# Electricity and Magnetism

- Physics 259 – L02
- Lecture 3

# Section 21.1

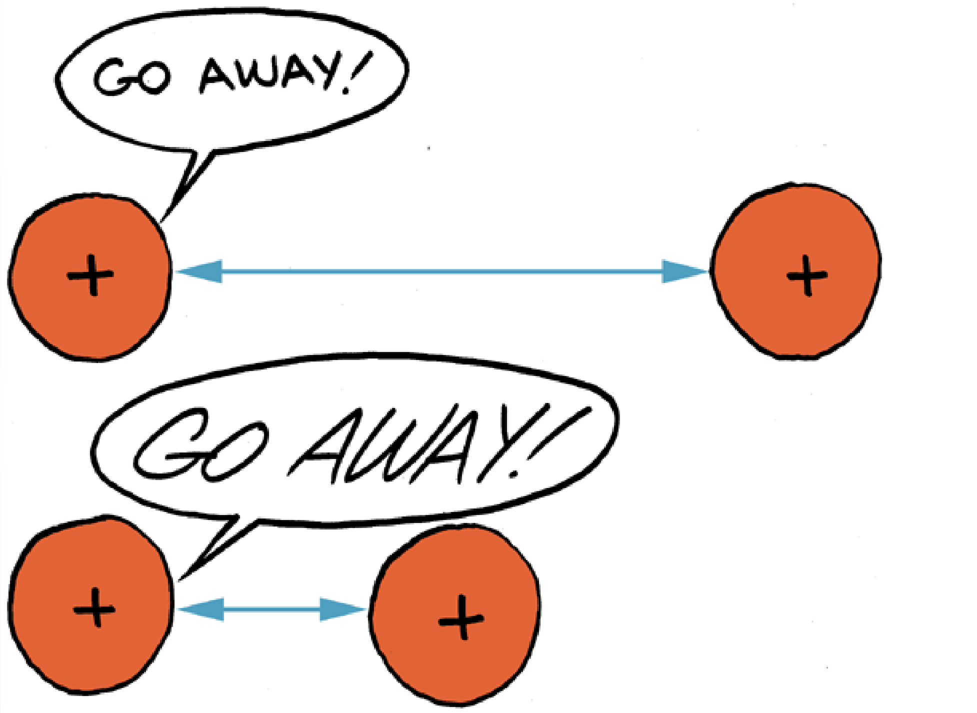
# What we know

- There are positive and negative charges
- Like charges repel each other
- Opposite charges attract each other
- The force between charged objects varies with distance
- The force between charged objects depends on the amount of charge

**HOW CAN WE QUANTIFY THIS?**

# Coulomb's Law

- Electric field decreases with distance



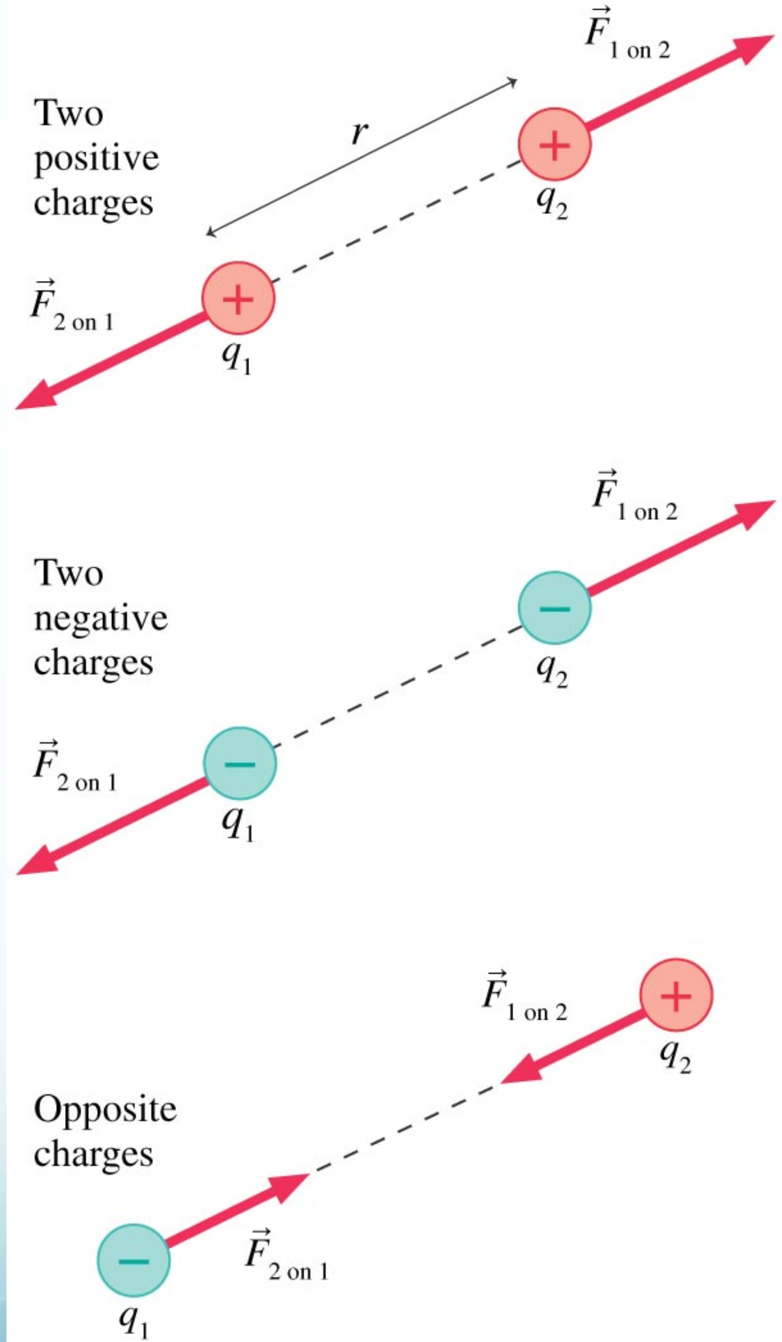

- The force that describes this behavior is known as **Coulomb's law**

# Coulomb's Law

Describes the forces that charged **particles** exert on each other:

**point charges**

The forces always act along the line joining the charges.



# Two Ways of Writing Coulomb's Law

$$\boxed{F_{1\,on\,2} = F_{2\,on\,1} = K\frac{|q_1||q_2|}{r^2}}$$

$K$ = electrostatic constant

$$K = 8.99\times10^{9}\,\frac{N\cdot m^2}{C^2}$$

$$\boxed{F_{1\,on\,2} = F_{2\,on\,1} = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}}$$

$\varepsilon_0$ = permittivity of free space

$$\varepsilon_0 = \frac{1}{4\pi K} = 8.85\times10^{12}\,\frac{C^2}{N\cdot m^2}$$

# Coulomb’s Law

## How to compute the magnitude and direction properly?


$$\left|\vec{F}_{21}\right| = K\frac{|q_1||q_2|}{r_{21}^2}$$

**1) Find the distance between the charges.**

**2) Draw a line passing through the two charges.**

**3) The force on $q_1$ due to $q_2$ has its tail at location 1 and points either towards $q_2$ or away from $q_2$.**

**4) Pick the direction according to basic rule of charges:**

Like charges repel, Opposite charges attract

# SI unit of charge: the **coulomb** (C)

**Fundamental charge:**

the smallest possible amount of free charge

= charge of one proton: $\boxed{e = 1.60 \times 10^{-19}\ C}$

Then 1 C is approximately **6.25 x 10$^{18}$ protons**.

1 C is **BIG!!**

$$\boxed{\begin{aligned} 1\ \mu C &= 1 \text{ microcoulomb} = 10^{-6}\ C \\ 1\ nC &= 1 \text{ nanocoulomb} = 10^{-9}\ C \end{aligned}}$$

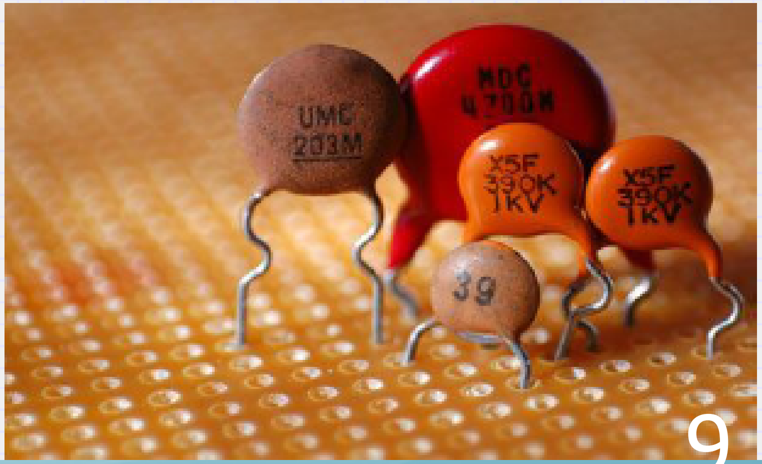
# 1 Coulomb is a great deal of charge

An average bolt of lightning

charge = 5 Coulombs
current = 50,000 Amperes
power = 500,000,000 Joules

so all the electrons in a copper penny have a total charge equivalent to 30,000 lightning bolts.

A single electron has 1.6E-19 Coulombs of charge.




Capacitors in circuits typically hold charges on the order of 10E-9 to 10E-3 Coulombs.

All materials contain very large numbers of charges, but they are usually in nearly perfect balance ($N_+ = N_-$).

# Scalars *vs.* Vectors

A **scalar** is any physical quantity that can be described by a single number.

- The temperature in the room is 20°C.

A **vector** is a physical quantity that has both a magnitude and a direction.

- Edmonton is 300 km north of Calgary.

# Vector Addition

Adding vectors requires taking not only their magnitudes into account, but also their directions.

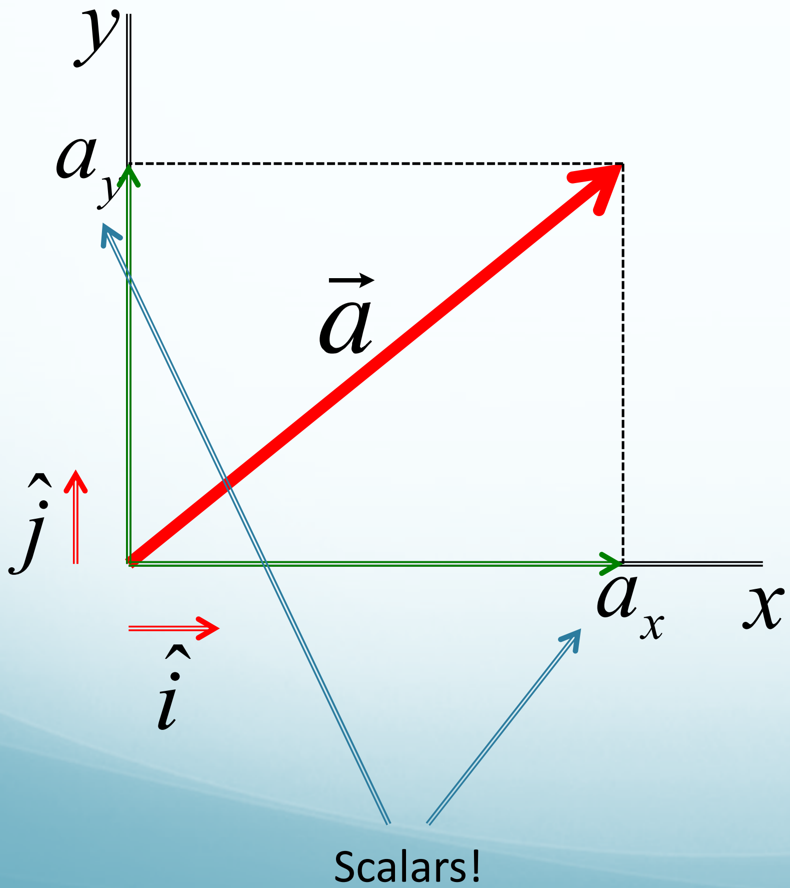
To find the sum of two vectors:

- Draw the first vector.
- Draw the second vector with the tail starting where the tip of the first vector ended.
- Draw a final vector from the tail of the first vector to the tip of the second vector.

$$\vec{C} = \vec{A} + \vec{B}$$

# Vector Components

Scalars are usually easier to use than vectors. So let's replace our vectors with scalar quantities called vector components.



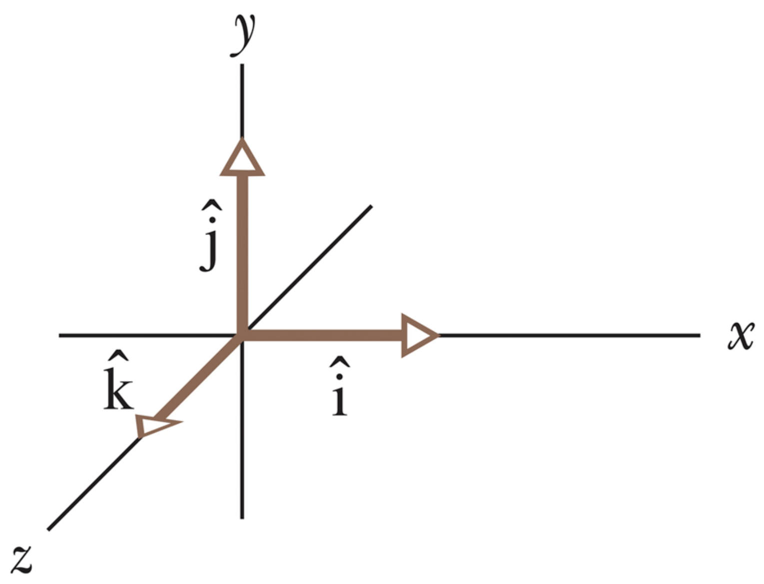

$$\vec{a} = a_x\hat{i} + a_y\hat{j}$$

$$\left|\vec{a}\right| = \sqrt{a_x^2 + a_y^2}$$

magnitude is always positive

# Unit vectors

The unit vectors point along axes.



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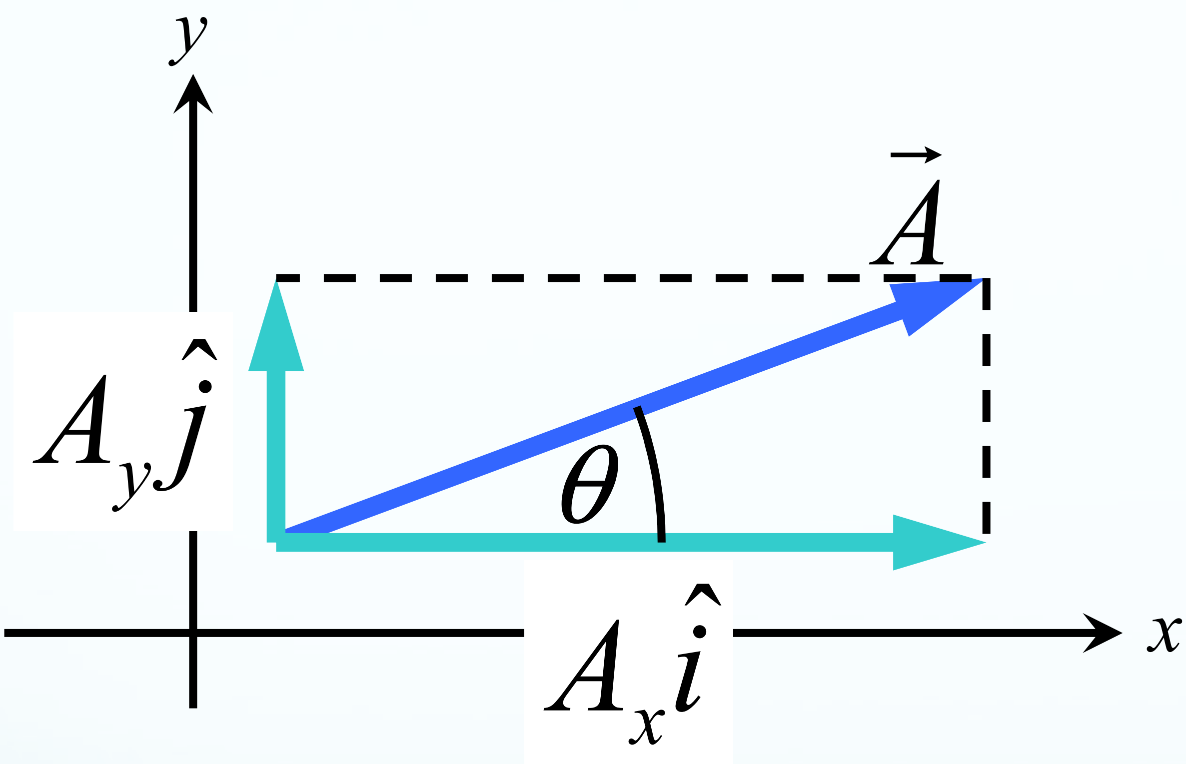
Unit→
Size→
Direction→

# Finding Components of Vectors




$$A_x = A\cos\theta$$

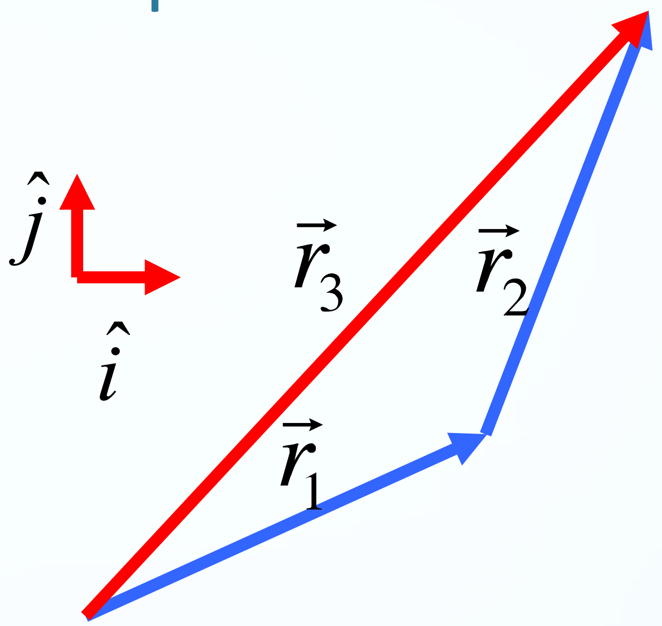
$$A_y = A\sin\theta$$

$$A^2 = A_x^2 + A_y^2$$

$$\theta = \tan^{-1}\left|\frac{A_y}{A_x}\right|$$

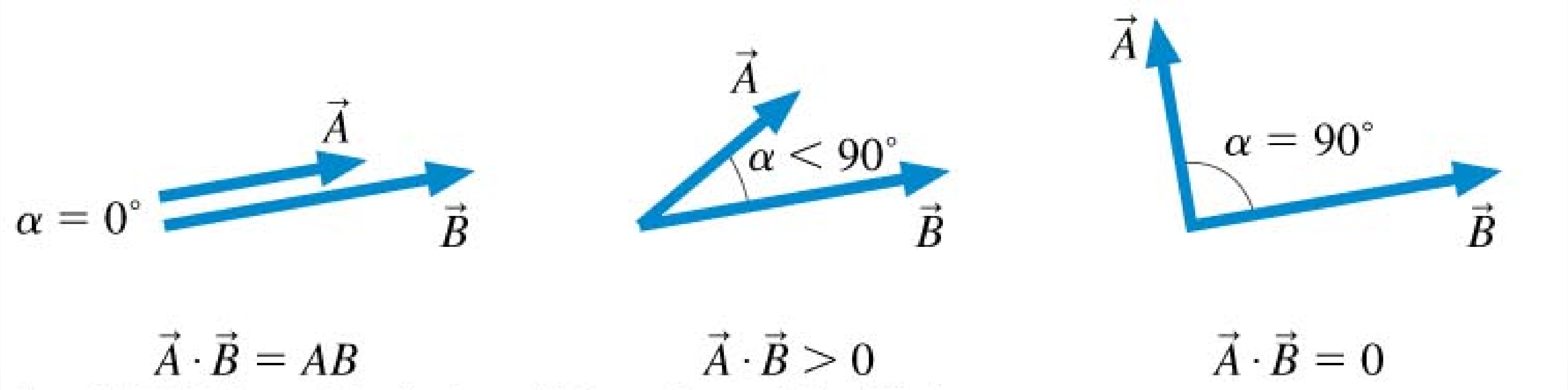
# Vector Addition using Components

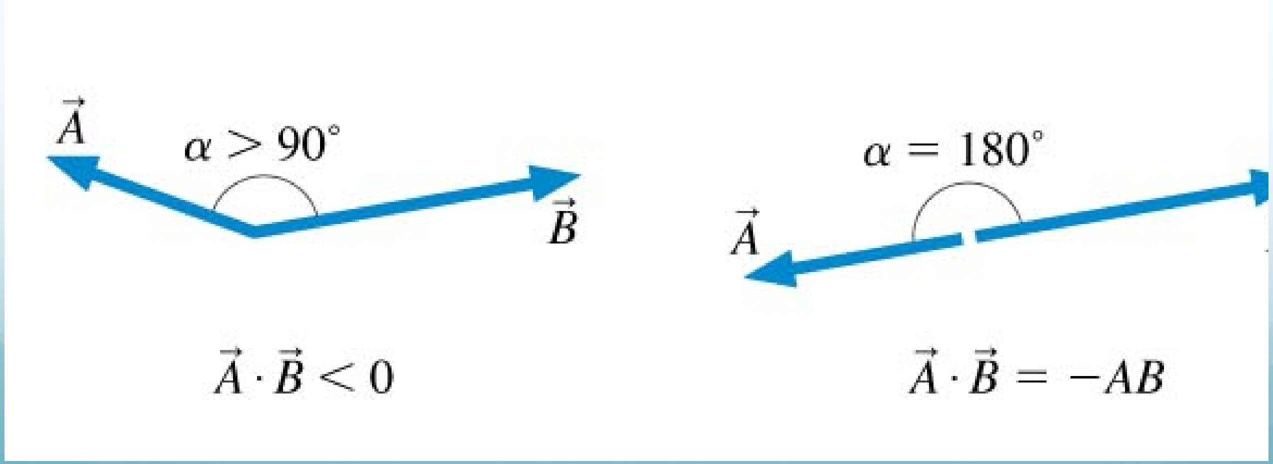
$$\boxed{\vec{r}_3 = \vec{r}_1 + \vec{r}_2}$$



# Dot Product of Two Vectors

$$\vec{A} \cdot \vec{B} = AB\cos\alpha$$

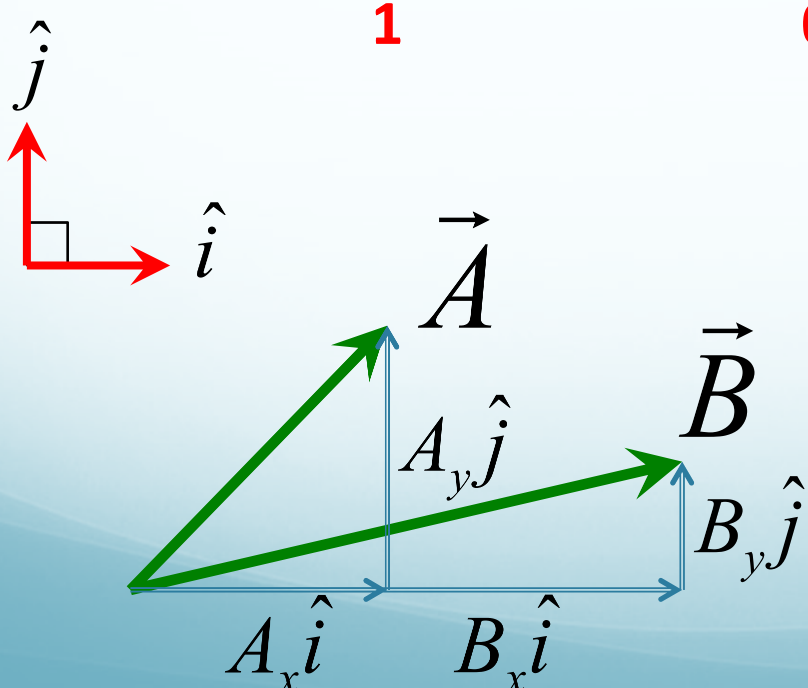


# Dot Product of Two Vectors

$$\vec{A}\cdot\vec{B}=\left(A_x\hat{i}+A_y\hat{j}\right)\cdot\left(B_x\hat{i}+B_y\hat{j}\right)$$

$$=A_xB_x\underbrace{\hat{i}\cdot\hat{i}}_{1}+A_xB_y\underbrace{\hat{i}\cdot\hat{j}}_{0}+A_yB_x\underbrace{\hat{j}\cdot\hat{i}}_{0}+A_yB_y\underbrace{\hat{j}\cdot\hat{j}}_{1}$$

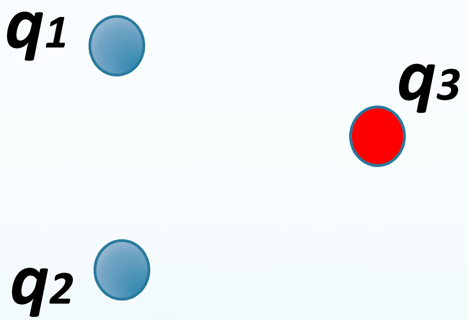



$$\boxed{\vec{A}\cdot\vec{B}=A_xB_x+A_yB_y}$$

# Superposition Principle

The total force on $q_3$ is the vector sum of the individual forces:

$$\vec{F}_{on\,3} = \vec{F}_{1\,on\,3} + \vec{F}_{2\,on\,3}$$



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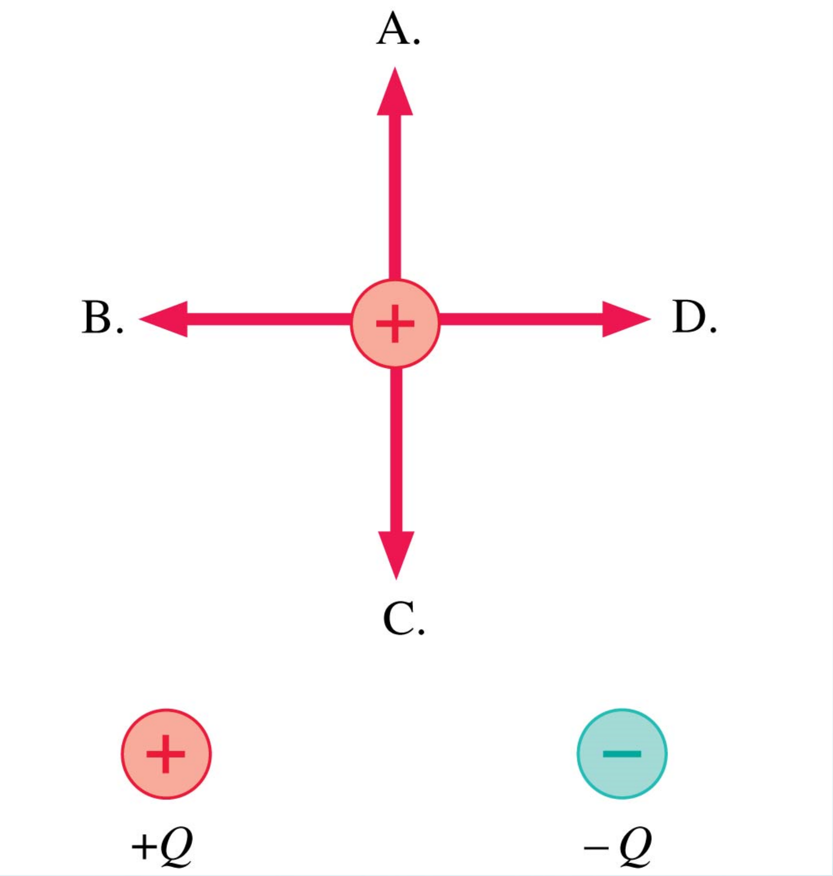
# TopHat Question

Which is the direction of the net force on the charge at the top?




E. None of these.

This section we talked about:

Chapter 21.1

See you on Friday



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