INTRODUCTION TO ELECTRODYNAMICS

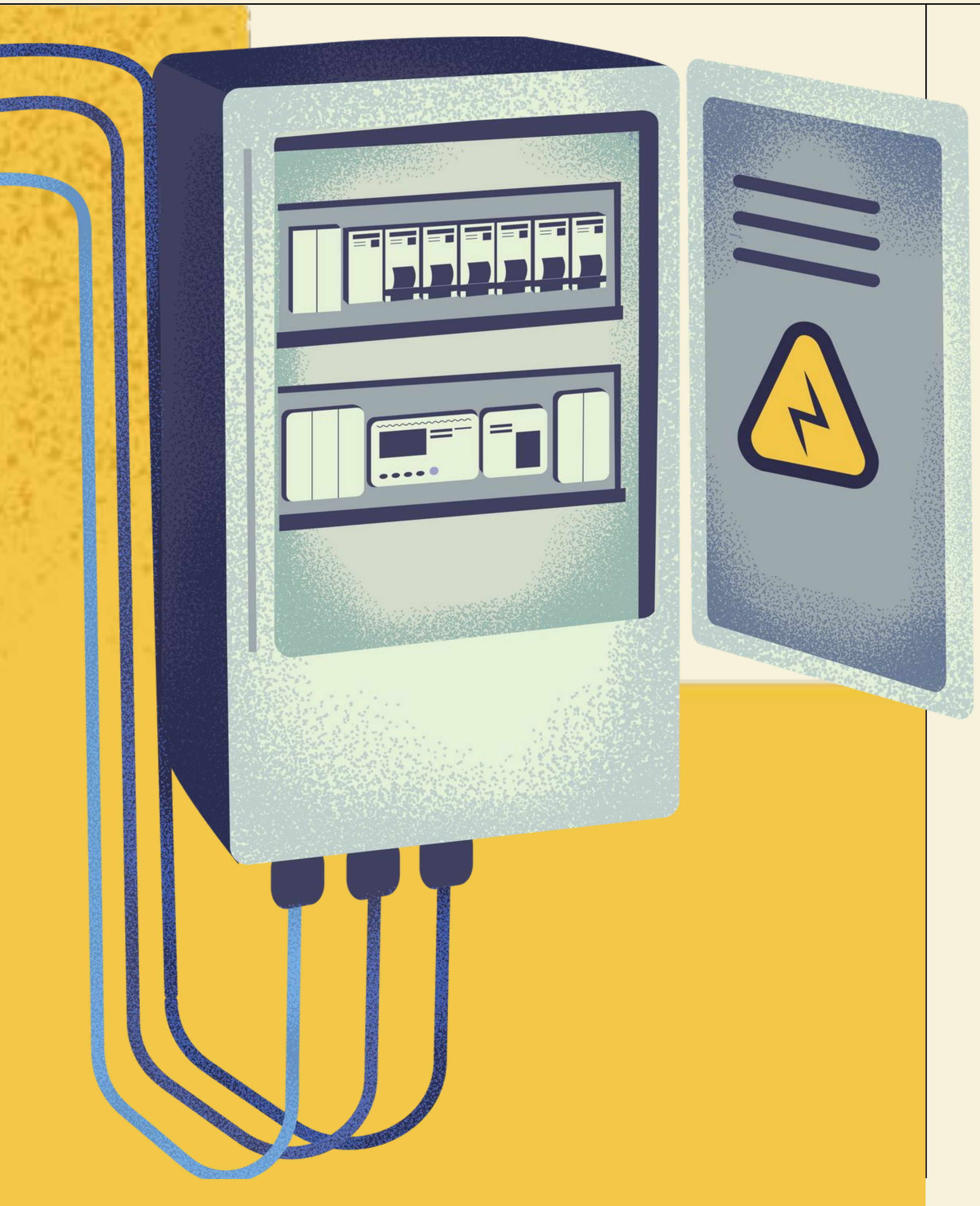
Dr. Zarina Kukhayeva

COURSE CONTENT

This course will cover a number of fundamental topics in classical electrodynamics, including a brief review of electricity and magnetism and detailed studies of the characterization, propagation, generation, and scattering of electromagnetic waves, and an introduction to covariant electrodynamics.

The main goal of this course is to have you engage in a process central to science: the attempt to model a broad range of physical phenomena using a small set of powerful fundamental principles. The specific focus of the course is an introduction to field theory, in terms of the classical theory of electricity and magnetism (E&M). The course also emphasizes the atomic structure of matter, especially the role of electrons and protons in matter.

REQUIRED LITERATURE:



- Lecture notes (available on moodle.astanait.edu.kz).
- Matter and Interactions by Ruth W. Chabay, Brucc A. Sherwood
- Introduction to electrodynamics David J. Griffiths, Prentice Hall, 07458
- Classical Electrodynamics by J. D. Jackson, Wiley, 3rd Ed.
- H.D. Young and R.A. Freedman, University Physics, 11th Edition, Pearson Education Inc., New York, 2004. Feynman,

Topic 1: Electric field.

AGENDA

01 Electric Charge and Force.

02 The Concept of "Electric Field".

03 The Electric Field of a Point Charge.

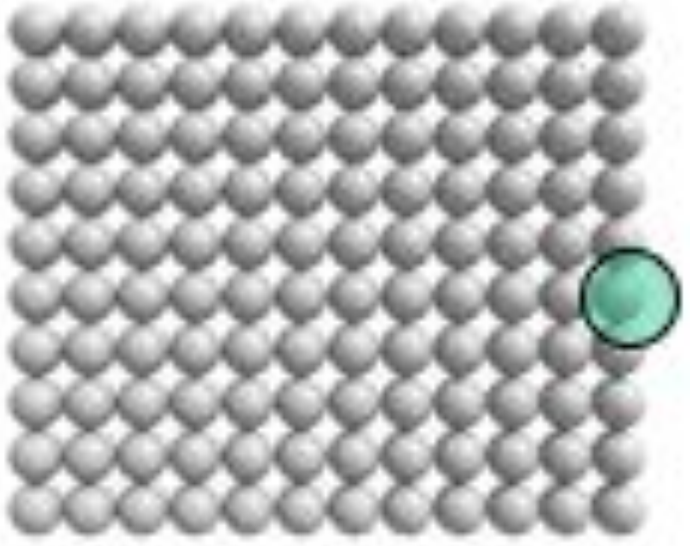
04 Superposition of Electric Fields.

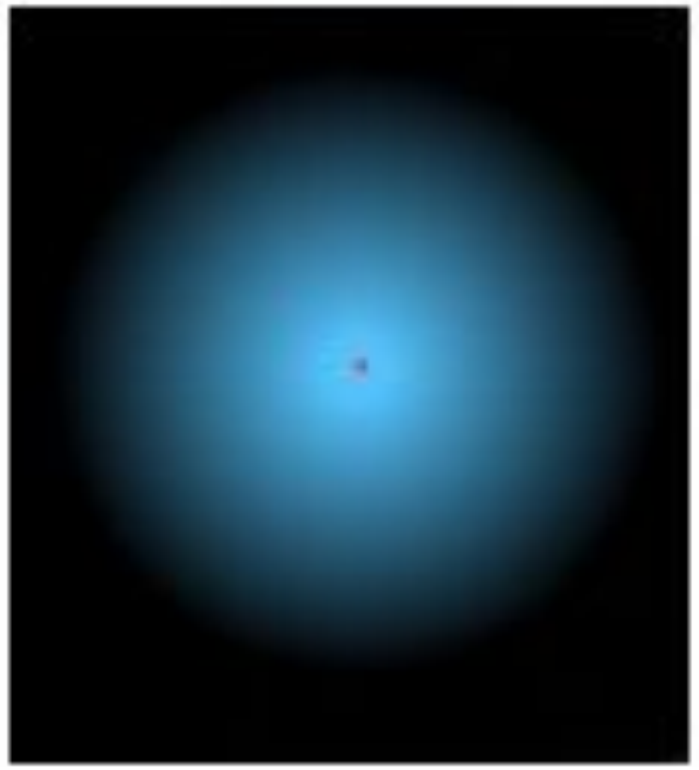
05 Computational Modeling of Electric Fields

Structure of Atom

Matter consists of atoms

1 cm^3 : ~10^{24} atoms





Nucleus

Proton is positively charged

neutron 0

$m_p \approx m_n \approx 1.7*10^{-27}$ kg

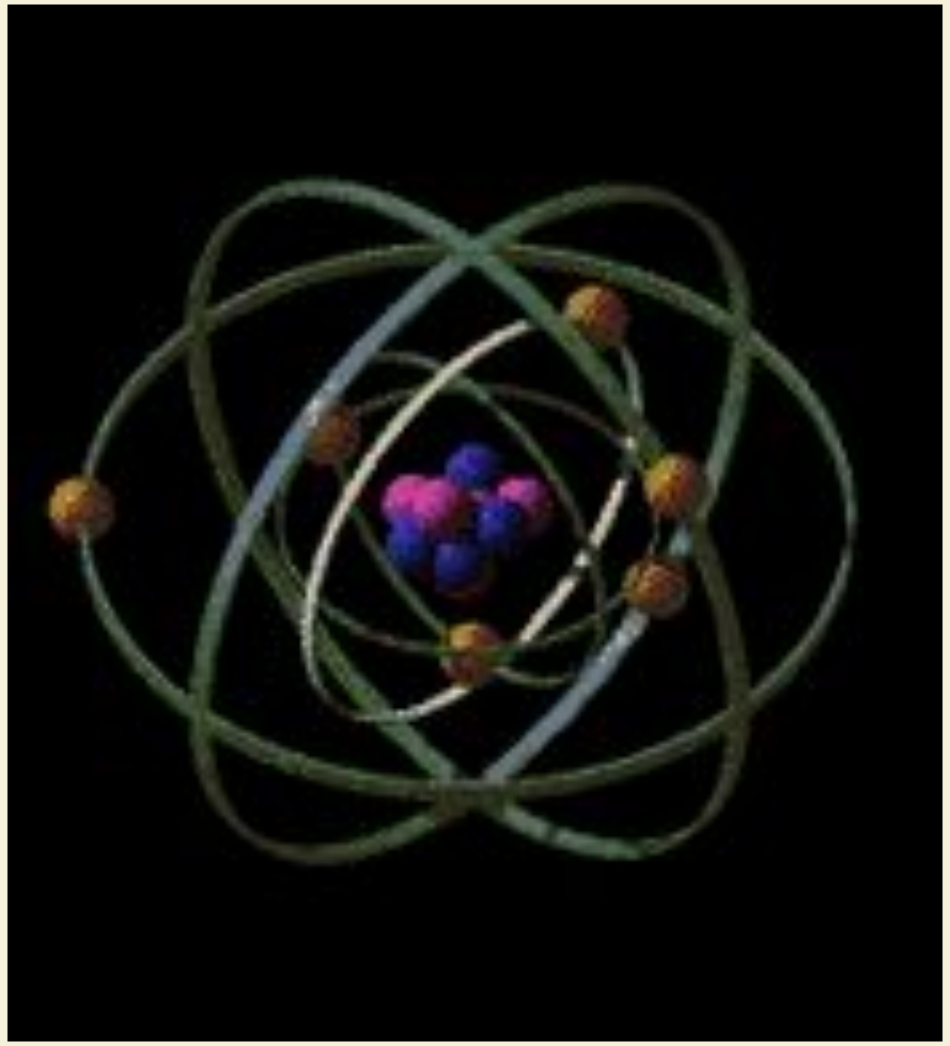
10^{-14}m

electron is negatively charged

Electron cloud size is about

10^{-10}m = 1Å

ELECTRON



The word electron was coined in 1894 by Johnstone Stoney (an Irish physicist) and is derived from the Latin electrum or the Greek elektron meaning amber (fossilized tree resin).

Point charge

- Charge is quantized in units of e

- Point charge: Size is small compared to the distance between it and other objects of interest
- Electric charge is an intrinsic property of the fundamental particles that everything is made

LAW OF ELECTRIC CHARGES

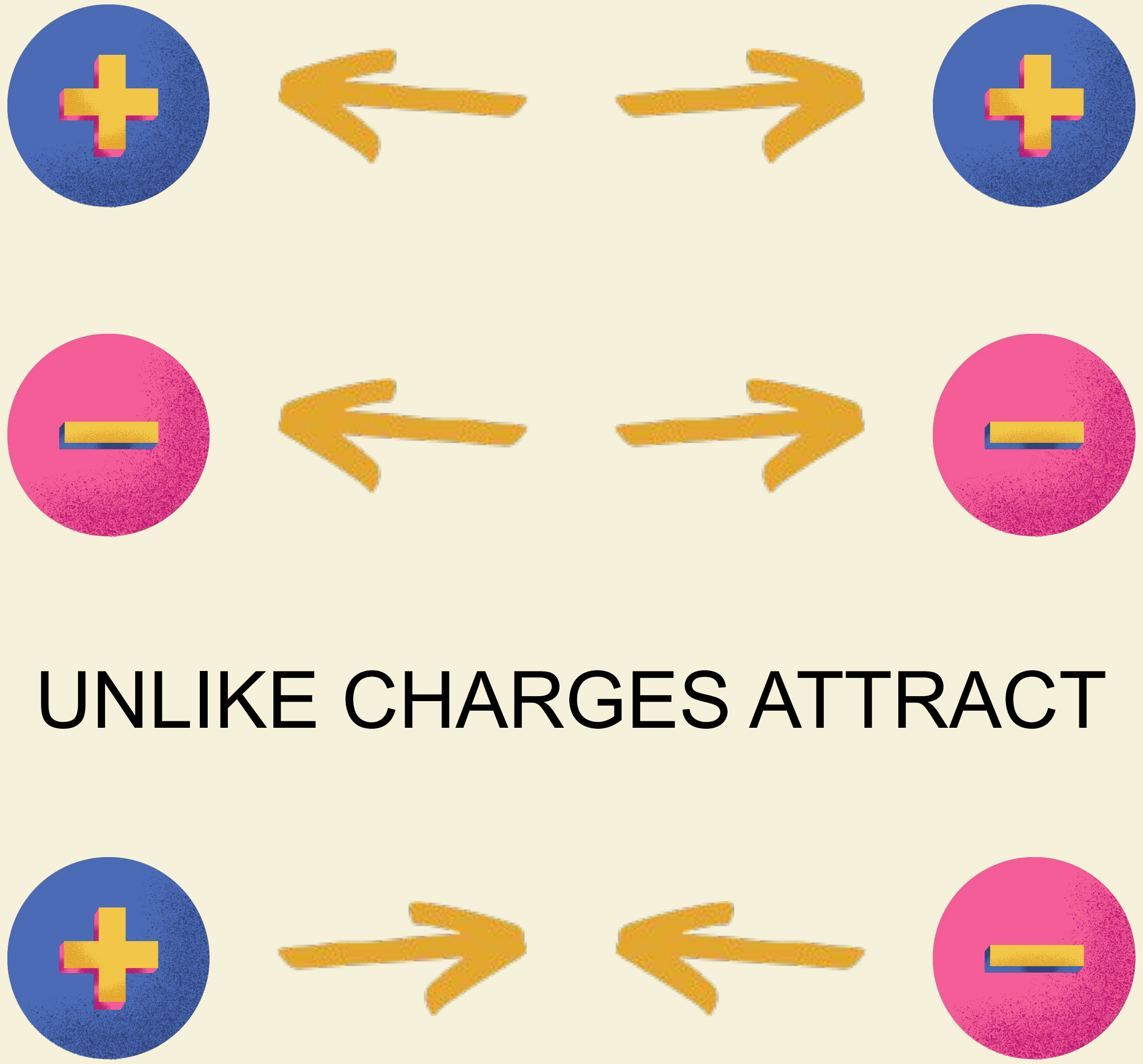
THE ELECTRIC FORCE IS THE ATTRACTION OR REPULSION BETWEEN CHARGED OBJECTS.

COULOMB'S LAW

The size of charges and the distance between them are both key factors in determining the strength of the electric force between charged objects.

LIKE CHARGES REPEL

UNLIKE CHARGES ATTRACT



LAW OF ELECTRIC CHARGES

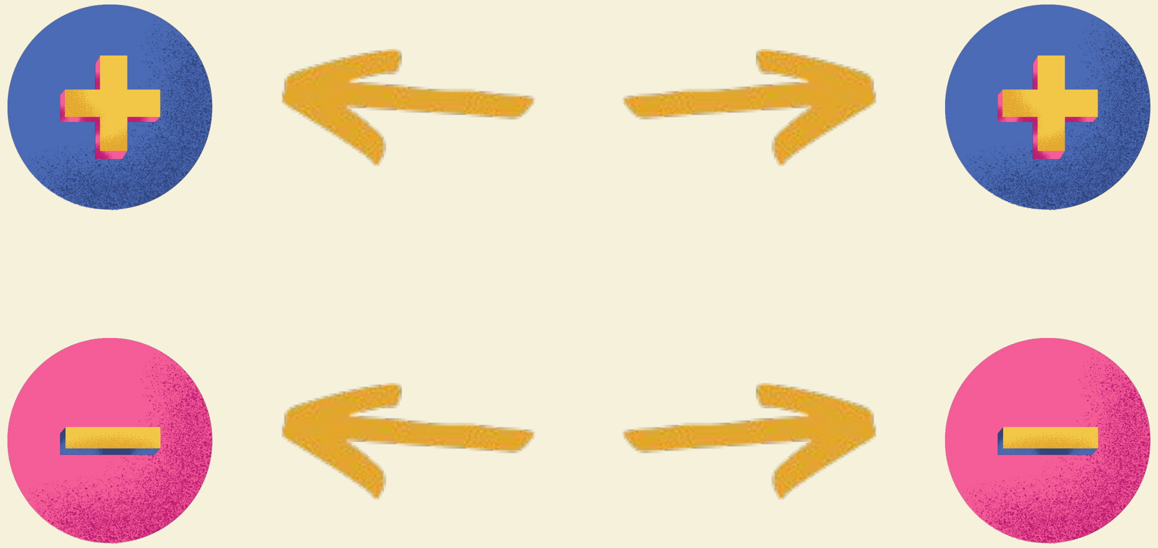
COULOMB'S LAW

The electric force law, called Coulomb’s law, describes the magnitude of the electric force between two point-like electrically charged particles:

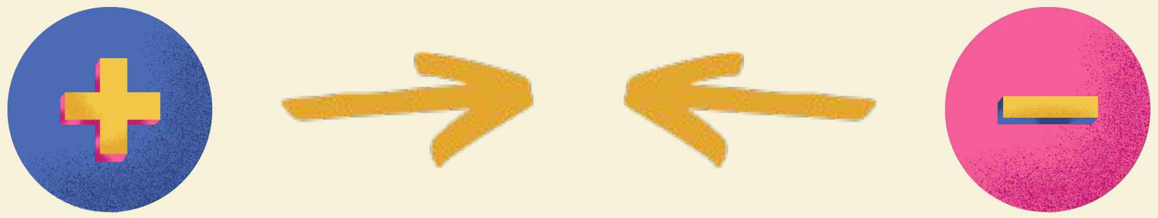
$$|\vec{F}| = F = \frac{1}{4\pi\varepsilon_0}\frac{|Q_1Q_2|}{r^2}$$

where Q1 and Q2 are the magnitudes of the electric charge of objects 1 and 2, and r is the distance between the objects.

LIKE CHARGES REPEL



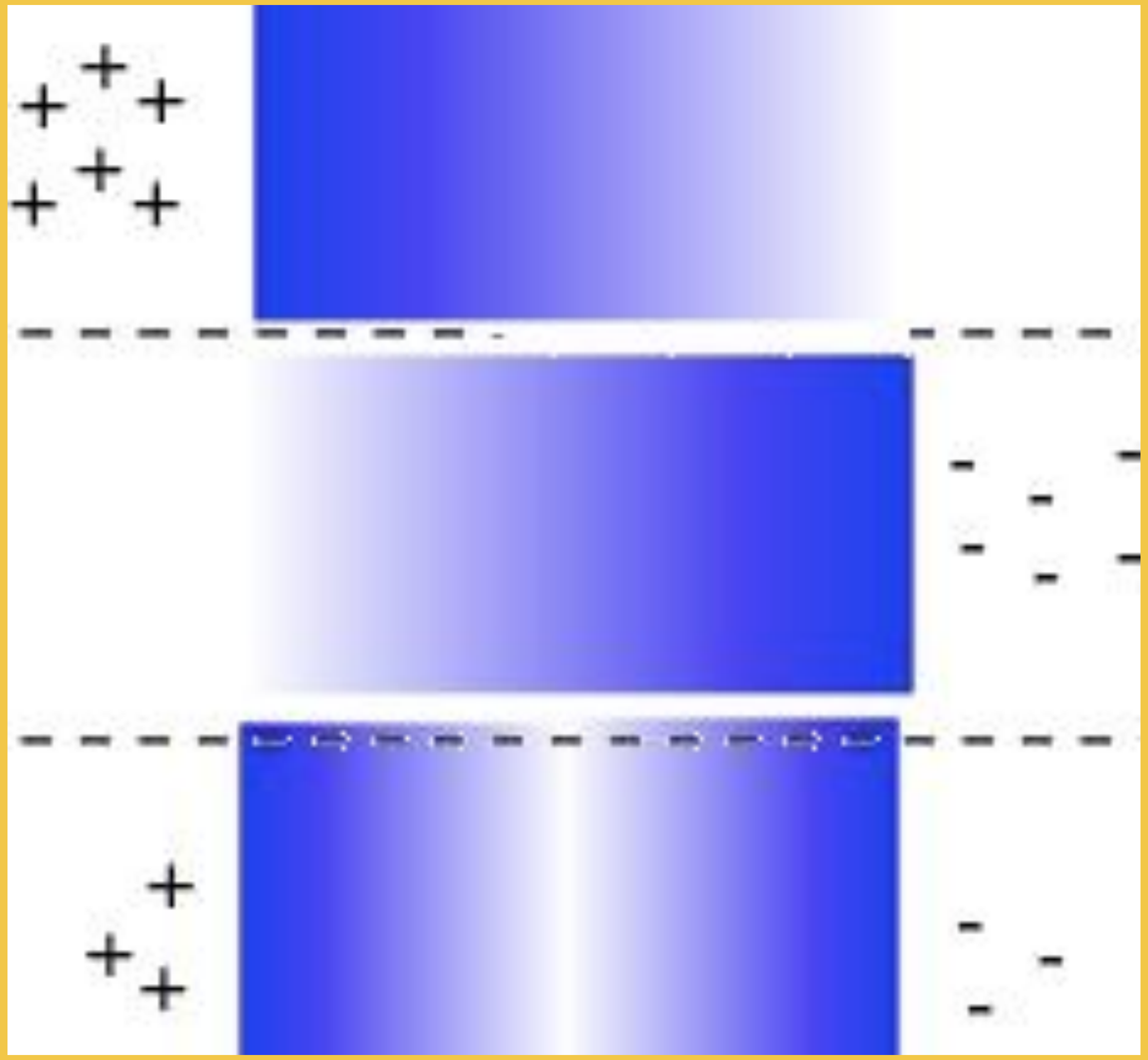
UNLIKE CHARGES ATTRACT



CHARGED PARTICLES

Particle	Mass	Charge	Radius
Electron	9×10^{-31} kg	$-e\,(-1.6 \times 10^{-19}\,\text{C})$	? (too small to measure)
Positron	9×10^{-31} kg	$+e\,(+1.6 \times 10^{-19}\,\text{C})$	?
Proton	1.7×10^{-27} kg	$+e$	$\sim 1 \times 10^{-15}$ m
Antiproton	1.7×10^{-27} kg	$-e$	$\sim 1 \times 10^{-15}$ m
Muon	1.88×10^{-28} kg	$+e\,(\mu^+)$ or $-e\,(\mu^-)$	?
Pion	2.48×10^{-28} kg	$+e\,(\pi^+)$ or $-e\,(\pi^-)$	$\sim 1 \times 10^{-15}$ m

The concept of electric field



There is something in space waiting for a charged particle to interact with it!

This virtual force is called electric field.

An electric field created by charge is present throughout space at all times, whether or not there is another charge around to feel its effect.

Electric field is defined as the electric force per unit charge. The direction of the field is taken to be the direction of the force it would exert on a positive test charge. The electric field is radially outward from a positive charge and radially in toward a negative point charge.

If we place a charge at that location in space, we can measure the force on the charge due to its interaction with the electric field at that location. We can determine the magnitude and direction of Electric field by measuring a force on a known charge q:

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

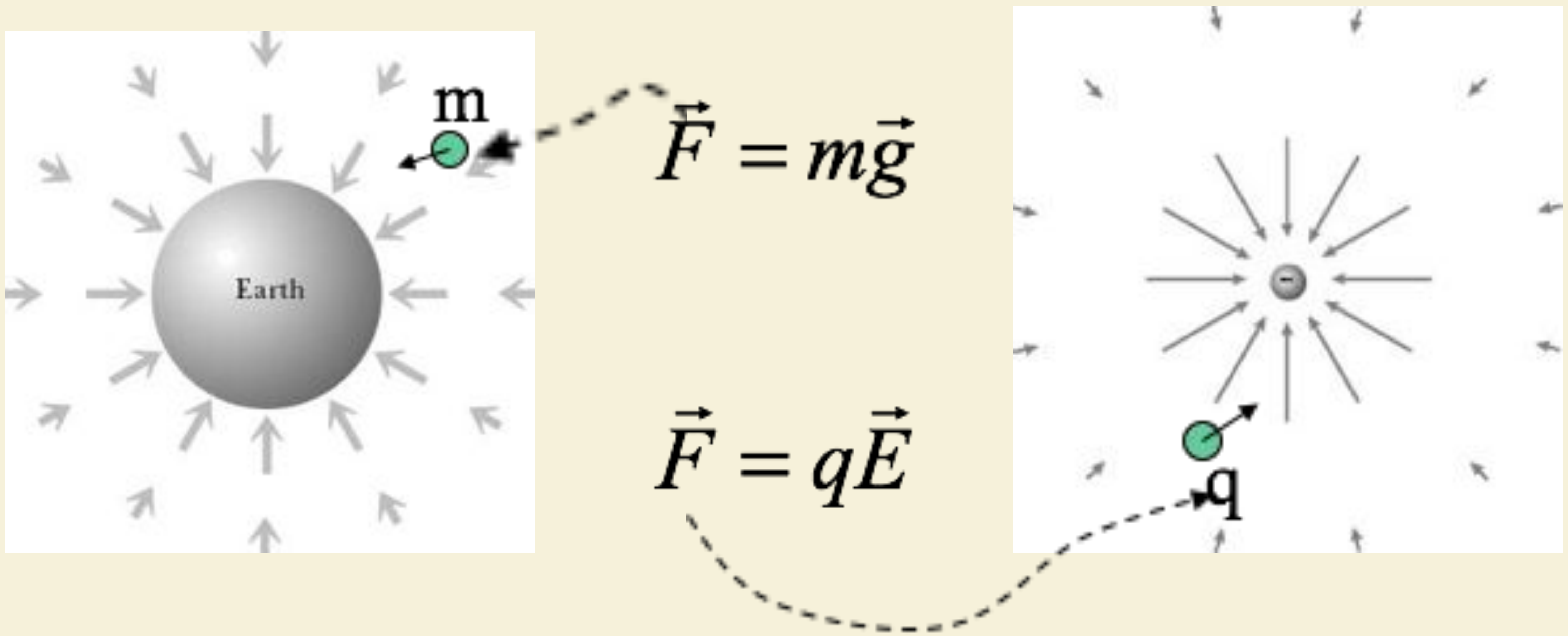
Electric field has units of Newtons per Coulomb N/C

THE PHYSICAL CONCEPT OF 'FIELD'

- Field: physical quantity, can be scalar or vector

- Examples:

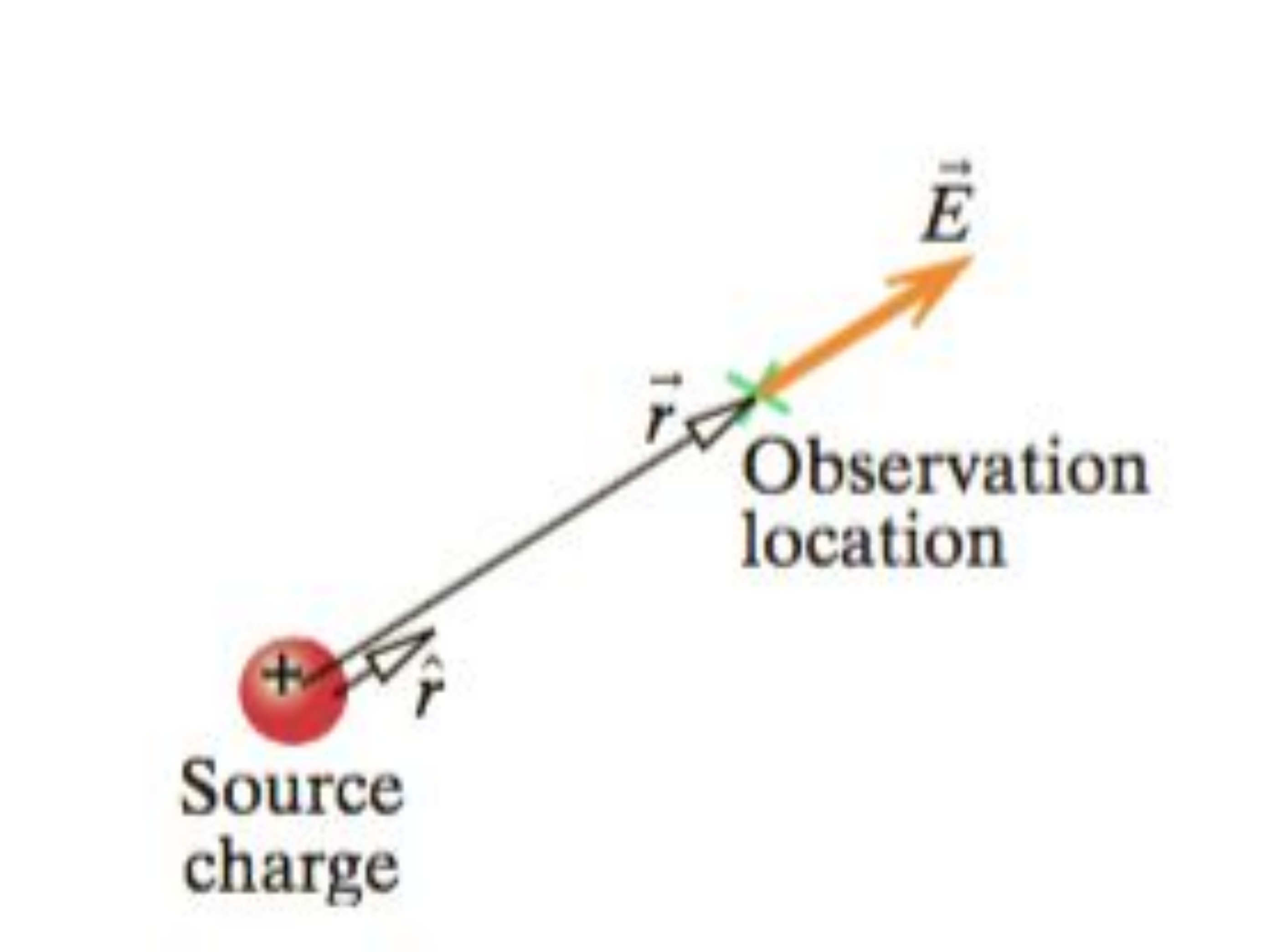
Temperature T(x,y,z,t)
Air flow, gravitational field



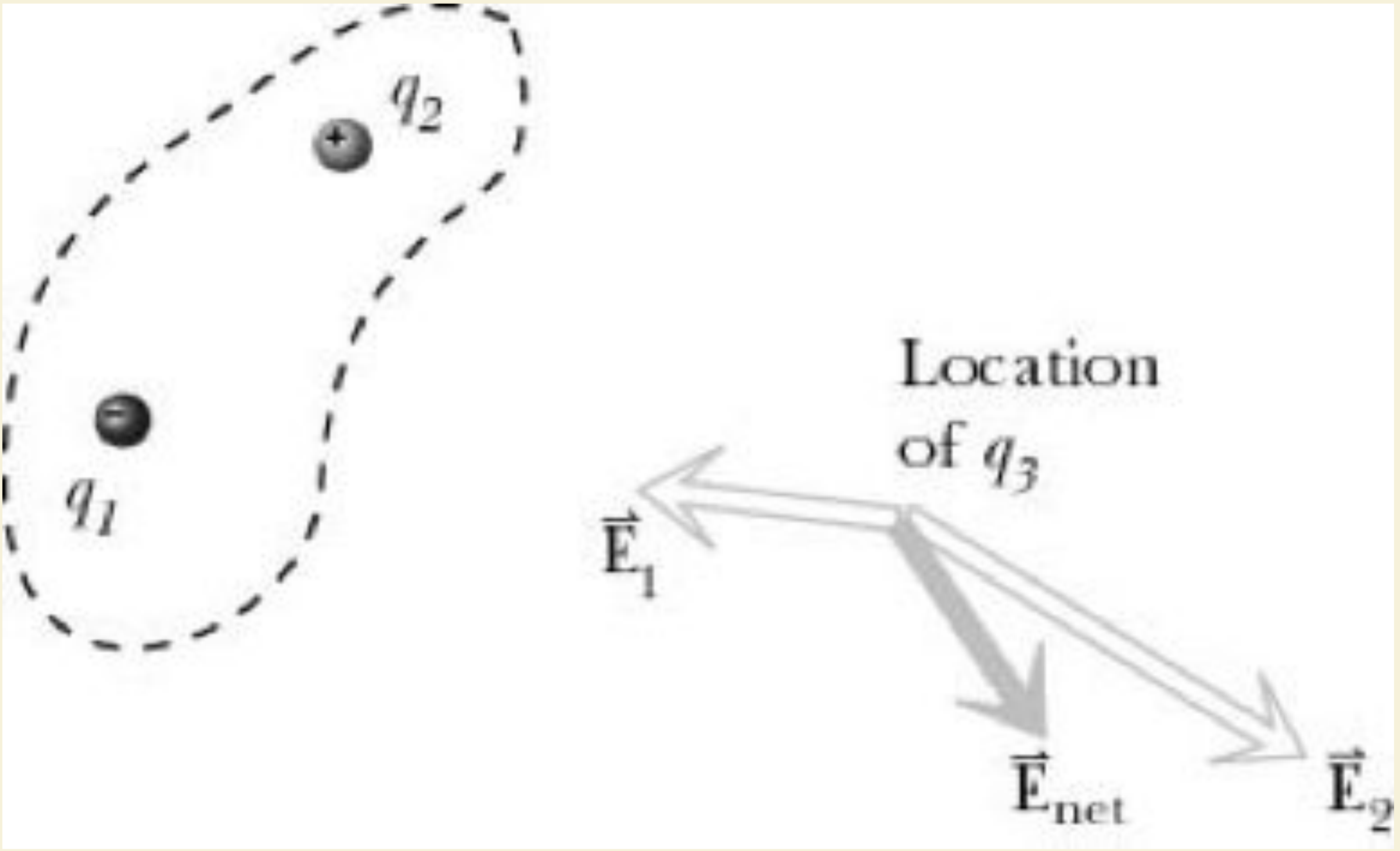
THE ELECTRIC FIELD OF A POINT CHARGE

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r}$$

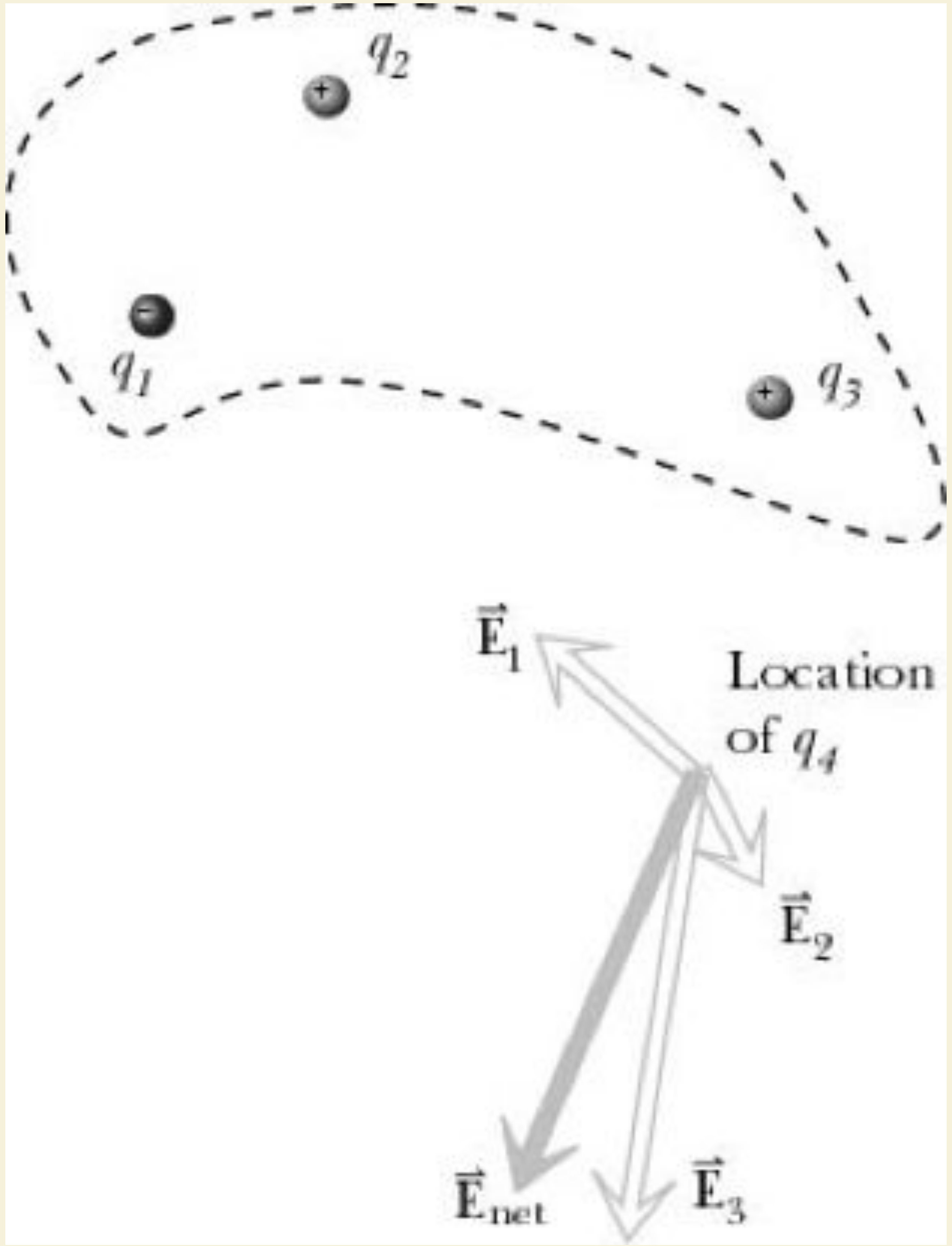
for the force on one point charge by another, we can find an algebraic expression for the electric field at a location in space called the “observation location”—the location where we detect or measure the field—due to a charged particle q1 (the “source charge”) at the source location. The electric field at the observation location



THE SUPERPOSITION PRINCIPLE



The net electric field at a location in space is a vector sum of the individual electric fields contributed by all charged particles located elsewhere.



Let’s solve some problems