Hewitt/Lyons/Suchocki/Yeh

Conceptual Integrated Science

Chapter 2

DESCRIBING MOTION

Aristotle on Motion

Aristotle classified motion into two kinds:

- Natural motion
  motion that is straight up or straight down
- Violent motion
  imposed motion resulting from an external push or pull

Galileo's Concept of Inertia

In the absence of a force, objects once set in motion tend to continue moving indefinitely.

Galileo's Concept of Inertia

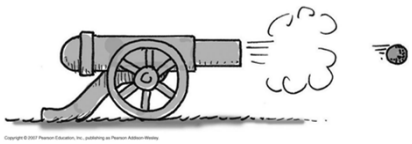
Legend of the Leaning Tower of Pisa:

Galileo showed that dropped objects fall to the ground at the same time when air resistance is negligible.

Galileo's Concept of Inertia

Discovery:

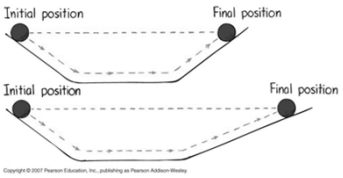
In the absence of friction, no force is necessary to keep a horizontally moving object moving.



Galileo's Concept of Inertia

Experiment:

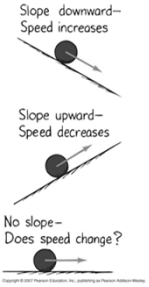
Balls rolling down inclined planes and then up others tend to roll back up to their original heights.



Galileo's Concept of Inertia

Experiment:

Balls rolling down or up inclined planes will alter their speeds depending on the direction.



Galileo's Concept of Inertia

Conclusion:

The tendency of a moving body to keep moving is natural—every material object resists *change* in its state of motion. This property of things to resist change is called **inertia**.

Mass—A Measure of Inertia

The amount of inertia possessed by an object depends on the amount of matter—the amount of material that composes it—its **mass:**

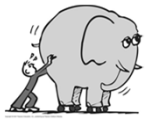
greater mass ⇒ greater inertia

smaller mass ⇒ smaller inertia

Mass—A Measure of Inertia

Mass

- Quantity of matter in an object
- Measure of inertia or sluggishness that an object exhibits in response to any effort made to start it, stop it, or change its state of motion in any way



Mass—A Measure of Inertia

Weight:

Amount of gravitational pull on an object

Weight and mass are proportional.

Twice the mass ⇒ twice the weight

Half the mass ⇒ half the weight

Mass—A Measure of Inertia

Mass versus volume:

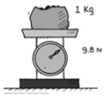
- **Mass** involves how much *matter* an object contains
- **Volume** involves how much *space* an object occupies

Mass—A Measure of Inertia

Standard unit of measurement for mass—the **kilogram**

1 kg of any material on Earth's surface *weighs* 9.8 Newtons (9.8 N)

Away from the Earth, as on the Moon or other small bodies, 1 kg of material weighs less than 9.8 N



Mass—A Measure of Inertia

Density is the measure of how much mass occupies a given space

Equation for density:

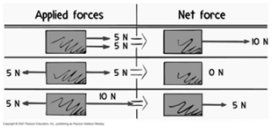
Density = $\frac{\text{mass}}{\text{volume}}$

in grams per cubic centimeter (g/cm^3) or kilograms per cubic meter (kg/m^3)

Force and Net Force

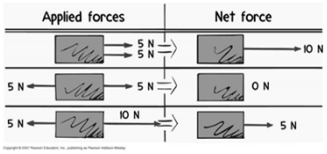
A **Force** is something that produces a change in the state of motion of an object.

Net force is a combination of all forces that act on an object. It is the net force that changes an object's state of motion.



Net Force

Net force is a vector, meaning it has both a magnitude (size) and direction.



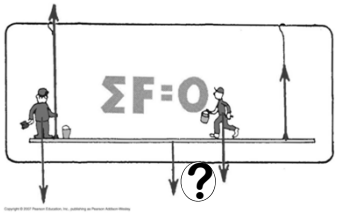
The Equilibrium Rule

The **equilibrium rule:**

"The vector sum of forces acting on a nonaccelerating object or system of objects equals zero.", or the net force on an object is zero.

Mathematical notation: $\Sigma F = 0$.

In the illustration below, there are upward and downward forces. What can be said about their sum?

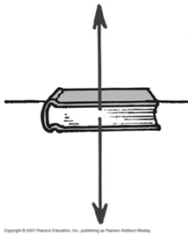


The sum of the forces must be zero!

What if this were not true? What would happen?

The Support Force

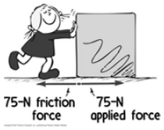
The force that supports an object on a surface against gravity is called the **support force**, often called the *normal force* (F_N).



Equilibrium of Moving Things

An object that moves at constant velocity is in **equilibrium**.

When two or more forces cancel to zero on a moving object, then the object is in equilibrium.



The Force of Friction

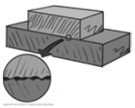
Friction —

- the resistive force that opposes the motion or attempted motion of an object through a fluid or past another object with which it is in contact
- always acts in a direction to oppose motion

The Force of Friction

Friction —

- between two surfaces, the amount depends on the kinds of material and how much they are pressed together
- due to surface bumps and also to the stickiness of atoms on the surfaces of the two materials



Speed and Velocity

Speed is described as the distance covered per amount of travel time

Equation for speed:

$$\text{Speed} = \frac{\text{distance covered}}{\text{travel time}}$$

Speed and Velocity

Average speed is the total distance traveled divided by the time of travel

Equation for average speed:

$$\text{Average speed} = \frac{\text{total distance covered}}{\text{travel time}}$$

Instantaneous speed is speed at any instant of time. Speed is a scalar quantity.

Speed and Velocity

Average velocity is the speed of an object combined with a direction of travel. For example, a car can be traveling a speed of 30 mph or a velocity of 30 mph east.

Instantaneous velocity is velocity at any instant of time.

Velocity is a vector quantity.

Acceleration

Acceleration is the rate at which velocity changes with time. The change in velocity may be in magnitude, in direction, or both. (m/s^2)

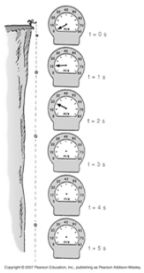
Equation for acceleration:

$$\text{Acceleration} = \frac{\text{change of velocity}}{\text{time interval}}$$

Acceleration

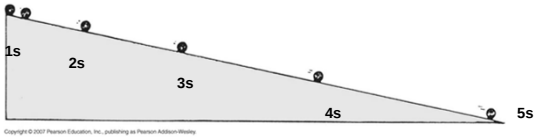
Free fall

When the only force acting on a falling object is gravity, (with negligible air resistance), the object is in a state of **free fall**.



Acceleration

Accelerating objects increase their interval distance with each second also.



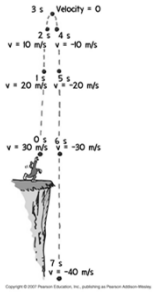
Acceleration

TABLE 2.2 Free Fall

Time of Fall (s)	Speed of Fall (m/s)	Distance of Fall (m)
0	0	0
1	10	5
2	20	20
3	30	45
4	40	80
5	50	125
.	.	.
.	.	.
.	.	.
t	$10t$	$\frac{1}{2}\,10t^2$

Acceleration

Objects thrown up into the air will also experience an acceleration due to gravity. Note what happens to the direction and magnitude of velocity at each point in the journey.



Acceleration

For the illustration below, which ball (A or B) will reach the end of the track first?

Acceleration

For the illustration below, which ball (A or B) will have the greatest speed at the end of the track?