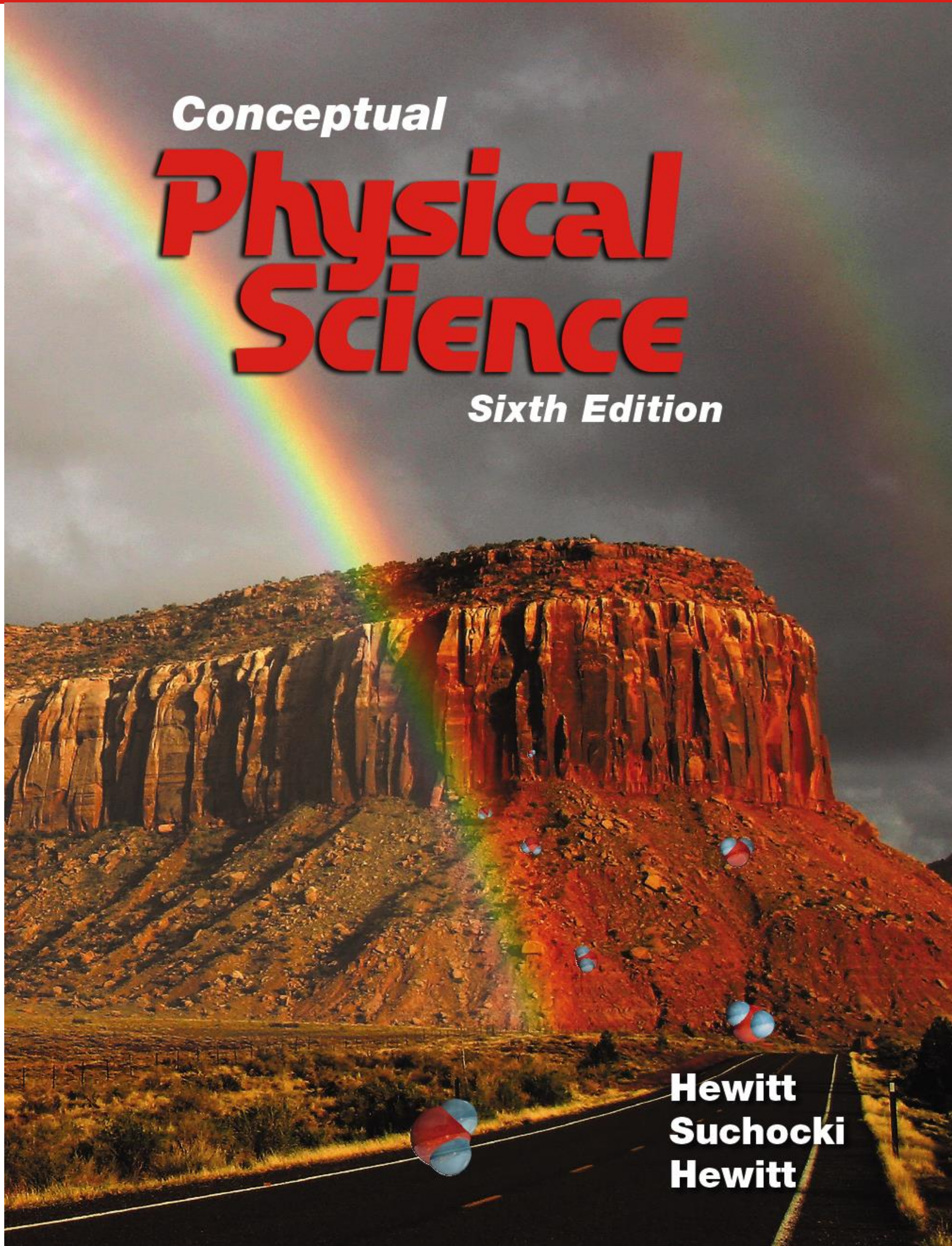
Chapter 2: Patterns of Motion and Equilibrium



This lecture will help you understand:

- Aristotle on Motion
- Galileo's Concept of Inertia
- Mass—A Measure of Inertia
- Net Force
- The Force of Friction
- Speed and Velocity
- Acceleration

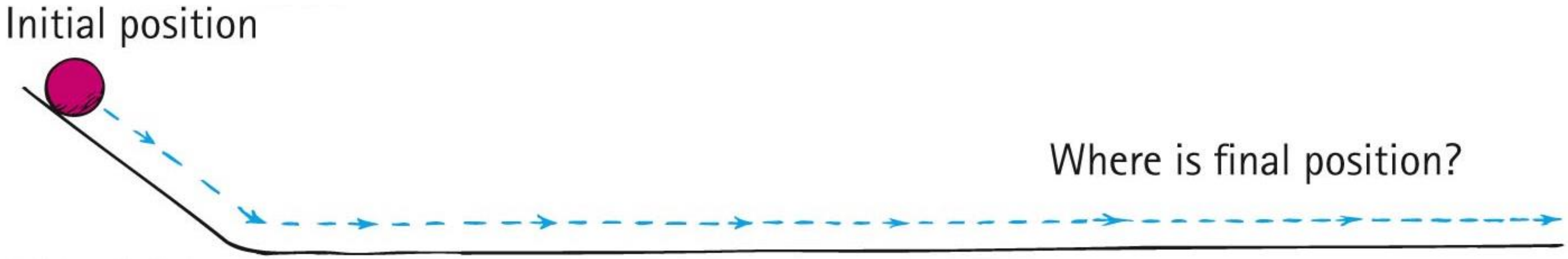
Aristotle on Motion

- 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

- Two assertions of Aristotle
  - Heavy objects fall faster then light objects
  - moving objects must have forces exerted on them to keep them moving.

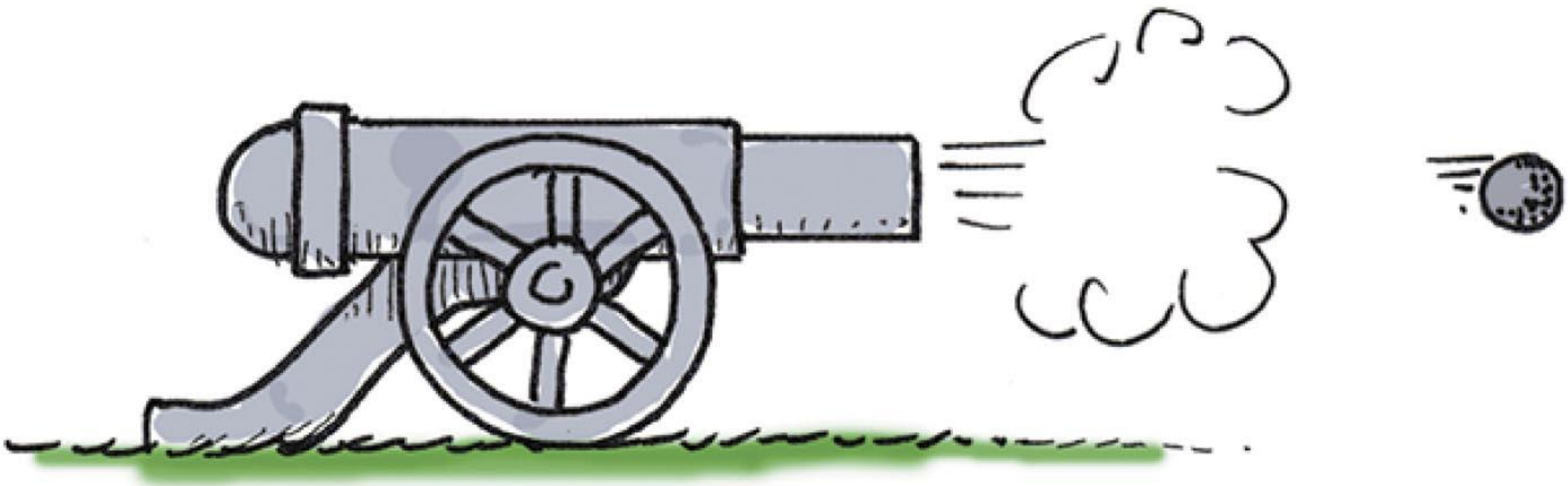
Galileo's Concept of Inertia

- Italian scientist Galileo demolished Aristotle's assertions in early 1500s.
- In the absence of a force, objects once set in motion tend to continue moving indefinitely.



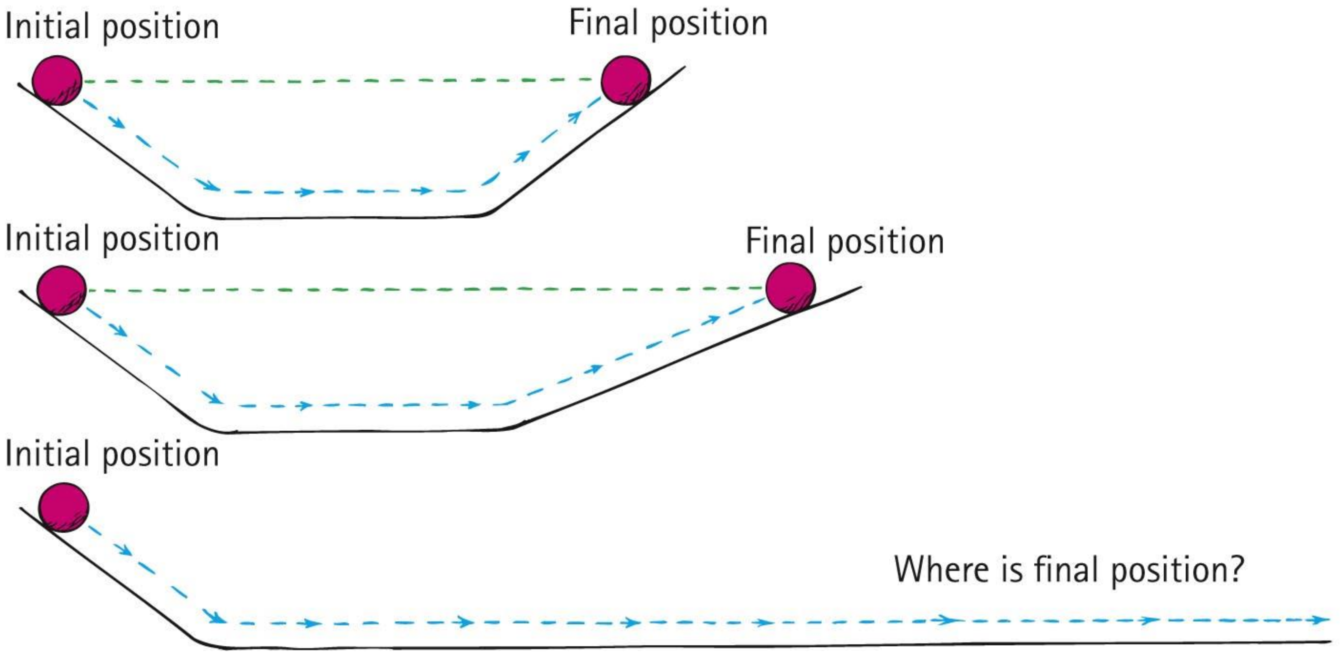
Galileo's Concept of Inertia

- 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

- 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 changes in motion is called ***inertia***.

Mass—A Measure of Inertia

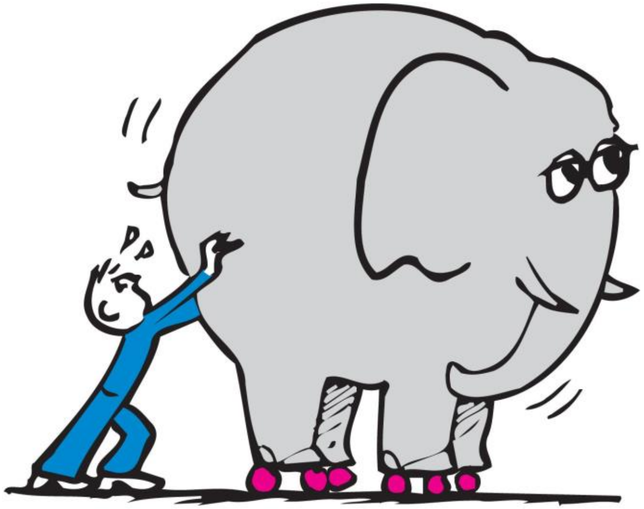
The amount of inertia possessed by an object depends on the amount of matter—the amount of material that composes it—its **mass:**

greater mass $\Rightarrow$ greater inertia

smaller mass $\Rightarrow$ 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
  - Proportional to mass

Twice the mass ⇒ twice the weight

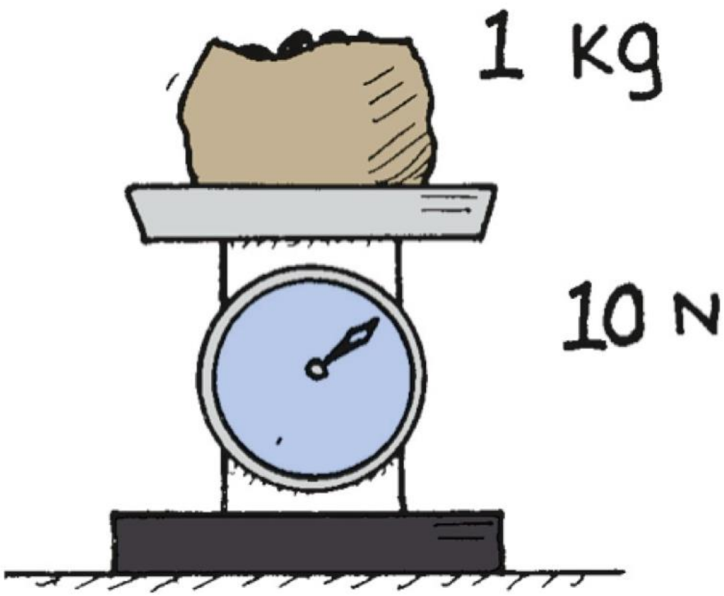
Half the mass ⇒ half the weight

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

- Kilogram
  - standard unit of measurement for mass
  - on Earth's surface, 1 kg of material weighs 10 newtons
  - Away from Earth (on the Moon), 1 kg of material weighs less than 10 newtons



Mass—A Measure of Inertia

- Measure of compactness
  - **Density** is the measure of how much mass occupies a given space
- Equation for density:

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

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

Mass—A Measure of Inertia
CHECK YOUR NEIGHBOR

The density of 1 kilogram of iron is

A. less on the Moon.

B. the same on the Moon.

C. greater on the Moon.

D. All of the above.

Mass—A Measure of Inertia
CHECK YOUR ANSWER

The density of 1 kilogram of iron is

A. less on the Moon.

B. the same on the Moon.

C. greater on the Moon.

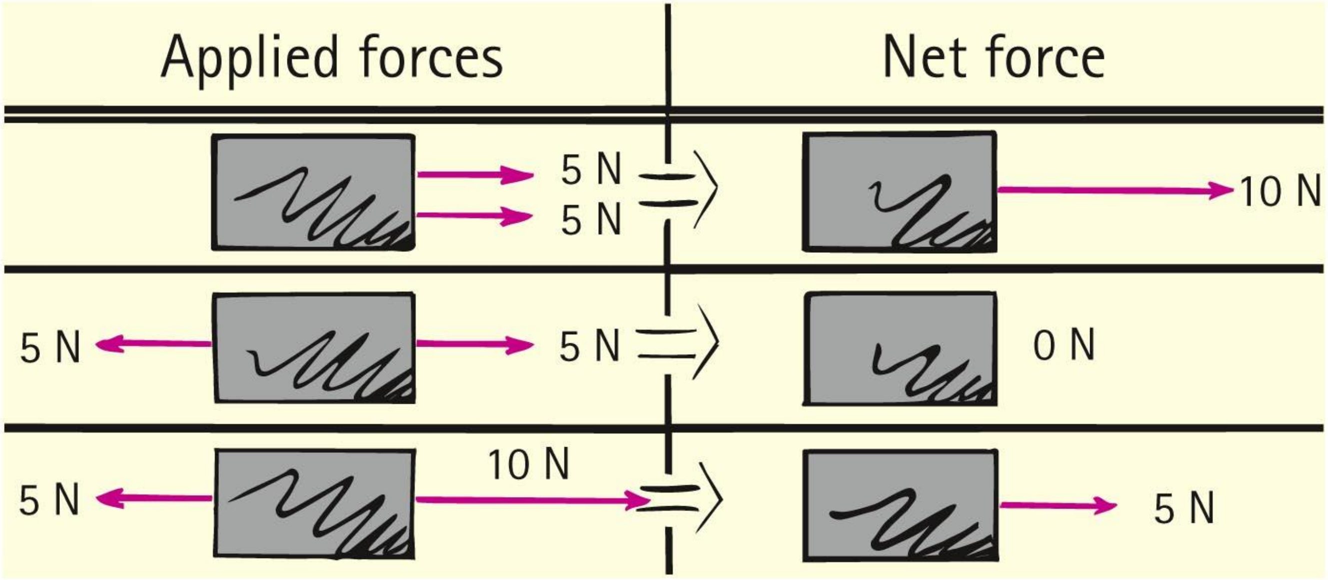
D. All of the above.

Explanation:

Both mass and volume of 1 kilogram of iron is the same everywhere, so density is the same everywhere.

Net Force

- Force
  - simply a push or a pull
- Net force
  - combination of all forces that act on an object
  - changes an object's motion



Net Force
CHECK YOUR NEIGHBOR

A cart is pushed to the right with a force of 15 N while being pulled to the left with a force of 20 N. The net force on the cart is

A. 5 N to the left.

B. 5 N to the right.

C. 25 N to the left.

D. 25 N to the right.

Net Force
CHECK YOUR ANSWER

A cart is pushed to the right with a force of 15 N while being pulled to the left with a force of 20 N. The net force on the cart is

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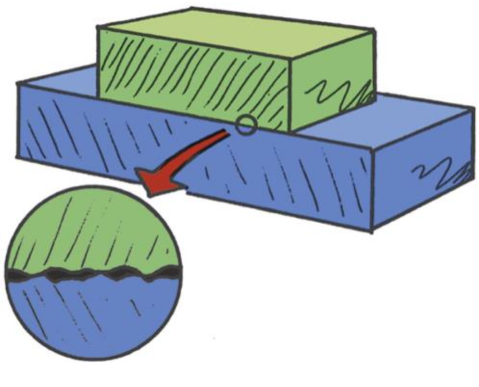
The Force of Friction

- 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 (continued)
  - 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

<u>Equation for speed:</u>

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

- **Velocity** is “directed” speed.

Speed and Velocity

- Average speed
  - is total distance traveled divided by travel time
    - Equation:

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

- Instantaneous speed
  - is speed at any instant of time

Speed and Velocity
CHECK YOUR NEIGHBOR

The average speed in driving 30 km in 1 hour is the same average speed as driving

A. 30 km in one-half hour.

B. 30 km in two hours.

C. 60 km in one-half hour.

D. 60 km in two hours.

Speed and Velocity
CHECK YOUR ANSWER

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A. 30 km in one-half hour.

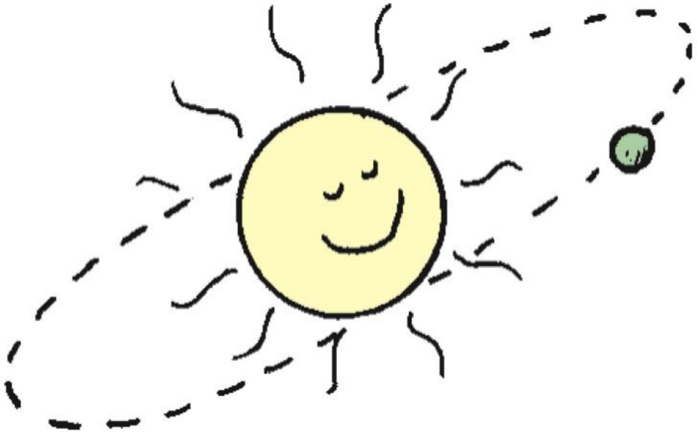
B. 30 km in two hours.

C. 60 km in one-half hour.

D. 60 km in two hours.

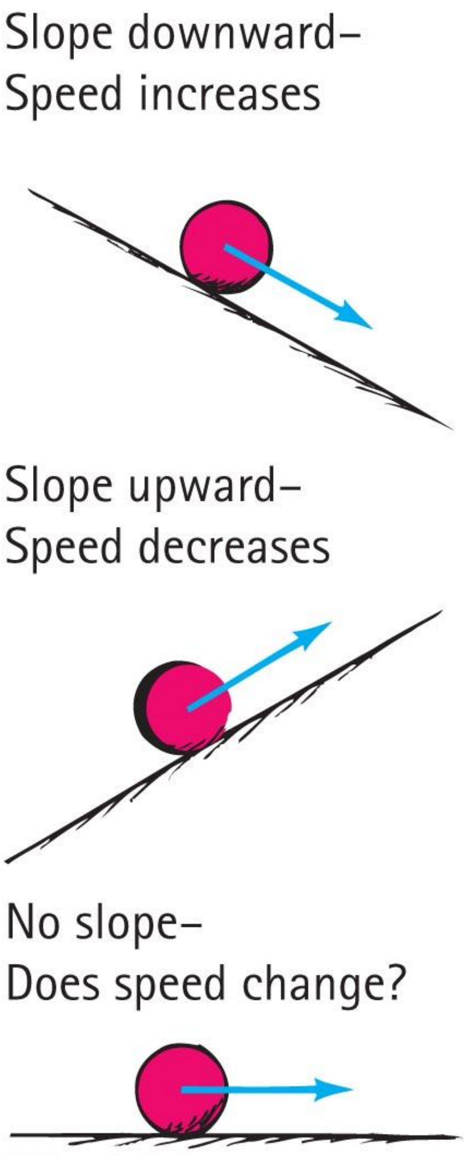
Motion is Relative

- Everything is always moving.
- At this moment, your speed relative to the Sun is about 100,000 kilometers per hour.
- When we say a space shuttle travels at 30,000 kilometers per hour, we mean relative to the Earth.



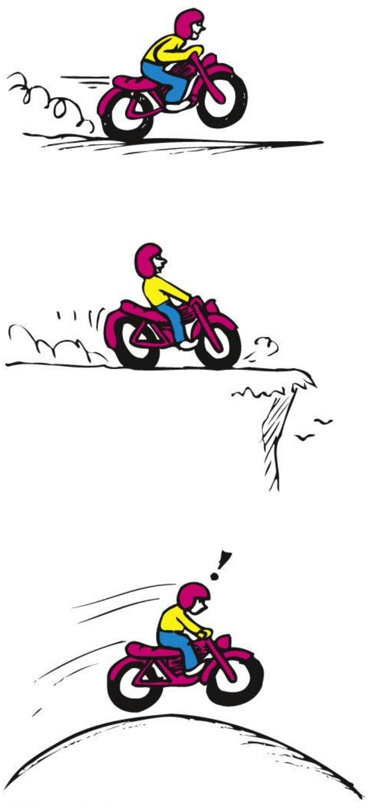
Acceleration

- Galileo first formulated the concept of acceleration in his experiments with inclined planes.



Acceleration

- **Acceleration** is the rate at which velocity changes with time. The change in velocity may be in magnitude, in direction, or both.



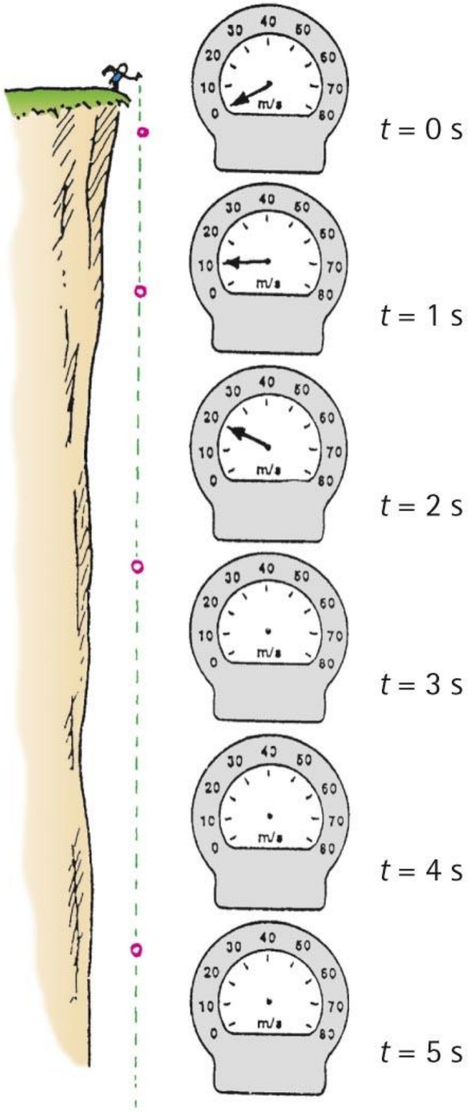
  - Equation for acceleration:

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

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
CHECK YOUR NEIGHBOR

If a falling object gains 10 m/s each second it falls, its acceleration is

A. 10 m/s.

B. 10 m/s per second.

C. Both of the above.

D. Neither of the above.

Acceleration
CHECK YOUR ANSWER

If a falling object gains 10 m/s each second it falls, its acceleration is

A. 10 m/s.

B. 10 m/s per second.

C. Both of the above.

D. Neither of the above.

Explanation:

It is common to express 10 m/s per second as 10 m/s/s, or 10 m/s^2.

Acceleration
CHECK YOUR NEIGHBOR

A free-falling object has a speed of 30 m/s at one instant. Exactly one second later its speed will be

A. the same.

B. 35 m/s.

C. more than 35 m/s.

D. 60 m/s.

Acceleration
CHECK YOUR ANSWER

A free-falling object has a speed of 30 m/s at one instant. Exactly one second later its speed will be

A. the same.

B. 35 m/s.

C. more than 35 m/s.

D. 60 m/s.

Explanation:

One second later its speed will be 40 m/s, which is more than 35 m/s.

Acceleration
CHECK YOUR NEIGHBOR

The distance fallen by a free-falling body

A. remains constant each second of fall.

B. increases each second when falling.

C. decreases each second when falling.

D. None of the above.

Acceleration
CHECK YOUR ANSWER

The distance fallen by a free-falling body

A. remains constant each second of fall.

B. increases each second when falling.

C. decreases each second when falling.

D. None of the above.

Explanation:

See Table 1.2 for verification of this. Falling distance ~ time squared.

TABLE 1.2 FREE-FALL VELOCITY ACQUIRED AND DISTANCE FALLEN

Time of Fall (s)	Velocity Acquired (m/s)	Distance Fallen (m)
0	0	0
1	10	5
2	20	20
3	30	45
4	40	80
5	50	125