

Chapter 4

Making Sense of the Universe: Understanding Motion, Energy, and Gravity



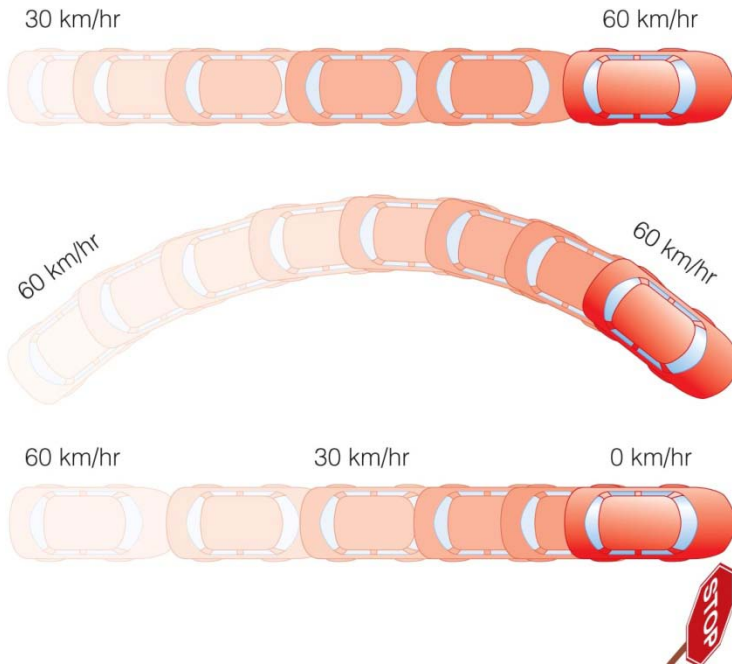
4.1 Describing Motion

Our goals for learning:

- How do we describe motion?
- How is mass different from weight?

How do we describe motion?

Precise definitions to describe motion:



- **Speed:** Rate at which object moves

$$\text{speed} = \frac{\text{distance}}{\text{time}} \quad \left(\text{units of } \frac{\text{m}}{\text{s}} \right)$$

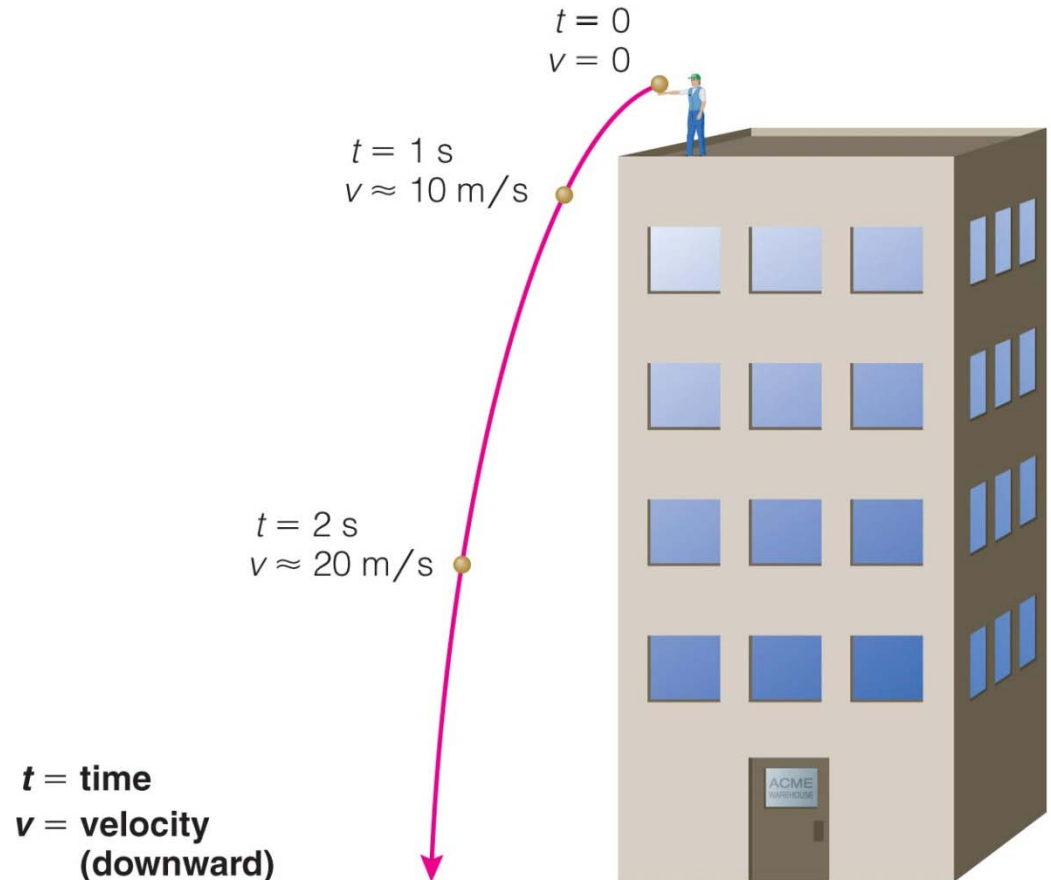
example: speed of 10 m/s

- **Velocity:** Speed and direction
example: 10 m/s, due east

- **Acceleration:** Any change in velocity
units of speed/time (m/s^2)

The Acceleration of Gravity

- All falling objects accelerate at the same rate (not counting friction of air resistance).
- On Earth, $g \approx 10 \text{ m/s}^2$: speed increases 10 m/s with each second of falling.



The Acceleration of Gravity (g)

- Galileo showed that g is the *same* for all falling objects, regardless of their mass.



Apollo 15 demonstration

Momentum and Force

- Momentum = mass \times velocity
- A **net force** changes momentum, which generally means an acceleration (change in velocity)
- Rotational momentum of a spinning or orbiting object is known as **angular momentum**

Thought Question:

Is there a net force? Y/N

1. A car coming to a stop.
2. A bus speeding up.
3. An elevator moving up at constant speed.
4. A bicycle going around a curve.
5. A moon orbiting Jupiter.

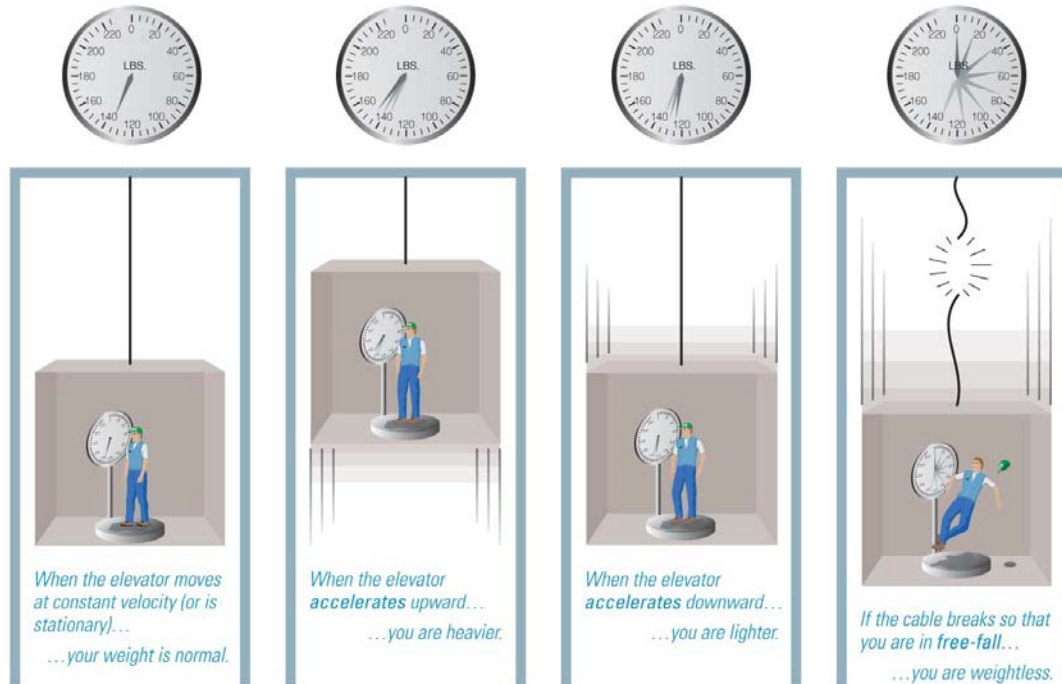
Thought Question:

Is there a net force? Y/N

1. A car coming to a stop. Y
2. A bus speeding up. Y
3. An elevator moving at constant speed. N
4. A bicycle going around a curve. Y
5. A moon orbiting Jupiter. Y

How is mass different from weight?

- **Mass** – the amount of matter in an object
- **Weight** – the *force* that acts upon an object



Interactive Figure 

You are weightless
in free-fall!

Thought Question

On the Moon:

- A. My weight is the same, my mass is less.
- B. My weight is less, my mass is the same.
- C. My weight is more, my mass is the same.
- D. My weight is more, my mass is less.

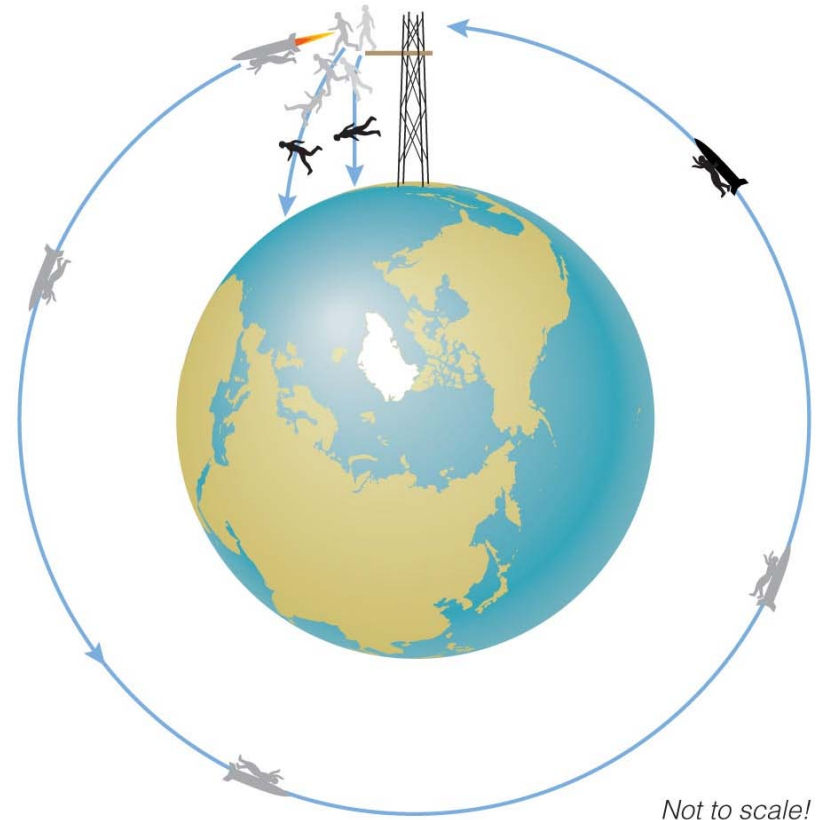
Thought Question

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Why are astronauts weightless in space?

- There *is* gravity in space
- Weightlessness is due to a constant state of free-fall



Interactive Figure 

What have we learned?

- How do we describe motion?
 - Speed = distance / time
 - Speed & direction => **velocity**
 - Change in velocity => **acceleration**
 - **Momentum** = mass x velocity
 - **Force** causes change in momentum, producing acceleration

What have we learned?

- How is mass different from weight?
 - Mass = quantity of matter
 - Weight = force acting on mass
 - Objects are weightless in free-fall