If you drive 100 miles in 2 hrs your speed is \( v = \frac{100 \text{ mi}}{2 \text{ hrs}} = ? \)

If you drive 20 m in 5 seconds your speed is ?
Speed is Relative

When sitting on a chair, your speed is zero relative to the Earth but 30 km/s relative to the Sun.

20 km/h = 12 mi/h = 6 m/s
40 km/h = 25 mi/h = 11 m/s
Average Speed

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

For example, if we drive a distance of 80 kilometers in a time of 1 hour, we say our average speed is 80 kilometers per hour. Also if we drive 320 km in 4 hours

Average speed = \frac{\text{total distance covered}}{\text{time interval}} = \frac{320 \text{ km}}{4 \text{ h}} = 80 \text{ km/h}
Check Yourself

1. What is the average speed of a cheetah that sprints 100 m in 4 s? How about if it sprints 50 m in 2 s?

2. If a car moves with an average speed of 60 km/h for an hour, it will travel a distance of 60 km. In 1 hour. (a) How far would it travel if it moved at this rate for 4 h? (b) For 10 h?

3. In addition to the speedometer on the dashboard of every car is an odometer, which records the distance traveled. If the initial reading is set at zero at the beginning of a trip and the reading is 40 km one-half hour later, what has been your average speed?

4. Would it be possible to attain this average speed and never go faster than 80 km/h?

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

\[
v = \frac{d}{t}
\]

\[
d = vt
\]
Velocity = Speed + Direction

e.g. 50 km/hr = speed
50 km/hr North = velocity

The car on the circular track may have a constant speed, but its velocity is changing every instant.

The speedometer of a car moving to the east reads 100 km/h. It passes another car that moves to the west at 100 km/h. Do both cars have the same speed? Do they have the same velocity?
If your speed is changing we say that you are accelerating. Suppose you are told that your driver will change speed from 50 mph to 70 mph. Is this a very large acceleration?

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

Suppose we are driving and in 1 second we steadily increase our velocity from 30 kilometers per hour to 35 kilometers per hour, and then to 40 kilometers per hour in the next second, to 45 in the next second, and so on. We change our velocity by 5 kilometers per hour each second. This change of velocity is what we mean by

\[
\text{Acceleration} = \frac{\text{change of velocity}}{\text{time interval}} = \frac{5 \text{ km/h}}{1 \text{ s}} = 5 \text{ km/h} \cdot \text{s}
\]
Acceleration applies to decreases as well as increases and also curved paths

- You go from rest to 90 km/hr in 10 s. What is your acceleration?

- In 2.5 s a car goes from 60 km/hr to 65 km/hr while a bike goes from rest to 5 km/hr in same time. Which undergoes a bigger acceleration?
Check Yourself

1. A particular car can go from rest to 90 km/h in 10 s. What is its acceleration?

2. In 2.5 s a car increases its speed from 60 km/h to 65 km/h while a bicycle goes from rest to 5 km/h. Which undergoes the greater acceleration? What is the acceleration of each vehicle?

3. What is the acceleration of a race car that whizzes past you at a constant velocity of 400 km/h?

4. Which has the greater acceleration, an airplane that goes from 1000 km/h to 1005 km/h in 10 seconds or a skateboard that goes from zero to 5 km/h in 1 second?
Suppose starting from rest you accelerate at 2 m/s/s (2 m/s^2).

How fast will you be going in 1s? 2s? 3s?

\[ a = \frac{\Delta v}{t} \]

\[ \Delta v = a \times t \]

velocity = acceleration x time
Galileo found that a ball rolling down an inclined plane will pick up the same amount of speed in successive seconds; that is, the ball will roll with unchanging acceleration.

$\text{Velocity acquired} = \text{acceleration} \times \text{time}$
Galileo and falling Bodies

<table>
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<th>Time</th>
<th>Total Distance</th>
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<tr>
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<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>

\[ d \sim t^2 \]

\[ d \text{ (meters)} \sim 5 \, t^2 \]

\[ a = g \sim 10 \, \text{m/s per sec} \]
Free Fall

- All objects moving under the influence of only gravity are said to be in free fall.
- All objects falling near the earth’s surface fall with a constant acceleration.
- Galileo originated our present ideas about free fall from his inclined planes.
- The acceleration is called the acceleration due to gravity, and indicated by g.
Acceleration due to Gravity

- Symbolized by $g$
- $g = 9.8 \text{ m/s}$ (We will occasionally use $10 \text{ m/s}$)
- $g$ is always directed downward
  - toward the center of the earth
How fast and how far?

\[ d = 5t \]
How fast and how far?

d = 5t
Free Fall -- an object dropped

Initial velocity is zero: \( v_0 = 0 \)

Acceleration: \( a = g \)

Using \( d = \text{avg velocity} \times \text{time} \)
Free Fall -- an object dropped

- Initial velocity is zero

\[ v_0 = 0 \]
\[ a = g \]

What would the speedometer reading on the falling rock shown be 5 s after it drops from rest? How about 6 s after it is dropped? 6.5 s?
Up and Down

- The velocities are opposite,
- it is customary to call *up* positive, and *down* negative.)

Whether moving upward or downward, the acceleration is 10 m/s² the whole time.
How fast and how far?

\[ v_f = at = g t = (-10 \text{m/s}^2) t \]

\[ V(1s) = (-10 \text{m/s}^2)(1s) = -10 \text{ m/s} \]

\[ V(2s) = (-10 \text{m/s}^2)(2s) = -20 \text{ m/s} \]

\[ V(3s) = (-10 \text{m/s}^2)(3s) = -30 \text{ m/s} \]

\[ V(4s) = (-10 \text{m/s}^2)(4s) = -40 \text{ m/s} \]

Distance traveled:
\[ d = \frac{1}{2} (\text{acceleration} \times \text{time} \times \text{time}) \]

\[ d = 0.5 \times g \times t^2 = 0.5 \times g \times t^2 \]

\[ d(1) = 0.5(-10 \text{m/s}^2)(1)^2 = -5 \text{m} \]

\[ d(2) = 0.5(-10 \text{m/s}^2)(2)^2 = -20 \text{m} \]

\[ d(3) = 0.5(-10 \text{m/s}^2)(3)^2 = -45 \text{m} \]

\[ d(4) = 0.5(-10 \text{m/s}^2)(4)^2 = -80 \text{m} \]
Check Yourself
A cat steps off a ledge and drops to the ground in 1/2 second. 1. What is its speed on striking the ground?

2. What is its average speed during the 1/2 second?

3. How high is the ledge from the ground?
Summary

- **Speed** How fast something moves. The distance traveled per unit of time.
- **Velocity** The speed of an object and specification of its direction of motion.
- **Acceleration** The rate at which velocity changes with time; the change in velocity may be in magnitude or direction or both.
- **Free fall** Motion under the influence of gravity only.
Summary of Formulas

- Speed = \( \frac{\text{distance}}{\text{time}} \)

- Average speed = \( \frac{\text{total distance covered}}{\text{time interval}} \)

- Acceleration = \( \frac{\text{change of velocity}}{\text{time interval}} \)

- Acceleration (along a straight line) = \( \frac{\text{change in speed}}{\text{time interval}} \)

- Velocity acquired in free fall, from rest; \( v = gt \)

- Distance fallen in free fall, from rest; \( d = \frac{1}{2} gt^2 \)