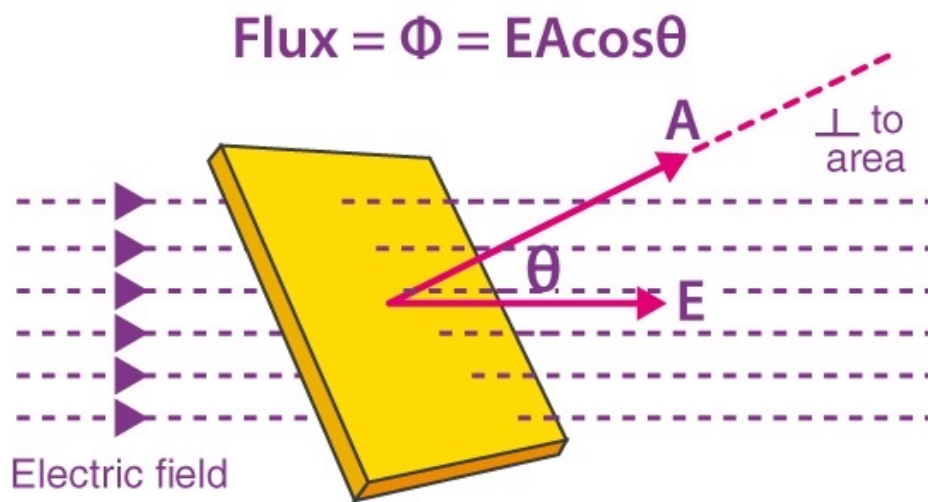
2.5.1



$$\vec{F} = q \vec{E}$$

2.5.2	Solve problems related to a point charge in an electric field
2.6.1	Define electric flux ϕ as the amount of electric field piercing a surface (not skimming along the surface) of area A.
2.6.4	For a closed surface, explain the algebraic signs associated with inward flux and outward flux.
2.6.5	Calculate the net flux ϕ through a surface by integrating the dot product of the electric field vector $\vec{E}$ and the area vector $d\vec{A}$ (for patch elements) over the surface

2.6.1



electric flux is a measure of how much electric field passes through a given surface.

2.6.4

Inward Flux (Negative Flux):

Inward flux occurs when the electric field lines enter the closed surface.

Outward Flux (Positive Flux):

Outward flux occurs when the electric field lines exit the closed surface.



2.6.5

The TOTAL FLUX is found by integrating over the ENTIRE SURFACE (sum of flux across each surface):

$$\Phi_E = \oint E \cdot dA$$

The circle on the integration sign simply means the surface is CLOSED.

2.7.2	Apply Gauss' law to relate the net flux ϕ through a closed surface (real or imaginary) to the net charge q_{enc} enclosed by the surface.
2.7.3	Show how the algebraic sign of the net enclosed charge corresponds to the direction (inward or outward) of the net flux through a Gaussian surface.
2.7.4	Explain why a charge outside a Gaussian surface makes no contribution to the net flux through the closed surface.
2.7.8	Explain electrostatic shielding (from external fields) by conductors.
2.7.9	Identify that the electrostatic field inside any isolated conductor is always zero.
2.7.10	Explain how cavities inside conductors are shielded from electric fields- electrostatic shielding

2.7.2

Gauss's Law states that the electric flux through any closed surface is equal to the net charge **Q inside the surface** divided by the permittivity of free space and is independent of the shape of that surface:

$$\Phi_E = \frac{Q}{\epsilon_0} = \oint E \cdot dA$$

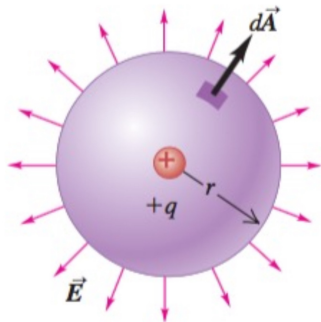
ϵ_0 : Permittivity free space = $8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$

Q: Net Charge; Unit: Coulomb (C)

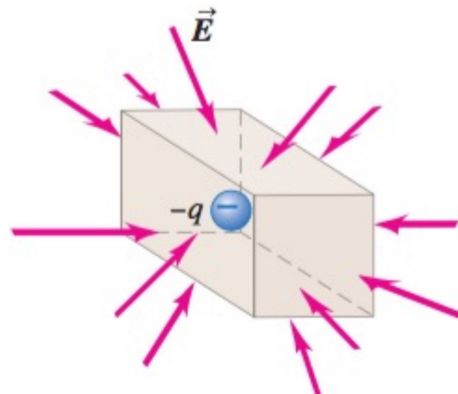
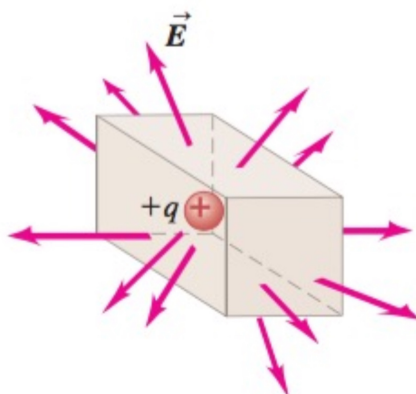
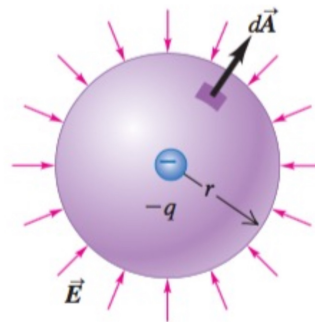
The surface enclosing the charges is imaginary,
called: **Gaussian surface**

2.7.3

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

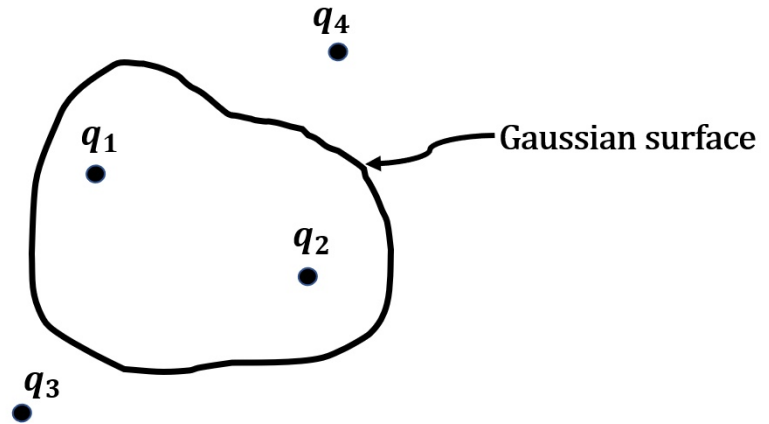


(b) Gaussian surface around negative charge:
negative (inward) flux



2.7.4

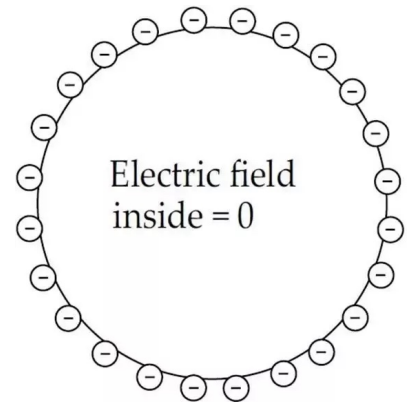
Gauss's Law only cares about the net charge enclosed by the surface. Charges outside might make electric fields, but these fields don't influence the net flux through the surface because their effects cancel each other—what goes in also comes out. Therefore, only the charges inside the surface contribute to the net flux according to Gauss's Law.



2.7.8

2.7.9

within an isolated conductor in an electrostatic state, the electric field inside is always zero. This occurs because the charges within a conductor, in an electrostatic equilibrium, redistribute themselves



2.7.10

when there's an electric field outside a metal object with a hole (like a cavity), the charges in the metal rearrange themselves so that the electric field can't get into the hole. It's like the metal "blocks" the electric field from reaching the inside, keeping it shielded from the outside field.

