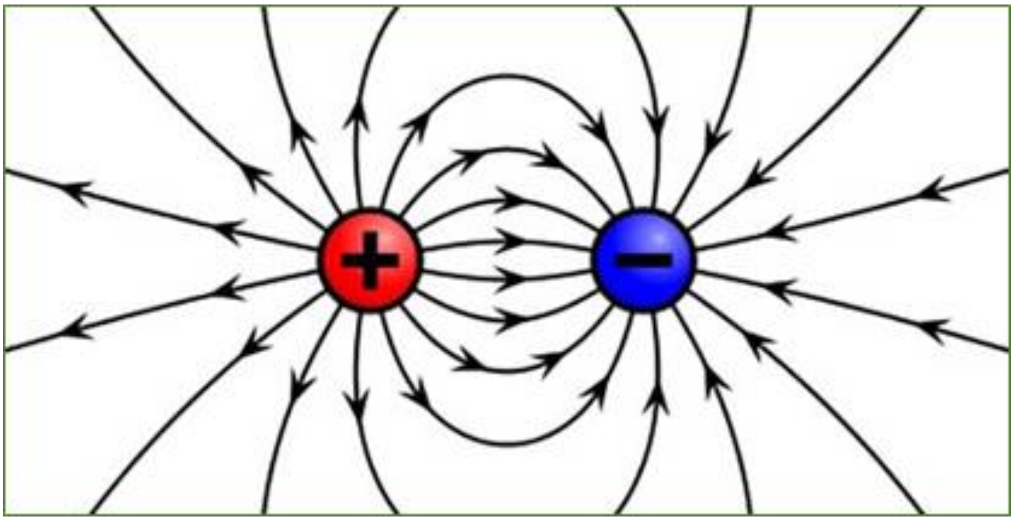
Student name/ …………………………………………..

Grad 12 advanced

2020 - 2021

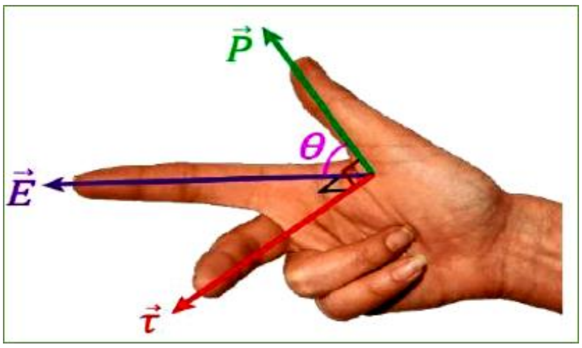
Chapter 2: Electric Fields



PHYSICS

GRAD 12 Advanced

$$\Phi = EA$$



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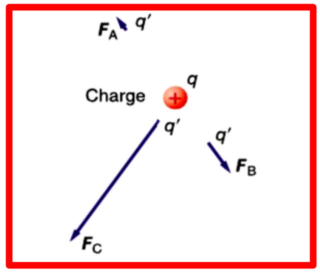
2.1 Definition of an electric Field

A field is defined as a property of space in which a material object experiences a force

The electric field is the space around an electrical charge

An electric field: E(r) is defined at any point in space, as the net electric force on a charge, divided by that charge



1. Now, consider point P a distance r from +q/.

2. An electric field E exists at P if a test charge +q/ has a

that point.

3. The direction of the E is the same as the direction of a force on + (pos) charge.

4. The magnitude of E is given by the formula (Electric Field Strengh)

$$E = \frac{F_{on\ q^/}}{q^/}$$

The strength of an electric field is equal to the force on a positive test charge divided by the strength of the test charge

Unit of $E = \frac{N}{C}$

The direction of E at a point is the same as the direction that a positive charge would move IF placed at that point.

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2.2 Field Lines

Electric Field Lines are: imaginary lines representing the path of a test charge when it placed free in an electric field

The following rules apply to electric field lines:

- Lines begin and end only at charges (beginning at **+** charges, ending at **-** charges) or at Infinity.(lines go away from **positive** charges and toward **negative** charges)
- Lines are closer together where the field is stronger.
- Larger charges have more field lines beginning or ending on them.

1- Electric Field lines never cross (Because if the intersection of two lines would have to the field intensity at the intersection point more than the direction this can not)

- At any location, the direction of the electric field is tangent to the electric field line that passes through that location.

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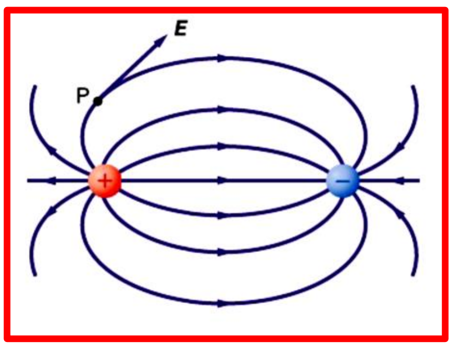

(**Notice that** lines leave **+ charges** and enter **- charges**. Also, **E** is strongest where field lines are most dense dense.

Before starting to draw the lines of the electric field, the following ratio should be applied

$$\frac{n_1}{n_2} = \frac{q_1}{q_2}$$

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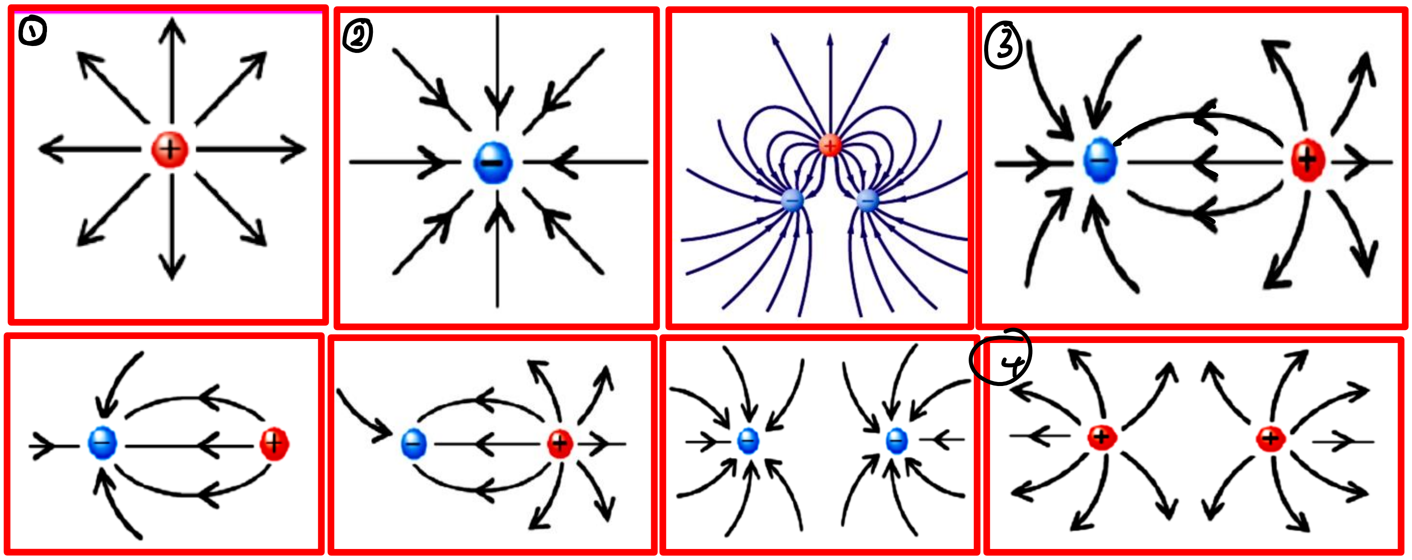

- **Depending** on the adjacent diagram, **complete** the following table as appropriate

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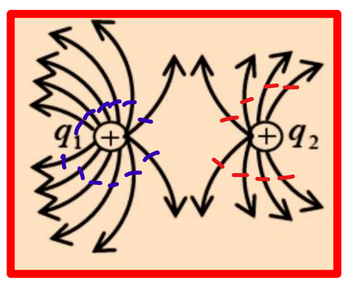
q_2	q_1	
		Type of charge
	$12nC$	Amount of

- **Depending** on the adjacent shape, **calculate the ratio** between the two charges



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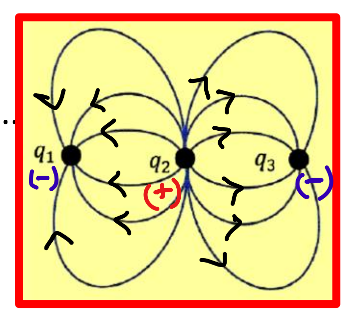
The diagram shows the electric field lines for three dot matrix charges



- **Calculate the ratio** $\frac{|q_1|}{|q_3|}$ ....

- If q_1 is negative, **what type** of q_2 and q_3

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2.3 Electric Field due to Point

Electric field strength (E): is equal to the force on a positive test charge divided by the strength of the test charge

$$F_e = k_c \frac{|qq_0|}{r^2} = \frac{1}{4\pi \in_0} \frac{|qq_0|}{r^2}$$

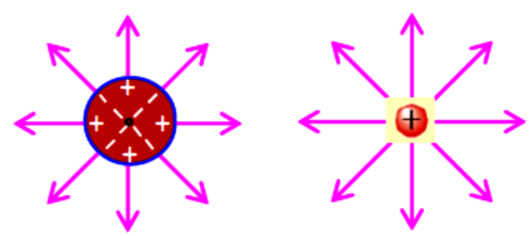
$$E = \left|\frac{F}{q_0}\right| = \frac{1}{4\pi \in_0} \frac{|q|}{r^2}$$

Electric field strength is vector quantity

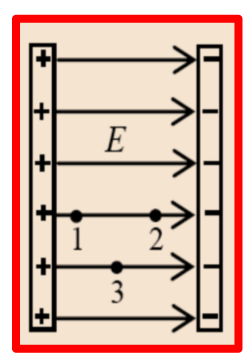
The superposition principle for the total electric field, $\vec{E}_t$, at any point in space with , due to n electric field sources can be stated as $\vec{E}_t = \vec{E}_1 + \vec{E}_2 + \cdots + \vec{E}_n$

Types of electric field :

1- **Irregular field**
- ✓ **Its intensity changes with the dimension**
- ✓ **Field lines are not parallel**
- ✓ **produced in point and spherical charges**



2- **Regular field**
- ✓ **Fixed at the magnitude and direction at all points in it**
- ✓ **Its field lines are straight and parallel**
- ✓ **How to get it: By two parallel plates charged with two equal and opposite different charges**



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Q1: In the adjacent figure, if the electric field strength at point (a) is 72 N / C, answer the following:

- **Calculate** the distance from point (a) to the charge

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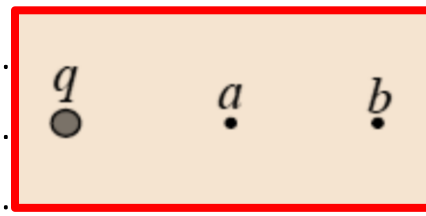
- **How much** is the intensity of the field at a point in the infinity ....

Q2: in the adjacent figure, if the distance (b) from the charge (q) is twice as much the distance the point (a), **find the ratio between** the intensity Field at (a) and field strength at point (b)?



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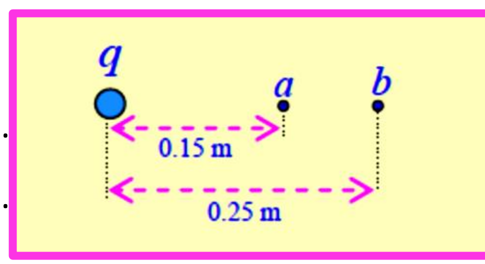
Q3: Points (a) and (b) are located in In the electric field of the point charge (q) As in the adjacent figure If the electric field strength at point (b) is equal (900 N / C)

Calculate the electric field strength at point (a)



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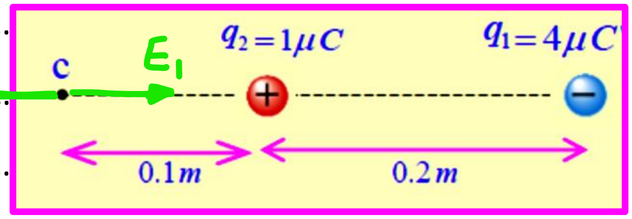
Q4: Based on the data in the figure Calculate the electric field strength at point (c)

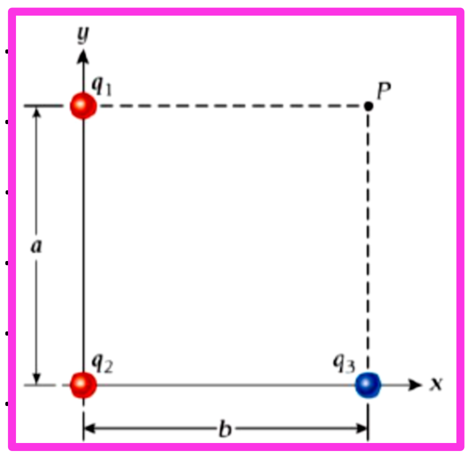


$E_1 = \frac{kq_1}{r_1^2} = \frac{9\times10^9 \times 4\times10^{-6}}{(0.3)^2} = 4.0\times10^5$ N/C

$E_2 = \frac{kq_2}{r_2^2} = \frac{9\times10^9\times1\times10^{-6}}{(0.1)^2} = 9.0\times10^5$ N/C

$E_{net} = (9\times10^5) - (4\times10^5) = 5\times10^5$ N/C ; to the left ((with −x-axis))

Q5: Figure shows three fixed point charges: q_1 = +1.50 μC, q_2 = +2.50 μC, and q_3 = −3.50 μC. Charge q_1 is located at (0, a), q_2 is located at (0, 0), and q_3 is located at (b, 0), where a = 8.00 m and b = 6.00 m. **What electric field** ($\vec{E}$) do these three charges produce at the point P = (b, a)



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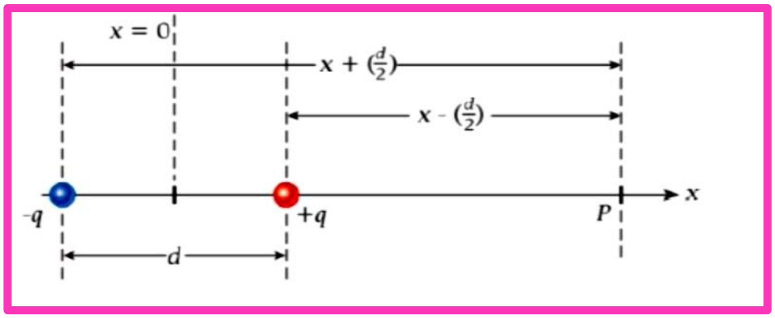
2.4 Electric Field due to a DipoleCharges

Electric Dipole consists of positive charge + q and negative –q equal in magnitude separated by a small distance, as in Figure



❖ **Calculate the electric field** strength from point p Located along the line between them

(On the X axis)

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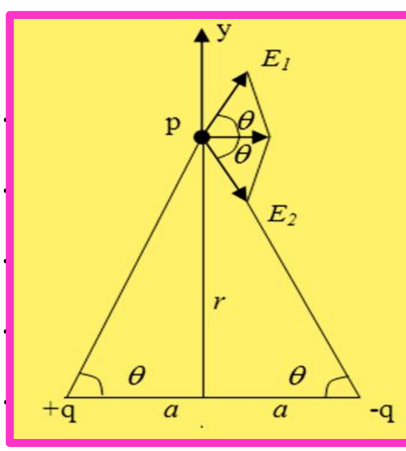
❖ Calculate the electric field strength from the + q and-q charges at point p on the equitable column of the dipole axis



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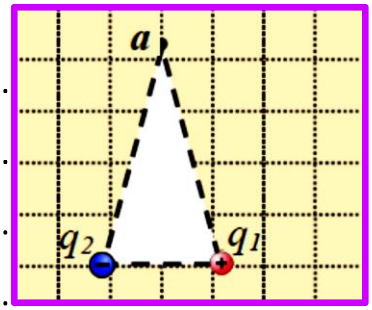
❖ Two equal and different electric charges q_1 +2μC and q_2 -2μC they form the dipole the distance between the two charges $d = 0.2mm$ as see in the figure

1- **Find the electric field** at point **a** a vertically from the center of the dipole axis distance 3.0cm



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2- **What is the amount** of bipolar torque for the two charges?

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2.5 general Charge Distributions

Now let's consider the electric field due to a general charge distribution. To do this, we divide the charge into differential elements of charge, *dq*, and find the electric field

For a charge distribution

$$dq = \lambda dx \quad \text{along a line;}$$

$$dq = \sigma dA \quad \text{over a surface;}$$

$$dq = \rho dV \quad \text{throughout a volume}$$

The magnitude of the electric field resulting from the charge distribution is then obtained from the differential charge

$$dE = k\frac{dq}{r^2}$$

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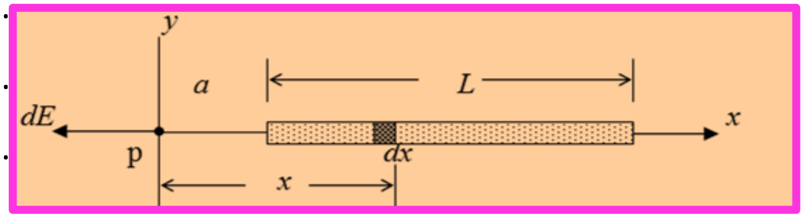
❖ **Find the intensity** of the electric field at the point **p** located at distance a from one end of the wire which carries the linear charge density λ



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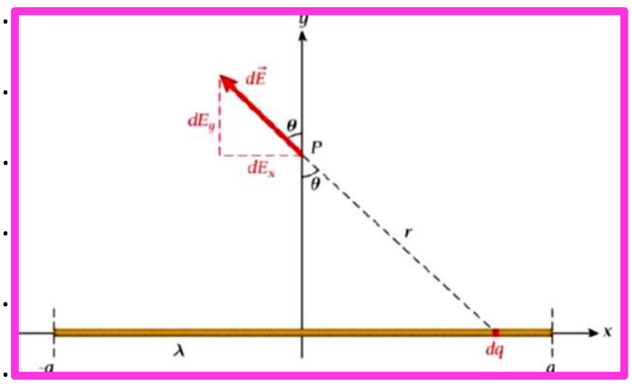
❖ **Calculate the electric** field at point p along the line that bisecting the wire



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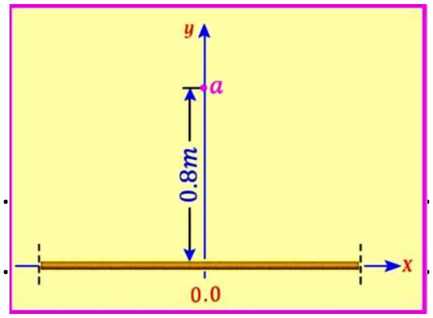
❖ The adjacent figure shows a straight wire of 1.2 m length and a positive charge with a longitudinal density of 4.0 μC / m using the

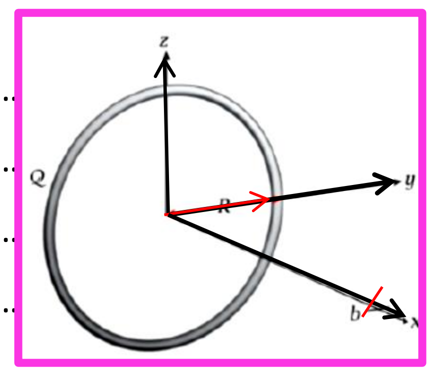
$$\int \frac{1}{(a^2+x^2)^{3/2}}\,dx = \frac{1}{a^2}\,\frac{x}{\sqrt{a^2+x^2}} + c$$

Answer the following :

1. **Calculate the field** strength of the wire charge at point a
2. Repeat Calculation if the wire is **infinite**



❖ Consider a charged ring with radius R = 0.250 m (Figure). The ring has uniform linear charge density and the total charge on the ring is Q = +5.00 μC. **What is the electric** field at a distance d = 0.500 m along the axis of the ring?



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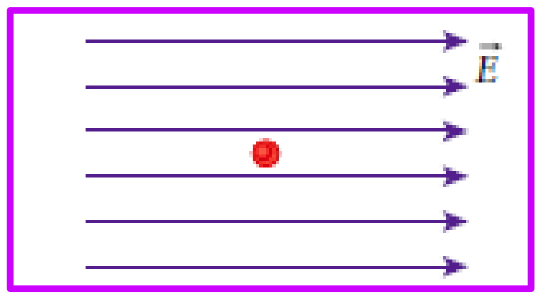
2.6 Force due to an electric Field

The force **F** exerted by an electric field E Eon a point charge **q** is given by

$$F_e = qE$$

- A small positively charged object is placed at rest in a uniform electric field as shown in the figure. **When the object is released**, it will



a) not move.

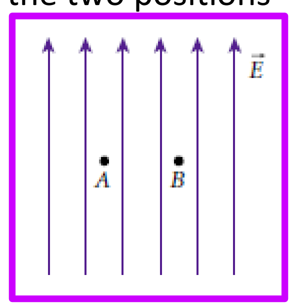
b) begin to move with a constant speed.

c) begin to move with a constant acceleration.

d) begin to move with an increasing acceleration.

e) move back and forth in simple harmonic motion.

- A small positively charged object could be placed in a uniform electric field at position *A* or position *B* in the figure. **How do the electric forces** on the object at the two positions compare?



a) The magnitude of the electric force on the object is greater at position *A*.

b) The magnitude of the electric force on the object is greater at position *B*.

c) There is no electric force on the object at either position *A* or position *B*.

d) The electric force on the object at position *A* has the same magnitude as the force on the object at position *B* but is in the opposite direction.

e) The electric force on the object at position *A* is the same nonzero electric force as that on the object at position *B*.

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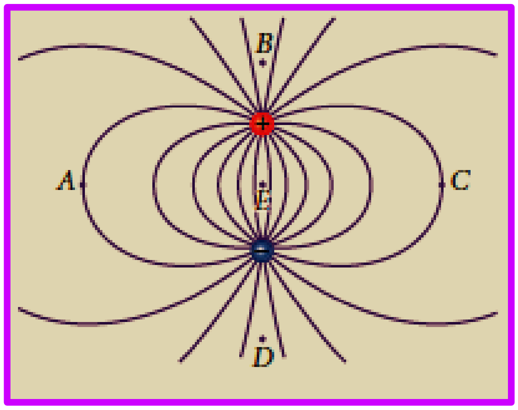
❖ The figure shows a two-dimensional view of electric field lines due to two opposite charges. **What is the direction of the electric field** at the five points *A, B, C, D,* and *E*? At which of the five points is the magnitude of the electric field the largest?



❖ **Indicate whether each of the following statements** about electric field lines is true or false.

a) Electric field lines point inward toward negative charges.

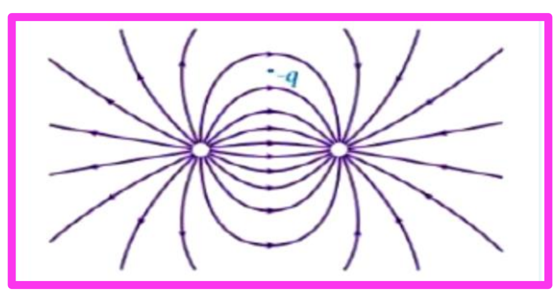
b) Electric field lines make circles around positive charges.

c) Electric field lines may cross.

d) Electric field lines point outward from positive charges.

e) A positive point charge released from rest will initially accelerate along the tangent to the electric field line at that point.

❖ A negative charge **−q** is placed in a nonuniform electric field as shown in the figure. **What is the direction** of the electric force on this negative charge?



a) →

b) ↑

c) ←

d) ↓

e) The force is zero.

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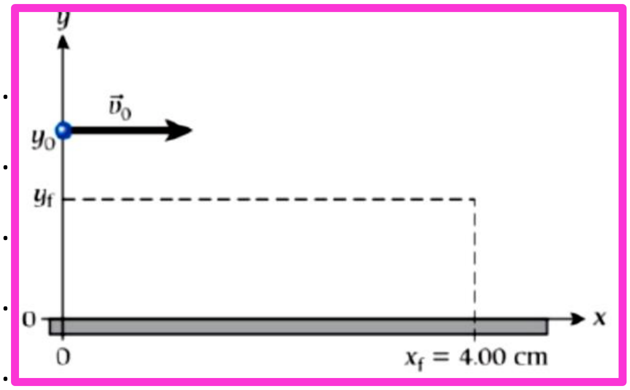
Q : An electron with a kinetic energy of 2000.0 eV (1 eV = 1.602 × 10^{-19} J) is fired horizontally across a horizontally oriented charged conducting plate with surface charge density +4.00 × 10^{-6} C/m^2. Taking the positive direction to be upward (away from the plate), **what is the vertical deflection of the electron** after it has traveled a horizontal distance of 4.00 cm?



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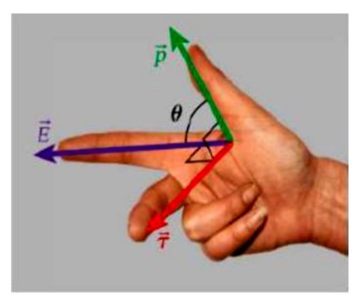
Dipole in an electric Field

The force **F** exerted by an electric field ***E*** Eon a point charge **q** is given by $\boldsymbol{F_e = qE}$

Where force produces a torque that can be calculated from the equation

$$\tau = Frsin\theta$$

Where r = d



$$\tau = qEdsin\theta$$

$$\tau = PEsin\theta$$

$$\vec{\tau} = \vec{P}\, x\, \vec{E}$$

As with all vector products, the direction of the torque is given by a right-hand rule. As shown in Figure, the thumb indicates the direction of the first term of the vector product, in this case p , and the index finger indicates the direction of the second term, E . The result of the vector product, τ , is then directed along the middle finger and is perpendicular to each of the two terms

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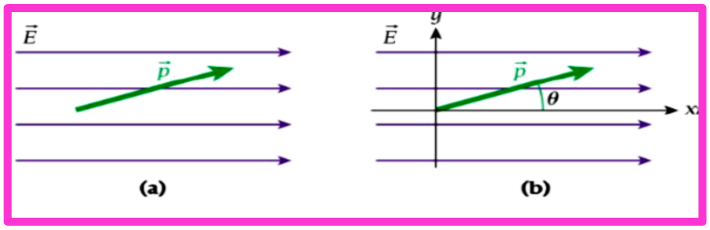
Q: An electric dipole with dipole moment of magnitude $p = 1.40 \times 10^{-12}$ Cm is placed in a uniform electric field of magnitude $E = 498$ N/C



(a) An electric dipole in a uniform electric field
(b) The electric field oriented inthe *x*-direction and the dipole in the *xy*-plane.

At some instant (in time) the angle between the electric dipole and the electric field is

θ = 14.5°. **What are the Cartesian components** of the torque on the dipole?

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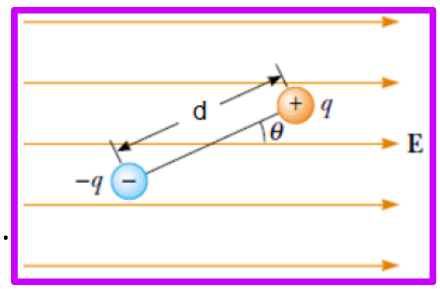
Two equal and different charges of type 4nC each placed in a regulated field of 15C / N And towards the positive x-axis as in the figure, the angle $\theta = 18$ and the distance between the two charges 1.5cm **Find** :



1- Bipolar torque
2- Torque

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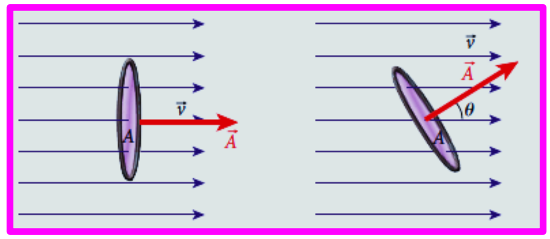
2.7 Electric Flux

The number of electric field lines that cross a certain surface perpendicular to it

Or the total number of electric field lines that passing throuh the unit area of this surface perpendicular to it (the electric flux is proportional to the number of electric field lines passing through the area.)

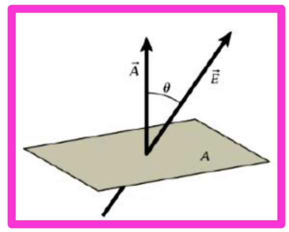


Or is the product of the field vector and the area vector

We can be calculated the Electric Flux by relationship

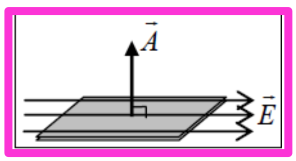
$$\emptyset = E.A = EAcos\theta$$

Electric Flux is scalor quntity



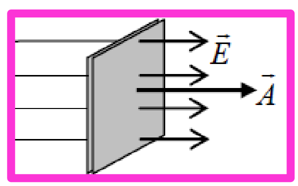
- ✓ If the field is parallel to the surface (θ = 90)

$$\emptyset = 0$$



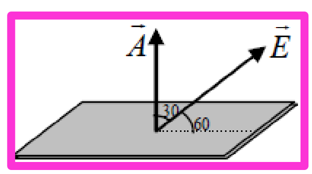
- ✓ If the field is perpendicular to the surface (θ = 0)

$$\emptyset = E.A$$



- ✓ If the angle between the field the surface for example (θ = 60)

$$\emptyset = E.A = EAcos30$$



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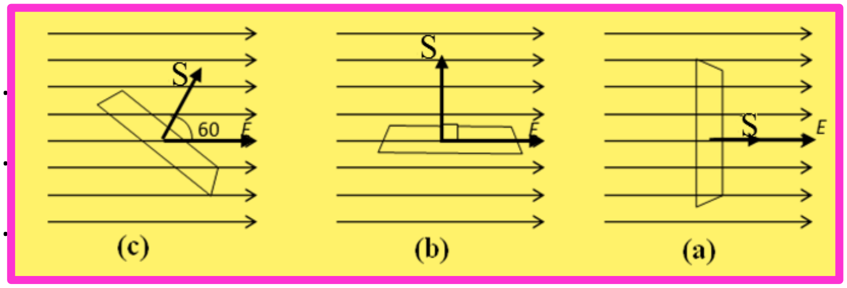
Q: Electric field E, passing thrugh a flat surface of area S, as in figure, **finds the electric field** flow from the surface in cases a, b, c



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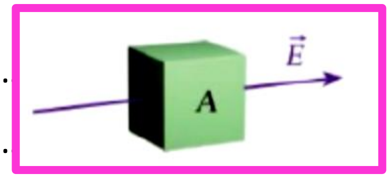
Q: Figure shows a cube that has faces with area A in a uniform electric field, E, that is perpendicular to the plane of one face of the cube. **What is the net electric** flux passing though the cube?



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2.8 Gauss's Law

Calculation the electrical flux in the case of a closed and not open surface

If the surface area is closed we use the: $\phi = \oint\!\!\oint \vec{E} \cdot d\vec{A}$

Unit iof flux $\frac{N.m^2}{C}$

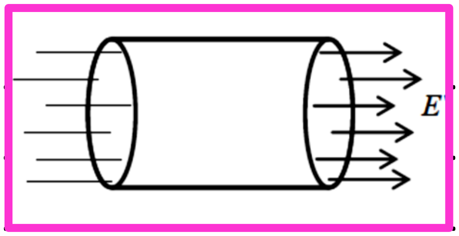
- When an object with a closed surface (box) does not contain charges, the electrical flow is zero because the resultant field effect. On the test charge placed inside the body is equal zero
- When there is a charge inside the box (a closed surface) is called **Surface of Gauss**

$$\phi = \frac{q}{\epsilon_0}$$

There is another version of Gaussian law: $\emptyset = \oiint E.dA = \frac{q}{\epsilon_0}$

Q: Cylinder with a base radius of(0.1 m) and a height of (0.8m). Its axis is parallel to the positive (x) axis as in the figure affected by a uniform electric field of intensity (400 N / C).

Calculate the electrical flux through the cylinder



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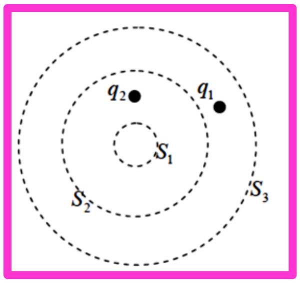
Q: The adjacent figure shows two point charges $q_1 = + 4\mu C$ and $q_2 = -6\mu C$ and three closed surfaces S_1, S_2, S_3 **Find the electrical flux that traverses each surface**



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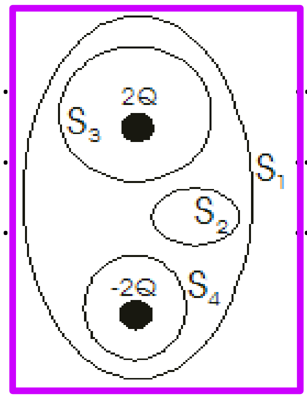
Q: In the figure below calculate the total flow (Ø) of surfaces S_1, S_2, S_3, S_4



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Q: The electric field E, intersecting a flat surface of area S, as in the figure, created the flow of the electric field from the surface in cases a, b, c.

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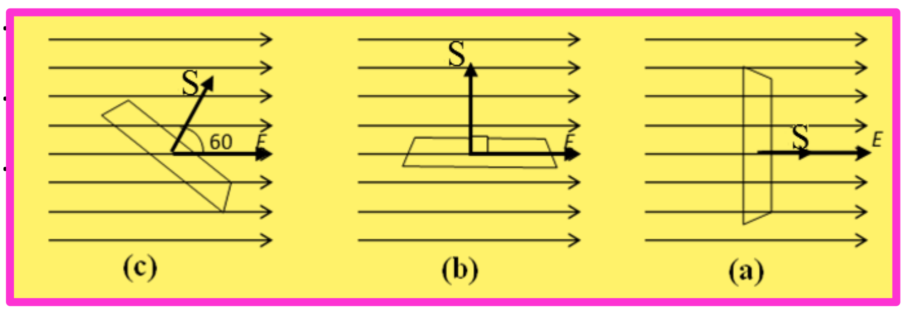
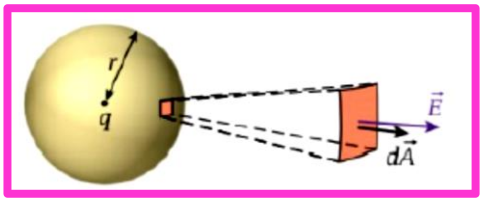


Gauss's Law and Coulomb's Law

Can Coulomb's Law be deduced by Gauss's Law?

Coulomb's law can be deduced by Gaussian law where we assume a point charge q surrounded by a Gaussian radius r.To calculate the electric field strength we use Gaussian law.



$$\phi_E = \oint \vec{E}.d\vec{SA} = \frac{qin}{\epsilon_0}$$

$$\phi_E = \oint EdA\cos\theta = \frac{qin}{\epsilon_0}$$

Since the field is regular, it comes out of integration

$$\phi = E\oint d\vec{A} = \frac{qin}{\epsilon_0}$$

$$\phi = E \times A = \frac{qin}{\epsilon_0}$$

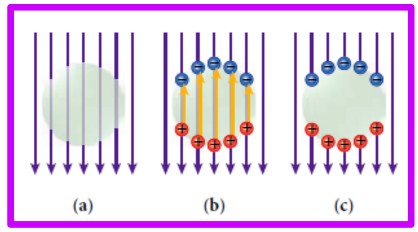
$$\phi = E \times (4\pi r^2) = \frac{qin}{\epsilon_0}$$

$$\boldsymbol{E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}}$$

$$\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} \times 4\pi r^2 = \frac{qin}{\epsilon_0} = \phi$$

Shielding

- The electrostatic field inside any isolated conductor is always zero
- Cavitie s insi de conductors are shielded from electric fields



- ✓ When placing a conductor inside an electric field (Conductors contain free electrons) (a)
- ✓ Electrons move with the effect of the electric field, leaving behind positive ions (b)
- ✓ The electrons assembled at one end and the positive ions create a field within the conductor that eliminates the outer field (c)

Q : A hollow, conducting sphere is initially given an evenly distributed negative charge. A positive charge +*q* is brought near the sphere and placed at rest as shown in the figure. **What is the direction of the electric field** inside the hollow sphere?

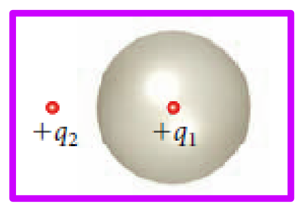
a) →

b) ↑

c) ←

d) ↓   e) The force is zero.

Q: A hollow, conducting sphere is initially uncharged. A positive charge, $+q_1$, is placed inside the sphere, as shown in the figure. Then, a second positive charge, $+q_2$, is placed near the sphere but outside it. Which of the following statements describes the net electric force on each charge?



a) There is a net electric force on $+q_2$ but not on $+q_1$.

b) There is a net electric force on $+q_1$ but not on $+q_2$.

c) Both charges are acted on by a net electric forcewith the same magnitude and in the same direction.

d) Both charges are acted on by a net electric force with the same magnitude but in opposite directions

e) There is no net electric force on either charge.

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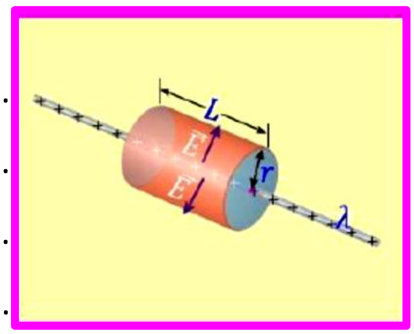
2.9 Special Symmetries

Cylindrical Symmetry

To calculate the amount of electric field produced by a straight, long-term wire with a linear charge density λ $dq = \lambda dl$

- We place a Gaussian surface in the form of a cylinder that surrounds the wire of length L and radius r
- The electric field resulting from the wire is perpendicular to the wire
- If the wire rotates around an axis along its length, the shape of the wire remains the same (Circular symmetry)
- If the wire is too long, the shape of the wire remains constant and the electric field remains unchanged (Transitional symmetry)

Q: Calculate the electric field produced by a conductive, straight, long-term, uniformly charged wire per unit length λ >0



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Q: A 4.5m-long wire holds charges that are regularly distributed the amount is 8nC. **Find the electric field** at a point away vertically about the middle of the wire by 0.2m (suppose the wire is infinite)

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Q: A total of 1.45×10^6 excess electrons are on an initially electrically neutral wire of length 1.13 m**. What is the magnitude of the electric field** at a point at a perpendicular distance of 0.401 m away from the center of wire? (*Hint:* Assume that 1.13 m is close enough to "infinitely long.")

a) 9.21×10^{-3} N/C b) 2.92×10^{-1} N/C c) 6.77×10^{1} N/C

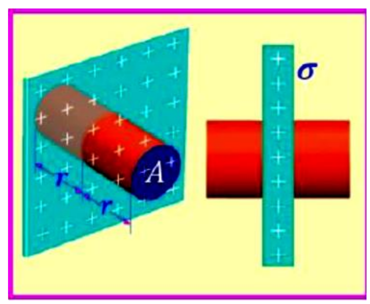
d) 8.12×10^{2} N/C e) 3.31×10^{3} N/C

Planar Symmetry

To calculate the amount of electric field produced by a thin, non-conductive flat plate whose area is infinite and carries a regulated charge Surface charge **σ** hence **dq =σ dA**

- We select a Gaussian surface in the form of a closed cylinder with an area of cross-section A and a length of 2r
- The electric field shall be perpendicular to both ends of the cylinder and parallel to its wall

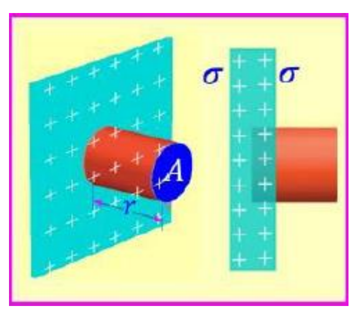
The electric field resulting from a flat, thin, non-conducting board Its area is infinite and carries a positive charge, and its charge per unit area is σ> 0



$$E = \frac{\sigma}{2\,\epsilon_0}$$

For an infinite conducting sheet with charge density $\sigma > 0$ on each surface, **we can find the electric field** by choosing a Gaussian surface in the form of a right cylinder

$$E = \frac{\sigma}{\epsilon_0}$$



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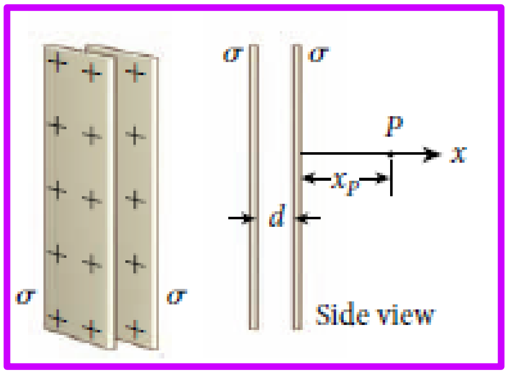
Q: Two infinite nonconducting plates are parallel to each other, with a distance d = 10.0 cm between them, as shown in the figure. Each plate carries a uniform charge distribution of σ = 4.5 μC/m^2. What is the electric field, E , at point P (with x_P = 20.0 cm)?

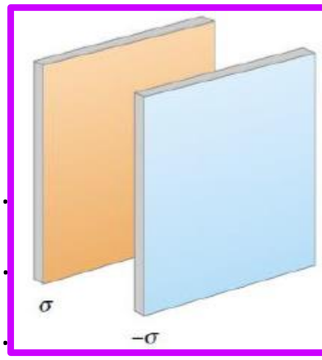
a) 0 N/C b) 2.54 $\hat{x}$ N/C c) $(-5.08 \times 10^5)\hat{x}$ N/C

d) $(5.08 \times 10^5)\hat{x}$ N/C e) $(-1.02 \times 10^6)\hat{x}$ N/C

f) $(1.02 \times 10^6)\hat{x}$ N/C



Q: Two infinite thin parallel plates' unconductors are a certain distance apart if the charge density Surface For the first plate is equal $\sigma_1 = 3\mu c/m^2$ and for the second plate is equal $\sigma_2 = -3\mu c/m^2$ **Find**



- ✓ **The intensity of the electric field** at the point between the plates

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- ✓ **The intensity of the electric field** is at the point outside the plates and to the right of the negative charge plate

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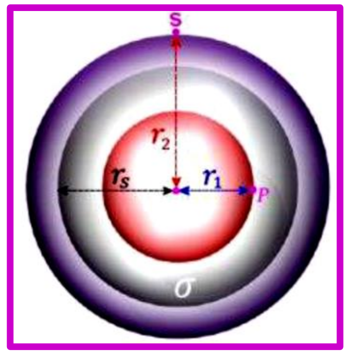
Spherical Symmetry

The spherical surface is hollow

To calculate the electric field strength resulting from a symmetrical distribution of charges on the surface of a hollow sphere radius (r_s)



1- Out of the charged body (greater than (rs))

$$E = K\frac{q}{r_2^{\,2}}$$

2- Inside the charged body (less than (rs))

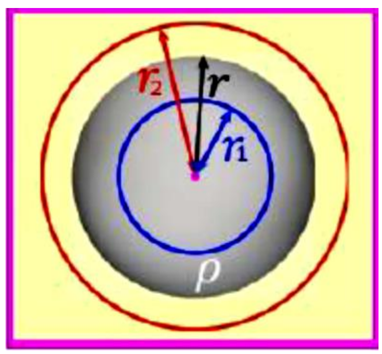
$$E = 0$$

3- On the charged body (rs)

$$E = K\frac{q}{r_s^{\,2}}$$

The spherical surface is solid

Calculate the intensity of the electric field resulting from an even uniform distribution over the size of a solid sphere with a radius (r) and a volumetric density ($\boldsymbol{\rho}$)



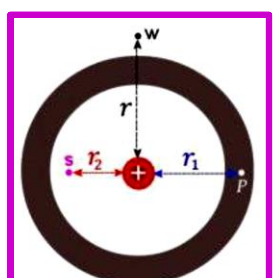
1- Out of the charged body (greater than (r))

$$E = K\frac{q}{r_2^{\,2}}$$

2- Inside the charged body (less than (r))

$$E = K\frac{q\,r_1}{r^3} \quad \text{Or} \quad E = K\frac{\rho\,r_1}{3\epsilon_0}$$

The field resulting from a point charge in the center of a thin sphere (Spherical structure) Made of conductive material



1- Inside the cavity $(r_2 < r_1)$ $E_s = k\frac{q}{r_2^{\,2}}$

2- Inside the spherical structure $E = 0$

3- Outside the spherical structure

$$E_w = k\frac{q}{r^2}$$

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Q: Spherical conductor carrying an electric charge of +6μC and a radius of 20 cm

Find the electric field at:

1- A point located on the Gaussian level, beyond the center of the spherical conductor 15cm

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2-A point located on the Gaussian level, away from the center of the spherical conductor 20cm

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3-A point located on the Gaussian level, away from the center of the spherical conductor 30cm

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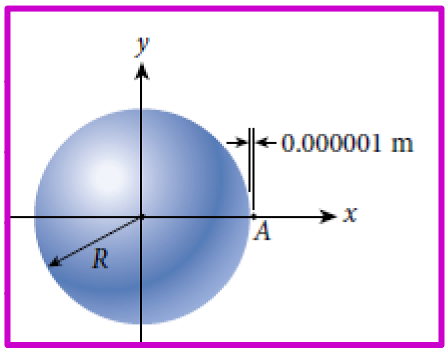
Q: A conducting solid sphere ($R = 0.15$ m, $q = 6.1 \times 10^{-6}$ C) is shown in the figure. Using Gauss s Law and two different Gaussian surfaces, **determine the electric field** (magnitude and direction) at point A, which is 0.000001 m outside the conducting sphere. (Hint: One Gaussian surface is a sphere, and the other is a small right cylinder.)



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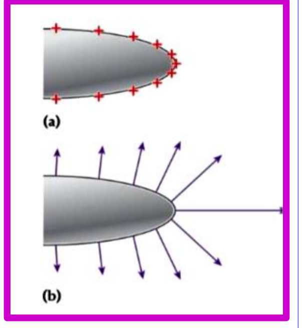
Sharp Points and Lightning rods



- The electric field is always perpendicular to any charged conductive surface (b)
- There is no component for the electric field parallel to the surface(There is no force or field along the surface of the conductor)
- Charges are distributed on the outer surface and concentrated at the pointed heads so that the field strength is as large as possible
- Field lines are convergent to each other at sharp points (b)

Lightning rod

- Lightning conductors are made of metal materials with sharp ends
- The sharp-edged lightning rod is heavily charged, creating a severe electric field
- The electric field ionizes air, allowing lightning to be discharged away from buildings