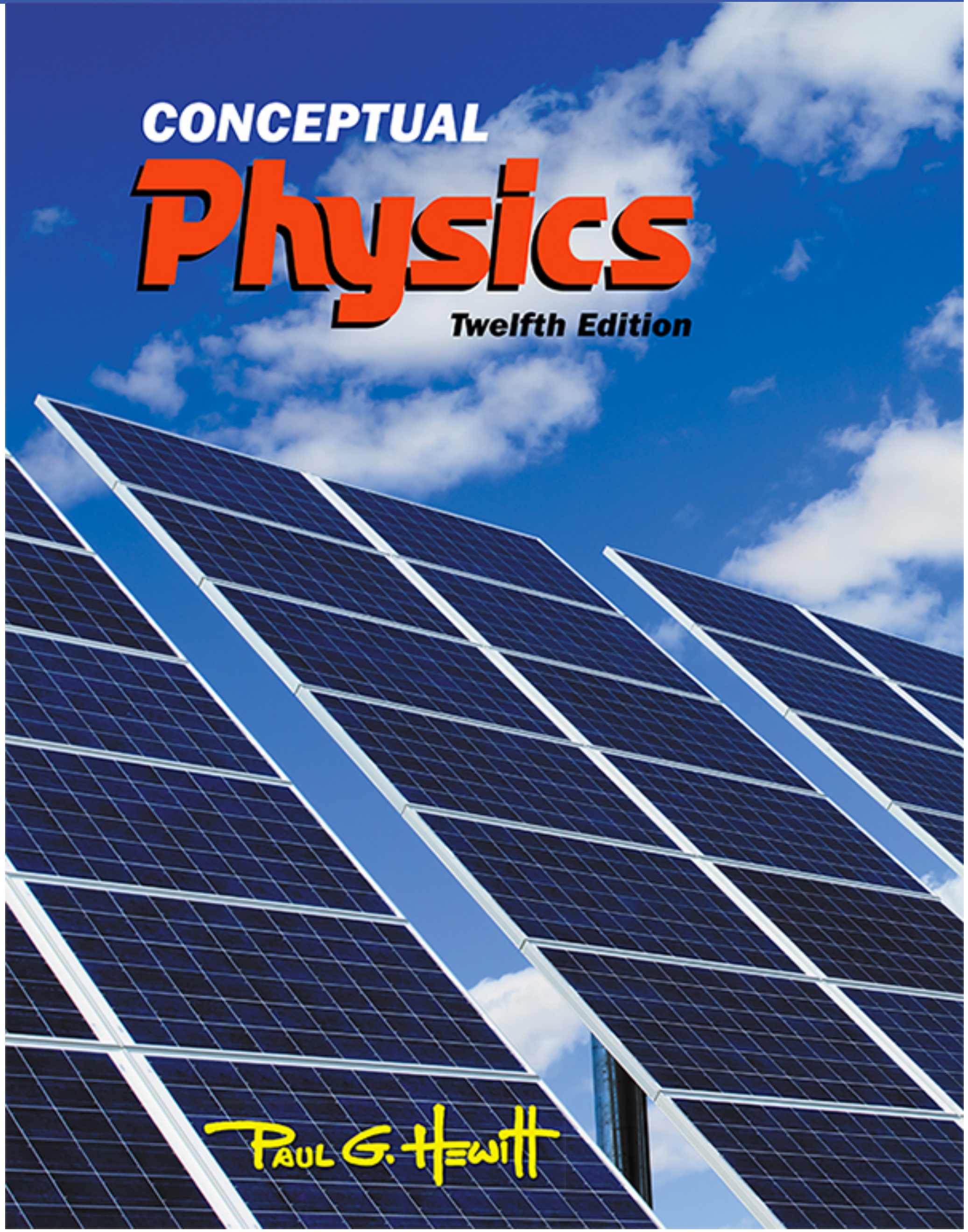
Lecture Outline



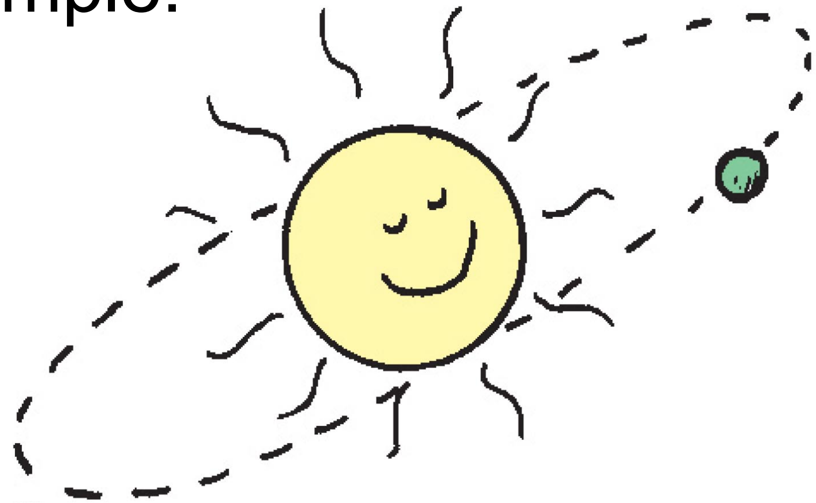
Chapter 3:
Linear Motion

This lecture will help you understand:

- Motion Is Relative
- Speed
- Velocity
- Acceleration
- Free Fall
- Velocity Vectors

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 s. Her speed is 2 m/s.

Average Speed

- The total 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.
B. 30 km in 2 hours.
C. 60 km in 1/2 hour.
D. 60 km in 2 hours.

Average Speed
CHECK YOUR ANSWER

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.

B. 30 km in 2 hours.

C. 60 km in 1/2 hour.

D. 60 km in 2 hours.

Explanation:

Average speed = total distance / time

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

Now, if we drive 60 km in 2 hours:

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

Same

Instantaneous Speed

- Instantaneous speed is the speed at any instant.
- Example:
  - When you ride in your car, you may speed up and slow down with speed at any instant that is normally quite different than your average speed.
  - Your instantaneous speed is given by your speedometer.

Velocity

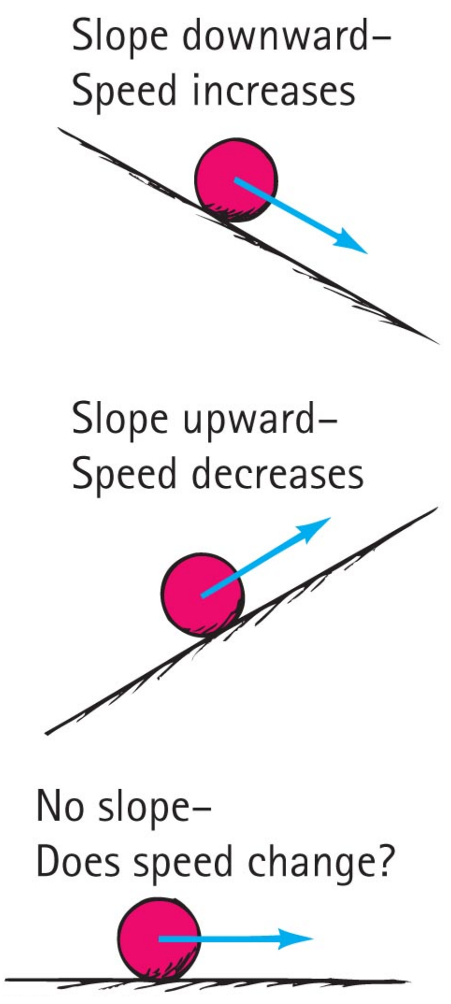
- A description of both
  - the instantaneous speed of the object.
  - the direction of travel.
- Velocity is a vector quantity. It has
  - Magnitude (speed) and Direction.
  - Velocity is "directed" speed.

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:
  - Your car's speed may presently be 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.
B. rounding a curve at a steady speed.
C. Both of the above.
D. Neither of the above.

Acceleration
CHECK YOUR ANSWER

An automobile is accelerating when it is

A. slowing down to a stop.
B. rounding a curve at a steady speed.
C. Both of the above.
D. Neither of the above.

Explanation:

- Change in speed (increase or decrease) per time 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.
B. rates but for different quantities.
C. the same when direction is not a factor.
D. the same when an object is freely falling.

Acceleration
CHECK YOUR ANSWER

Acceleration and velocity are actually

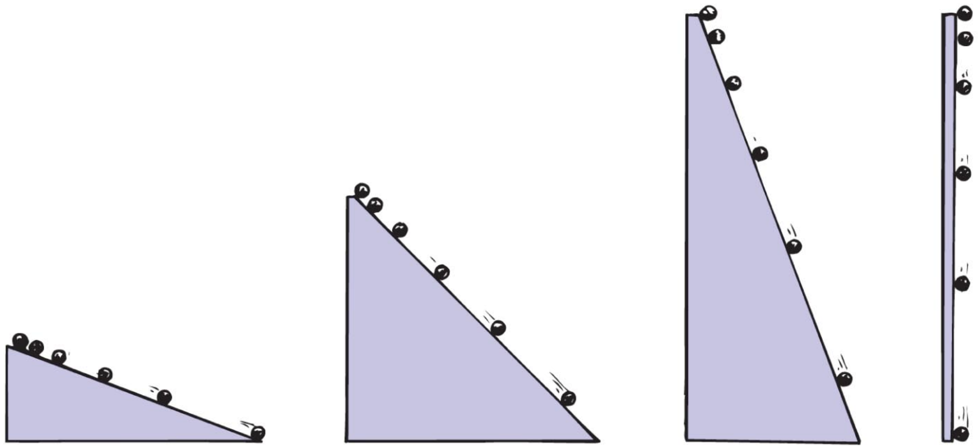
A. the same.
B. rates but for different quantities.
C. the same when direction is not a factor.
D. the same when an object is freely falling.

Explanation:

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

Acceleration

- Galileo increased the inclination of inclined planes.
  - Steeper inclines result in greater accelerations.
  - When the incline is vertical, acceleration is at maximum, the same as that of a falling object.
  - When air resistance is negligible, all objects fall 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, that is, 10 m/s^2 (more precisely, 9.8 m/s^2).

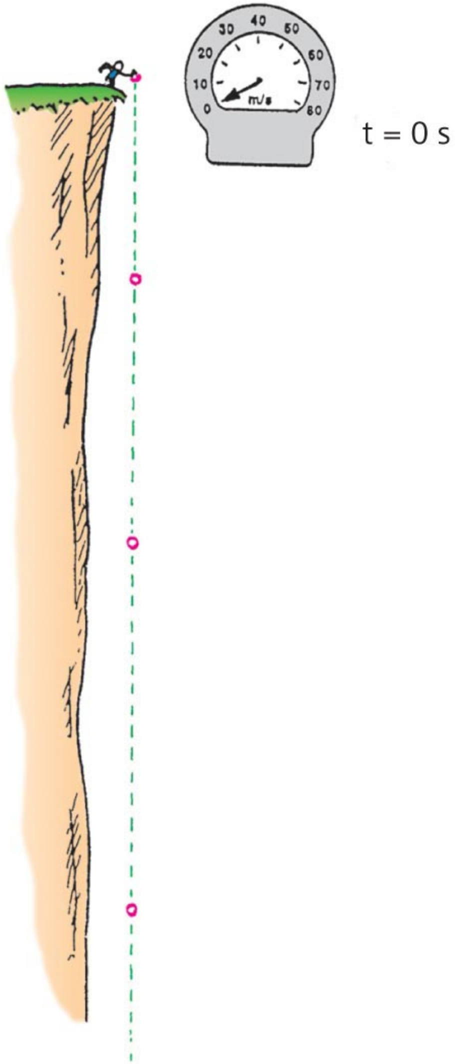
Free Fall—How Fast?

- The velocity acquired by an object starting from rest is

  Velocity = acceleration × 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

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

A. the same.
B. 35 m/s.
C. more than 35 m/s.
D. 60 m/s.

Free Fall—How Fast?
CHECK YOUR ANSWER

At a particular instant a free-falling object has a speed of 30 m/s. Exactly 1 s 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.

Free Fall—How Far?

- The distance covered by an accelerating object starting from rest is

  Distance $=$ (1/2) $\times$ acceleration $\times$ time $\times$ time

- Under free fall, when acceleration is 10 m/s^2, the distance fallen is
  - 5 m after 1 s.
  - 20 m after 2 s.
  - 45 m after 3 s.

  And so on.

Free Fall—How Far?
CHECK YOUR NEIGHBOR

What is the distance fallen after 4 s for a freely falling object starting from rest?

A. 4 m
B. 16 m
C. 40 m
D. 80 m

Free Fall—How Far?
CHECK YOUR ANSWER

What is the distance fallen after 4 s for a freely falling object starting from rest?

A. 4 m
B. 16 m
C. 40 m
D. **80 m**

Explanation:

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

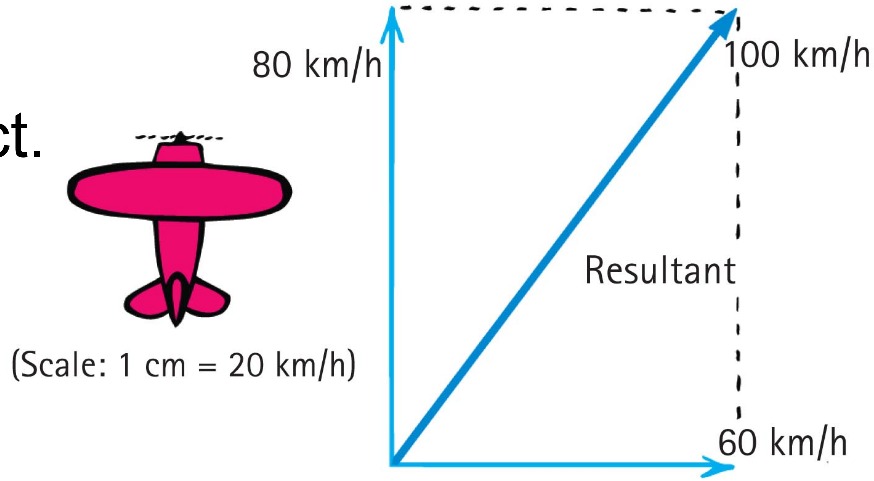
So: Distance = (1/2) × 10 m/s^2 × 4 s × 4 s

So: Distance = 80 m

Vectors
CHECK YOUR NEIGHBOR

The 60-km/h crosswind blows the 80-km/h airplane off course at 100 km/h. If the crosswind were 80 km/h, the airplane would travel at 113 km/h at an angle of

A. less than 45 degrees.
B. 45 degrees.
C. more than 45 degrees.
D. None of the above are correct.



Vectors
CHECK YOUR ANSWER

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A. less than 45 degrees.
B. 45 degrees.
C. more than 45 degrees.
D. None of the above are correct.

Comment:

The parallelogram would then be a square with a 45-degree diagonal.

Vectors
CHECK YOUR NEIGHBOR

You run horizontally at 4 m/s in a vertically falling rain that falls at 4 m/s. Relative to you, the raindrops are falling at an angle of

A. 0°.
B. 45°.
C. 53°.
D. 90°.

Vectors
CHECK YOUR ANSWER

You run horizontally at 4 m/s in a vertically falling rain that falls at 4 m/s. Relative to you, the raindrops are falling at an angle of

A. 0°.
B. 45°.
C. 53°.
D. 90°.

Explanation:
The horizontal 4 m/s and vertical 4 m/s combine by the parallelogram rule to produce a resultant of 5.6 m/s at 45°. Again, the parallelogram is a square.