Preview of Period 3: Motion and Forces

3.1 More about Rates – Speed and Velocity

What is the relationship among speed, distance and time of travel?

What is the difference between speed and velocity?

3.2 Introduction to Forces

What causes a change in velocity?

3.3 Changing Velocity: Acceleration

What happens when an object accelerates?

3.4 The Relationship between Force, Mass, and Acceleration

What determines an object's acceleration?

3.5 Net Forces

How do forces acting on an object combine?

3.6 The Forces Acting on Falling Objects

What determines how fast an object falls?

Act. 3.1: Speed and Velocity

Speed = Distance traveled / Time elapsed

$$s = \frac{D}{t} \qquad \text{(Equation 3.1)}$$

s = speed (in meters/second or miles/hour)

D = distance (in meters or miles)

t = time elapsed (in seconds or hours)

(Ex 3.1)

If you drive for 2 hours at a constant speed and travel 120 miles, what is your average speed for the trip?

$$s = \frac{D}{t} = \frac{120 \text{ miles}}{2 \text{ hours}} = \frac{60 \text{ miles}}{1 \text{ hour}} = 60 \text{ MPH}$$

To find the time *t*, begin by multiplying both sides of Equation 3.1 by *t* and canceling.

$$s = \frac{D}{t} \quad \text{or} \quad s\ t = \frac{D\ \cancel{t}}{\cancel{t}}$$

Then divide both sides by *s* and cancel.

$$\frac{\cancel{s}\ t}{\cancel{s}} = \frac{D}{s} \quad \text{or} \quad t = \frac{D}{s}$$

What is the Difference between Speed and Velocity?

Speed is a rate indicating **how fast** an object moves.

Velocity is a rate that specifies the **speed AND the direction** of motion.

(Example 3.2)

If you drive for 3 hours at a constant speed of 55 miles per hour, how far have you traveled?

Solve Equation 3.1 for *D* by multiplying both sides by *t* and canceling.

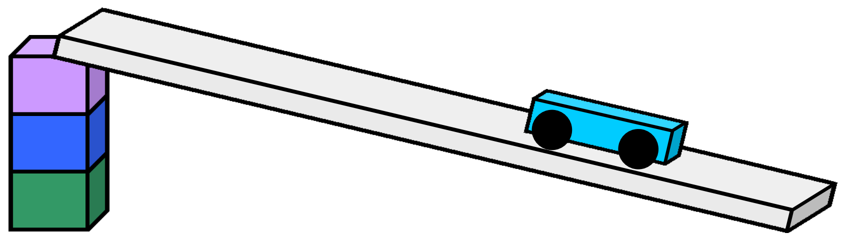
$$s = \frac{D}{t} \qquad s\ t = \frac{D\ \cancel{t}}{\cancel{t}} = D$$

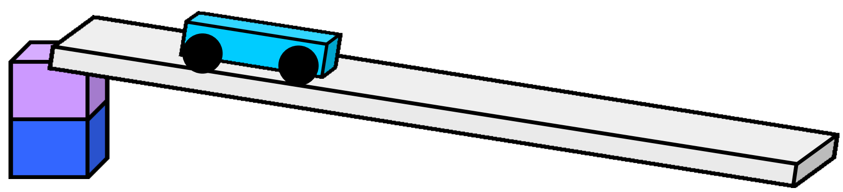
$$= \frac{55 \text{ miles}}{\cancel{\text{hour}}} \times 3\ \cancel{\text{hours}} = 165 \text{ miles}$$

To specify your **velocity** for the trip, you must indicate the direction of travel as well as the speed, such as **55 miles per hour due west.**

Act. 3.2: Changes in Velocity

A force is required to change the speed or direction of motion of an object.





What force acts on the cart to change its velocity as it rolls down the higher ramp and then down the lower ramp?

Act. 3.3: Acceleration

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time elapsed}}$$

$$a = \frac{v_{final} - v_{initial}}{t} = \frac{v_f - v_i}{t} \qquad \text{(Equation 3.2)}$$

a = acceleration (in m/s^2 or $\frac{mi/hr}{sec}$)

v_f = final velocity (in m/s or mi/hr)

v_i = initial velocity (in m/s or mi/hr)

t = time elapsed (in sec)

(Ex 3.3) You are driving at a constant speed of 40 miles per hour. You increase your speed to 60 miles per hour in 5 seconds. What is your acceleration during these 5 seconds?

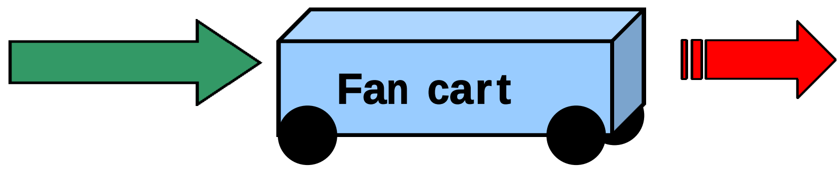
$$a = \frac{v_f - v_i}{t} = \frac{60\ mi/hr - 40\ mi/hr}{5\ sec} = \frac{20\ mi/hr}{5\ sec}$$

$$= \frac{4\ mi/hr}{sec}$$

Solving Equation 3.2 for v_{final} gives the velocity in the case of constant acceleration.

$$v_{final} = a\,t + v_{initial}$$

Act. 3.4 Force, Mass, and Acceleration



- The greater the force of the fan, the larger the acceleration of the cart.
- The greater the mass of the cart, the smaller the acceleration of the cart.

Force = mass x acceleration

$$F = M\,a$$

F = force (in newtons)
M = mass (in kilograms)
a = acceleration (in m/s^2)

(Ex 3.5) How much force is required to accelerate a 4000 kg truck at a constant rate of 5 m/s^2 ?

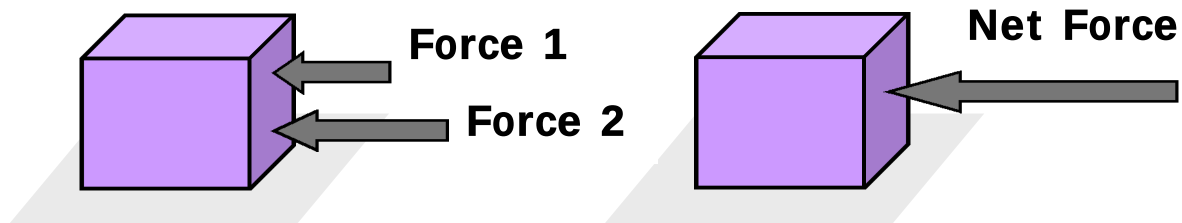
$$F = M\,a = 4{,}000 \text{ kg} \times 5 \text{ m/s}^2 = 20{,}000 \text{ N}$$

Act. 3.5: Net Force

A **force** is required to change the speed or direction of motion of an object.

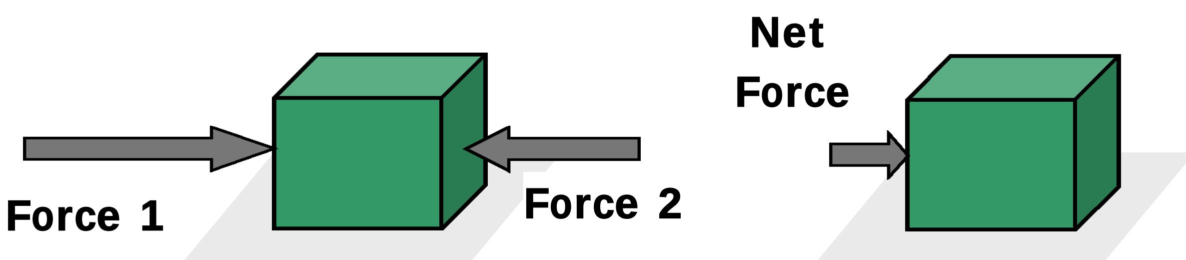
(This is Newton's First Law of Motion)

The **net force** of two forces acting in the same direction is their sum.



Net Force = Force 1 + Force 2

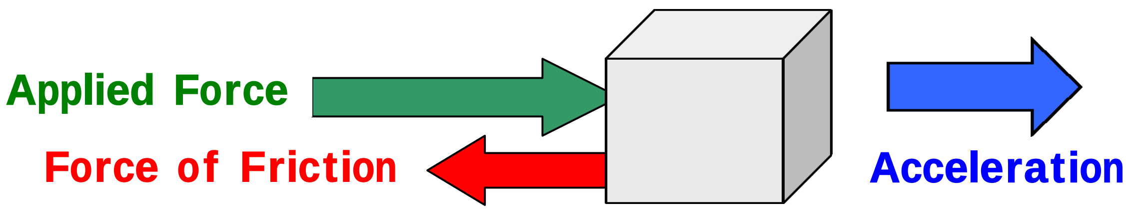
The **net force** of two forces acting in opposite directions is their difference



Net force = Force 1 - Force 2

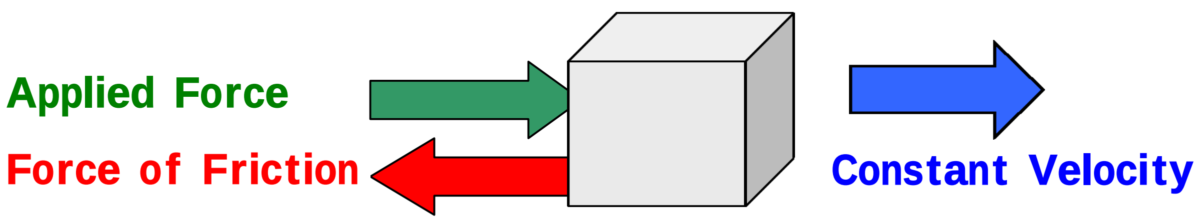
Act. 3.5: Net Force and Motion

An Applied Force Larger than the Force of Friction



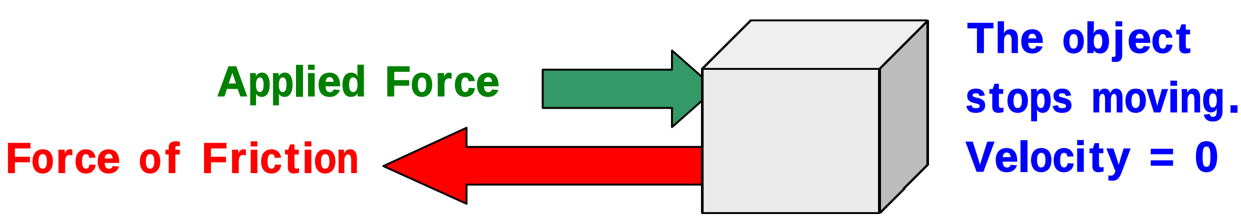
If the applied force is greater than the force of friction, the box accelerates across a level floor in the direction of the applied force.

An Applied Force Equal to the Force of Friction



If the applied force is equal to the force of friction, the box moves with constant velocity across a level floor in the direction of the applied force.

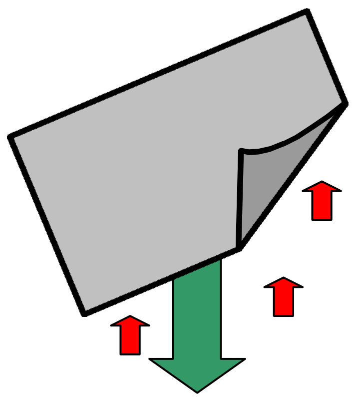
An Applied Force Less than the Force of Friction



If the box is in motion and the applied force is less than the force of friction, the box comes to a stop.

Act. 3.6: Forces on Falling Objects

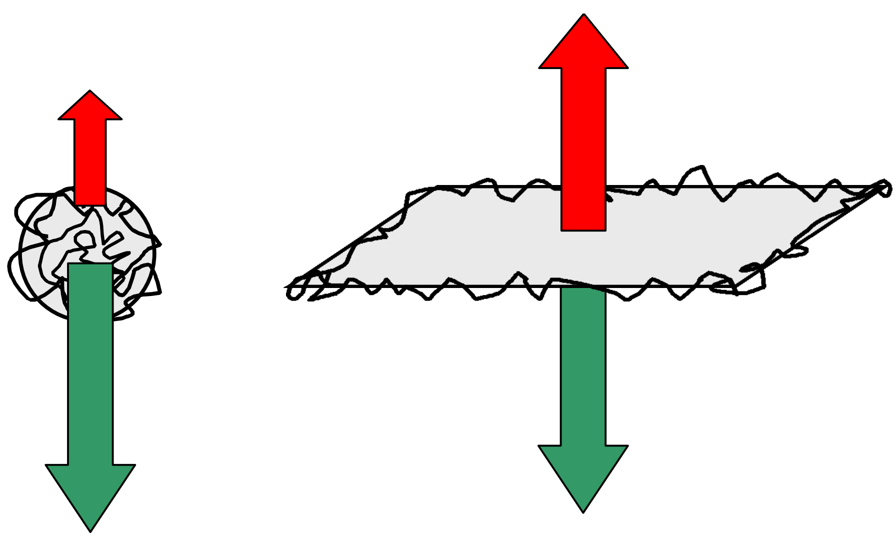
- As an object moves through air, it collides with air molecules.
- Each molecule exerts a force on the object, slowing its velocity slightly.



The force of gravity pulls the paper down.

Collisions with air molecules exert a force up on the paper.

Force of air resistance



Force of gravity

Period 3 Summary

3.1: A **rate is a ratio.** Common ratios include speed, velocity, and acceleration.

The ratio, Distance traveled/Time elapsed, = speed (or velocity, if the direction of motion is indicated)

3.2: A change in velocity occurs when a net force acts on a moving object.

- A **force is any push or pull** on an object.
- The net force of all forces acting in the **same direction is the sum of the forces.**
- The net force of forces acting in **opposite directions is the difference of the forces**.

3.3: Acceleration is the rate of change in velocity per change in time.

Acceleration is the result of a net force acting on an object.

Period 3 Summary, Continued

3.4: The acceleration of gravity causes objects to fall toward Earth at the rate of $9.8\ m/s^2$ (or $32\ ft/s^2$ in English units).

3.5: The net force acting on an object = the product of the object's mass and its acceleration: $F = M a$

- **The net force on an object that is not accelerating is zero.**

Period 3 Review Questions

R.1 What is the difference between speed and velocity? A device on the dashboard of your car is called a speedometer. Why isn't it called a velocity meter? How could you build a velocity meter?

R.2 Define acceleration. What caused the fan cart demonstrated in class to accelerate?

R.3 What can happen to the motion of an object when two forces act on it in opposite directions?

R.4 What causes falling objects to accelerate? Which falls at a faster rate – a sheet of paper slightly crumpled or a sheet crumpled into a tight ball? Why?

R.5 What can happen to the motion of a moving object when an applied force is exerted on the object? Consider the cases of applied forces that are greater than, equal to, and less than the force of friction between the object and the surface it moves across. What size of an applied force is needed to start in motion an object at rest?