Welcome to PHY2054C

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- Office hours: MoTuWeTh 10:00-11:00am (and after class) at PS140
- Book: “Physics” 8 ed. by Cutnell & Johnson, Volume 2 and PHY2054 Lab manual for your labs.
- One Midterm (July 14) and final (August 4). Homework. Recitations.
- Grade: Midterm 35%, Final 35%, Recitations Attendance 5%, Homework 15%, Lab 10%.
- Homework via the **www.WebAssign.com** web site. You must self enroll (see syllabus for name and access key of class).
- Class web site: www.physics.ucf.edu/~cvelissaris/Summer11/PHY2054 (Syllabus and WebAssign self enrolment instruction already posted).

2054 Class General Structure

- The electric field, potential and DC circuits.
  Medium difficulty.
- The magnetic field, induction and AC circuits.
  Very hard (the hardest of the class).
- The Electromagnetic Wave (light). Very easy.
- Geometrical optics and optical instruments.
  Hard but very interesting.
- Wave (physical) optics and wave phenomena.
  Very hard. New concepts and hard to visualize.

2054 Class Structure Part 1.

- Electric charges, forces and Fields. (Ch 18)

  The electric charge. Quantization and types of electric charge. Atomic structure. Conductors and Insulators. Coulomb's law. The Electric Field and Electric field lines. Electric flux and Gauss law. Superposition of electric forces and fields.

- Electric potential and Capacitance. (Ch 19)

  Electric potential energy and electric potential. Equipotential surfaces. Capacitors. Energy stored in an Electric Field. Dielectrics.

- Electric Current, Resistors and circuits. (Ch 20)

  Electric current. Resistance and Ohm's law. Resistors connected in series and in parallel. Capacitors in series and in parallel. Batteries, emf force and dc circuits. Energy and power consumed in dc circuits. The two rules of Kirchhoff for circuits. Ammeters and Voltmeters.

- The Magnetic Field. (Ch 21)

  Magnetic field and Magnetic field lines. Magnetic force on a moving charge and the right hand rule. Magnetic forces and torques on electric currents. Magnetic fields generated by electric currents. Solenoids and loops. Ampere's law.

- Electromagnetic induction. (Ch 22)

  Magnetic flux. Farady's law. Lenz law. Transformation of electrical energy into kinetic and vice versa. Inductance. Self inductance and mutual inductance. Transformers. Magnetic field energy. AC motors and generators

- Midterm Exam. (July 14)

2054 Class Structure Part 2.

- Electromagnetic induction. (Ch 22)

  Magnetic flux. Farady's law. Lenz law. Transformation of electrical energy into kinetic and vice versa. Inductance. Self inductance and mutual inductance. Transformers. Magnetic field energy. AC motors and generators

- AC (alternating) currents (Ch 23)

  Phasors. Resistances, capacitative and inductive reactances. Impedance. Power consumed in an ac circuit. R-L, R-C and R-L-C circuits. Resonance.

- Electromagnetic waves. (Ch 24)

  Nature of light. Frequency, wavelength and speed of light. Radiation Energy and Pressure. Polarization of light.

- Reflection of light and Mirrors (Ch 25)

  Flat and spherical (concave and convex) mirrors. Ray tracing and Mirror equation. Thin lenses. The mirror equation and the magnification equation.

- Refraction of light and Lenses. (Ch 26)

  Index of refraction. Snell's law and refraction of light. Dispersion of light. Lenses and ray tracing through lenses. The lens equation and the magnification equation. The human eye and defects of vision, the magnification lens and the microscope, the telescope.

- The Wave nature of light (Ch 27).

  Young's double slit experiment. Constructive and destructive interference. Diffraction of light and resolving power of optical instruments.

- Final Exam. (August 4)

Part 1.

- Electric charges and Fields.

The electric charge. Quantization and types of electric charge. Atomic structure. Conductors and Insulators.

Coulomb's law. The Electric Field and Electric field lines.

Charge induction and polarization. Conductors and insulators in Electric fields. Capacitors.

Electric flux and Gauss law.

The electric charge

- Electric charge is a fundamental property of matter. Signifies that the particle carrying an electric charge participates in electromagnetic interactions.
- Known from antiquity electron = ηλεκτρον = amber
- Two types of electric charge, + and –. Electric forces can be attractive (opposite charges) or repulsive (same charges).
- Electric charge is conserved and quantized.

Electric charge and Matter.

- Atom. Electrons orbiting a small nucleus consisting of neutrons & protons.

- The electron carries negative charge equal and opposite to the charge of the proton. Neutrons carry no electric charge.

- The atom is electrically neutral. The number of electrons is equal to the number of protons (atomic number).

- Ion. A charged atom where an electron has been knocked off or acquired.

electron

$$m_e = 9.1 \times 10^{-31} kg$$

$$q_e = e = -1.6 \times 10^{-19} C$$

proton

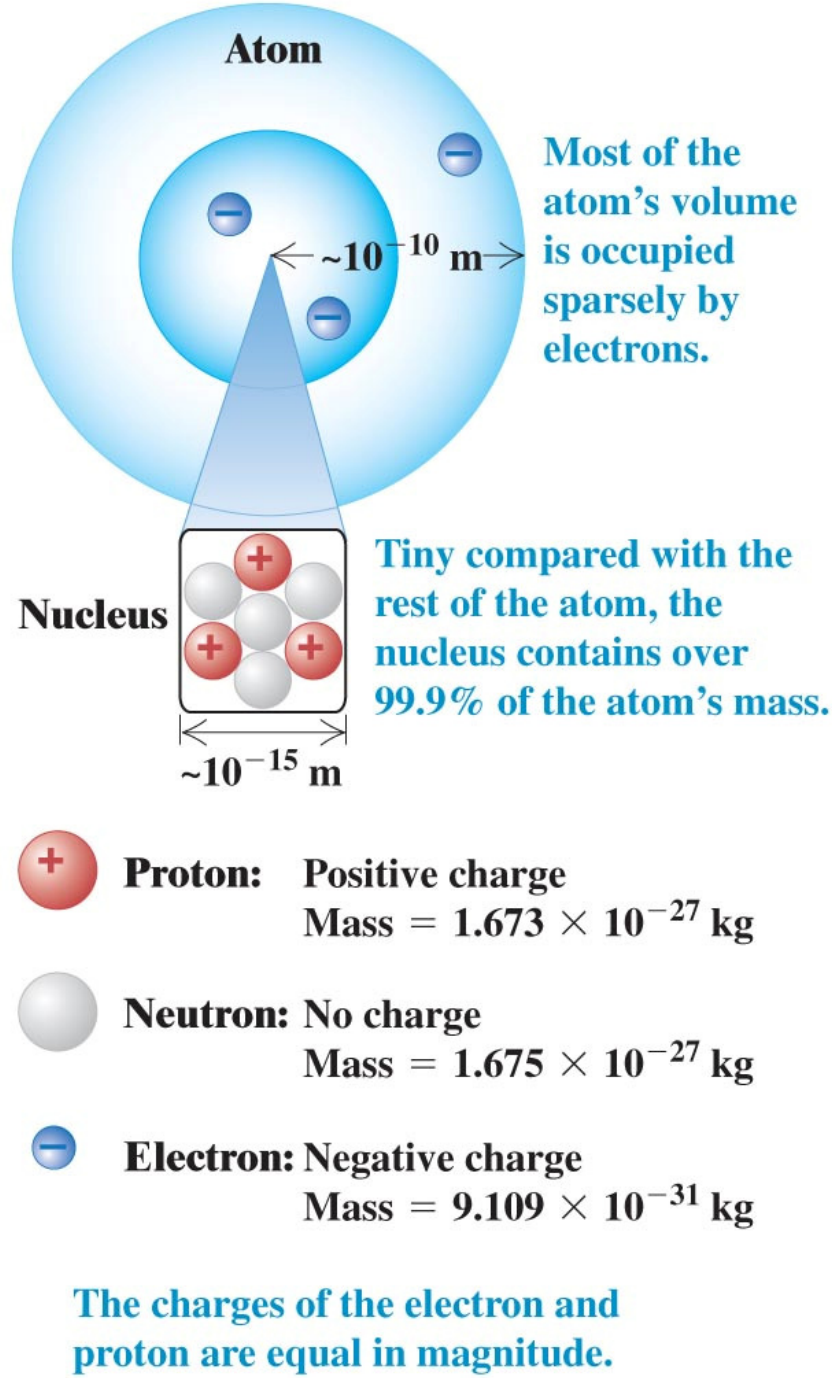
$$m_p = 1.673 \times 10^{-27} kg$$

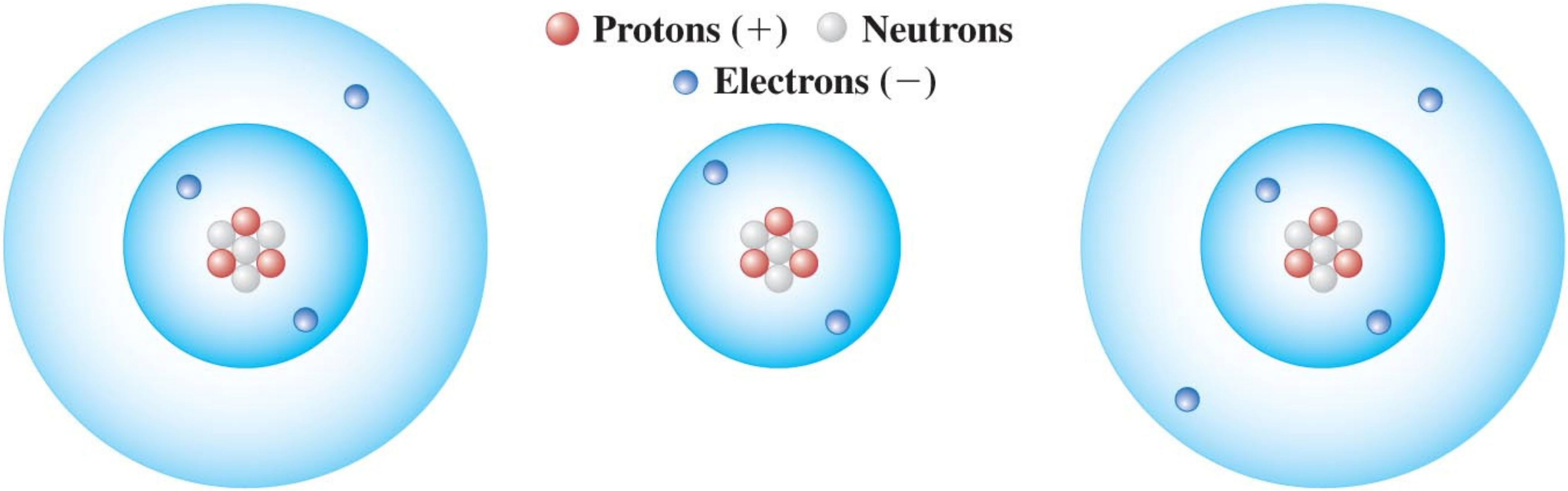
$$q_p = -e = 1.6 \times 10^{-19} C$$

neutron

$$m_n = 1.675 \times 10^{-27} kg$$

$$q_n = 0$$





(a) Neutral lithium atom (Li):

3 protons (3+)
4 neutrons
3 electrons (3−)

Electrons equal protons:
Zero net charge

(b) Positive lithium ion (Li^{+}):

3 protons (3+)
4 neutrons
2 electrons (2−)

Fewer electrons than protons:
Positive net charge

(c) Negative lithium ion (Li^{-}):

3 protons (3+)
4 neutrons
4 electrons (4−)

More electrons than protons:
Negative net charge

Conductors and Insulators

- Conductors. Materials where the outer electrons of the atoms are free to move from atom to atom (they don't belong to a particular atom). Most metals. Charges move freely inside the conductor.
- Insulators. Electrons are associated with a particular atom. Very few electrons can move free in an insulator.

Part 2

- Electric charges and Fields.

The electric charge. Quantization and types of electric charge. Atomic structure. Conductors and Insulators.

Coulomb’s law. The Electric Field and Electric field lines.

Charge induction and polarization. Conductors and insulators in Electric fields. Capacitors.

Electric flux and Gauss law.

The Coulomb force

Coulomb in 1784 studied the electric force between two charged spheres and found:

$$\left|\vec{F}\right| = k\frac{|Q_1||Q_2|}{r^2} \quad k = 8.987\times10^9\ N\cdot m^2/C^2$$

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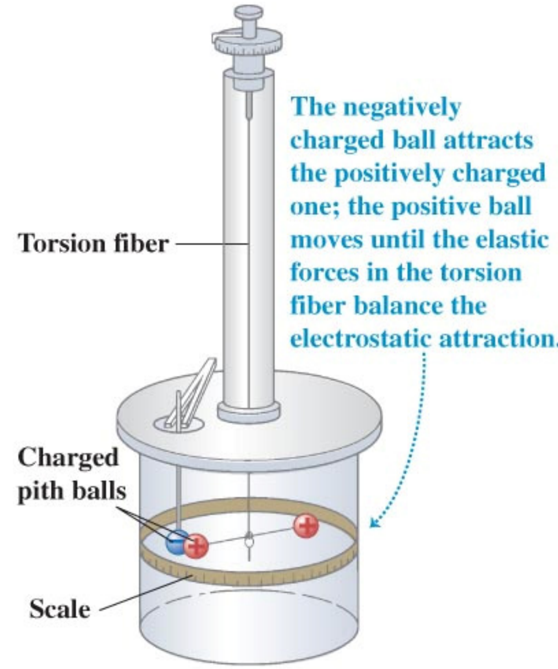
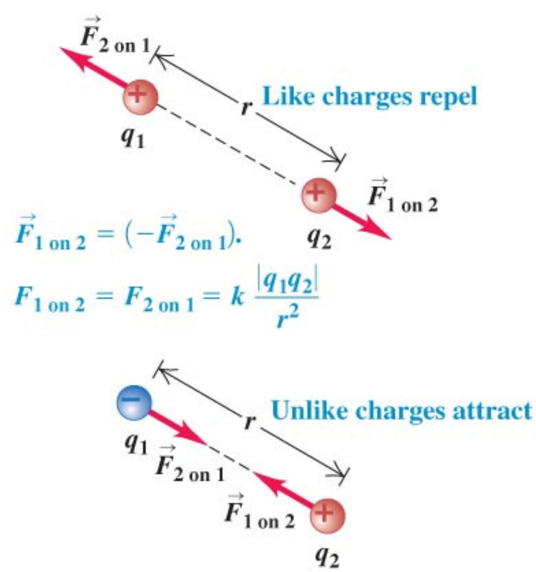


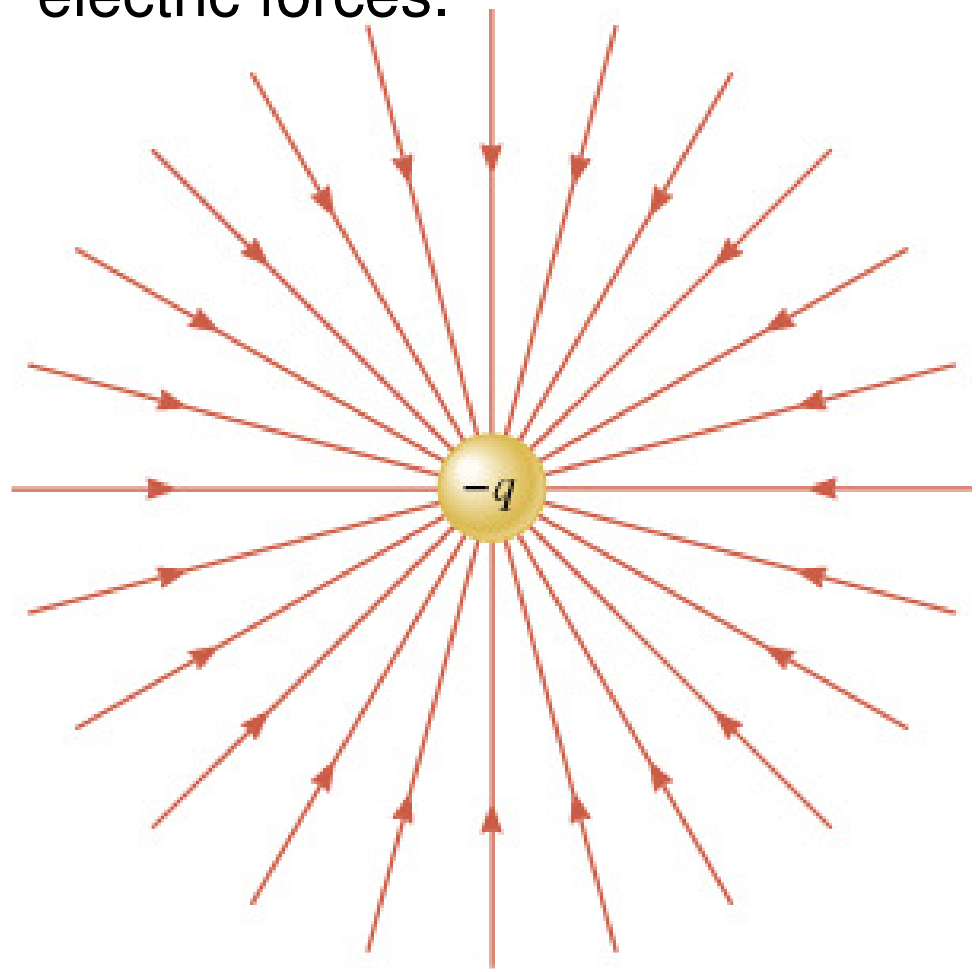
(a) A torsion balance of the type used by Coulomb to measure the electric force



(b) Interaction of like and unlike charges

Michael Faraday 1791 - 1867

Every charge generates around it an electric field. The charged particle is never by itself. It is always accompanied by its own field which is the generator of electric forces.



The Electric Field.

- This concept of "force" field was introduced to explain the counterintuitive concept of action-at-a-distance (two bodies exercise each other a force while they are not in contact).

- Consider a charge Q. If we introduce an arbitrary "test" charge q at some distance r from the charge Q a Coulomb force |F| will be exercised on q (and vice versa). But |F|/q is constant (independent of the "test" charge q) as you can see from Coulomb's law.

- We call the ratio |F|/q the Electric Field E generated by the charge Q.

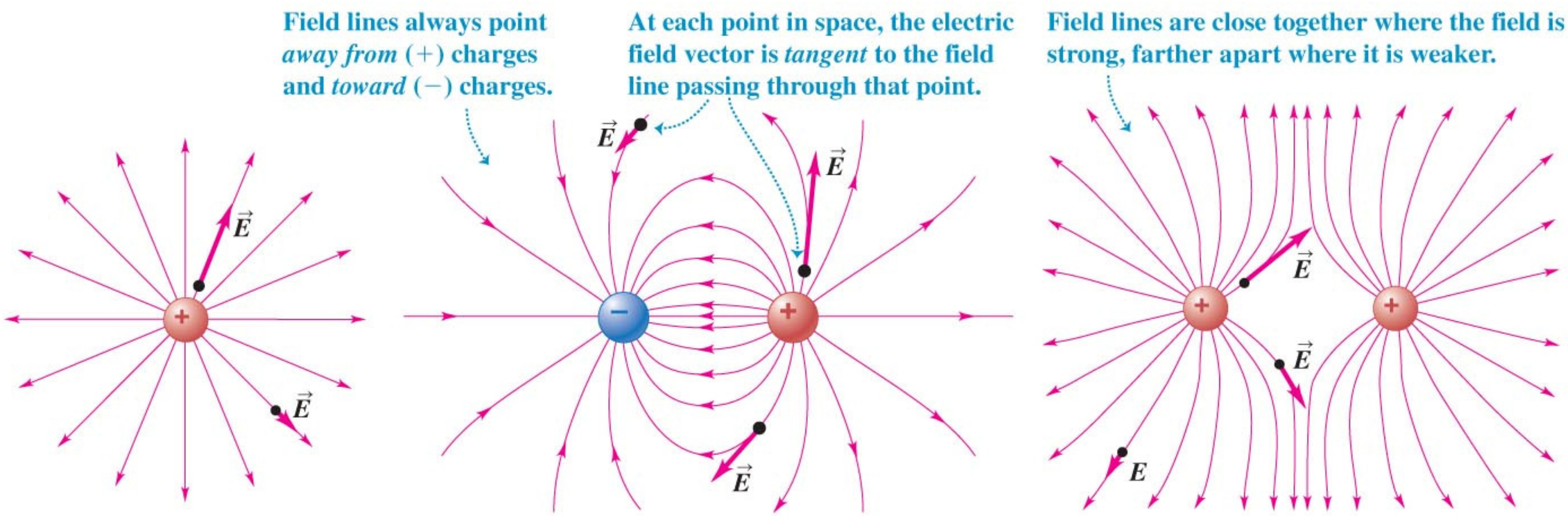
- An (arbitrary) charge distribution generates an electric field around it. Any "test" charge introduced comes in "contact" with the Electric field and feels the Coulomb force.

The Electric Field - II.

- The Electric Field is a “vector field” that is we associate at each point of space a vector whose magnitude and direction depends on the charge distribution that generated the Electric Field.

- Electric Field lines: The set of lines with the property that the Electric Field at each point of the line is tangent to the line. They are lines of force.

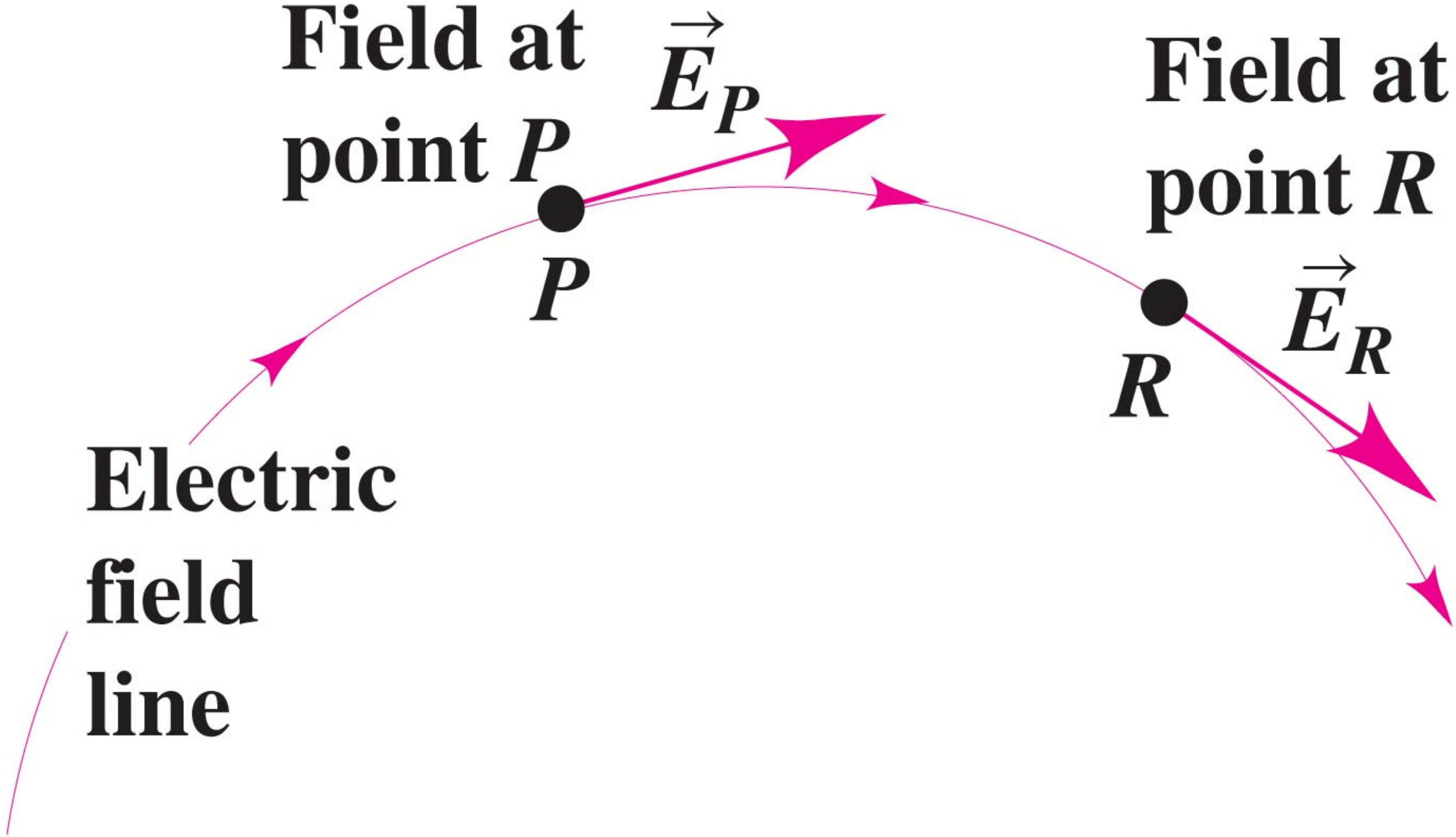
- Orientation of the Electric field lines. They point away from the positive charges towards the negative charges.



(a) A single positive charge

(b) Two equal and opposite charges (a dipole)

(c) Two equal positive charges



Field at
point P
$\vec{E}_P$
P
Field at
point R
$\vec{E}_R$
R
Electric
field
line

Part 3

- Electric charges and Fields.

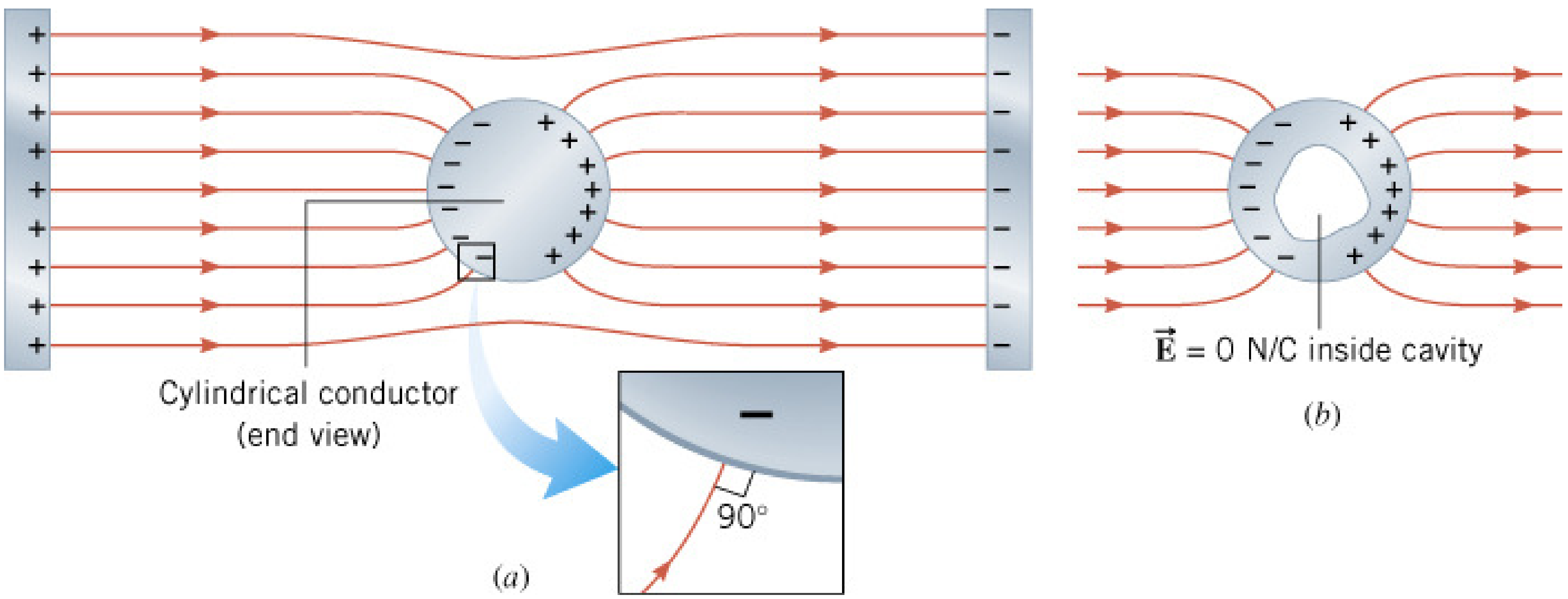
The electric charge. Quantization and types of electric charge. Atomic structure. Conductors and Insulators.

Coulomb's law. The Electric Field and Electric field lines.

Conductors and insulators in Electric fields. Charge induction and polarization. Capacitors.

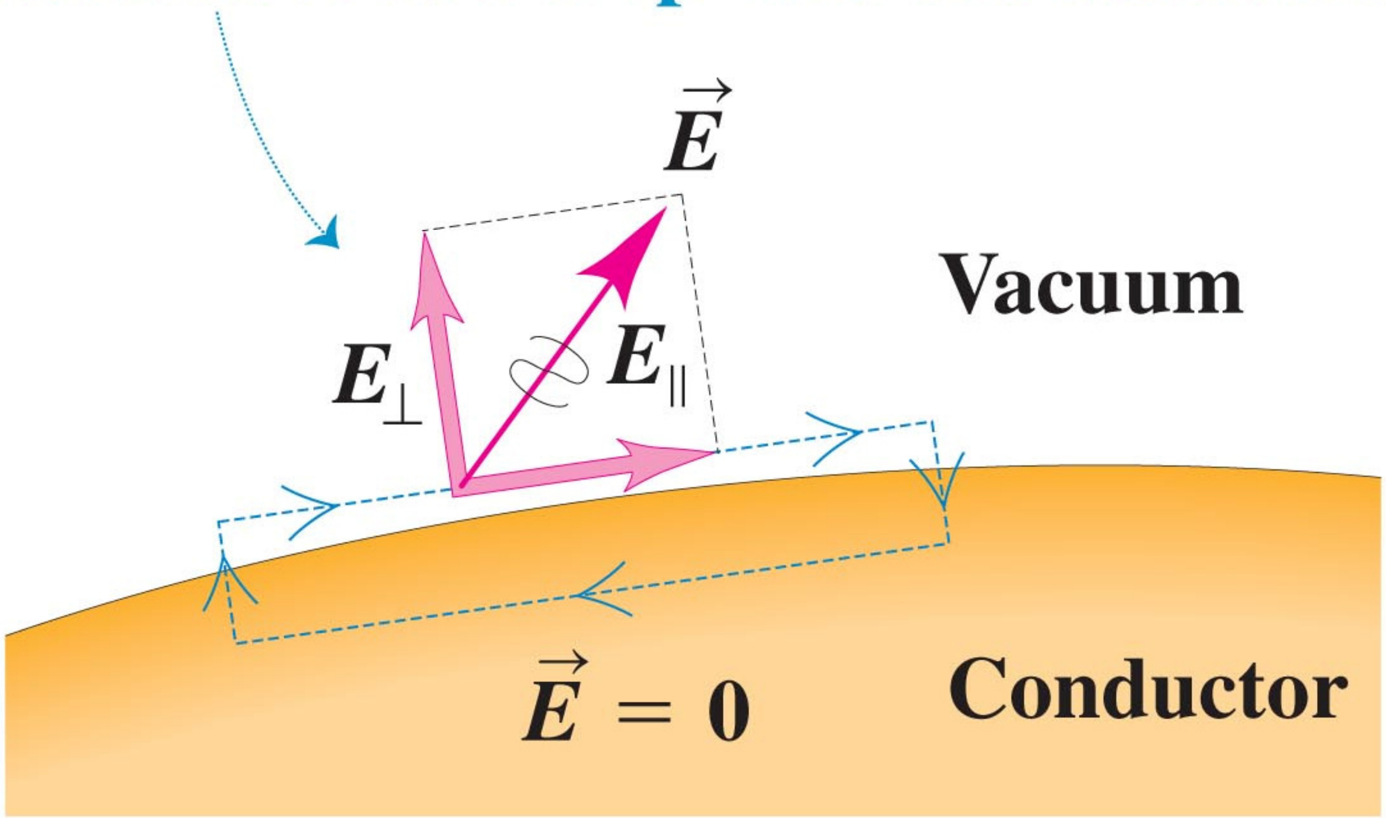
Electric flux and Gauss law.

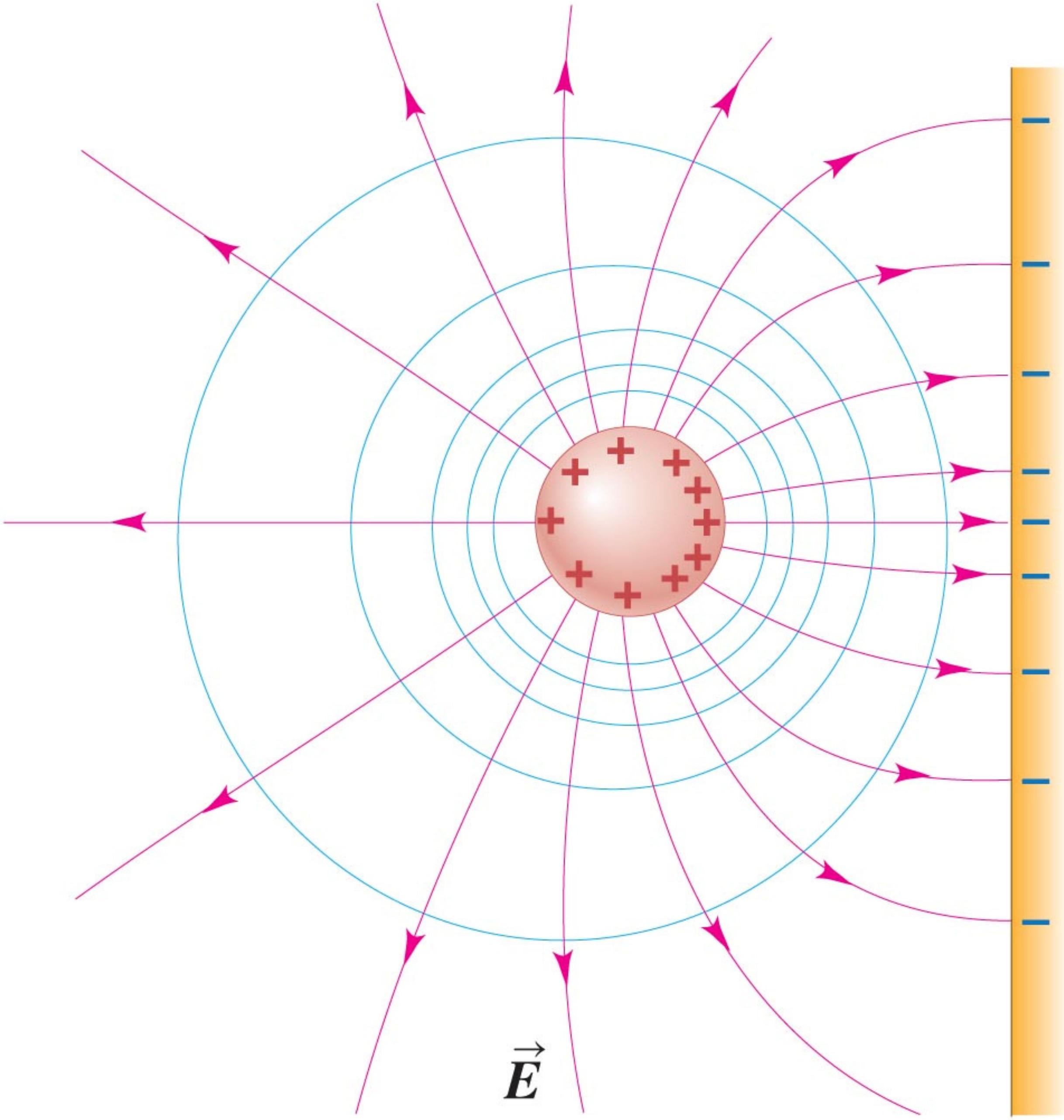
The free charges inside a conductor distribute themselves at the conductor's surface in such a way so that the Electric field inside the conductor is zero.



This doesn't happen!

If the electric field at the surface of a conductor had a tangential component $E_{\parallel}$, the electron could move in a loop with net work done.

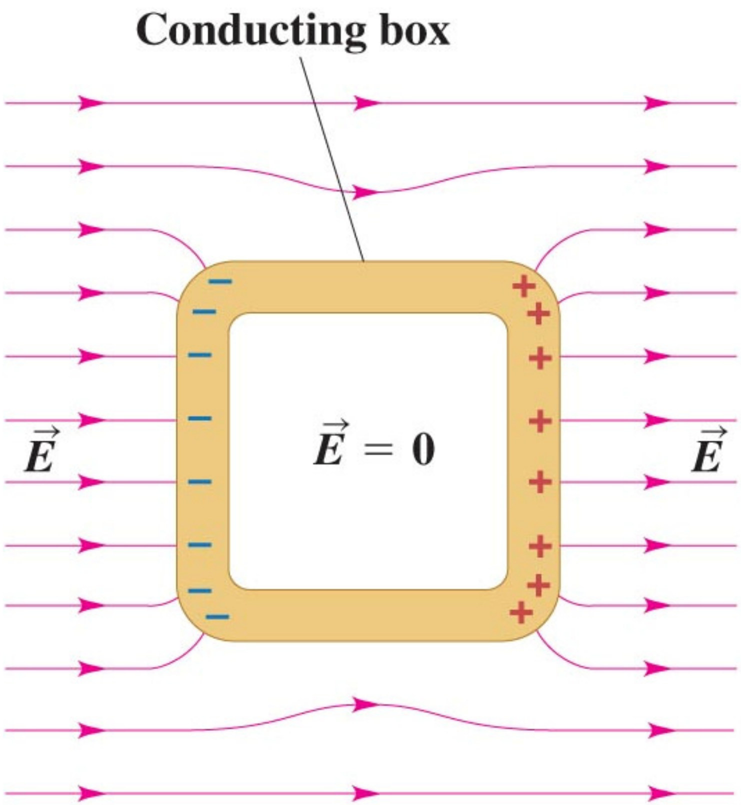




The electric field at the conductor's surface is normal to the surface.

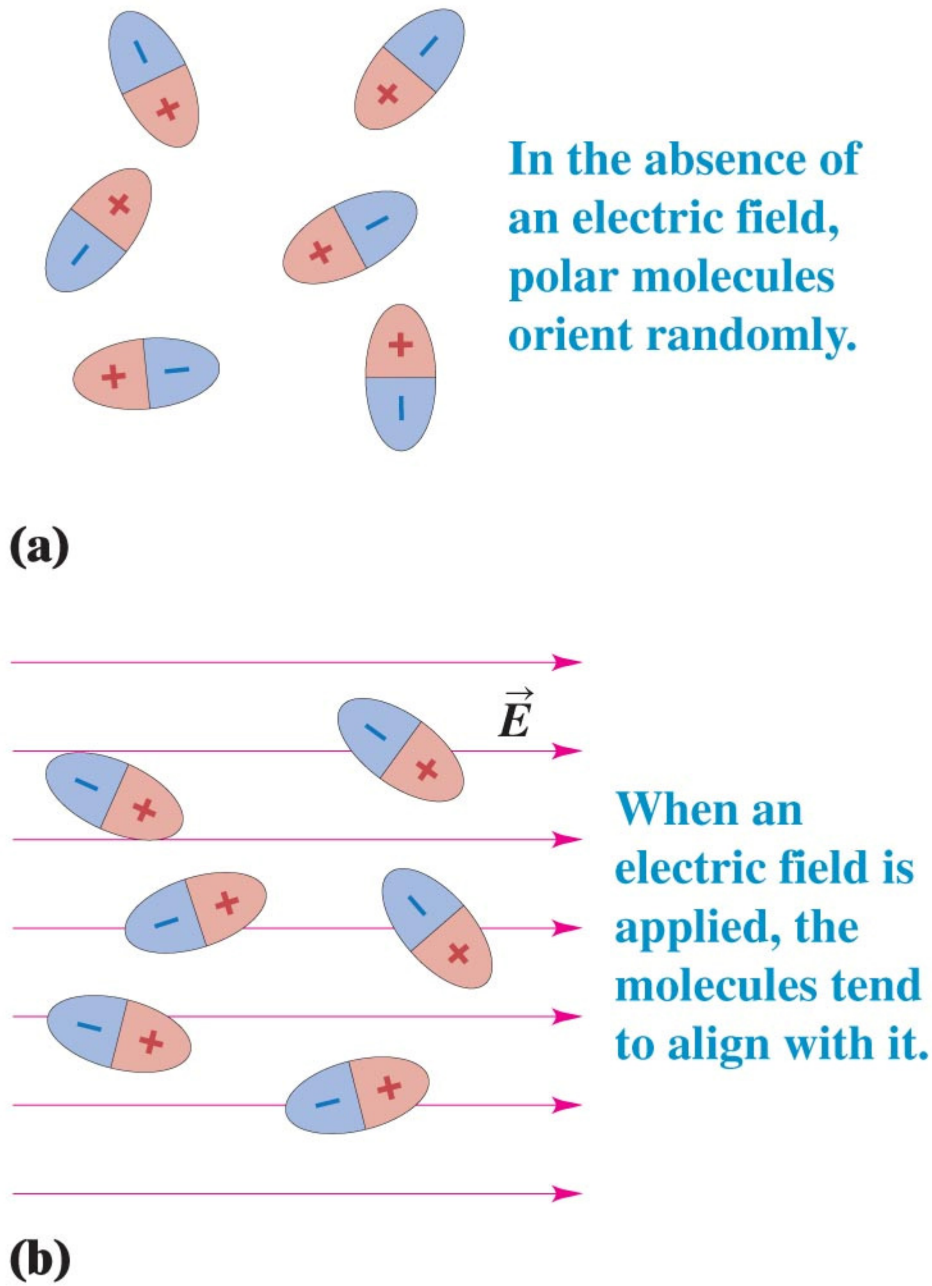
The field induces charges on the left and right sides of the conducting box.

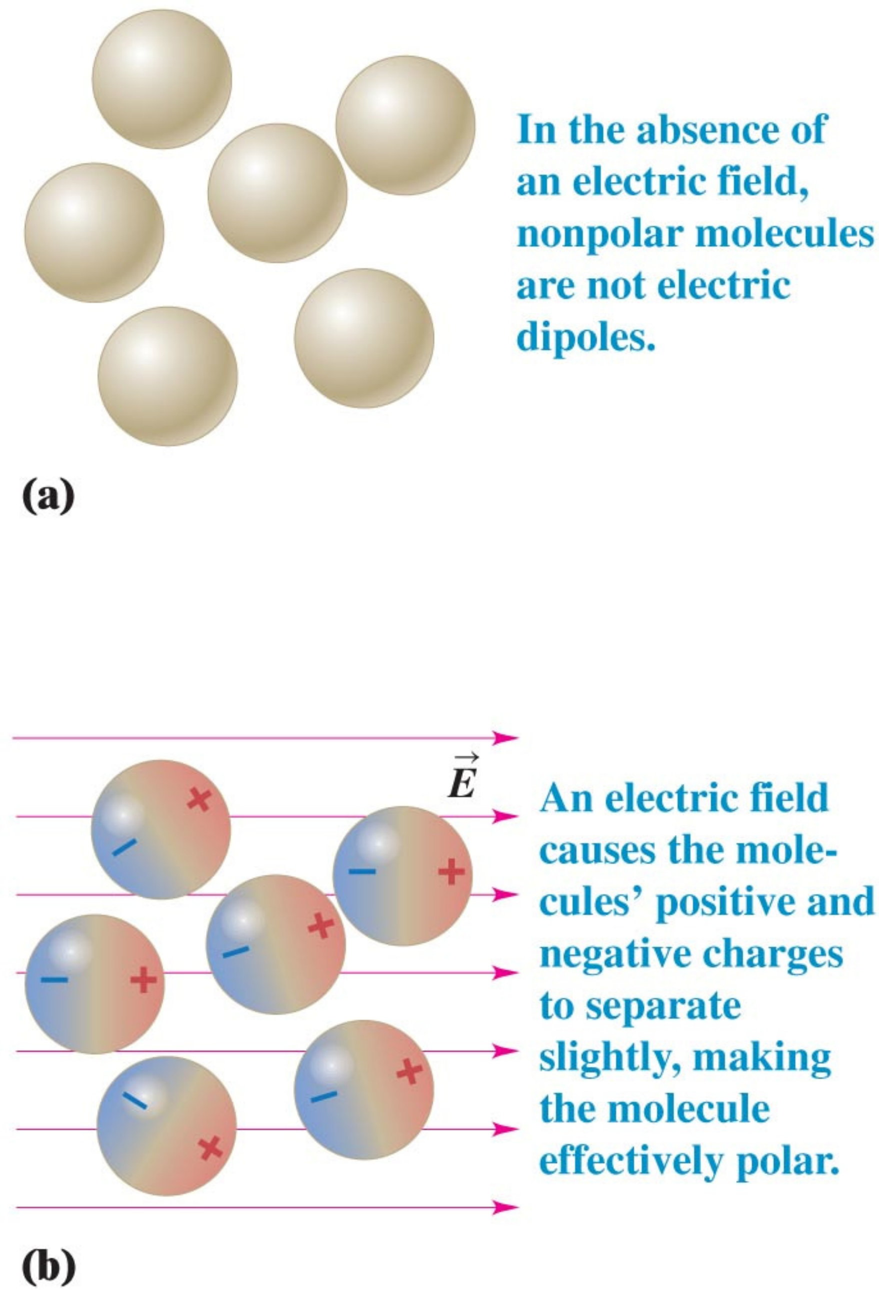
The total electric field inside the box is zero; the presence of the box distorts the field in adjacent regions.



(a)

(b)


In the absence of an electric field, polar molecules orient randomly.
(a)
$\vec{E}$
When an electric field is applied, the molecules tend to align with it.
(b)


In the absence of an electric field, nonpolar molecules are not electric dipoles.
(a)
$\vec{E}$
An electric field causes the molecules' positive and negative charges to separate slightly, making the molecule effectively polar.
(b)

Question

- A charge Q is introduced in an Electric Field $\vec{E}$

  What is the Coulomb force (magnitude and orientation) that the charge Q is going to feel?

Question

- A charge Q is introduced in an Electric Field $\vec{E}$

  What is the Coulomb force (magnitude and orientation) that the charge Q is going to feel?

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

The force on a positive test charge points in the direction of the electric field.

The force on a negative test charge points opposite to the electric field.

Induction and Polarization

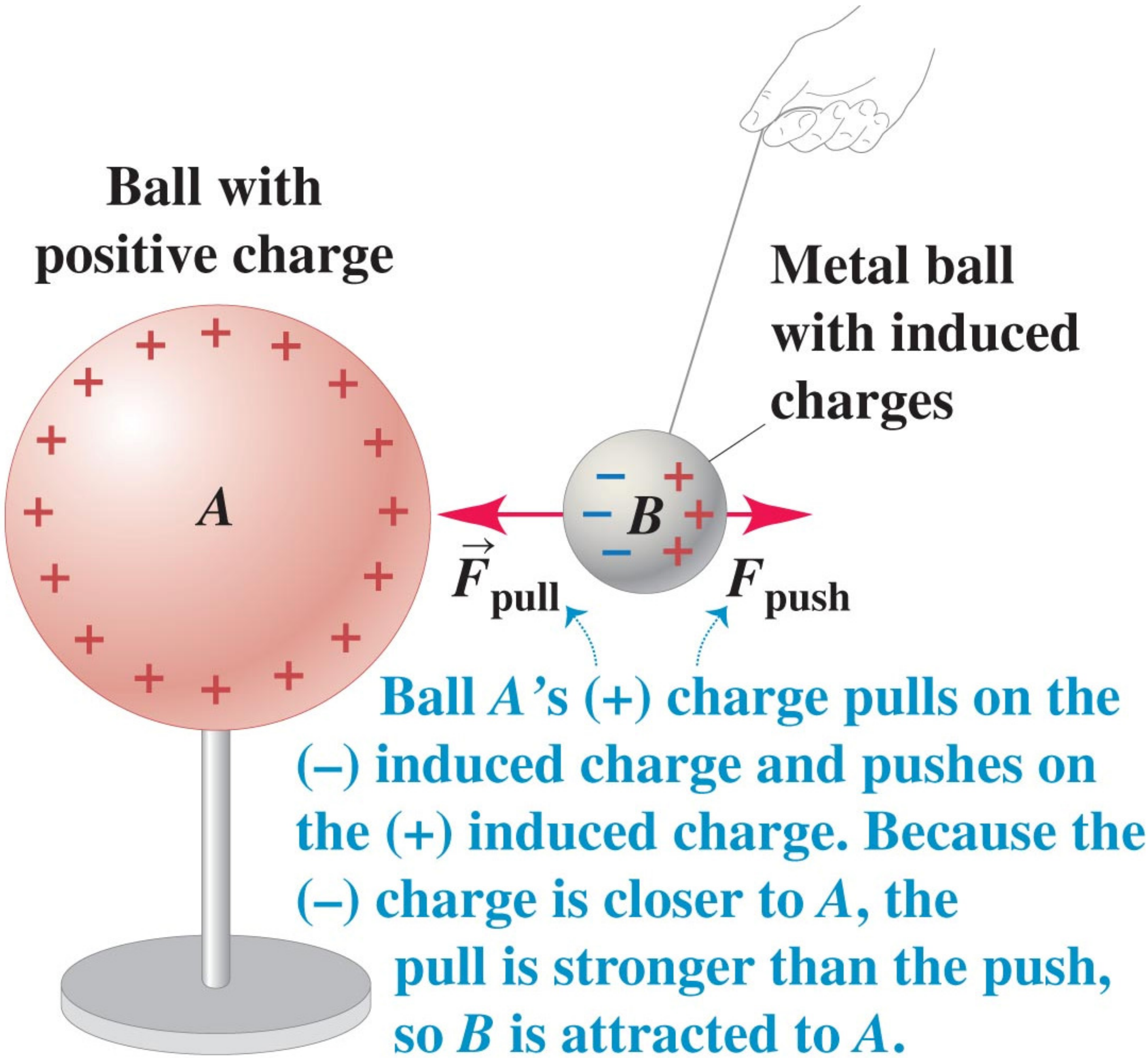
- Induction. Redistribution of charges in a material because of the presence of external charges (or external field).
- Polarization. The separation of the electron center of mass form the nucleus center of mass in an atom because of external charges. Atom behaves like an electric dipole.
- Electric Dipole. A positive and an equal negative charge separated by a distance D. Although the total charge is 0 an electric field is generated.

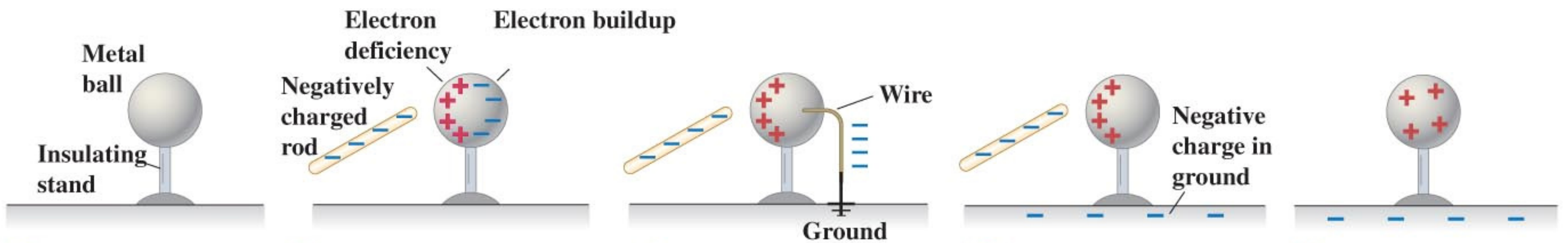
Conductors in external Electric Fields

- If we place a conductor in an external Electric Field, freely moving charges in the conductor will re-distribute themselves on the conductor's surface until the TOTAL (external + induced) electric field inside the conductor becomes 0.

- Conductors are Electric Field "shields".

- The freely moving charges in a conductor always accumulate themselves on the surface of the conductor.


Ball with
positive charge
A
Metal ball
with induced
charges
B
$\vec{F}_{pull}$
F_{push}
Ball A's (+) charge pulls on the (–) induced charge and pushes on the (+) induced charge. Because the (–) charge is closer to A, the pull is stronger than the push, so B is attracted to A.



1 Uncharged metal ball

2 Negative charge on rod repels electrons, creating zones of negative and positive **induced charge.**

3 Wire lets electron build-up (induced negative charge) flow into ground.

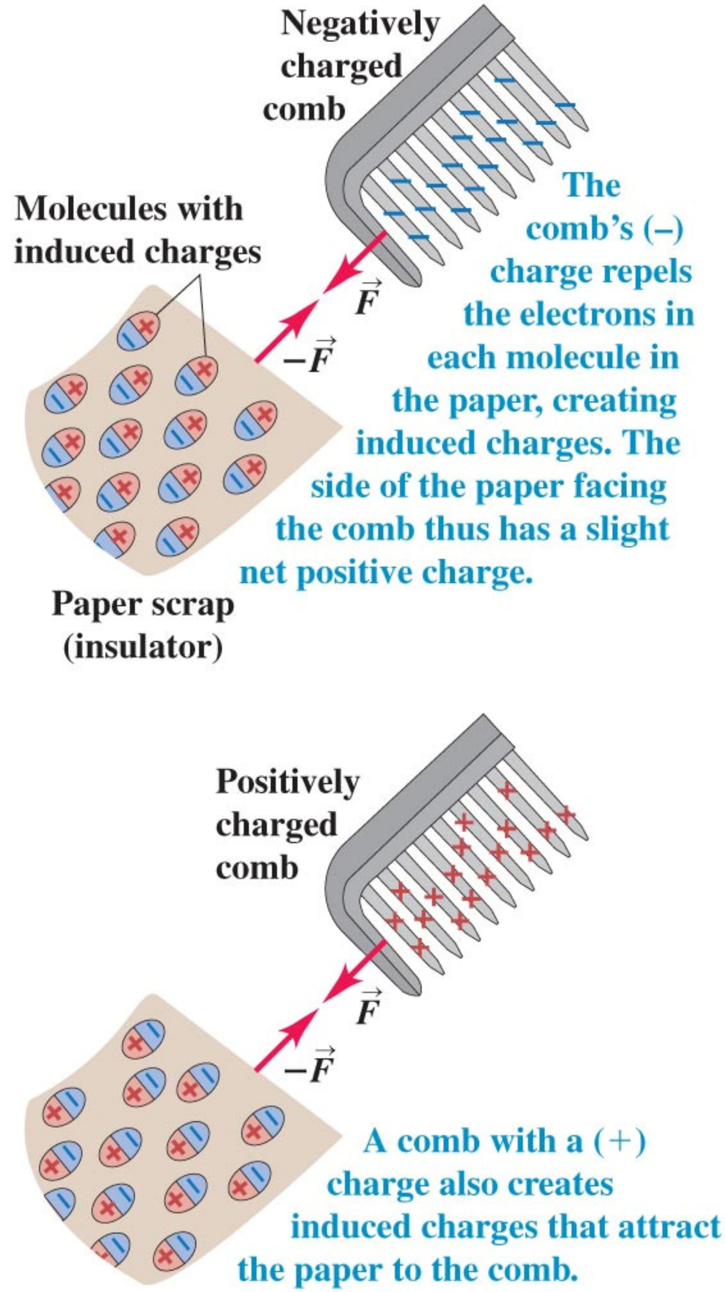
4 Wire removed; ball now has only an electron-deficient region of positive charge.

5 Rod removed; positive charge spreads over ball.

Insulators in external Electric Fields

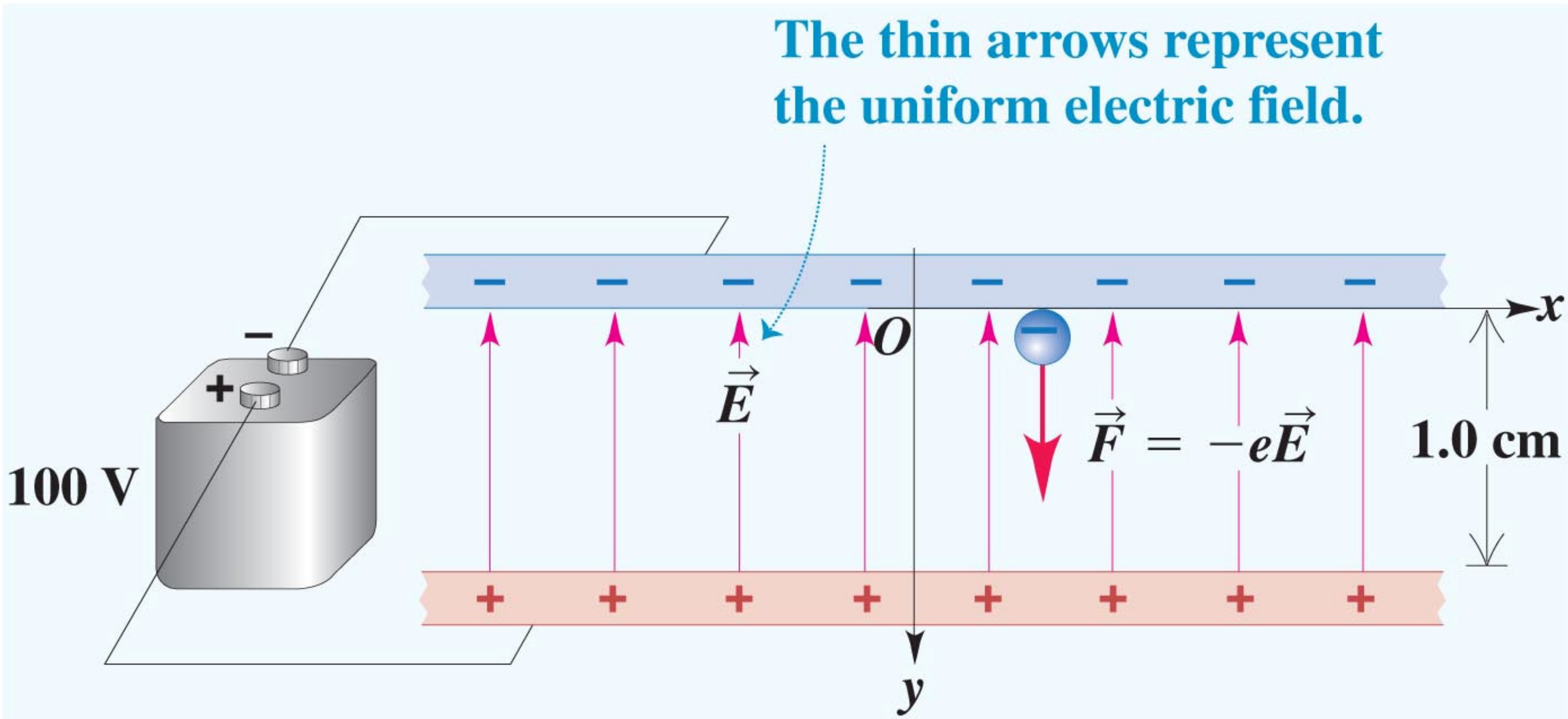
- If we place a insulator in an external Electric Field, the (atomic) dipoles in the material will orient themselves according to the direction of the external Electric Field. The TOTAL field in the insulator will be less than the external field but it will not become 0.

- Inductors do NOT "shield" from Electric Fields.


Negatively charged comb
Molecules with induced charges
$\vec{F}$
$-\vec{F}$
The comb's (–) charge repels the electrons in each molecule in the paper, creating induced charges. The side of the paper facing the comb thus has a slight net positive charge.
Paper scrap (insulator)
Positively charged comb
$\vec{F}$
$-\vec{F}$
A comb with a (+) charge also creates induced charges that attract the paper to the comb.

Capacitors

- Two parallel plates that carry equal and opposite sign charge.
- The electric field in the area between the plates is constant and uniform (electric field lines are straight lines).
- The electric field outside the area between the parallel plates is 0.


The thin arrows represent
the uniform electric field.
100 V
$\vec{E}$
O
x
y
$\vec{F} = -e\vec{E}$
1.0 cm

Part 4

- Electric charges and Fields.

The electric charge. Quantization and types of electric charge. Atomic structure. Conductors and Insulators.

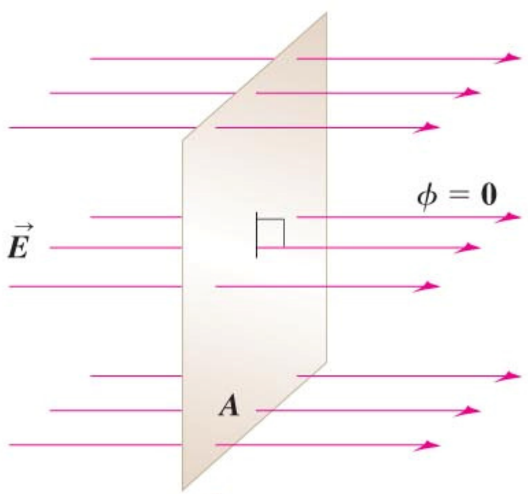
Coulomb’s law. The Electric Field and Electric field lines.

Charge induction and polarization. Conductors and insulators in Electric fields. Capacitors.

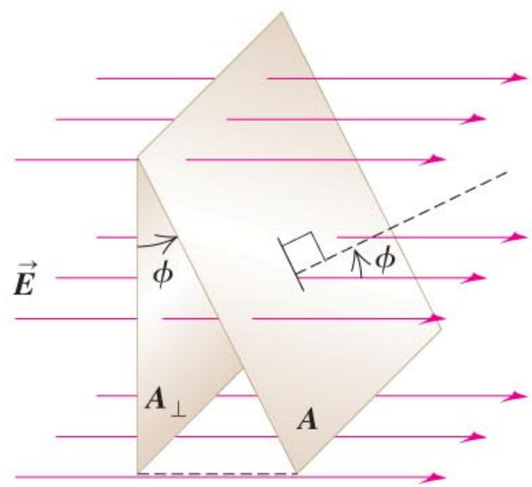
Electric flux and Gauss law.

Electric Flux.

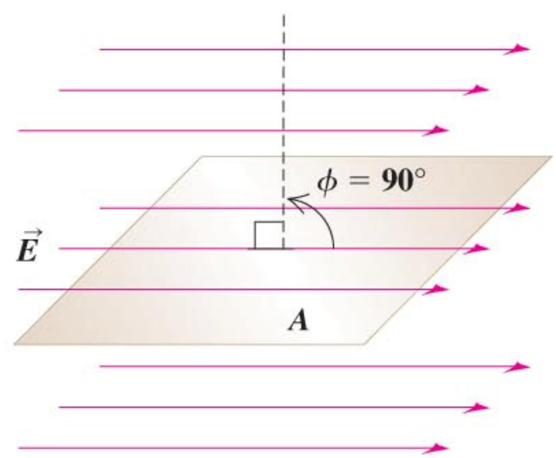
Consider an Electric Field and an area A (formed by a closed loop) inside the region with the field. Question: How much Electric Field is passing through the surface?



Electric field $\vec{E}$ is perpendicular to area A; the angle between $\vec{E}$ and a line perpendicular to the surface is zero.
The flux is $\Phi_E = EA$.



Area A is tilted at an angle ϕ from the perpendicular to $\vec{E}$.
The flux is $\Phi_E = EA \cos \phi$.



Area A is parallel to $\vec{E}$ (tilted at 90° from the perpendicular to $\vec{E}$).
The flux is $\Phi_E = EA \cos 90 = 0$.

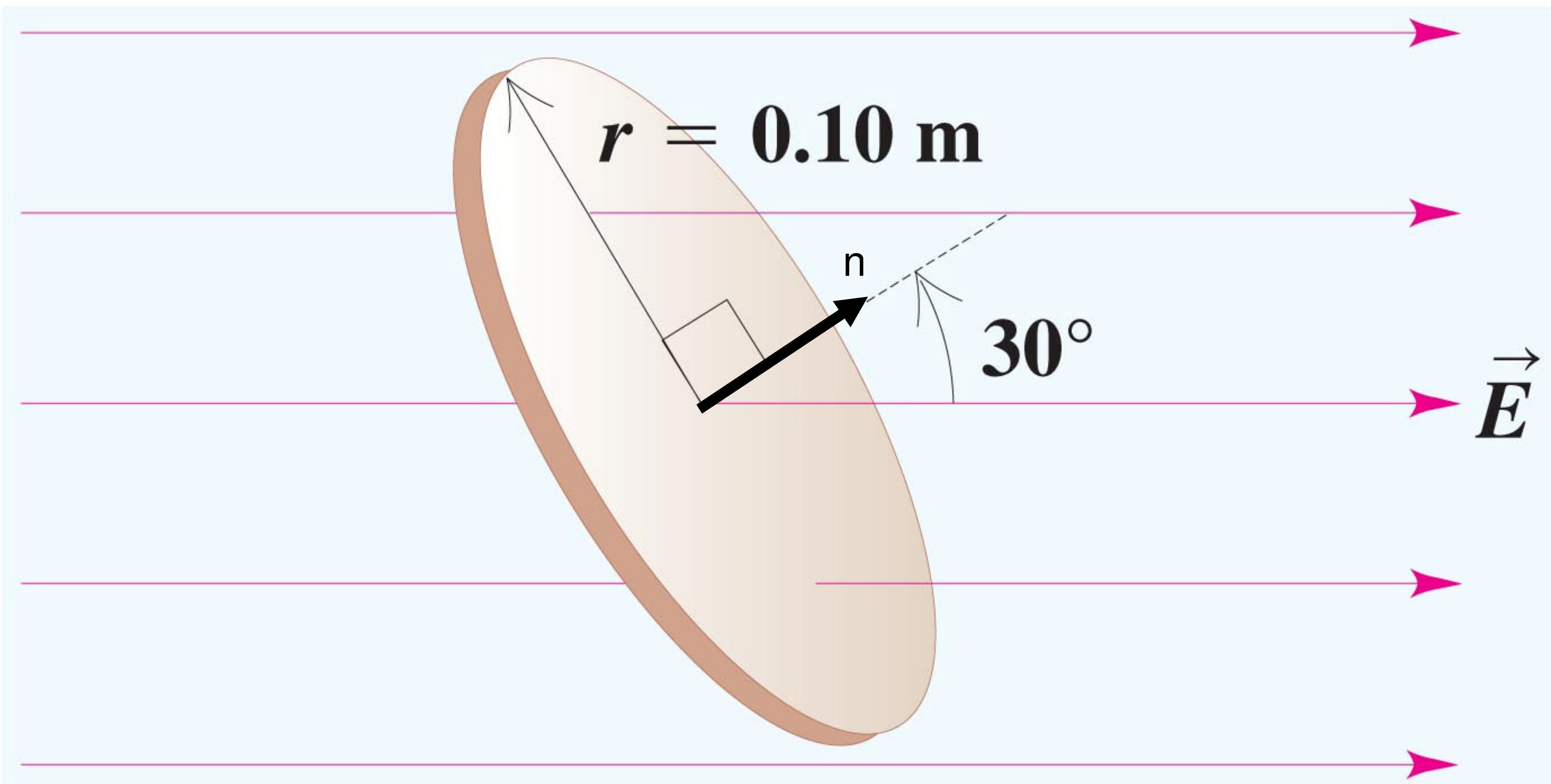
Electric Flux.

- Consider an Electric Field and an area A (formed by a closed loop) inside the region with the field. Question: How much Electric Field is passing through the surface?

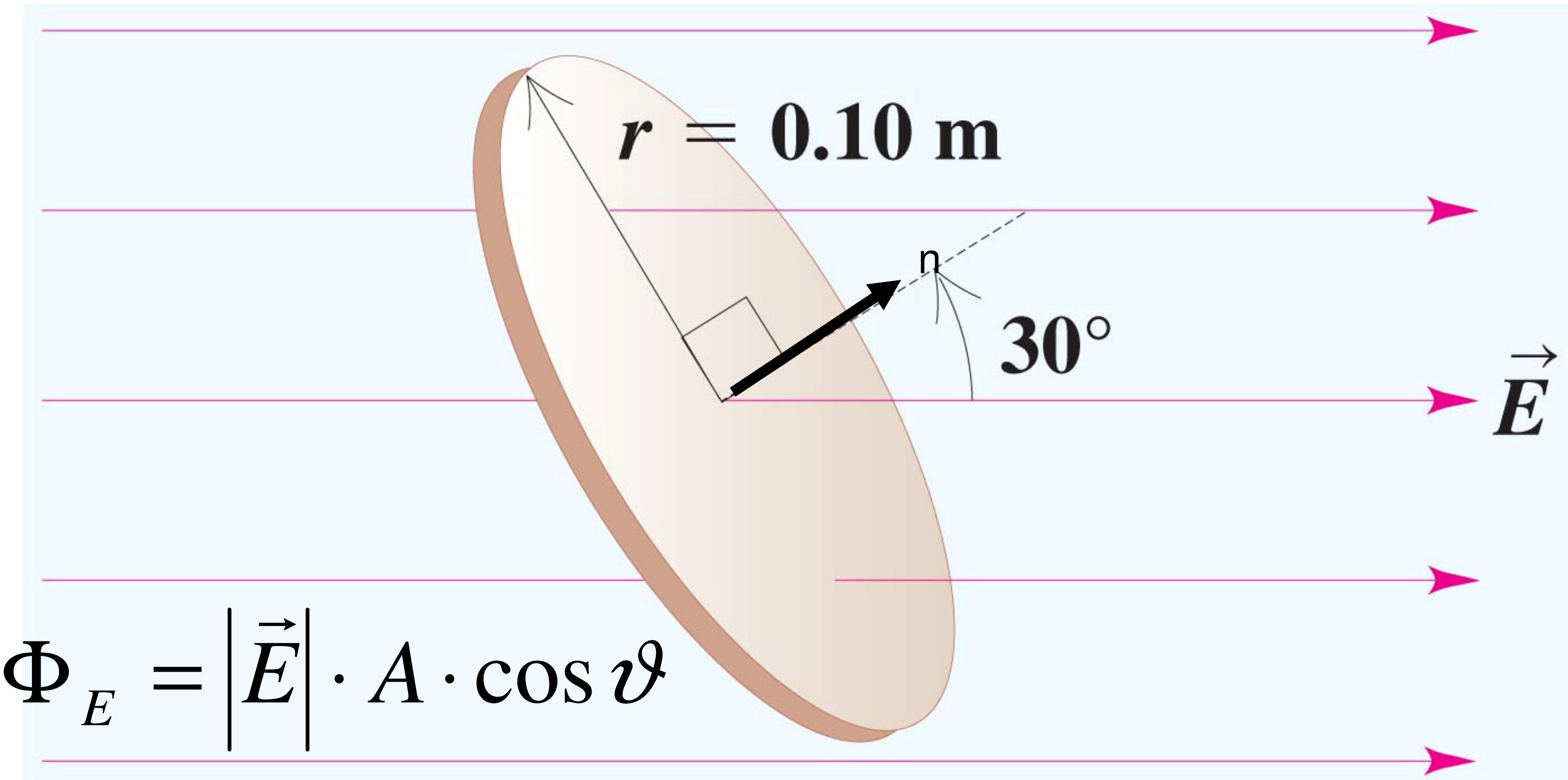
- The answer depends on the strength of the field E, the size of the area and the orientation of the area relative to the orientation of the field.

Electric Flux.

$$\Phi_E = \left|\vec{E}\right| \cdot A \cdot \cos\vartheta$$



Orientation of a surface in math is done with a unit vector n that is perpendicular to the surface:

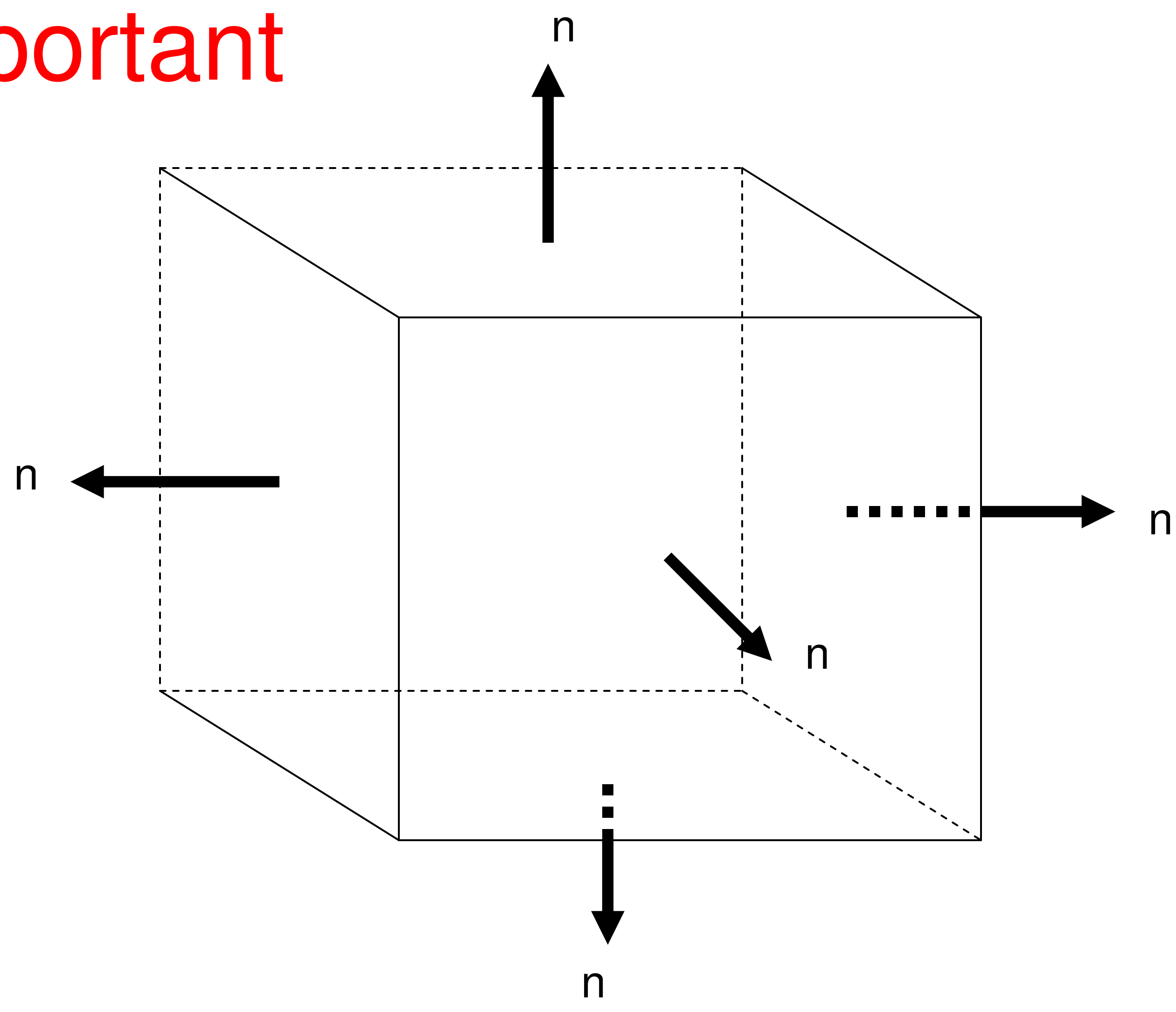


$$\Phi_E = \left|\vec{E}\right| \cdot A \cdot \cos\vartheta$$

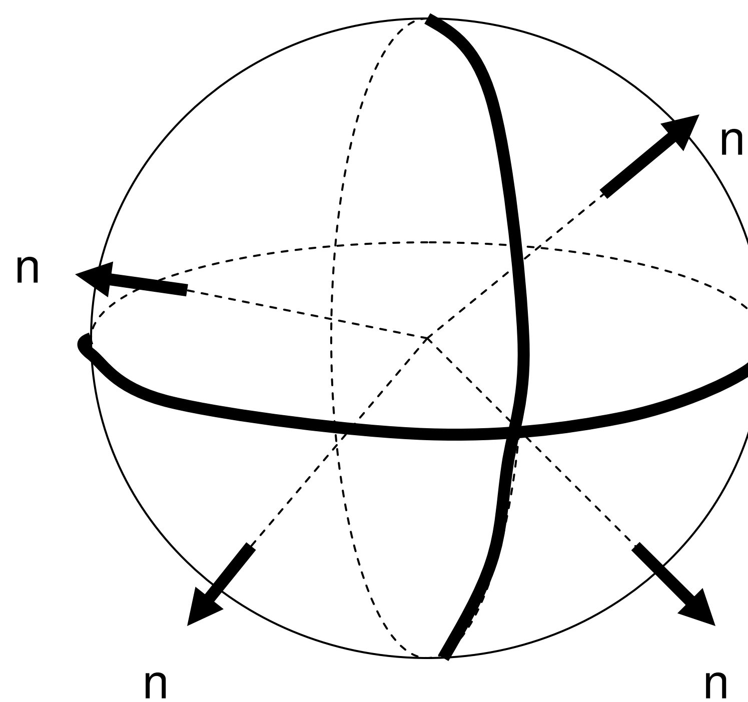
Flux may be positive or negative. Flux sign shows the direction of the flow of the Vector field through the surface, with respect to the chosen orientation of the Surface (where the unit vector n points)

If we have a **CLOSED** surface (like the one below) the orientation of the surface at some point of that surface is defined with the unit vector n that is normal to the surface at the point of interest and it points **OUTSIDE** the **CLOSED** surface.

Important



Another example: Orientation of a spherical surface at various points of the surface. The unit vector n is not only perpendicular to the sphere but points OUTSIDE the CLOSED spherical surface.



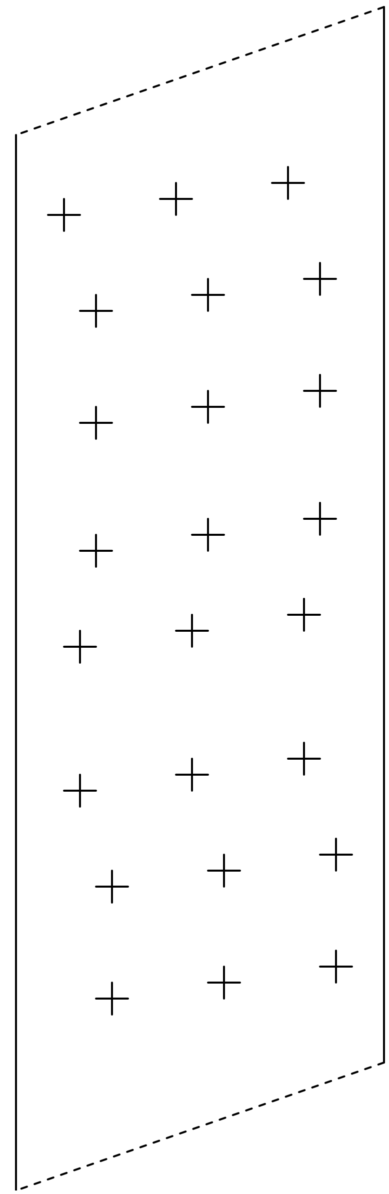
Gauss Law

- The electric flux through a closed surface is equal to the TOTAL charge enclosed by the surface over the constant ε_0.

$$\Phi_{closed} = \frac{Q_{enclosed}}{\varepsilon_0}$$

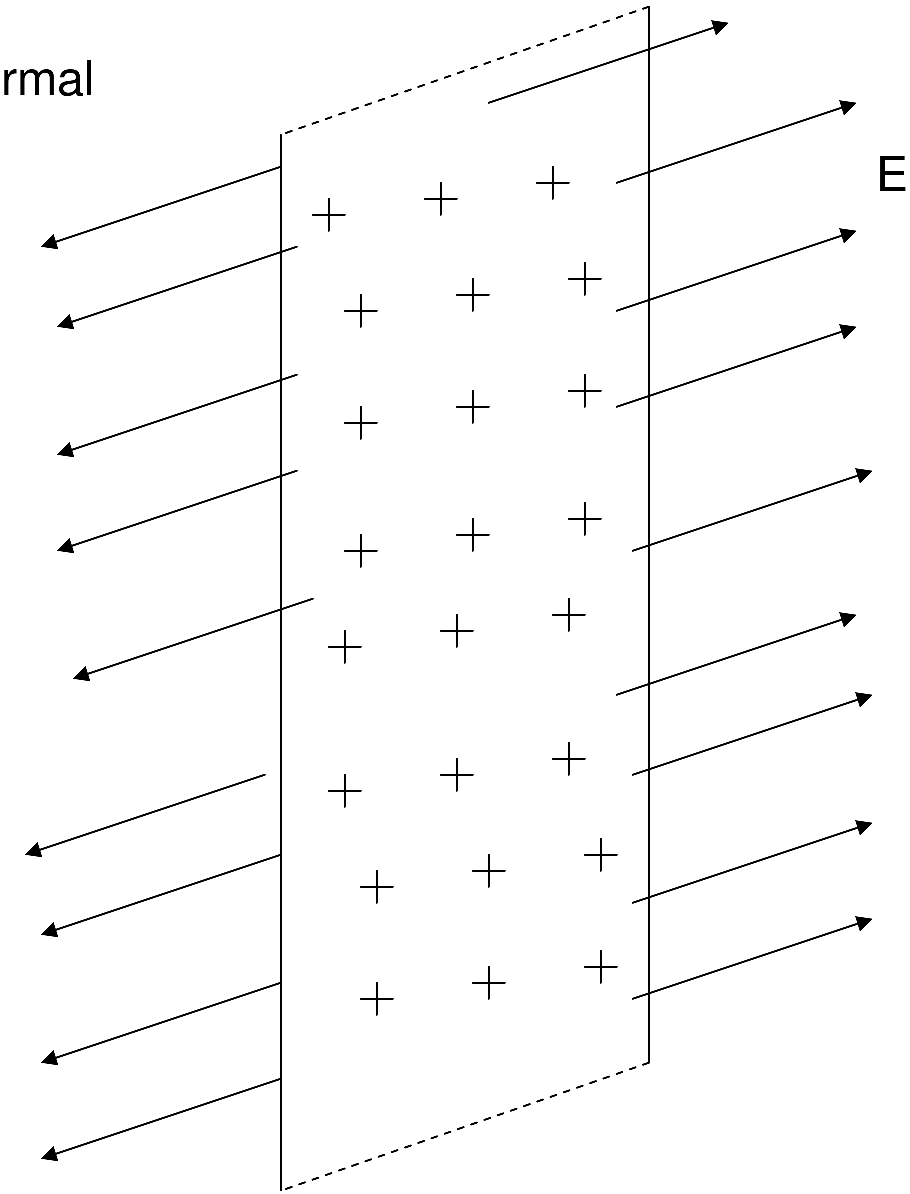
Remember the rule for the orientation of the closed surface. At some parts of the Surface the field flux may be positive and at other parts of the surface the flux may be negative.

Applications of Gauss law: The Electric Field of an infinite charged metallic sheet with surface charge density σ



Applications of Gauss law: The Electric Field of an infinite charged metallic sheet with surface charge density σ

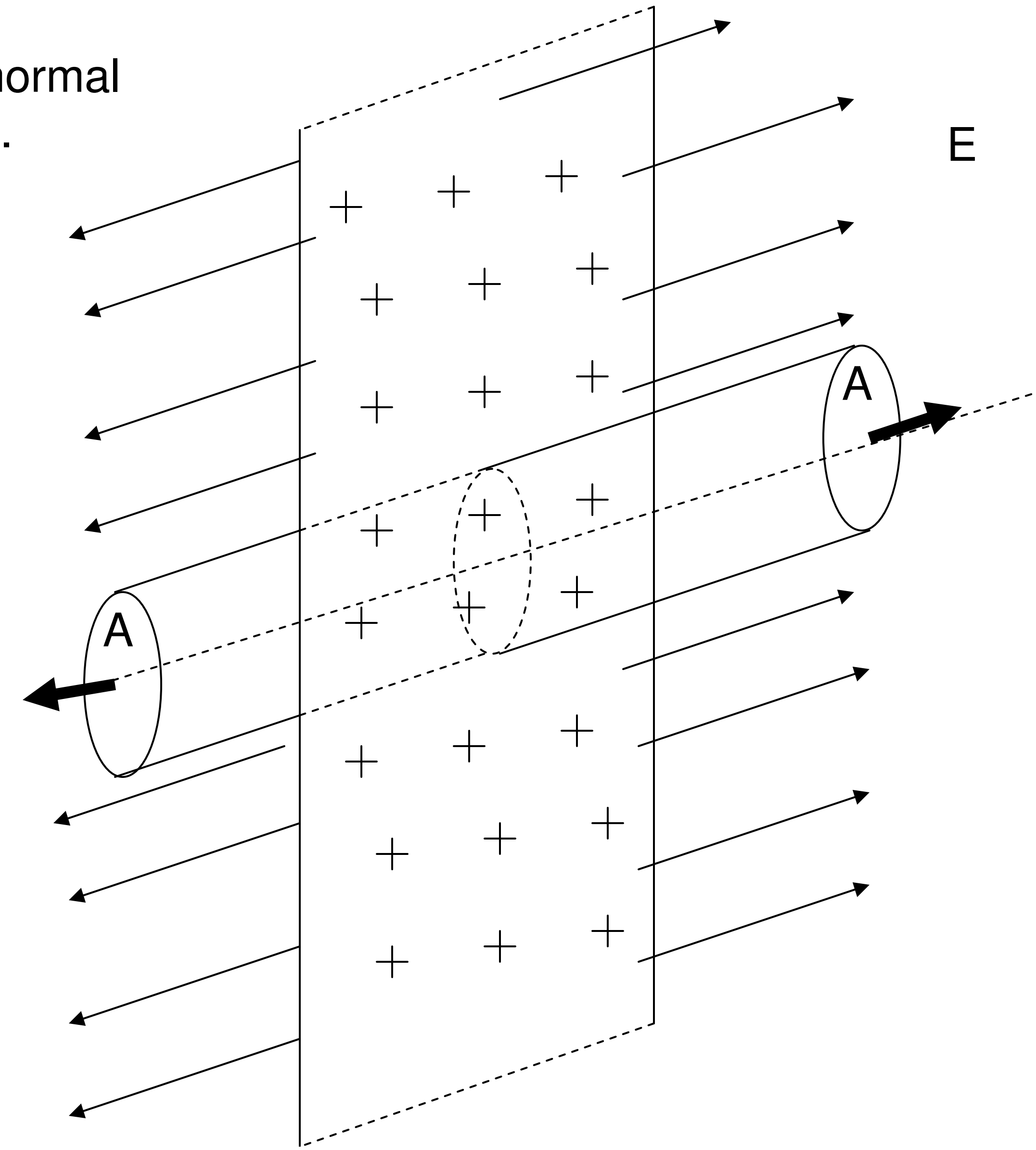
By symmetry electric field lines are normal to the surface and point away from it.



Applications of Gauss law: The Electric Field of an infinite charged metallic sheet with surface charge density σ

By symmetry electric field lines are normal to the surface and point away from it.

Take cylindrical surface normal to the plane. Base surface A.



Applications of Gauss law: The Electric Field of an infinite charged metallic sheet with surface charge density σ

By symmetry electric field lines are normal to the surface and point away from it.

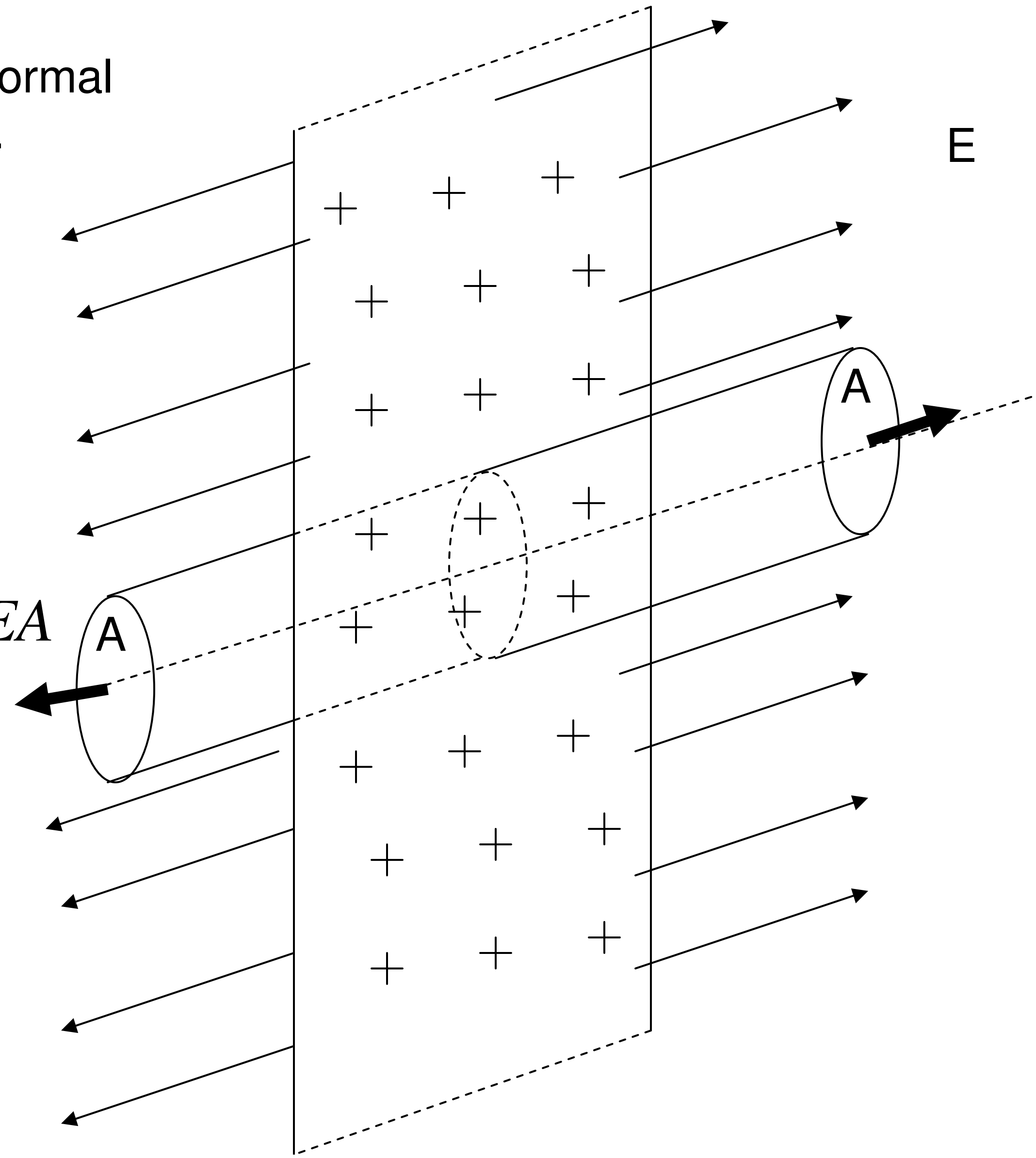
Take cylindrical surface normal to the plane. Base surface A.

No flux is passing from the side surface only from the two bases.

$$\Phi_{total} = EA\cos(0) + EA\cos(0) = 2EA$$

$$\Phi_{total} = \frac{Q_{total}}{\varepsilon_0} = \frac{A\sigma}{\varepsilon_0}$$

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



The Electric Field of an infinite charged metallic sheet with surface charge density σ is:

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

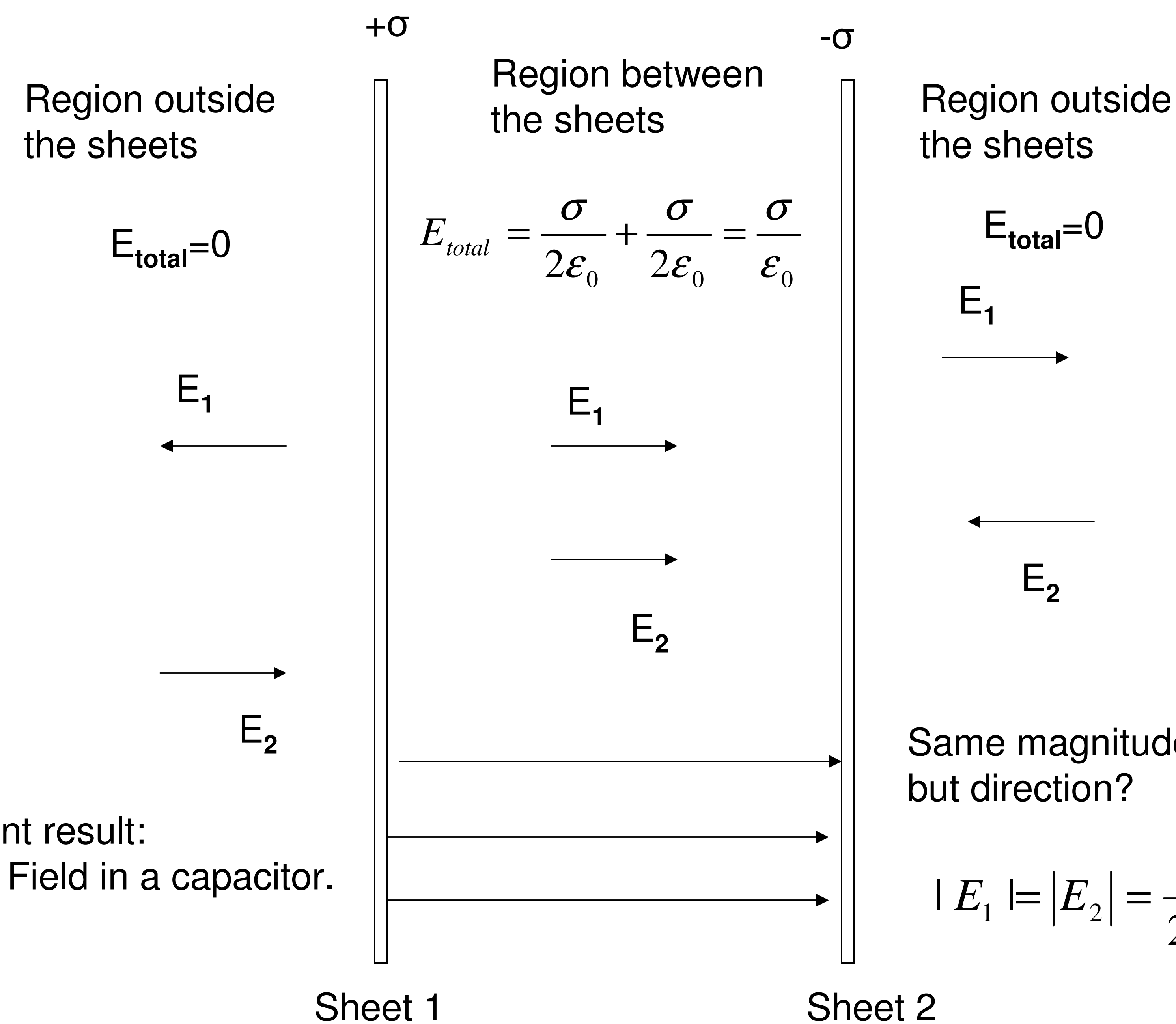
Depending on the sign of the charge it can point away or towards the sheet. Field is constant in magnitude and direction at each side of the sheet.

The Electric Field of an infinite charged metallic sheet with surface charge density σ is:

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

Depending on the sign of the charge it can point away or towards the sheet. Field is constant in magnitude and direction at each side of the sheet.

Important Question: If you have more than one sheet what is the resultant Electric Field? **Hint:** Add the individual Electric Field (vector) contributions.

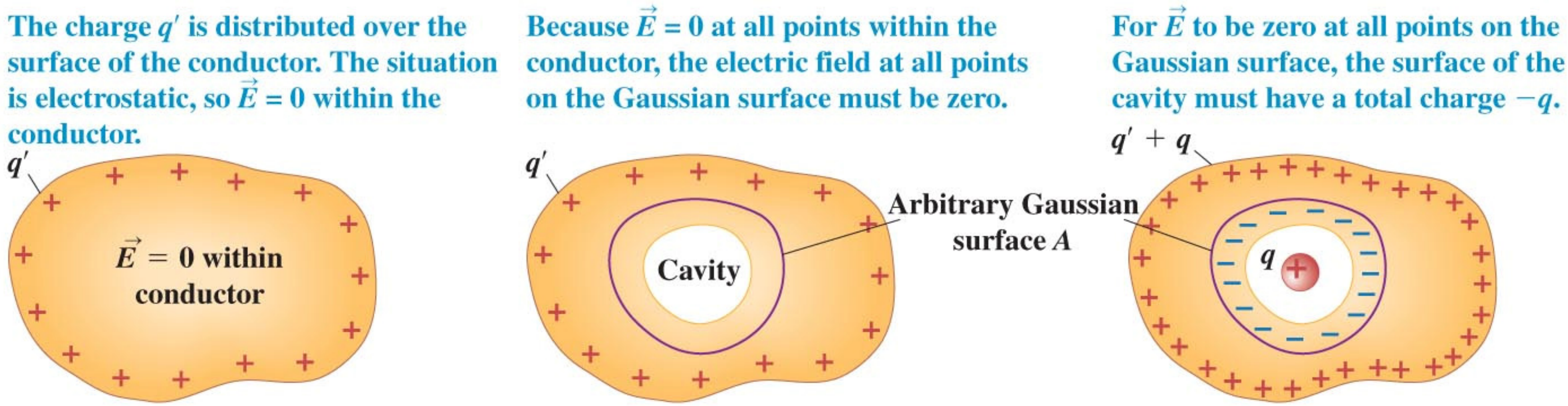


Same magnitude of E but direction?

$$|E_1| = |E_2| = \frac{\sigma}{2\varepsilon_0}$$

Important result:
Electric Field in a capacitor.

Application of Gauss law: Conductor with a hole and a charge in it.



(a) Solid conductor with charge q'

(b) The same conductor with an internal cavity

(c) An isolated charge q is placed in the cavity

Problem Solving Strategy for Electric Field Calculations

- Be sure to use a consistent set of units. Distances must be in meters, charges in coulombs. If you are given cm or nC, don't forget to convert.

- Usually, you will use components to compute vector sums. Use proper vector notation. Distinguish carefully between scalars, vectors, and components of vectors. Indicate your coordinate axes clearly on your diagram, and be certain that the components are consistent with your choice of axes.

- In working out directions of vectors, be careful to distinguish between the *source point S* and the *field point P*. The field produced by a positive point charge always points in the direction from source point to field point; The opposite is true for a negative point charge.