PHYSICS 570 – Master's of Science Teaching – *R. Sonnenfeld*

Order of Videos …

Lecture 1, Introduction and Tribocharging
"Diff. between elec. and mag."
"Two types of charge"
"Charging by Polarization"
Lecture 2, Scientific Notation and Coulomb's Law
Lecture 3, Vectors and Electric field

PHYSICS 570 – Master's of Science Teaching

“Electricity”
Lecture 1 – Introduction

Instructor – Richard Sonnenfeld
mpsonnenfeld@gmail.com
575-835-6434

Lecture 1 – Outline

Introduction / Expectations

The difference between electricity and magnetism.

The tribo-series

Charges … attraction and repulsion
“Electrostatics”

About Instructor

BSE Physics and Mech. Engineering

(Princeton U)

Ph.D. Experimental Physics – Tunneling microscopes

(University of California, Santa Barbara)

IBM Almaden Research

(Tribology of Hard Disk Drives)

Engineering Dir. – Hard disk drives

(Seagate, Maxtor, Quantum Corps)

Physics Professor – NM Tech

Physics of Lightning, instruments to measure lightning

Tell me about yourselves

What do you want from this course?

I am glad to answer individual questions about points of curiosity or how to integrate this into your classroom.

Give me suggestions on how to strengthen science teaching in NM in general.

Grading

Do the homework, watch the lectures, think about the labs (just like you tell <u>your</u> students!)

Homework, labs, lecture questions, and two "oral exams" (by telephone)

I am here to help you learn physics so you can teach it.

I already assume you are committed.

Text

I tried to find a text that was appropriate for smart people who had not had a physics course before.

The text I selected is "Conceptual Physics Fundamentals" by Paul. G. Hewitt.

The text is interesting and makes physics fun. The text is light on mathematics but good for concepts. I will be adding additional mathematics in lecture.
and with homework assignments

Course Goals – Physics

I hope at the end of this course you will know the difference between charge, current, electric field, potential, voltage, potential energy, power, resistivity and resistance and be able to teach these concepts.

Course Goals – Math

You will learn scientific notation, and how to calculate with it.

You will learn about vectors and how to add them with pictures and with math ("by components")

You will get GREAT applications for Trig., algebra, exponents and fractions

Course Goals – Engineering

You will learn how to build and analyze simple electrical circuits.

You will learn to use a multimeter.

Topics: Electricity

– Charges, Coulombs Law
– Electric Fields, Potential
– Currents
– DC Circuits
– Superconductivity, more advanced circuits.

This material is all found in Hewitt Chapter 10, with some parts of Hewitt Chapter 2 and Ch. 5, plus supplementary materials from Randall Knight's "Physics".

Topics: Electromagnetism & Light

This is an advertisement for the follow-on course

– Properties of waves (sound and light) – interference, diffraction
[Hewitt 12]

– Light waves, reflection, refraction, polarization, Snell's Law.
[Hewitt 13]

– Lenses and resolution
[Hewitt 14]

– Magnetic fields, forces, and induction (how motors and generators work)
[Hewitt 11]

The Lab Kit!

– Your lab fee pays for a kit containing materials for experiments.

It includes:

Teflon rod (white)

Nylon rod (black)

Acrylic rod (clear)

Rabbits fur and silk (go find a T-shirt for cotton)

A multimeter

Light bulbs, wire, and alligator leads

LEDs

Additional materials.

Amber, or “Electrum” from which we get “Electron” and “Electricity”

You can directly transfer charge to an object (for example by rubbing it)

Or you can charge it by “induction” or “polarization” (I will demonstrate)

Demos … Balloons, Electroscope

Triboseries

THESE CHARGE POSITIVE

acrylic (lucite, plexiglas)

wool

silk

paper

nylon

cotton

hard rubber

saran-wrap

teflon

THESE CHARGE NEGATIVE

(When rubbed on something higher)

Watch the demos

1) The difference between electricity and magnetism
2) There are two types of charges as you can see with an electroscope.
3) You can charge objects by induction without touching them.

PHYSICS 589 – Master's of Science Teaching

“Electricity”
Lecture 2 – Scientific Notation and Coulomb's Law

Instructor – Richard Sonnenfeld
rsonnenfeld@gmail.com
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Lecture 2 – Outline

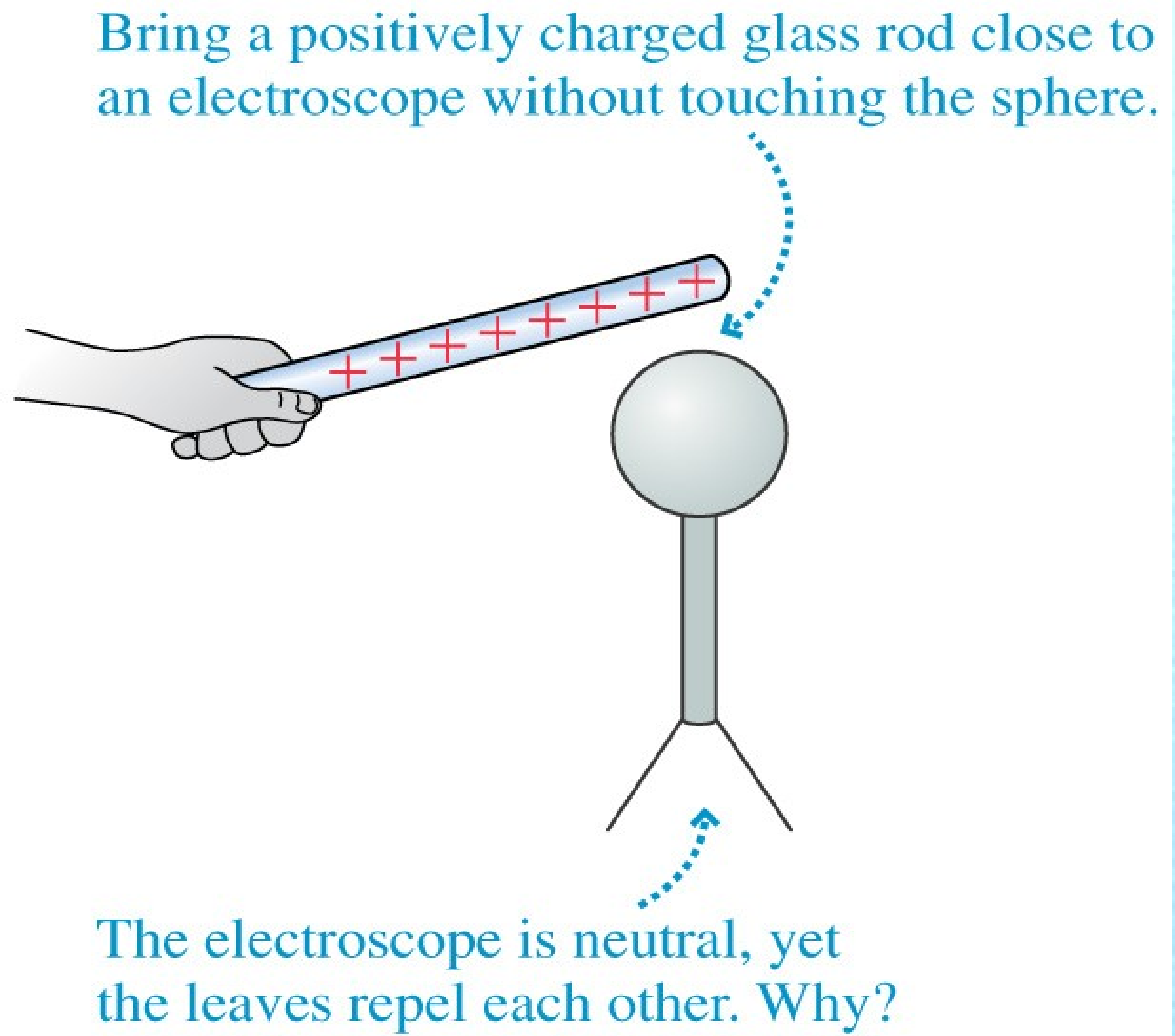
“Electrostatics”

Calculating with Scientific Notation

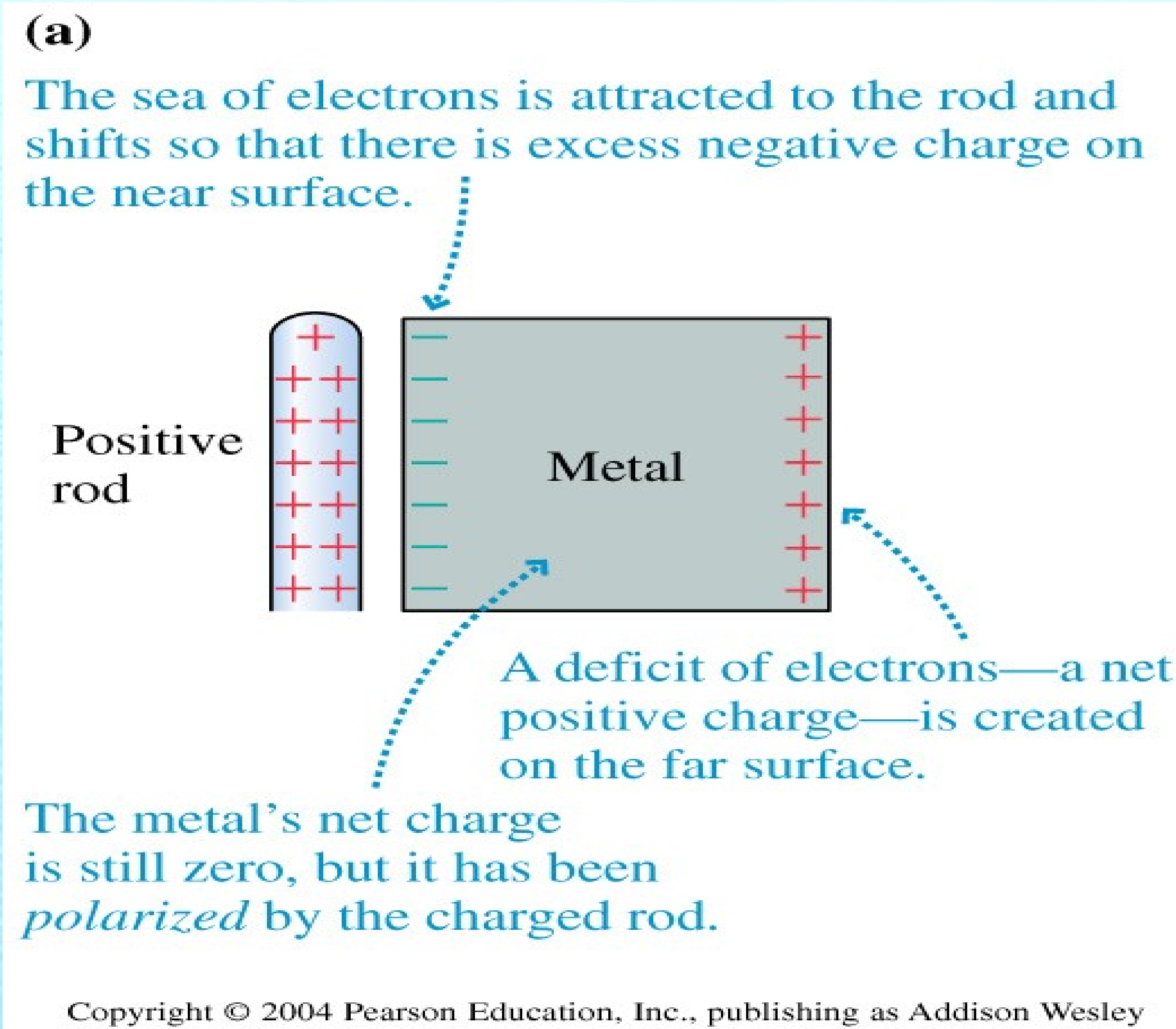
Coulomb's law

Using Vectors

Electric Forces on Metals - I



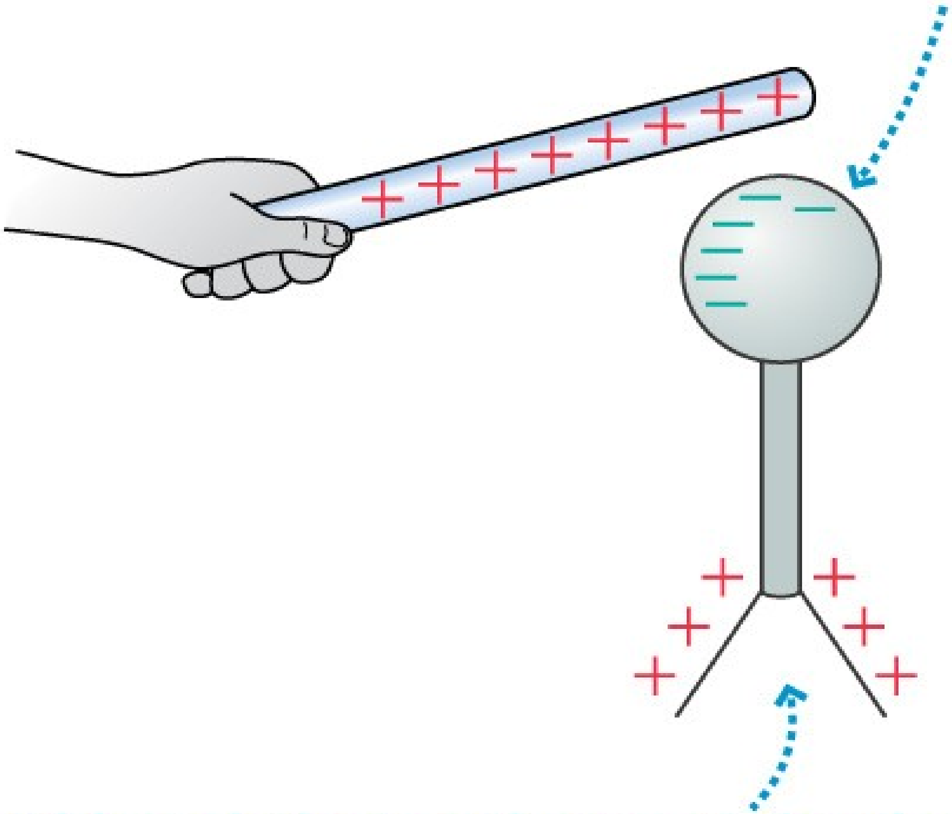
Electric Forces on Metals - II



Electric Forces on Metals - III

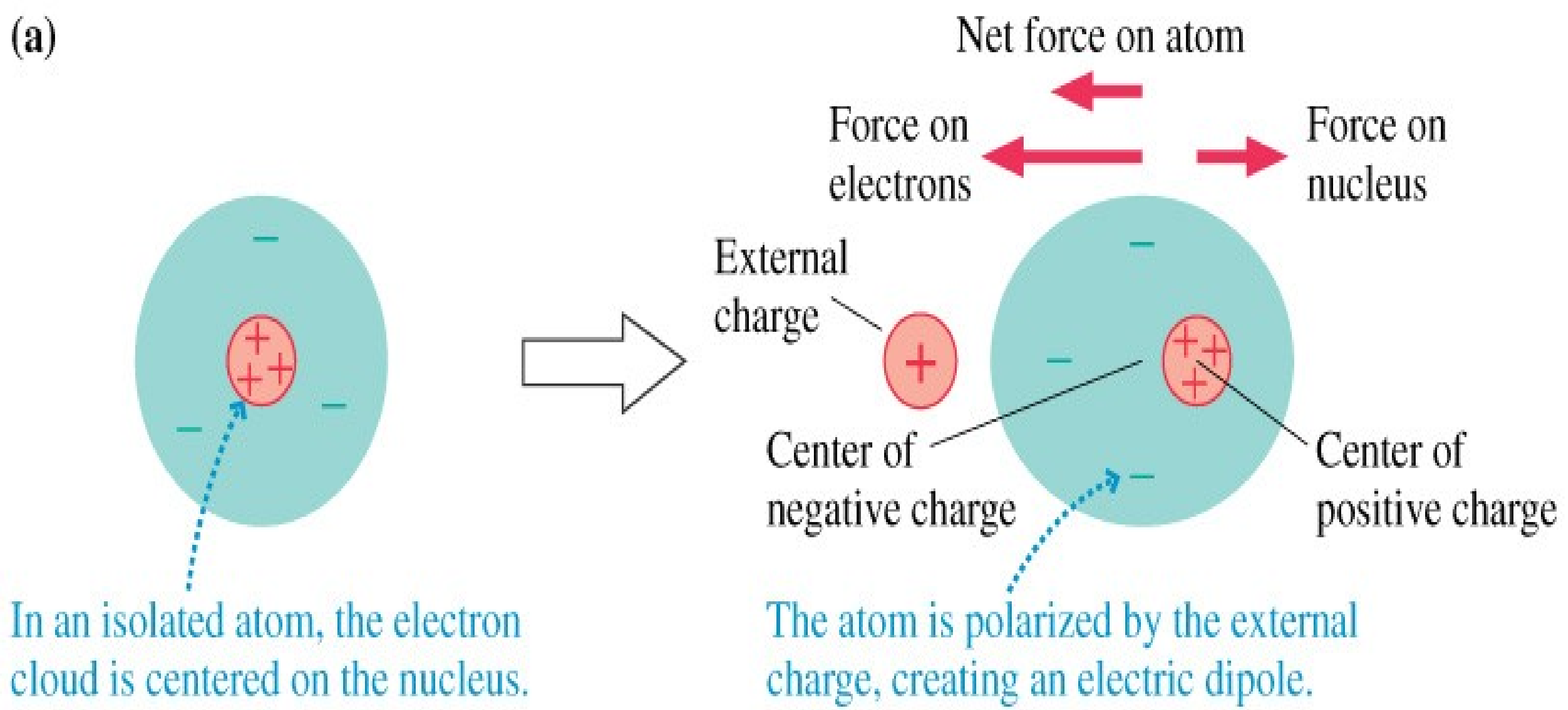
(b)

The electroscope is polarized by the charged rod. The sea of electrons shifts toward the rod.



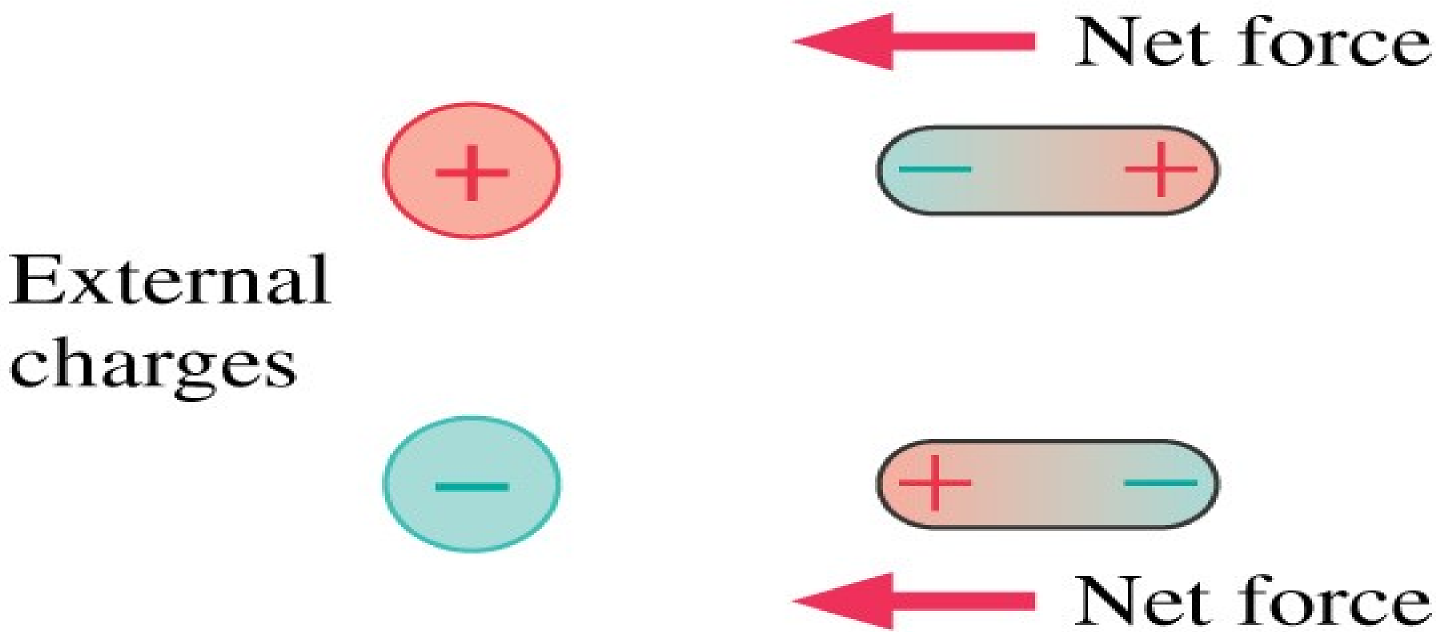
Although the net charge on the electroscope is still zero, the leaves have excess positive charge and repel each other.

Electric Forces on Insulators I



Electric Forces on Insulators II

(b)



Electric dipoles can be created by either positive or negative charges. In both cases, there is an attractive net force toward the external charge.

Review

Explain in a few sentences why a charged teflon rod attracts an uncharged aluminum can.

Draw sketches of the charges on the rod and can to support your explanation.

What is true?

[A] Only electrical conductors may be charged

[B] Only electrical insulators may be charged

[C] Both conductors and insulators may be charged

[D] You can't charge anything, only polarize it.

You rub a teflon with rabbits fur and make it negatively charged.

[A] The negatively charged teflon rod weighs slightly more than in did before it was rubbed and the rabbits fur a bit less.

[B] Neither material changes its weight.

[C] Both materials are lighter than before

[D] The teflon is lighter than it was

What is charge?

A (neutral) atom contains equal numbers of protons and electrons

An ion has some extra (or some fewer) electrons for its protons

Protons and electrons have equal and opposite charges
… this is a mystery.

To quantify the forces on charges, we have “Coulomb's Law”

$$F = k\frac{q_1 q_2}{d^2}$$

If charges are both + or both -, the force is repulsive, otherwise attractive.

$$k = 9.0 \times 10^9\, N \cdot m^2 / C^2$$

$$k = 9{,}000{,}000{,}000\,(9\text{ billion})\, N \cdot m^2 / C^2$$

A formula in physics (or engineering) vs. a formula in algebra.

In algebra the variables tend to be x, y, z, a, b, c.

They don't “mean” anything.

They stand for “unknown”

Physicists have favorite letters.

F usually means “force”

Q or q usually means charge

r or d usually means distance

Coulomb's law to a mathematician (e.g.)

$$y = m \frac{a\,b}{c^2}$$

Coulomb's law to a physicist

$$F = k \frac{q_1\,q_2}{d^2}$$

What's a Coulomb?

A coulomb is an amount, like a Mole. There are 6,240,000,000,000,000,000 electrons in a coulomb.

We need scientific notation immediately!!!
A coulomb= 6.24×10^{18} electrons

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

What's an Ampere? (Amp)

An Ampere is a Coulomb/Second

You've probably heard of “Amps”
If you have a 120 Watt light-bulb
it uses about 1 Amp … that's
6,240,000,000,000,000,000 electrons
a second running through your
filament so you read.
1 Coulomb/second is a lot easier to say
than 6,240 ….

Scientific Notation

Was invented to make it easier to work with very large or very small numbers.

To convert to scientific notation, multiply or divide by a power of 10 so that the resulting number remains the same.

$$426.7 = 4.267 \times 10^{2}$$

$$0.00004267 = \frac{4.267}{10^{5}} = 4.267 \times 10^{-5}$$

Converting to/from Scientific Notation

Worked Examples

Calculating with Scientific Notation

Multiplication/Division

Multiply the coefficients

Add exponents that are being multiplied
Subtract for Division.

Raising to Powers

Raise coefficients to powers

Multiply exponents

Calculating with Scientific Notation

Worked Examples

$$(8.0\times10^{2})(3.0\times10^{4})=(8\times3)\times10^{(2+4)}=24\times10^{6}=2.4\times10^{7}$$

$$\frac{(8.0\times10^{2})}{(3.0\times10^{4})}=(\frac{8}{3})\times10^{(2-4)}=2.666\times10^{-2}=0.02666$$

$$(4.0\times10^{-5})^{3}=(4^{3})\times10^{(-5\times3)}=64\times10^{-15}=6.4\times10^{-14}$$

Calculating with Scientific Notation

Calculating with Scientific Notation

Why does ten to the zero = 1?

Force between atoms

What is force between two ions in table salt?

Na(+) and Cl (-)?

$$F = k\frac{q_1 q_2}{d^2}$$

$$k = 9.0 \times 10^9\, N \cdot m^2/C^2$$

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

$$d = 5.0 \times 10^{-10}\, m$$

Force between nucleii

What is force between the two halves of a Uranium nucleus?

$$F = k\frac{q_1 q_2}{d^2}$$

$$k = 9.0 \times 10^9 \, N \cdot m^2/C^2$$

$$q_1 = q_2 = 41 \, q_e$$

$$d = 5.0 \times 10^{-15} \, m$$

“Nuclear Energy” is actually electrical energy!!

Coulomb's Law Worksheet

“Two negative charges that are both 50 microcoulombs push each other apart with a force of 15 N. How far apart are the two charges?”

Coulomb's Law is actually a vector equation.

Now you know how to do the calculation part … we need to learn about vectors.

Principle of Superposition

States that the force from multiple charges is the sum of force from individual charges (as if the others weren't there) So long as you mean the VECTOR SUM.

$$\overrightarrow{F_{12}} = k \frac{q_1 q_2}{d_{12}^2} \widehat{r_{12}}$$

$\widehat{r_{12}}$ is math shorthand for "force is along the line joining the charges."

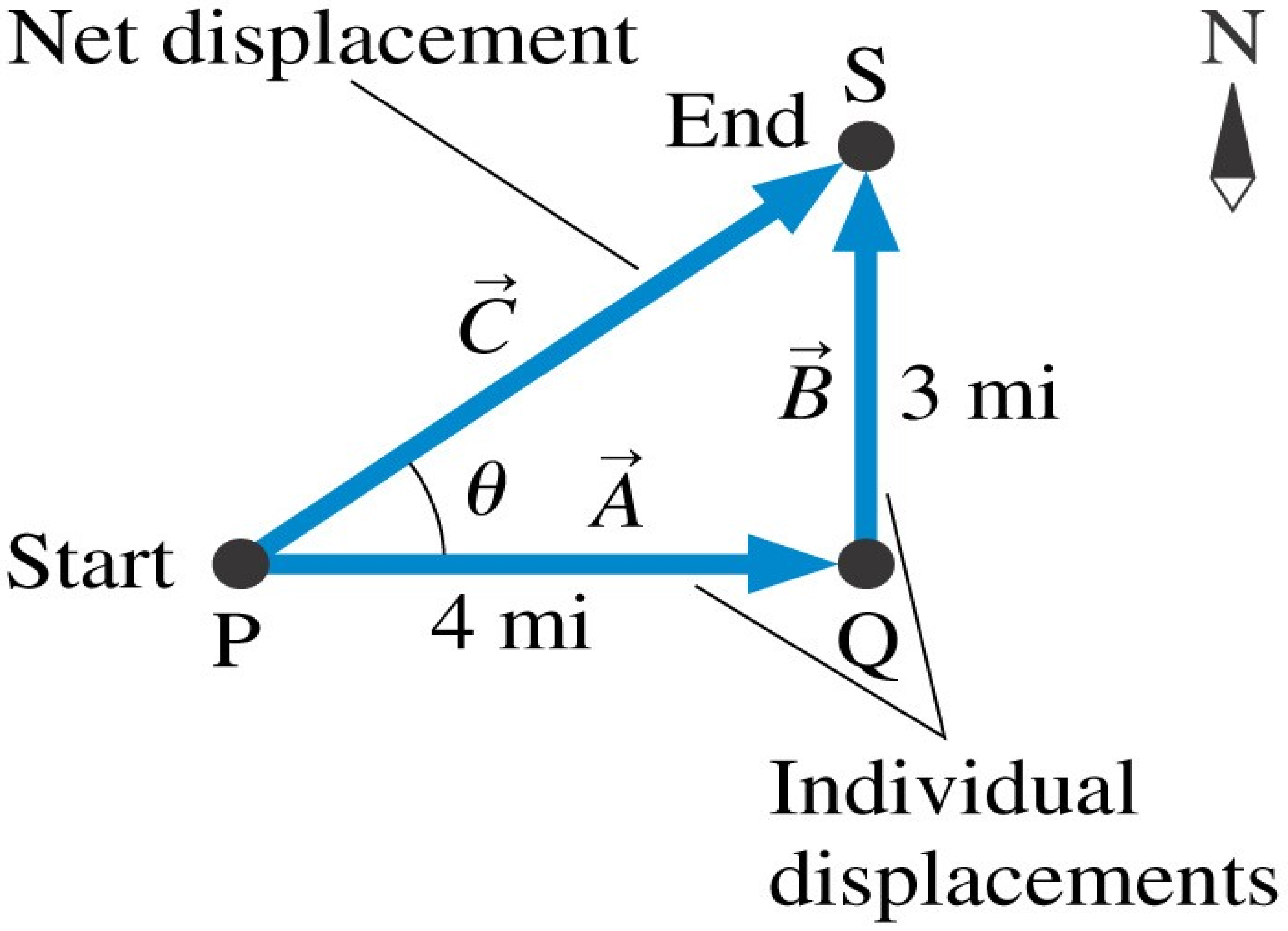
What's a vector? What's a scalar?

A scalar is a physical quantity having only a magnitude (e.g. temperature).

A vector has a magnitude AND a direction. Vectors are represented by arrows, and the arrow gives the direction.

Position is a vector because you are not just 80 miles from Albuquerque, you are 80 miles SOUTH of Albuquerque.

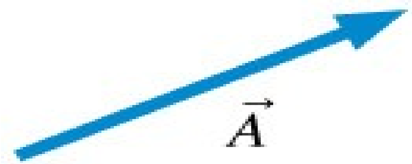
Other vectors? Other scalars?


Net displacement
N
S
End
$\vec{C}$
$\vec{B}$
3 mi
θ
$\vec{A}$
Start
P
4 mi
Q
Individual
displacements

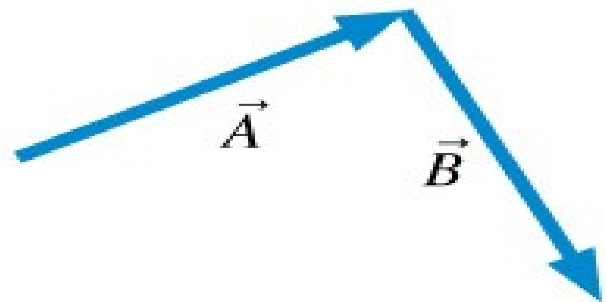
Addition of vectors by drawing

To add $\vec{B}$ to $\vec{A}$:

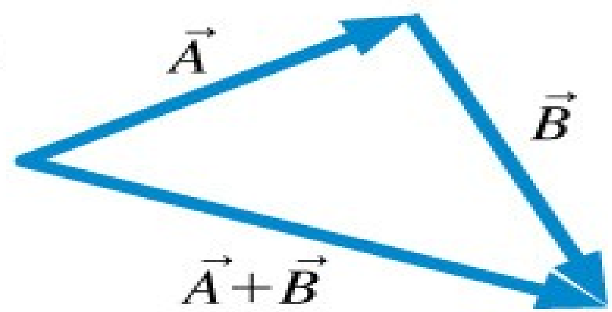
❶ Draw $\vec{A}$.

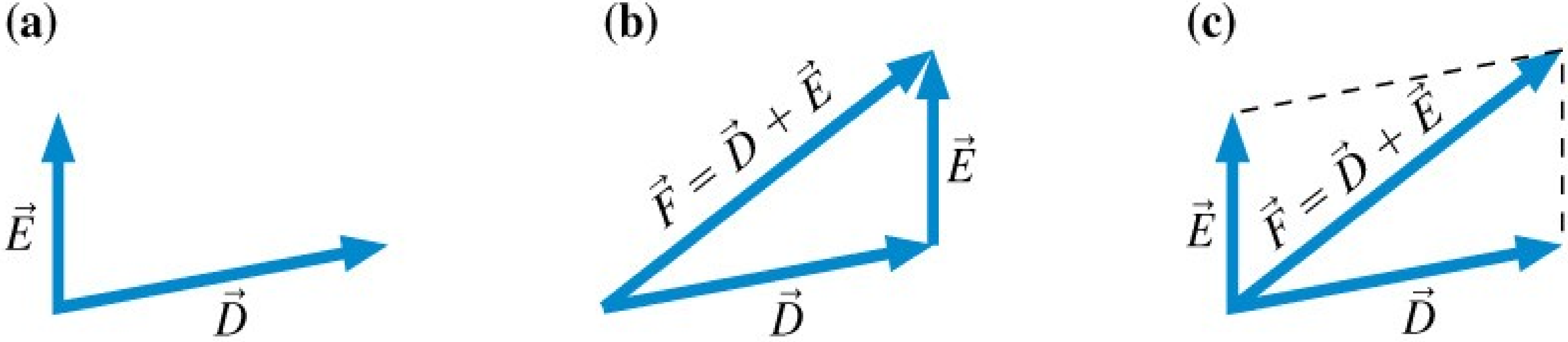


❷ Place the tail of $\vec{B}$ at the tip of $\vec{A}$.



❸ Draw an arrow from the tail of $\vec{A}$ to the tip of $\vec{B}$. This is vector $\vec{A} + \vec{B}$.



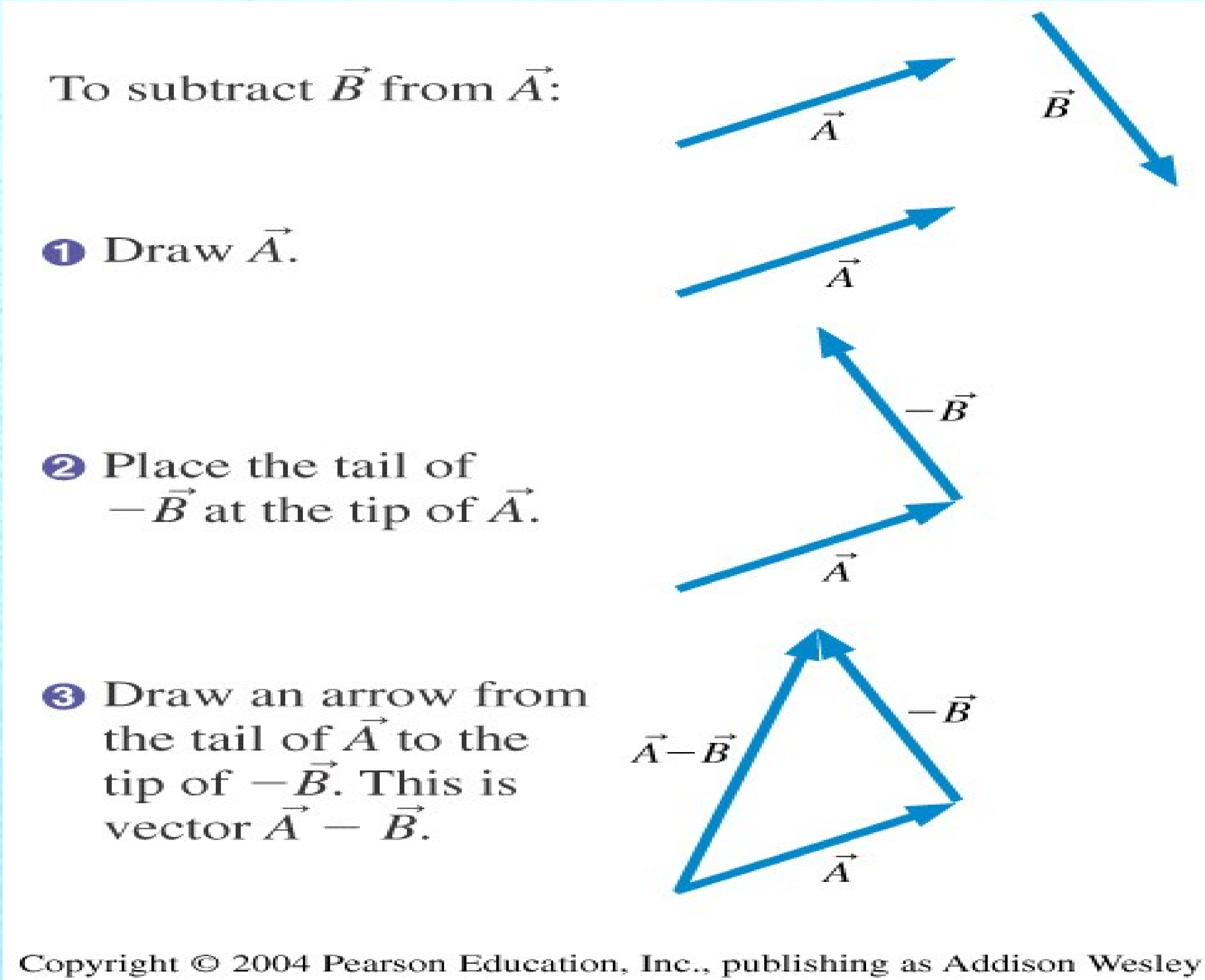


What is $\vec{D} + \vec{E}$?

Tip-to-tail rule:
Slide the tail of $\vec{E}$ to the tip of $\vec{D}$.

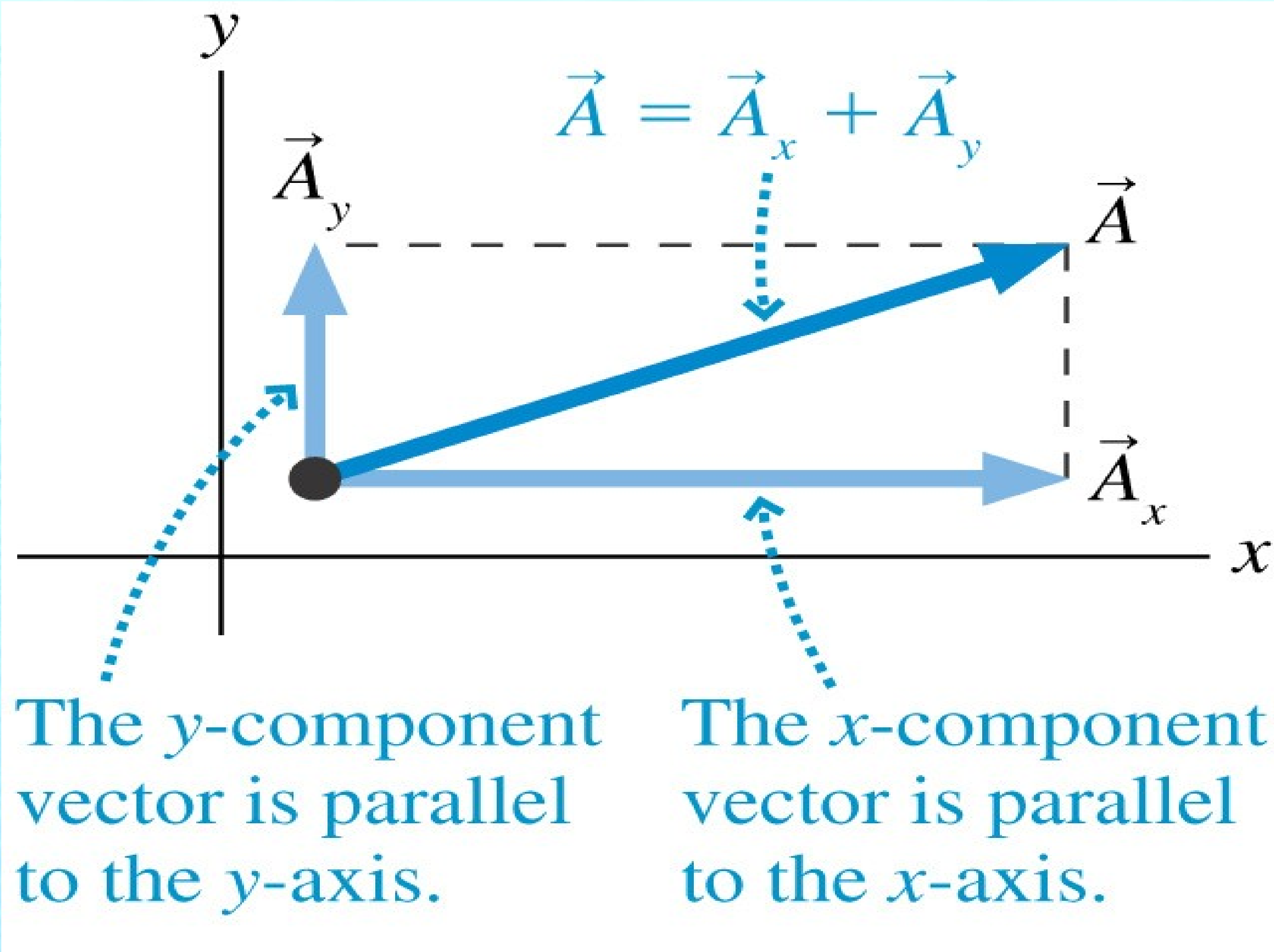
Parallelogram rule:
Find the diagonal of the parallelogram formed by $\vec{D}$ and $\vec{E}$.

Subtraction of vectors by drawing

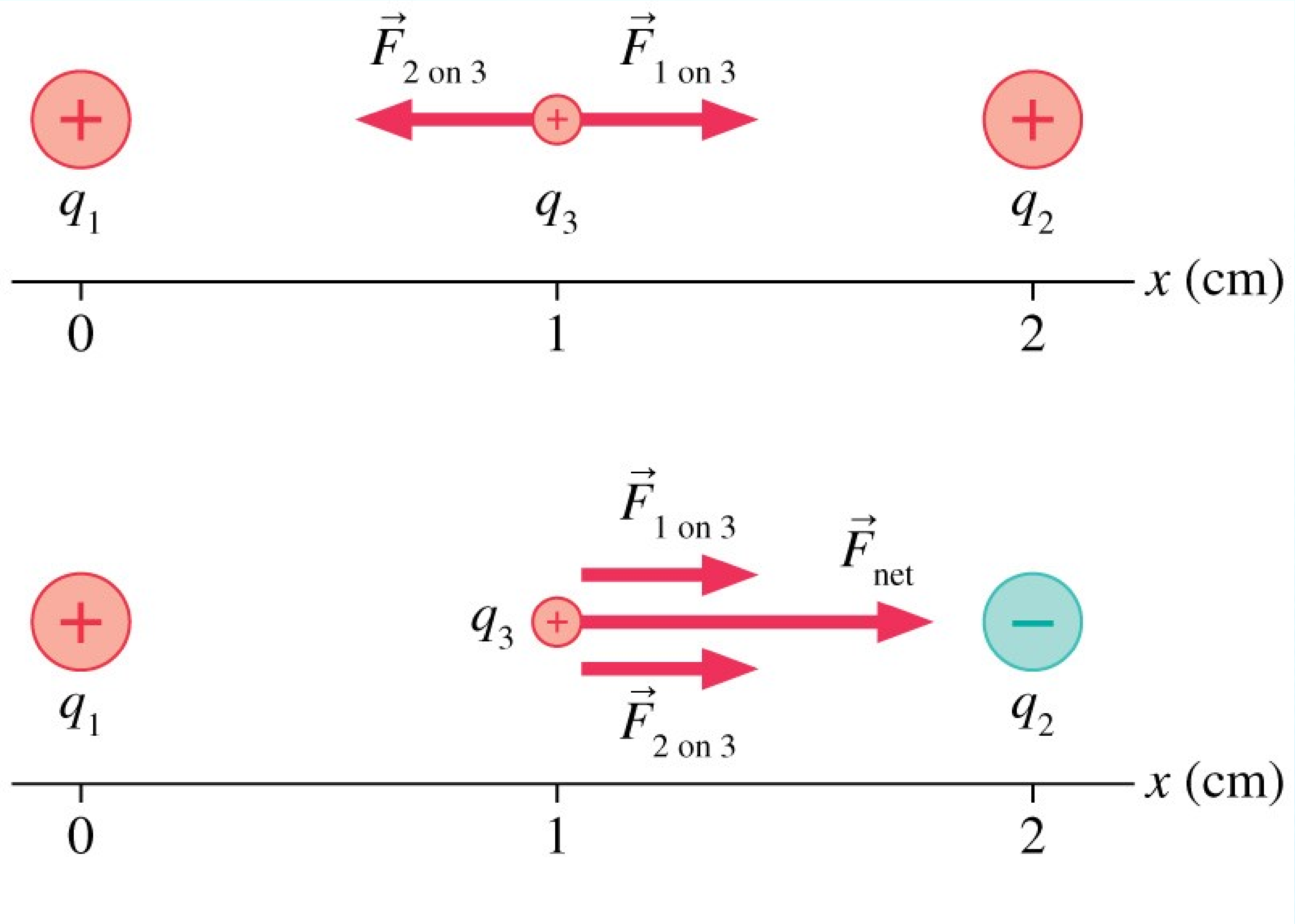


Addition/Subtraction Practice

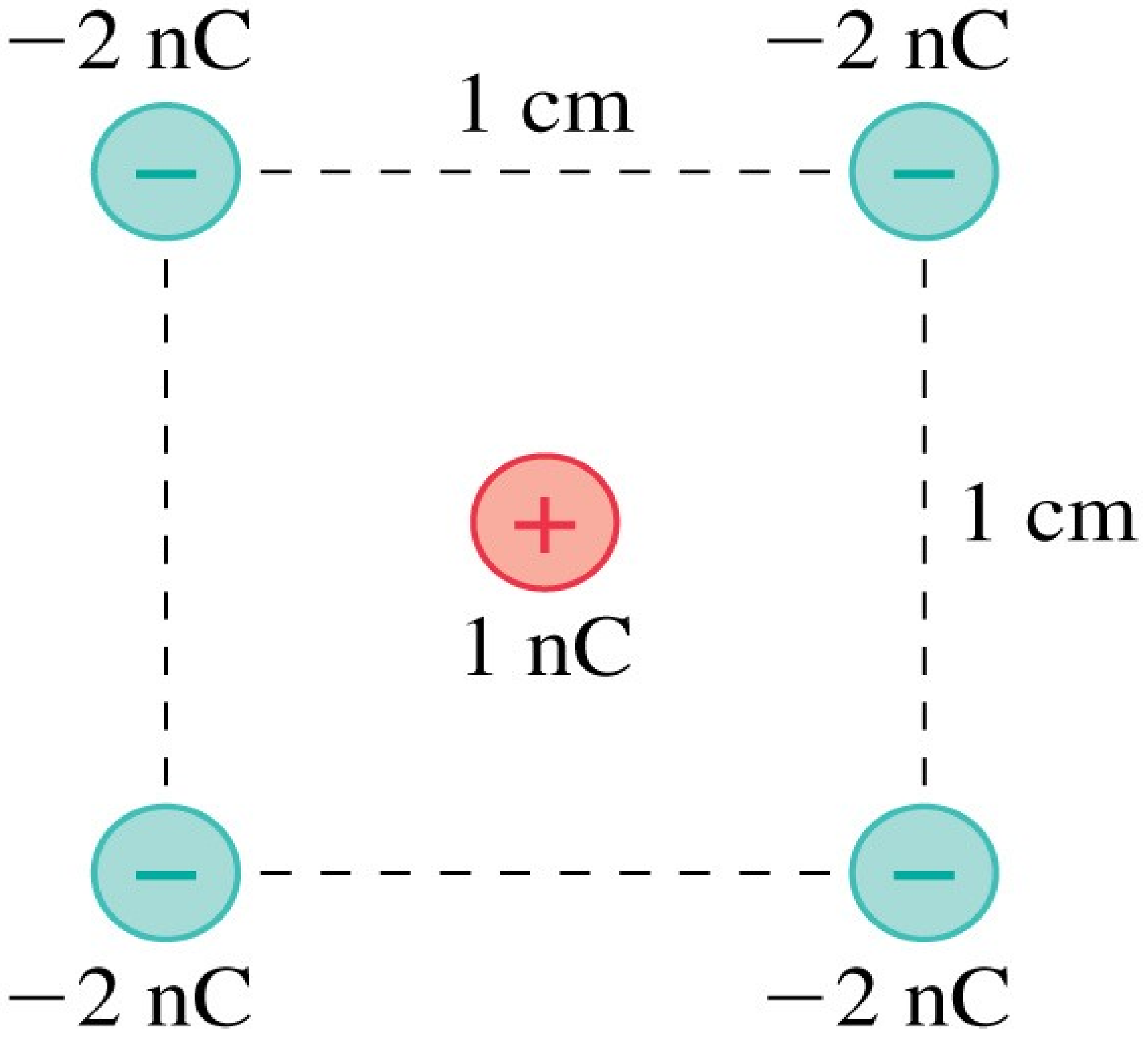
Vector components



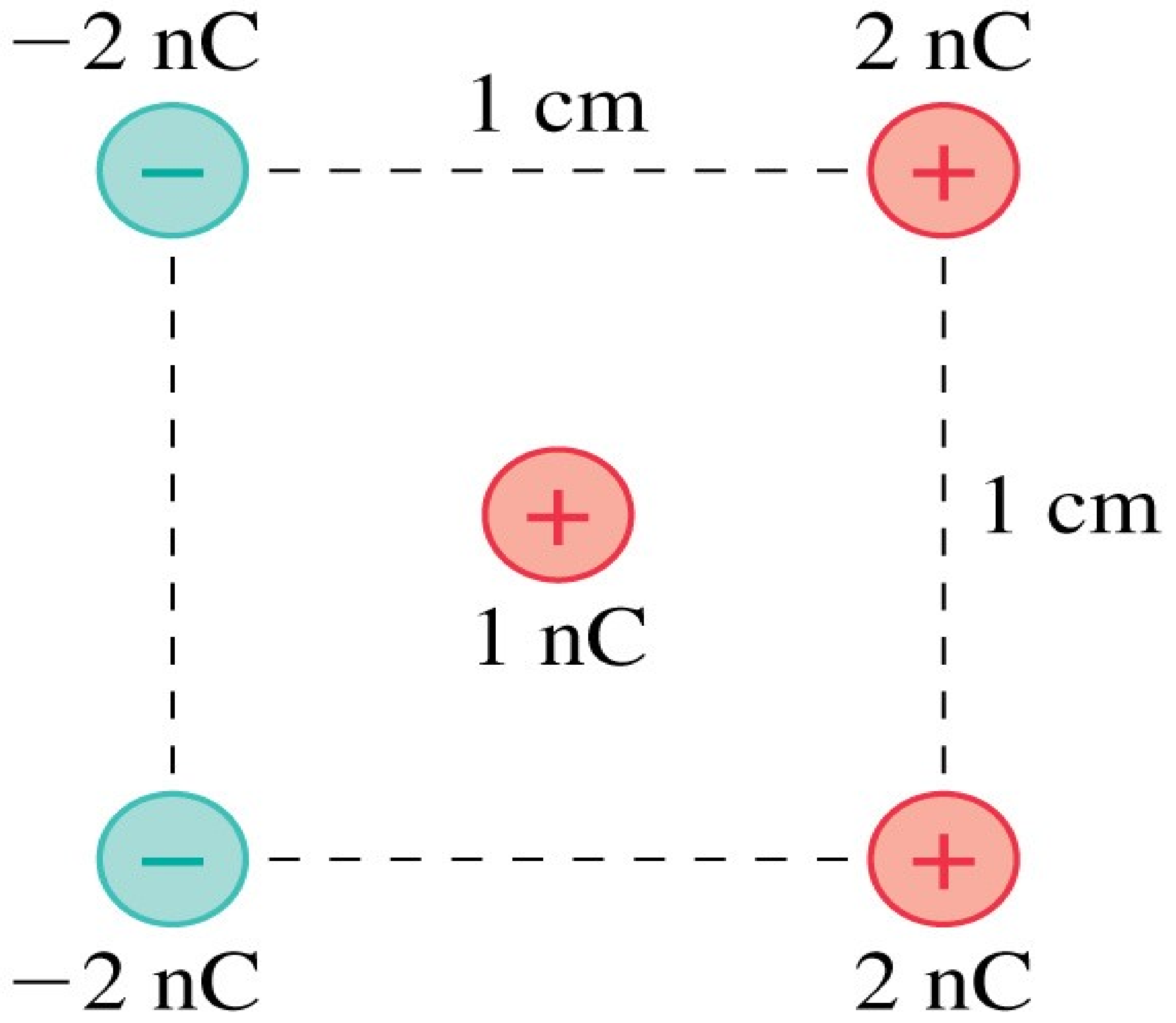
Coulomb's Law w/ Vectors



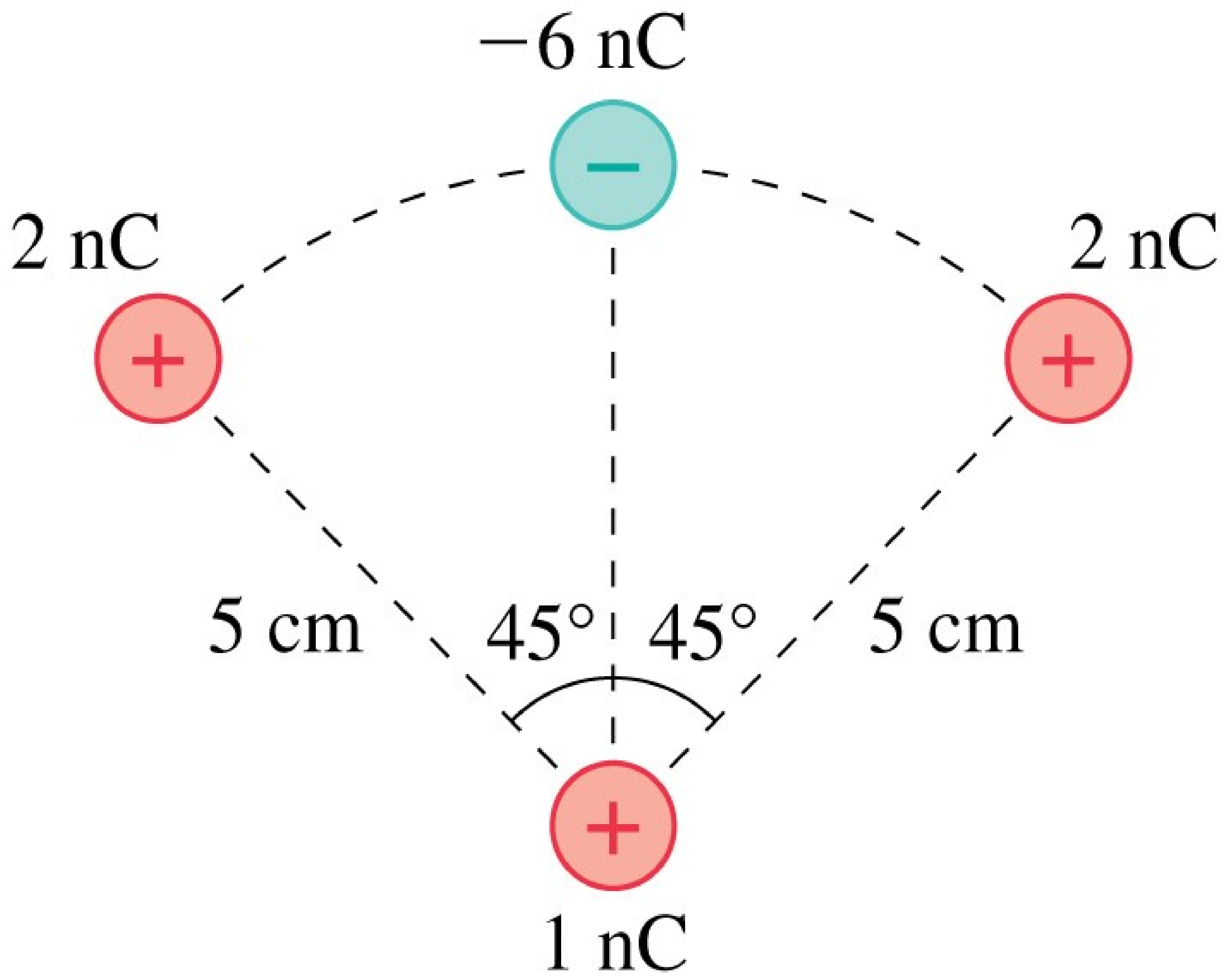
Coulomb's Law w/ Vectors



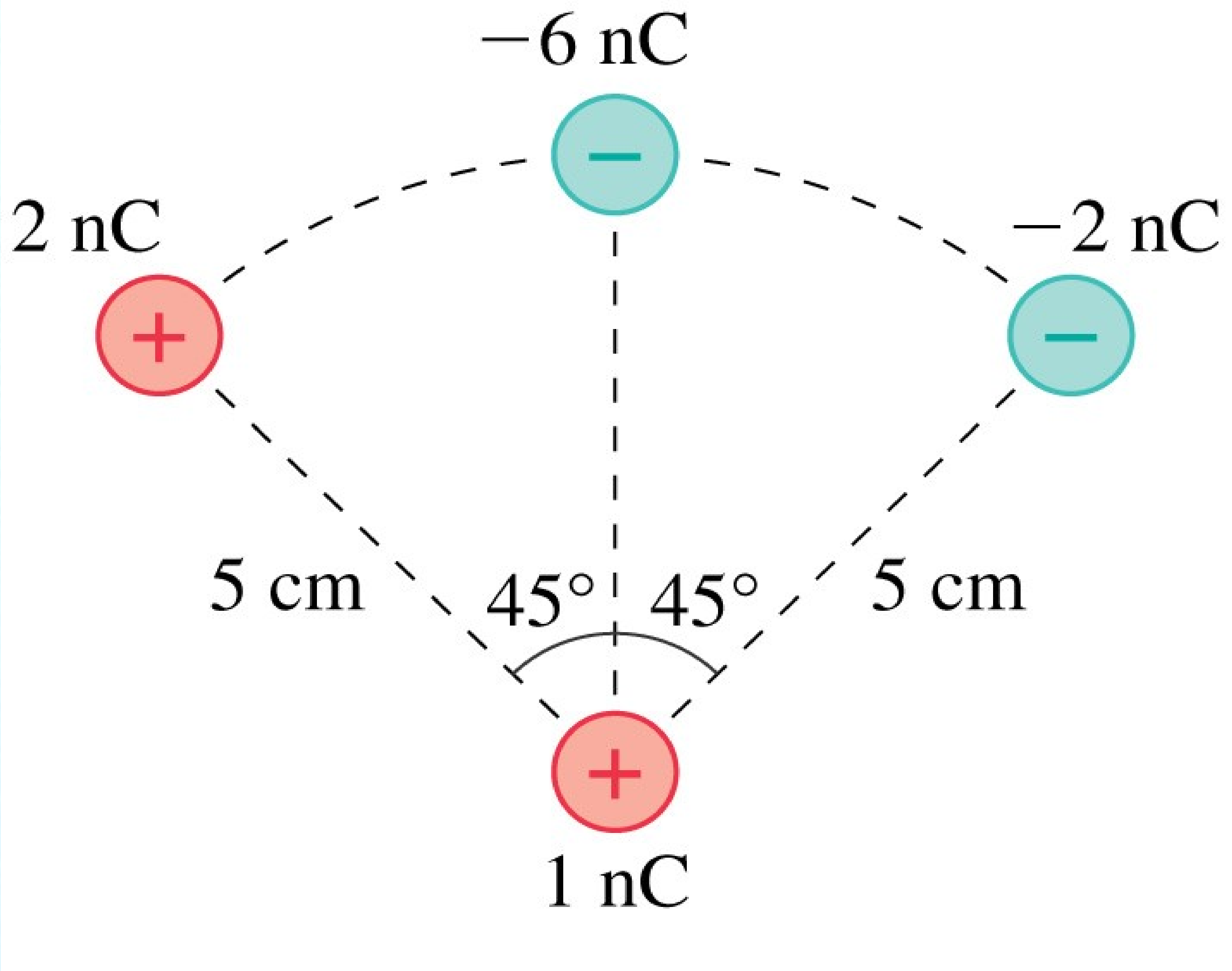
Coulomb's Law w/ Vectors



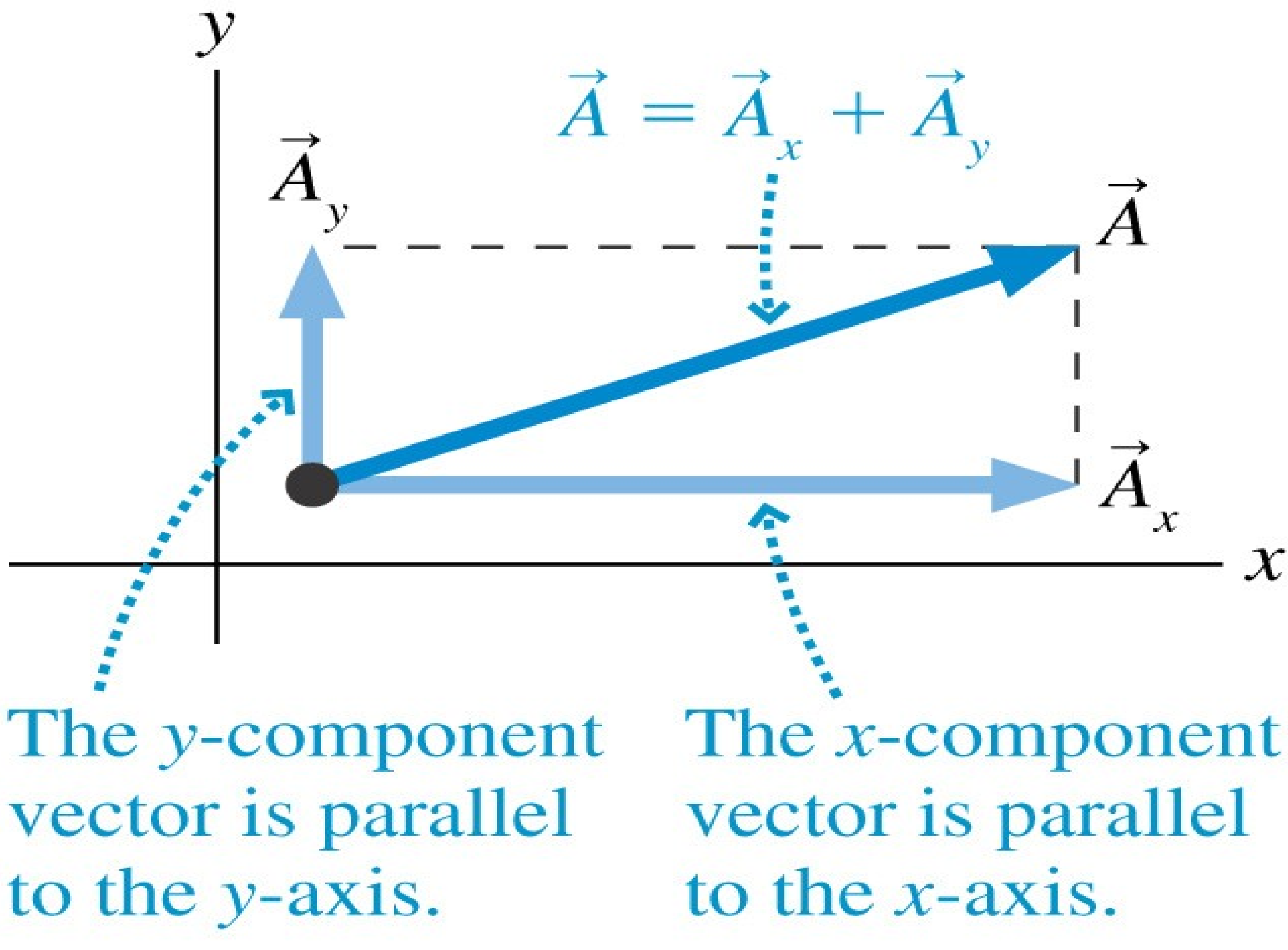
Coulomb's Law w/ Vectors



Coulomb's Law w/ Vectors



Vector components



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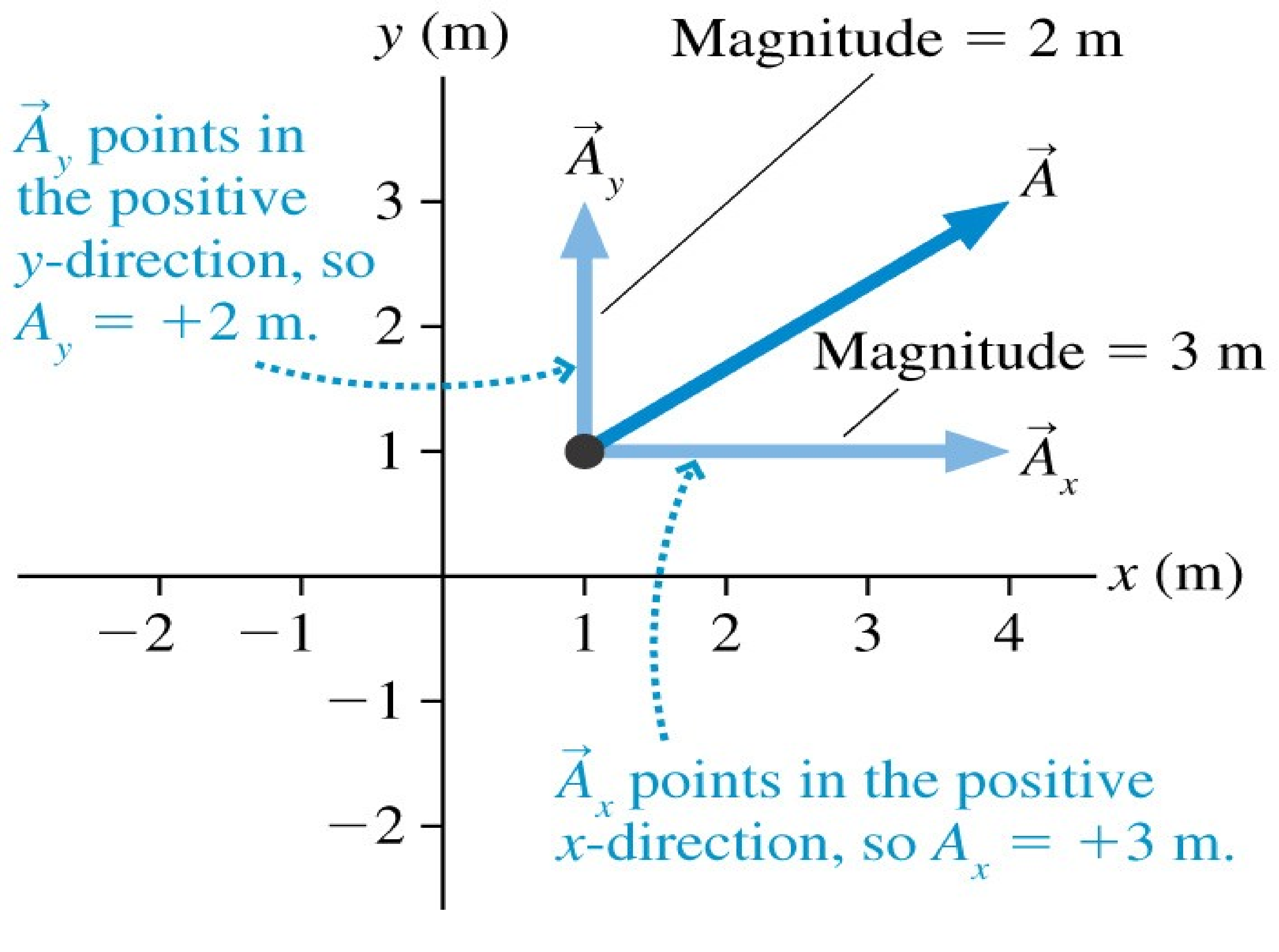
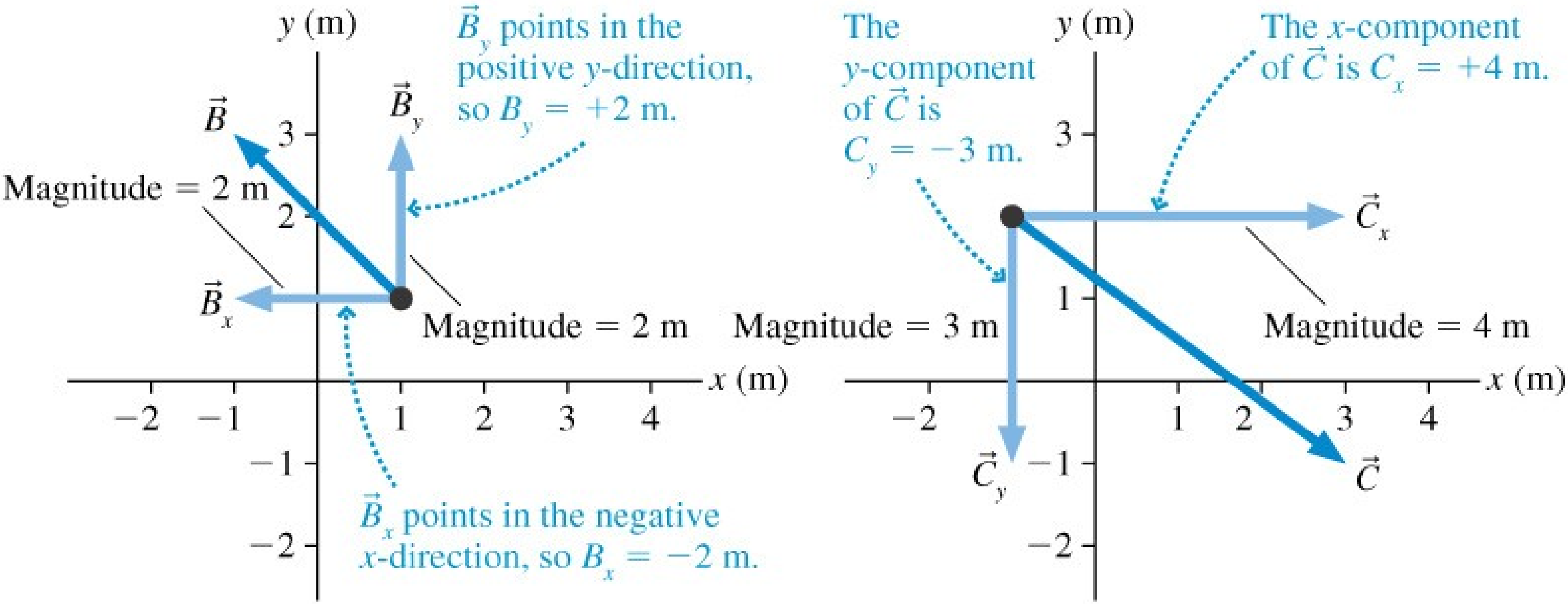
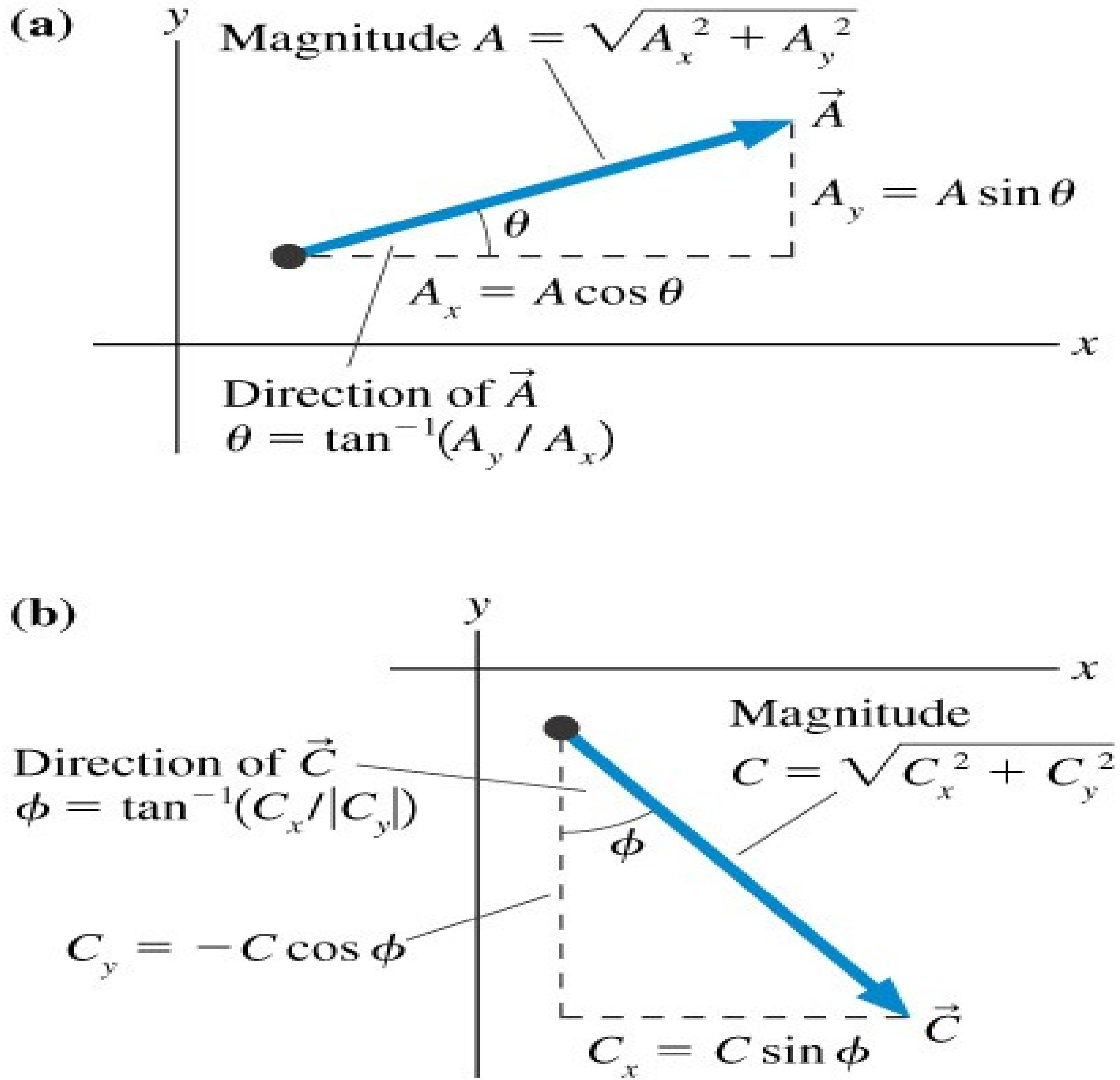


Vector components



Vector components



Component Practice I

Component Practice II