Conceptual Physics
11th Edition

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Chapter 3:
LINEAR MOTION

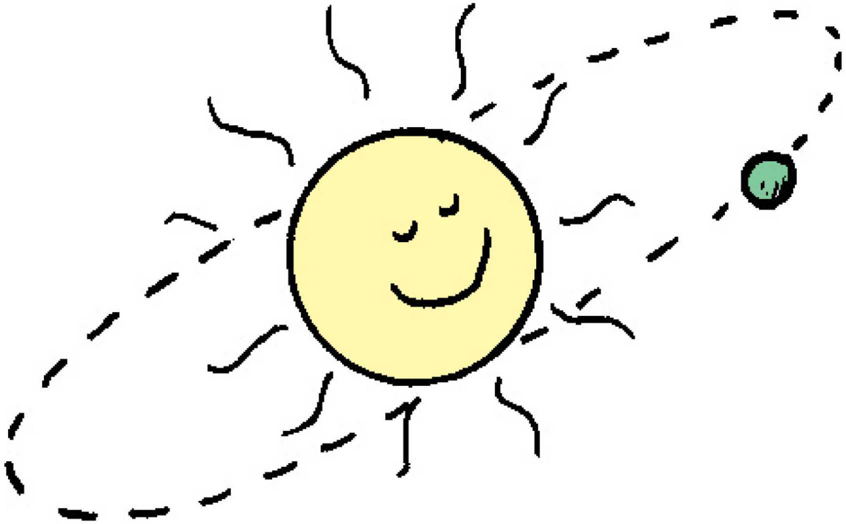
This lecture will help you understand:

- Motion Is Relative
- Speed : Average and Instantaneous
- Velocity
- Acceleration
- Free Fall

Motion Is Relative

Motion of objects is always described as *relative* to something else. For example:

- You walk on the road relative to Earth, but Earth is moving relative to the Sun.
- So your motion relative to the Sun is different from your motion relative to Earth.



Speed

- Defined as the distance covered per amount of travel time.
- Units are meters per second.
- In equation form:

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

Example: A girl runs 4 meters in 2 sec. Her speed is 2 m/s.

Average Speed

- The entire distance covered divided by the total travel time
  - Doesn’t indicate various instantaneous speeds along the way.
- In equation form:

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

Example: Drive a distance of 200 km in 2 h and your average speed is 100 km/h.

Average Speed
CHECK YOUR NEIGHBOR

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

A. 30 km in 1/2 hour.

C. 30 km in 2 hours.

D. 60 km in 1/2 hour.

G. 60 km in 2 hours.

Average Speed
CHECK YOUR ANSWER

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A. 30 km in 1/2 hour.

C. 30 km in 2 hours.

D. 60 km in 1/2 hour.

G. 60 km in 2 hours.

Explanation:

Average speed = total distance / time

So, average speed = 30 km / 1 h = 30 km/h.

Same

Now, if we drive 60 km in 2 hours:

Average speed = 60 km / 2 h = 30 km/h

Instantaneous Speed

Instantaneous speed is the speed at any instant.

Example:

- When you ride in your car, you may speed up and slow down.
- Your instantaneous speed is given by your speedometer.

Velocity

- A description of
  - the instantaneous speed of the object
  - what direction the object is moving

- Velocity is a vector quantity. It has
  - magnitude: instantaneous speed
  - direction: direction of object’s motion

Speed and Velocity

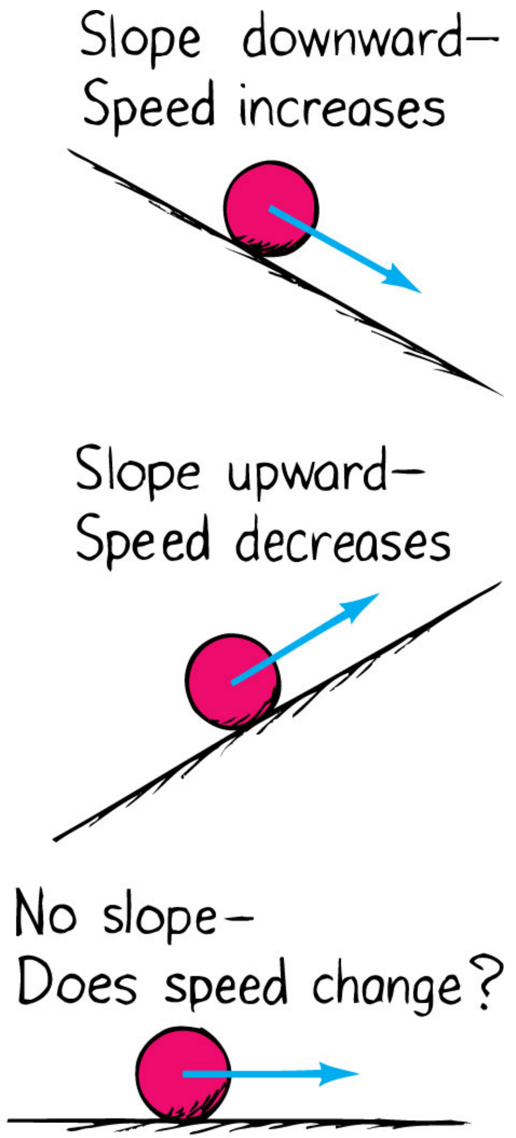
- Constant speed is steady speed, neither speeding up nor slowing down.
- Constant velocity is
  - constant speed and
  - constant direction (straight-line path with no acceleration).

Motion is relative to Earth, unless otherwise stated.

Acceleration

Formulated by Galileo based on his experiments with inclined planes.

Rate at which velocity changes over time

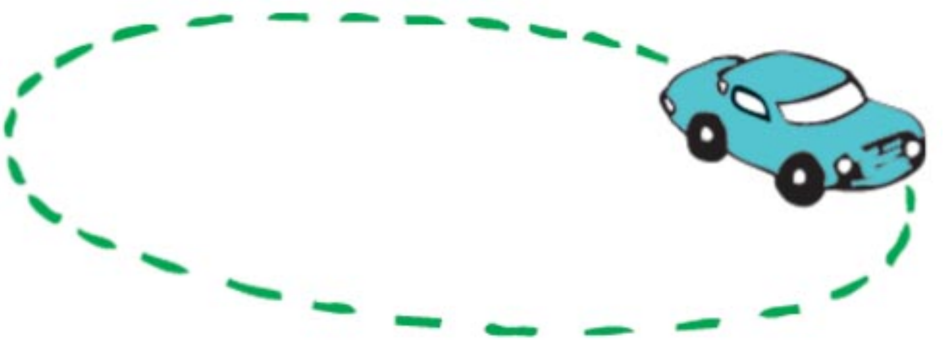


Acceleration

Involves a

- change in speed, or
- change in direction, or
- both.

Example: Car making a turn



Acceleration

In equation form:

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

Unit of acceleration is unit of velocity / unit of time.

Example:

- You car's speed right now is 40 km/h.
- Your car's speed 5 s later is 45 km/h.
- Your car's change in speed is 45 – 40 = 5 km/h.
- Your car's acceleration is 5 km/h/5 s = 1 km/h/s.

Acceleration
CHECK YOUR NEIGHBOR

An automobile is accelerating when it is

A. slowing down to a stop.

C. rounding a curve at a steady speed.

D. Both of the above.

G. Neither of the above.

Acceleration
CHECK YOUR ANSWER

An automobile is accelerating when it is

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D. Both of the above.

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Explanation:

- Change in speed (increase or decrease) is acceleration, so slowing is acceleration.
- Change in direction is acceleration (even if speed stays the same), so rounding a curve is acceleration.

Acceleration
CHECK YOUR NEIGHBOR

Acceleration and velocity are actually

A. the same.

C. rates but for different quantities.

D. the same when direction is not a factor.

G. the same when an object is freely falling.

Acceleration
CHECK YOUR ANSWER

Acceleration and velocity are actually

A. the same.

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D. the same when direction is not a factor.

G. the same when an object is freely falling.

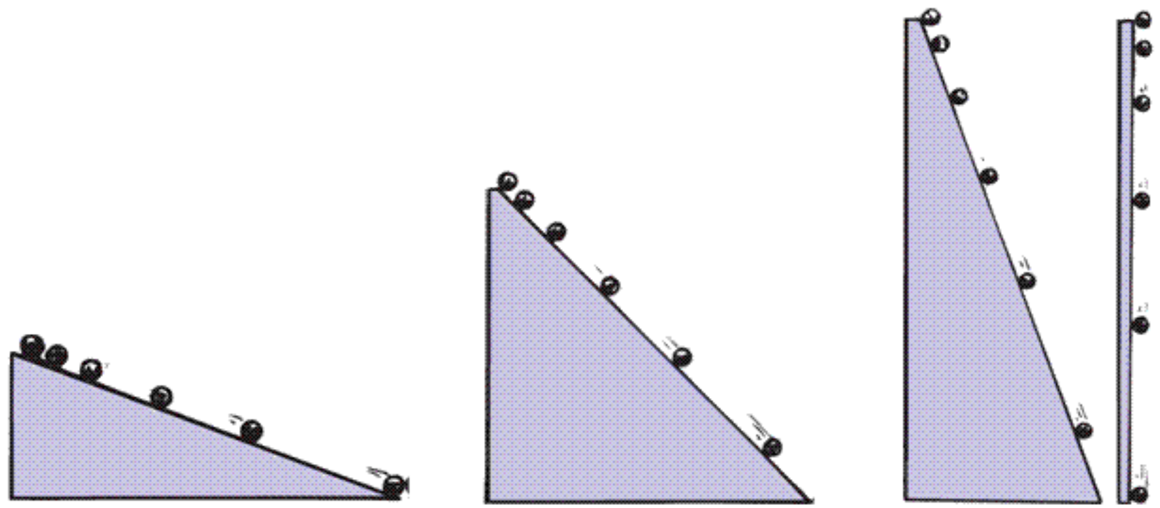
Explanation:

- Velocity is the rate at which distance changes over time,
- Acceleration is the rate at which velocity changes over time.

Acceleration

Galileo increased the inclination of inclined planes.

- Steeper inclines gave greater accelerations.
- When the incline was vertical, acceleration was max, same as that of the falling object.
- When air resistance was negligible, all objects fell with the same unchanging acceleration.



Free Fall

Falling under the influence of gravity only - with no air resistance

- Freely falling objects on Earth accelerate at the rate of 10 m/s/s, i.e., 10 m/s^2 (more precisely, 9.8 m/s^2).

Free Fall—How Fast?

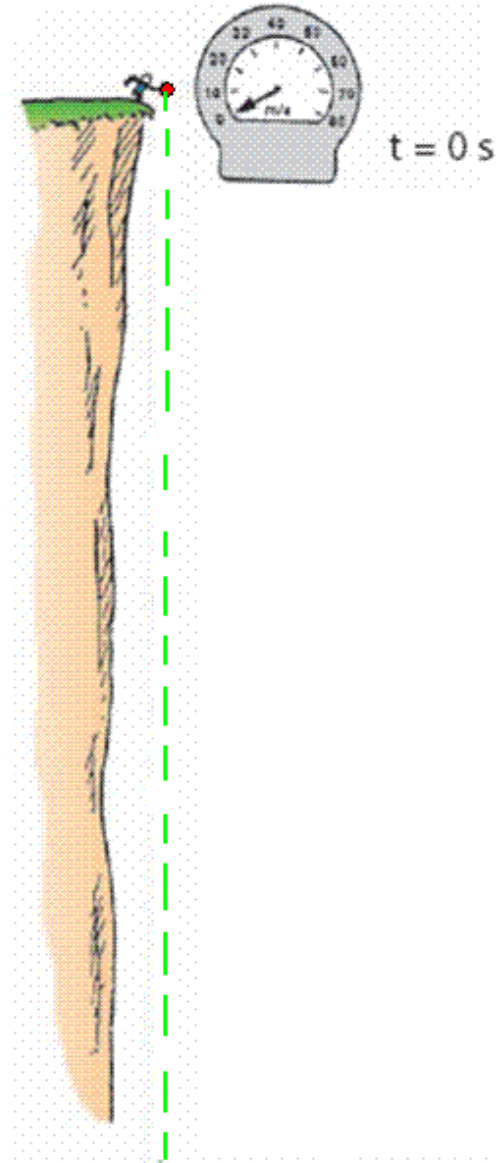
The velocity acquired by an object starting from rest is

Velocity = acceleration x time

So, under free fall, when acceleration is 10 m/s^2, the speed is

- 10 m/s after 1 s.
- 20 m/s after 2 s.
- 30 m/s after 3 s.

And so on.



Free Fall—How Fast?
CHECK YOUR NEIGHBOR

A free-falling object has a speed of 30 m/s at one instant. Exactly 1 s later its speed will be

A. the same.

C. 35 m/s.

D. more than 35 m/s.

G. 60 m/s.

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CHECK YOUR ANSWER

A free-falling object has a speed of 30 m/s at one instant. Exactly 1 s later its speed will be

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C. 35 m/s.

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G. 60 m/s.

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

Free Fall—How Far?

The distance covered by an accelerating object starting from rest is

Distance = (1/2) x acceleration x time x time

So, under free fall, when acceleration is 10 m/s^2, the distance is

- 5 m/s after 1 s.
- 20 m/s after 2 s.
- 45 m/s after 3 s.

And so on.

Free Fall—How Far?
CHECK YOUR NEIGHBOR

What is the distance covered of a freely falling object starting from rest after 4 s?

A. 4 m

C. 16 m

D. 40 m

G. 80 m

Free Fall—How Far?
CHECK YOUR ANSWER

What is the distance covered of a freely falling object starting from rest after 4 s?

A. 4 m

C. 16 m

D. 40 m

G. 80 m

Explanation:

Distance = (1/2) x acceleration x time x time

So: Distance = (1/2) x 10 m/s^2 x 4 s x 4 s

So: Distance = 80m