Properties of vectors

Equality: two vectors are equal if they have the same magnitude and direction

Addition: triangular method; parallelogram method or adding components (note that A+B=B+A)

$$A+B=(A_x+B_x, A_y+B_y)$$

Subtraction: A-B=A+(-B)

Multiplying or dividing by a scalar: 3A is a vector with the same direction as A and three times the magnitude.

$$3A=(3A_x, 3A_y)$$

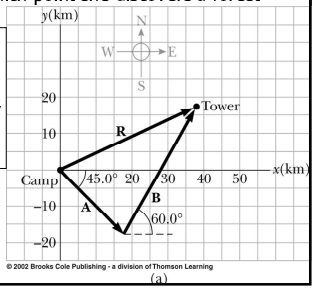
Strategy with vectors

- ❑Select a coordinate system
- ❑Sketch the vector to be added or subtract and label them
- ❑Find the x and y component of each vector
- ❑Find the resultant components
- ❑Use the Pythagorean theorem to find the magnitude of the resultant vector
- ❑Use a suitable trigonometric function to find the angle the resultant vector makes with the positive x axis

Vectors: example

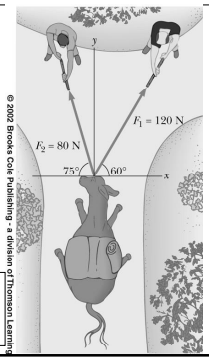
A hiker begins a trip by first walking 25.0 km southeast from her base camp. On the second day she walks 40.0 km in the direction 60.0 degrees northeast, at which point she discovers a forest ranger's tower.

a) Determine the component of the hiker's displacement on the 1st and 2nd day
b) Determine the total displacement



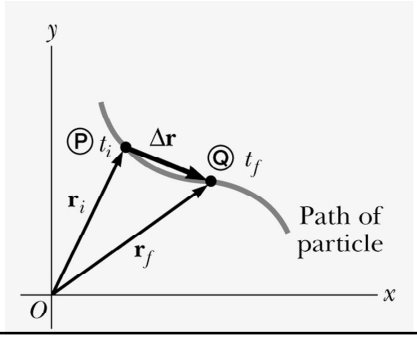
(a)

Example of summing vectors



What is the magnitude and direction of the resultant force applied to the donkey?

2-D motion



2-D motion: definitions

displacement

$$\Delta\vec{r}=\vec{r}_f-\vec{r}_i$$

Average velocity

$$\bar{\vec{v}}=\frac{\Delta\vec{r}}{\Delta t}$$

Average acceleration

$$\bar{\vec{a}}=\frac{\Delta\vec{v}}{\Delta t}$$

Instantaneous velocity

$$\vec{v}=\lim_{\Delta t\to 0}\frac{\Delta\vec{r}}{\Delta t}$$

Instantaneous acceleration

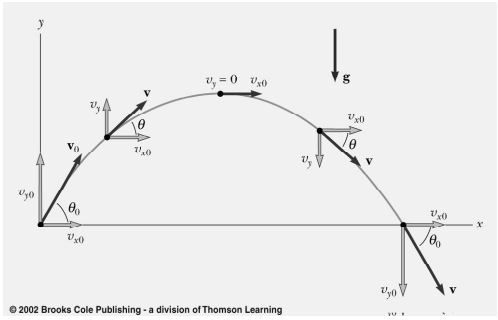
$$\vec{a}=\lim_{\Delta t\to 0}\frac{\Delta\vec{v}}{\Delta t}$$

2-D motion

True or false:
- A body cannot accelerate if its speed is constant
- A particle can have constant velocity and varying speed

Is there acceleration in a car
- when you press the accelerator?
- when your car is on cruise control?
- when you hit the brakes?

Projectile motion



Projectile motion

- It can be described as a superposition of two independent motions in the x and y directions
- Provided air resistance is negligible, the horizontal component of velocity $\mathbf{v}_x$ remains constant
- The vertical component of the acceleration is equal to the free fall acceleration **g**
- The vertical component of the velocity $\mathbf{v}_y$ and the displacement in the **y** direction are identical to those of a freely falling body

Projectile motion: strategy

- Select a coordinate system and sketch the path of the particle
- Resolve the initial velocity in its x and y components
- Treat the horizontal and vertical motion independently
- Follow method for constant velocity to analyse x motion
- Follow method for constant acceleration to analyse the y motion

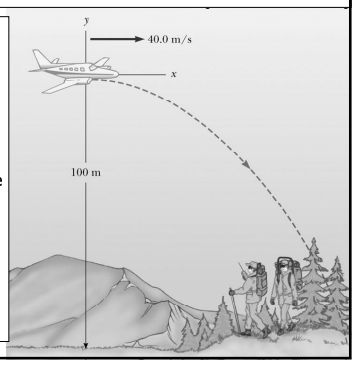
Projectile motion

As a projectile moves in its parabolic path, the velocity and acceleration vectors are perpendicular to each other:
a) Everywhere along its path
b) At the peak of its path
c) Nowhere along its path
d) Not enough information

If you are carrying a ball and running at constant speed and wish to throw the ball so that you can catch it when it comes back down, should you:
a) Throw the ball at an angle of 45deg and maintain the same speed?
b) Throw the ball straight in the air, and slow down to catch it?
c) Throw the ball straight in the air and maintain the same speed?

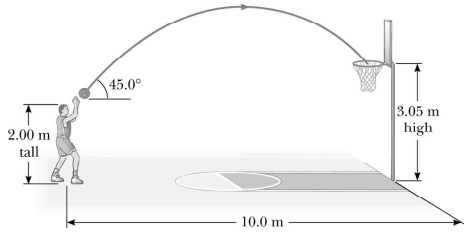
Projectile motion: example

An Alaskan rescue plane drops a package of emergency rations to stranded hikers. The plane is traveling horizontally at 40.0 m/s at height of 100 m above the ground.
a) Where does the package strike the ground relative to the point at which it was released?
b) What are the horizontal and vertical components of the velocity of the package just before it hits the ground?



Projectile motion: example

A basketball player 2.0 m tall, wants to make a basket from a distance of 10.0 m. If he shoots the ball at 45.0 deg, at what initial speed must he throw the ball so that it goes through the hoop without striking the backboard?

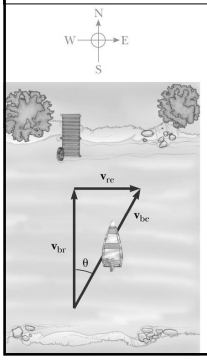


Relative velocity

A passenger at the rear of a train traveling at 15 m/s relative to the Earth throws a baseball with a speed 15 m/s in the direction opposite to the motion of the train. What is the velocity of the baseball relative to the Earth?

$$\vec{v}_{be} = \vec{v}_{bt} + \vec{v}_{te}$$

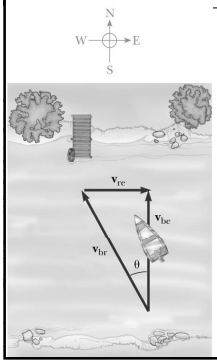
Relative velocity



The boat is heading due north as it crosses a wide river with velocity of 10.0 km/h relative to the water. The river has a uniform velocity of 5.00 km/h due east. Determine the velocity of the boat with respect to an observer on the riverbank?

$$\vec{v}_{be} = \vec{v}_{br} + \vec{v}_{re}$$

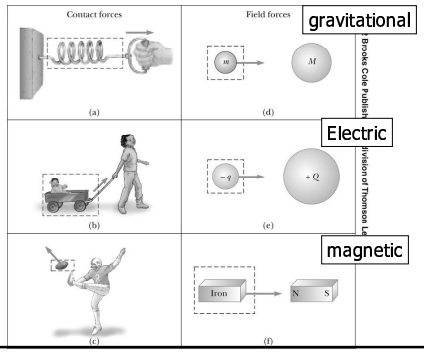
Relative velocity



If now the boat moves at the same speed 10 km/h relative to the water but wants to travel due north, in what direction should it move relative to the water?

$$\vec{v}_{be} = \vec{v}_{br} + \vec{v}_{re}$$

Chapter 4: The laws of motion



Newton's first law

If the net force exerted on an object is zero, the object continues in its original state of motion:

- an object at rest, remains at rest;
- an object moving with some velocity continues with that same velocity.

Net force: the sum of all external forces

$$\sum \vec{F}_i = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots$$

Mass and inertia

Inertia is the tendency of an object to continue in its original motion in the absence of a force

Mass is the resistance of an object to changes in its motion due to a force

Newton's second law

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass

$$\vec{a} = \frac{\sum \vec{F}_i}{m}$$

$$\sum F_{ix} = ma_x$$

$$\sum F_{iy} = ma_y$$

Units

$1N \equiv 1Kgm/s^2$

Mass, Acceleration and Force

TABLE 4.1 Units of Mass, Acceleration, and Force

System	Mass	Acceleration	Force
SI	kg	m/s^2	$N = kg \cdot m/s^2$
U.S. customary	slug	ft/s^2	$lb = slug \cdot ft/s^2$

Note: 1 N = 0.225 lb.