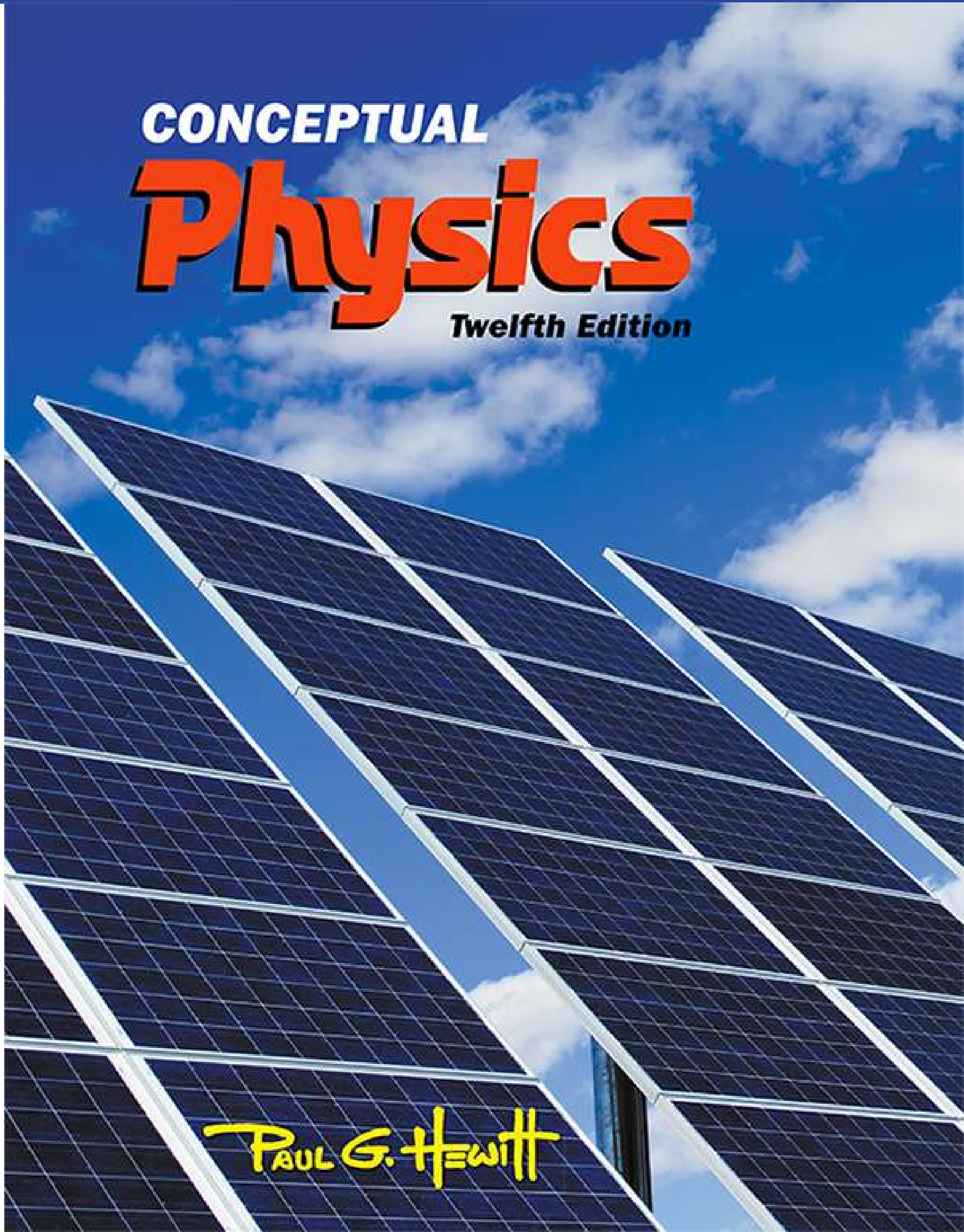
Lecture Outline

Chapter 3: Linear Motion

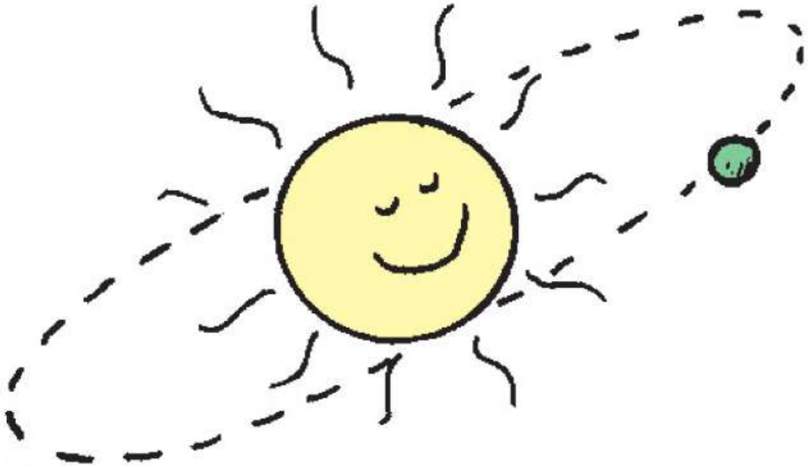


This lecture will help you understand:

- 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

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

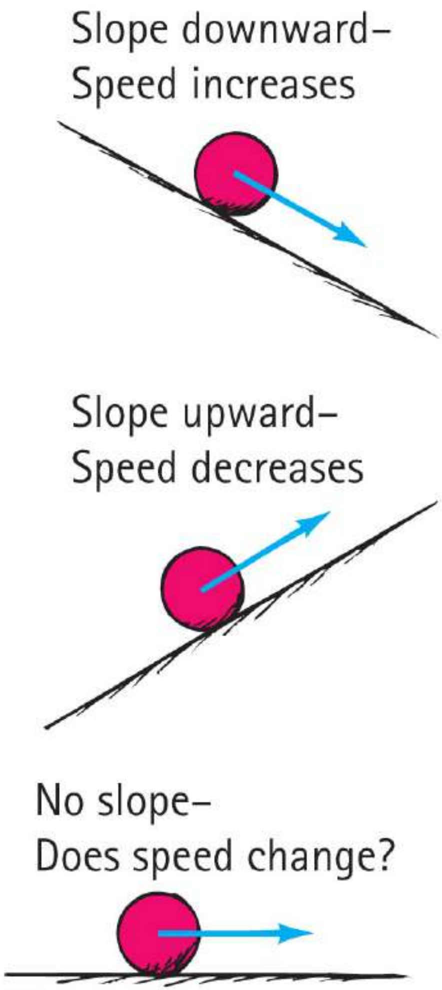
- A description of both
  - the instantaneous speed of the object.
  - the direction of travel.
- Velocity is a vector quantity. It has
  - Magnitude (speed) and Direction.
  - Velocity is "directed" speed.

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.

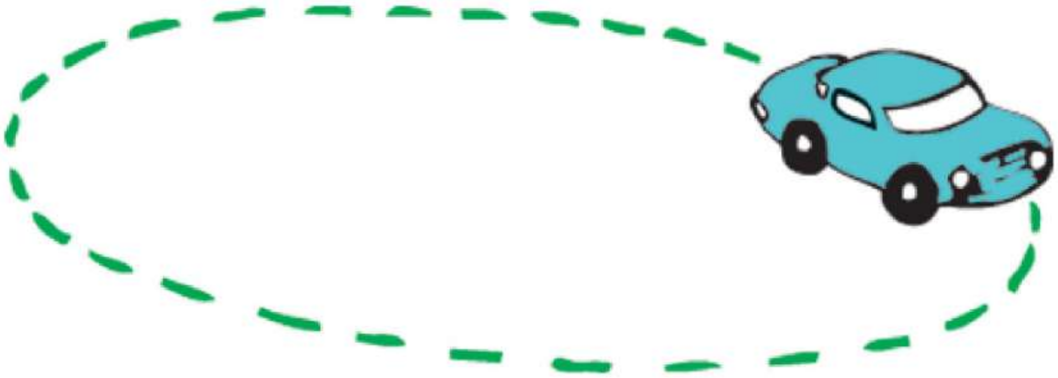
Acceleration

- Formulated by Galileo based on his experiments with inclined planes.
- Rate at which velocity changes over time.



Acceleration, Continued

- Involves a
  - change in speed, or
  - change in direction, or
  - both.
- Example: Car making a turn.



Acceleration, Continued-1

- 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

C. **Both 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, Continued

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, Continued

Acceleration and velocity are actually

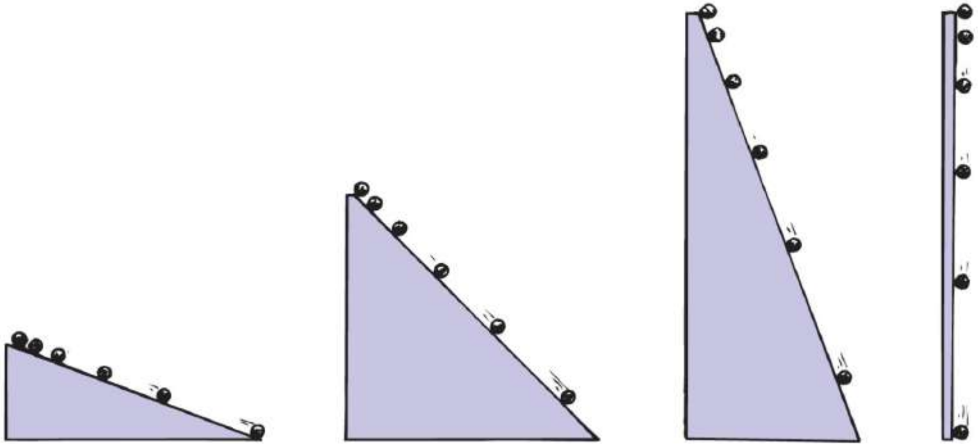
B. **rates but for different quantities.**

Explanation:

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

Acceleration, Continued-2

- 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).

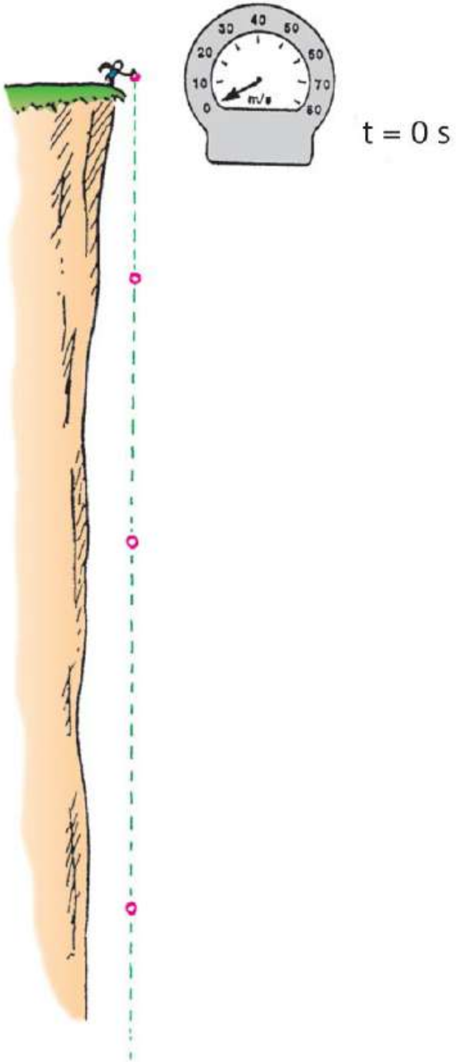
Free Fall—How Fast?

- The velocity acquired by an object starting from rest is

$$\text{Velocity} = \text{acceleration} \times \text{time}$$

- 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

C. **more than 35 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

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

- Under free fall, when acceleration is 10 m/s^2, the reversible arrow
  - 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 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?

D. **80 m**

Explanation:

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

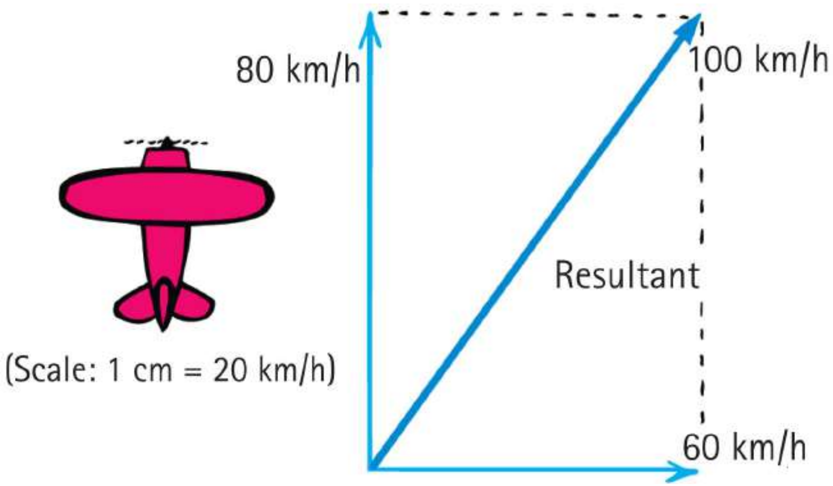
So: Distance = (1/2) × 10 m/s^2 × 4 s × 4 s

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

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

B. **45 degrees.**

Comment:

The parallelogram would then be a square with a 45-degree diagona

Vectors
CHECK YOUR NEIGHBOR, Continued

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, Continued

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

B. **45°.**

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.