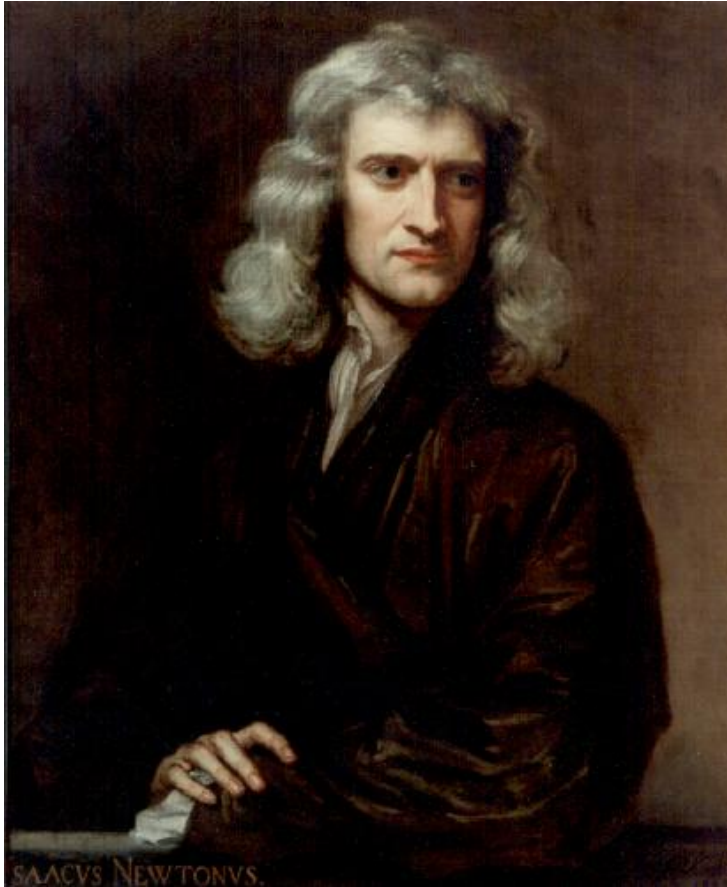


Newton's Laws of Motion

Chapter 2: pages 37-53

Review questions 1, 5-10, 14, 17, 21-24, 30

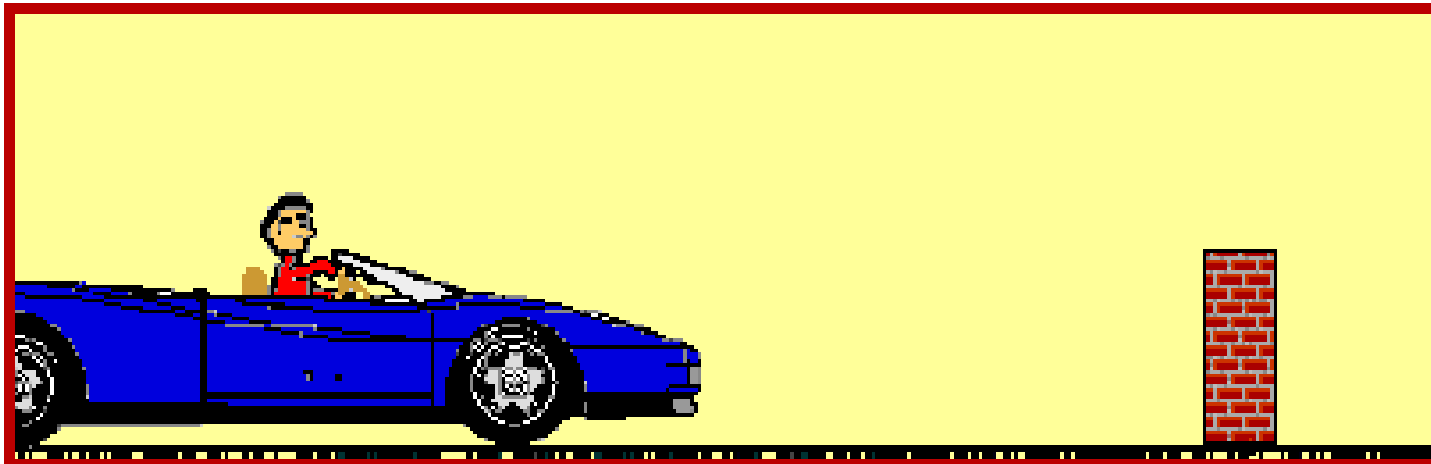
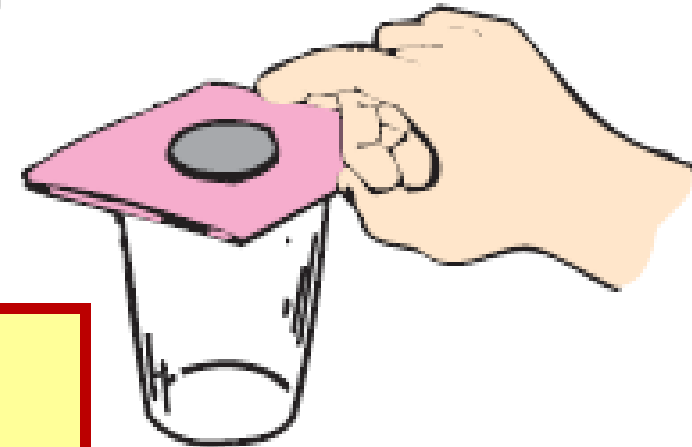
Sir Isaac Newton



- Born 1642
- 1665 began individual studies
- Proved universal gravitation
- Invented the Calculus
- Reflector telescope 1672
- *Mathematical Principles of Natural Philosophy* (“*Principia*”)

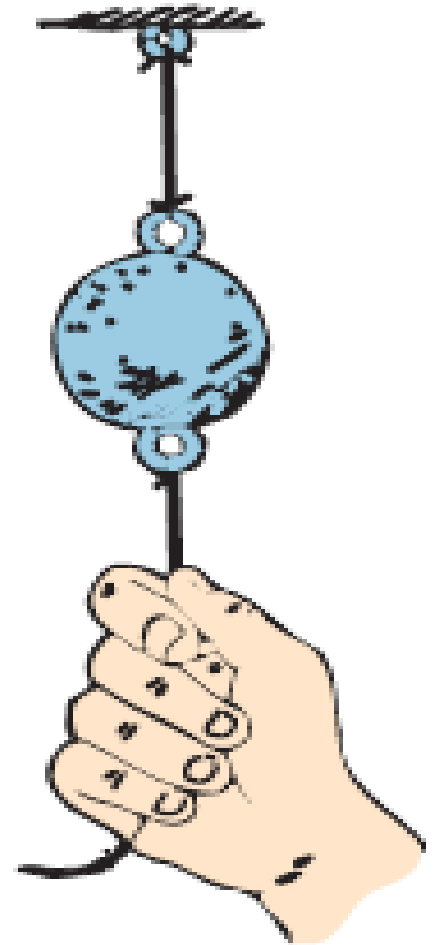
First Law of Motion

- “Every object continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it.”
- “CONTINUES” = INERTIA



Mass

- How much matter
- Measure of inertia









Second Law of Motion

- “The acceleration of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and is inversely proportional to the mass of the object.”
- Means “acceleration” $\sim \frac{\text{Force}}{\text{mass}}$
- “ \sim ” (say “is proportional to”)

Second Law

$$a = \frac{F}{m}$$

- Acceleration is directly proportional to force
- Acceleration is inversely proportional to mass

Here's directly proportional.



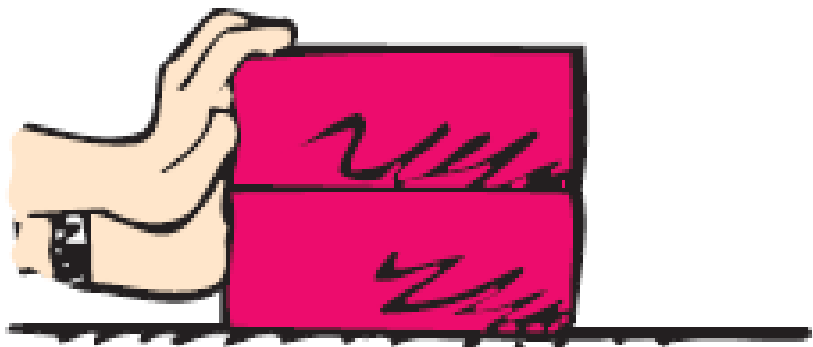
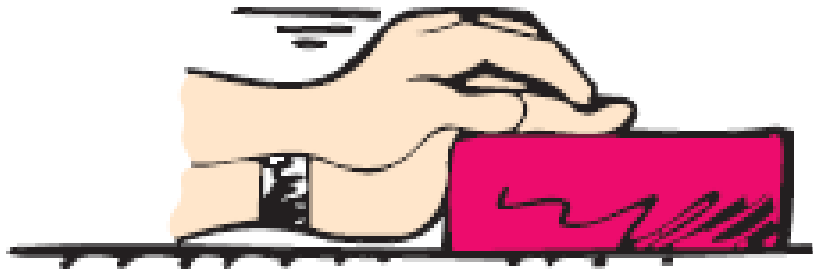
Here's inversely proportional.



Increase forces



- Force on brick creates acceleration
- Twice force on brick creates more acceleration
- Double force of bricks requires double force



Acceleration equation

$$*a* = \frac{F}{m}$$

- Double the force
- Also need to double the mass
- Direct proportion—constant ratio

Acceleration

- Change in velocity over time
a = change in velocity ÷ time

$$a = \frac{F}{m}$$

- Force over mass
- How can this be?

Acceleration

$$\frac{\Delta v / t}{t}$$

- Change in velocity over time
- Definition of acceleration

Acceleration

Force causes acceleration

Force over mass

$$a = \frac{F}{m}$$

Freely falling objects

- Acceleration of gravity is 9.81 m/s^2

- Use g , a constant

- 9.81 m/s^2

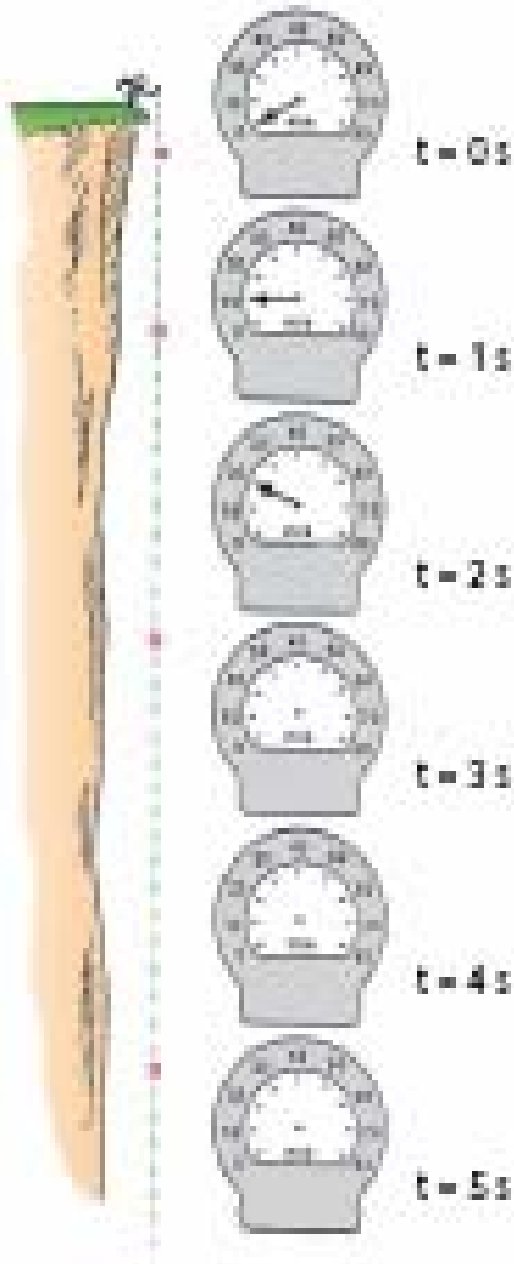
- round to 10 m/s^2

- For lecture calculations

$$a = \frac{F}{m}$$

$$g = \frac{F}{m}$$

Acceleration of Gravity



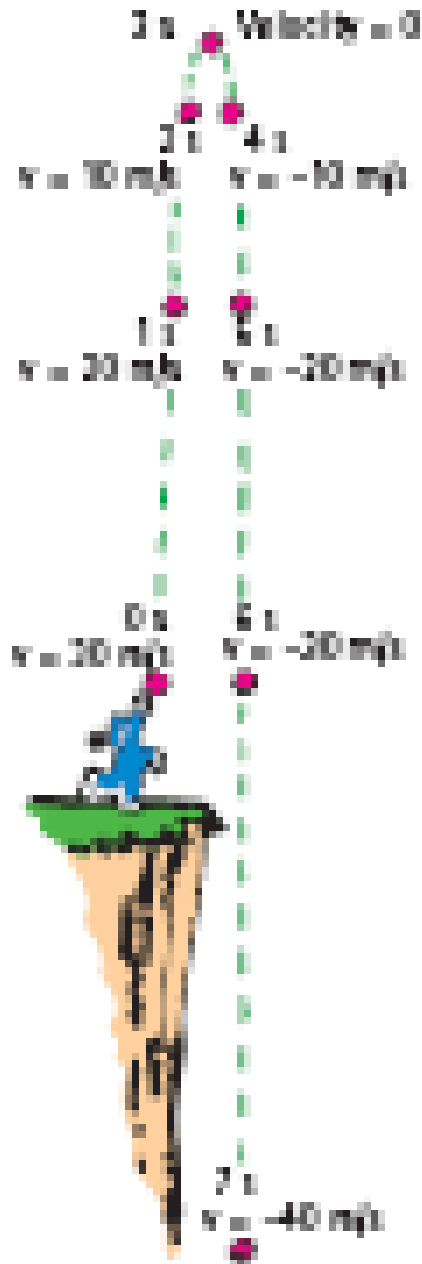
- Acceleration same for each second of travel
- Free falling objects

Acceleration of Gravity

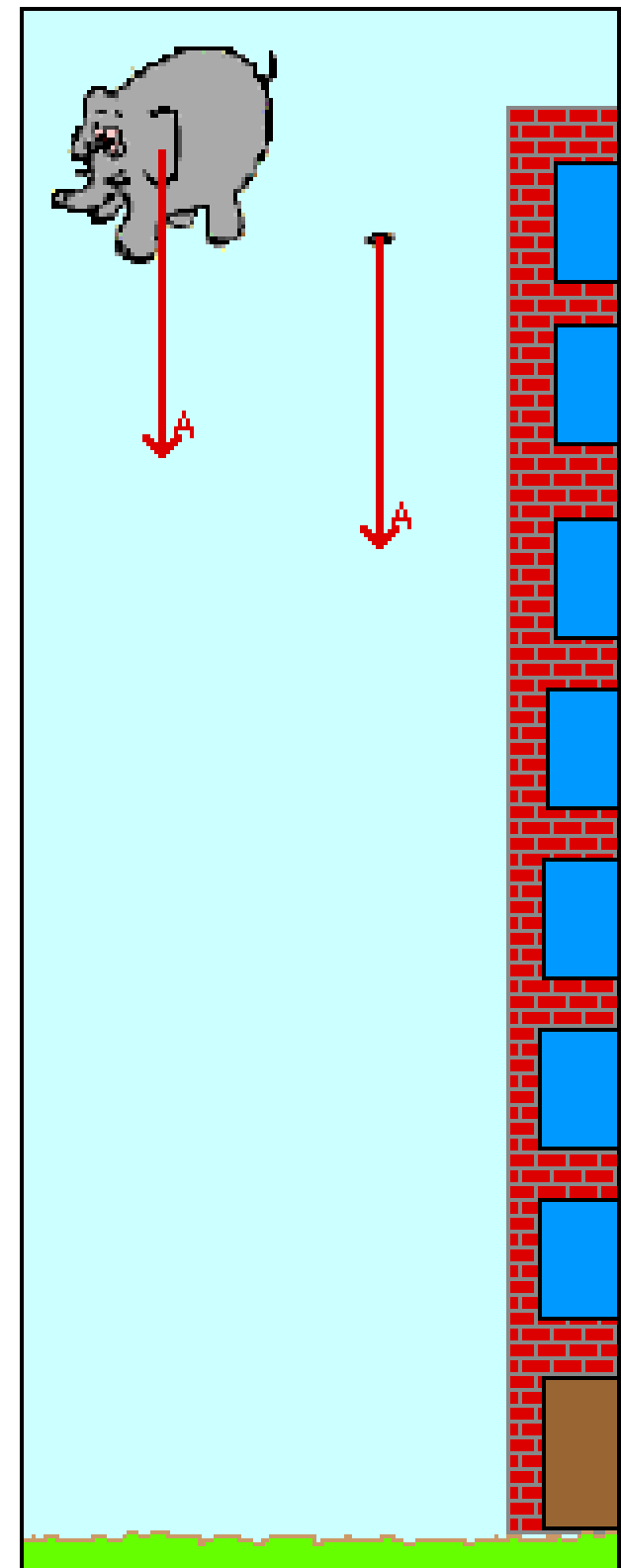
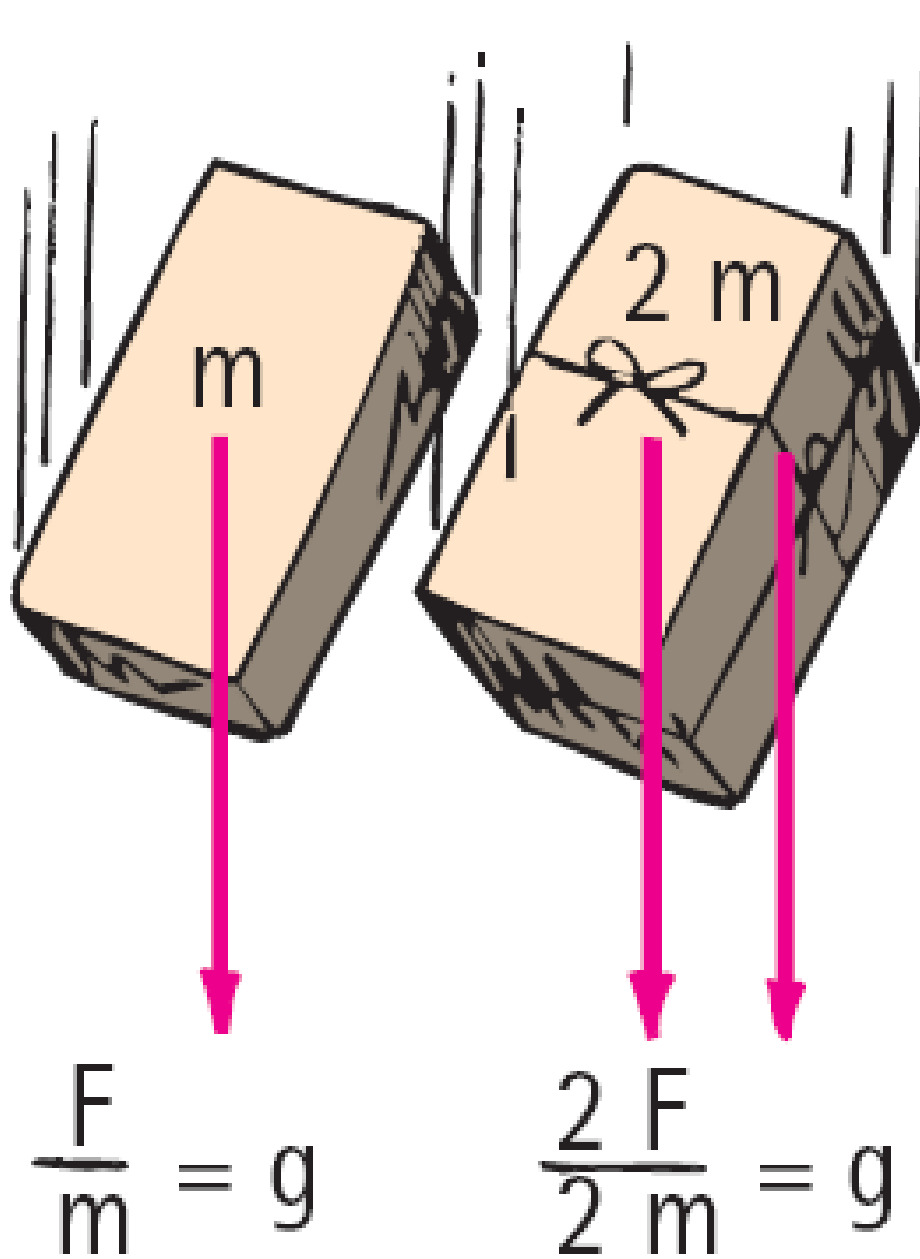
- Free fall of object
- Speed increases 10 m/s for every second of fall
- $\frac{10 \text{ m/s}}{\text{s}} = \frac{10\text{m}}{\text{s}^2}$

| Time elapsed (seconds) | Speed (meters/second) |
|------------------------|-----------------------|
| 0 | 0 |
| 1 | 10 |
| 2 | 20 |
| 3 | 30 |
| 4 | 40 |

Acceleration of Gravity



- Upward throw 30 m/s
- Gravity acts against it
- Slows to stop at 10 m/s²
- Falls and gains speed at 10 m/s²
- Neglecting air resistance



- <http://www.physicsclassroom.com/mmedia/newtlaws/eff.html>

Weight is a Force

$$g = \frac{F}{m} \rightarrow \textit{Weight} = mg$$

Weight is a Force

- Function of g
(acceleration of gravity)
- Proper units:
 - Gravity m/s^2
 - Force $kg\ m/s^2$
 - Mass kg
- Different planet—
Different g
different weight for
the same mass

$$g = \frac{F}{m}$$

$$mg = F$$

Freely falling objects

- Boulder vs. feather

$$a = \frac{F}{m} \qquad a = \frac{F}{m}$$

- Boulder has more inertia, but not more acceleration—so how come it falls faster?

Galileo's investigation of motion

- Surface area changes air resistance
- Objects reach terminal velocity due to air resistance
- In vacuum, this is not a factor



Acceleration

- Neglect air resistance for these equations

$$a = \Delta v / \Delta t \rightarrow v = at$$

- acceleration is velocity divided by time
- velocity acquired is acceleration multiplied by time

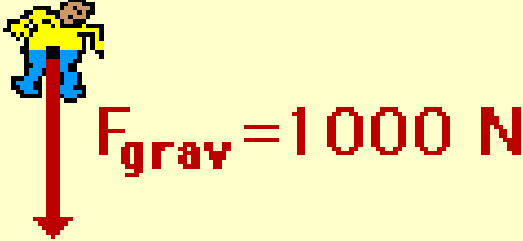
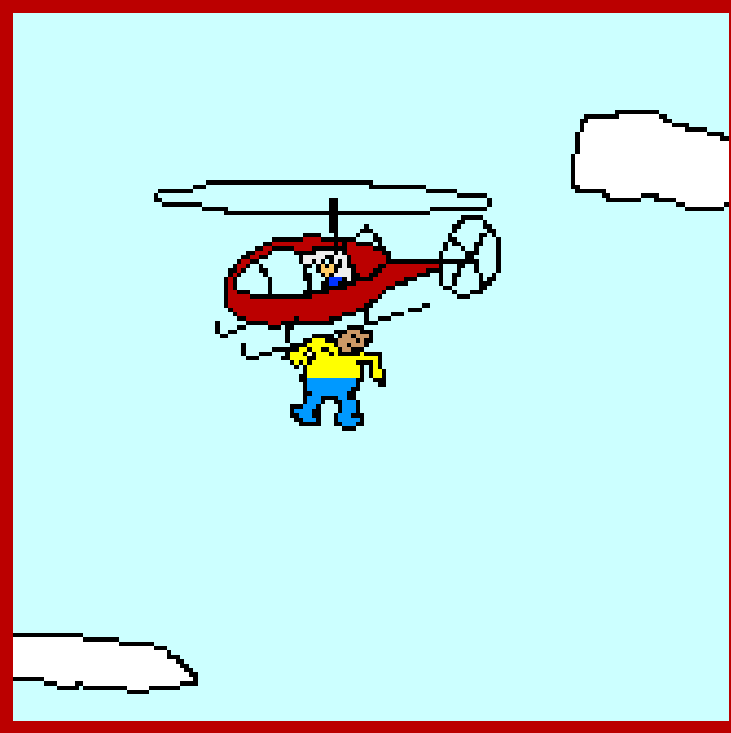


Air Resistance

- Friction of air against falling object
- Air resistance depends on
 - Speed
 - Frontal area exposed to air
- Acceleration is less than g due to air resistance



Air Resistance

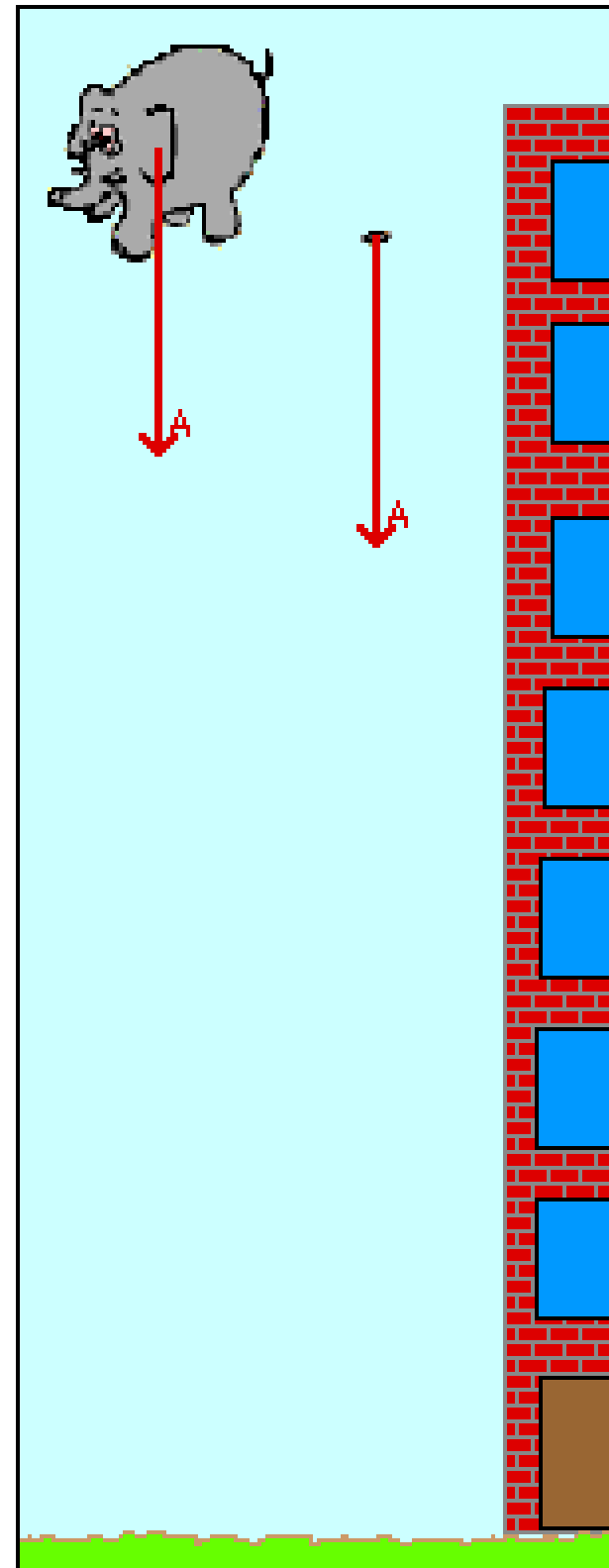

$$a = \frac{F_{\text{net}}}{m}$$
$$a = \frac{1000 \text{ N}}{100 \text{ kg}}$$
$$a = 10.0 \text{ m/s}^2$$

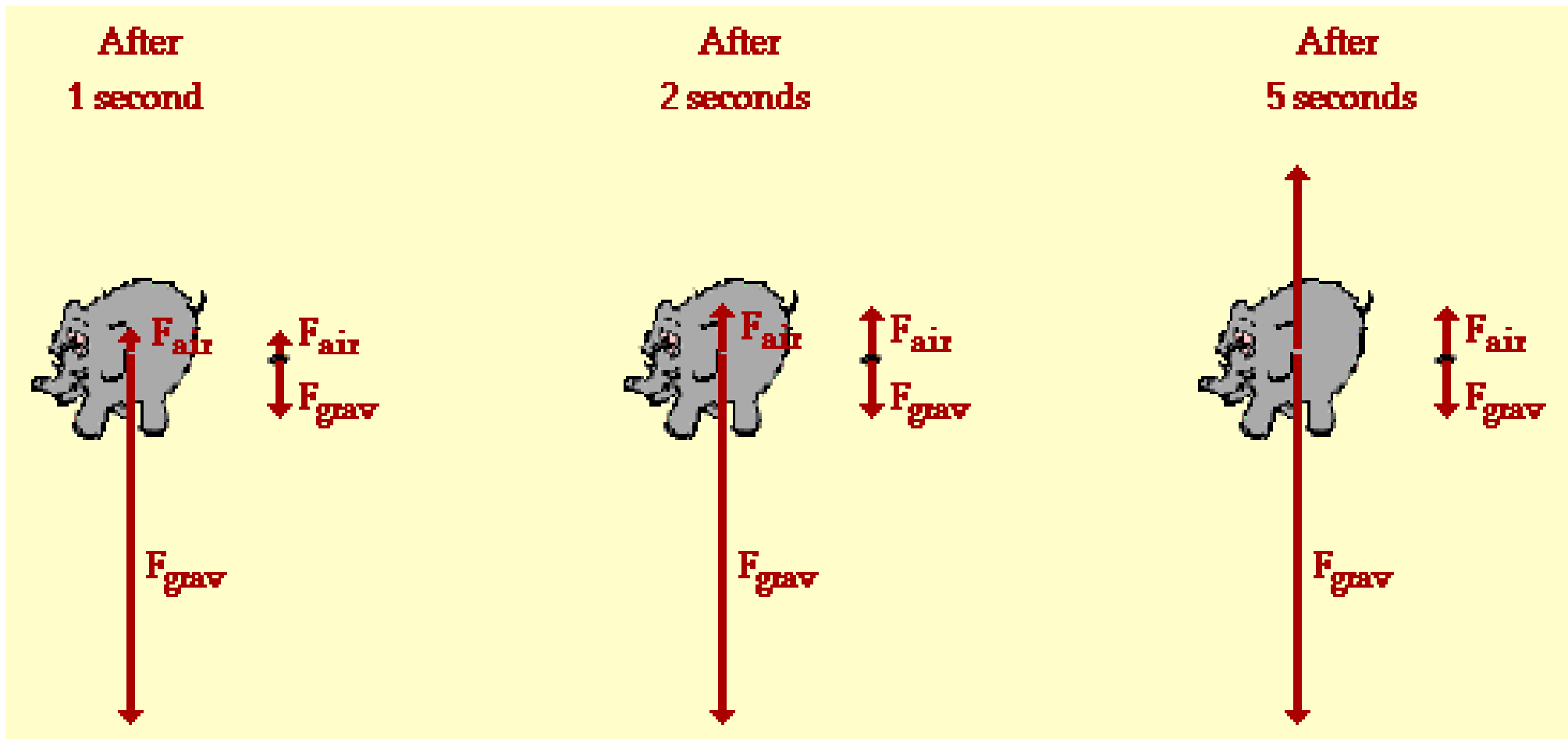
(down)

- Parachute increases frontal area, increases air resistance
- Increased air resistance balanced with slower speed

Air Resistance

- Greater air resistance for elephant, because it is larger
- Greater weight because it is more massive
- More speed required to gain air resistance to overcome the greater weight





- Force of air resistance balances greater mass at greater speed
- Heavier skydiver has greater terminal velocity than lightweight skydiver

Zero Acceleration

- Motionless objects
- Downward force created by gravity
- Upward force created by surface

Zero Acceleration



- Push down on spring
- Spring pushes up on you
- Each molecule of table acts like microscopic spring pushing up on object

Zero Acceleration

- Cart crossing room without acceleration
- Net force is zero
- Force applied
 pushing force = frictional force

Friction

- Works against forces
- Opposite direction
- Not dependent on speed
- Not dependent on area of contact
- Only dependent on weight

Third Law of Motion

- “Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.”
- Force is an interaction between objects
- Action—reaction pairs

Force interaction

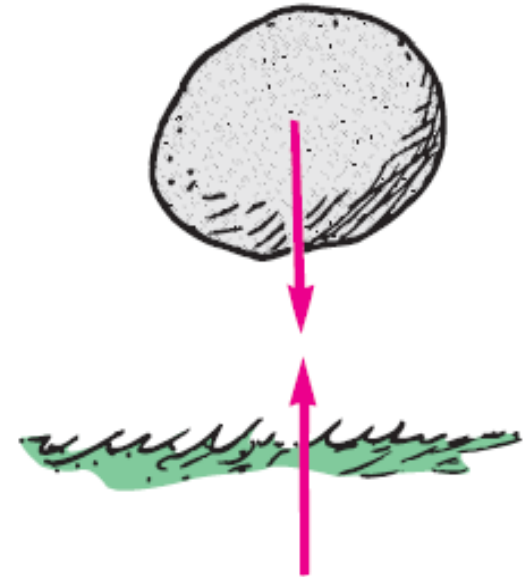
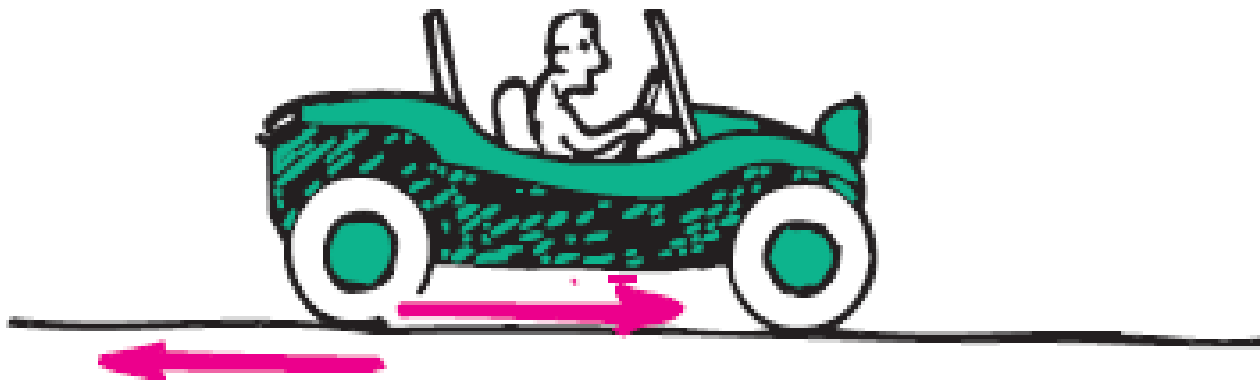
$$\frac{F}{m} = a$$

$$\frac{F}{m} = a$$

$$\frac{F}{m} = a$$

Action—reaction pairs

- Force on object moves it
- Force by object acts on other things
- Always equal





Action— reaction pair

- Hammer exerts force on nail
- Nail exerts equal force on hammer

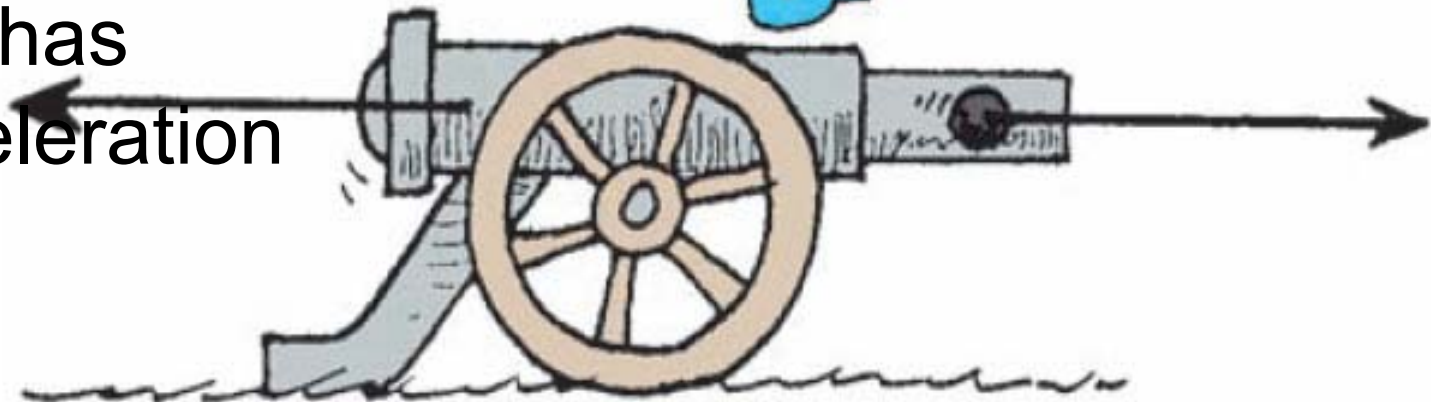
Action—reaction pairs

- Consider firing a cannon
- Force on cannonball and on cannon the same
- cannonball has less mass than cannon
- Cannonball has greater acceleration

$$F \frac{F}{m} = a$$

$$\frac{F}{m} = a$$

m
BAM!



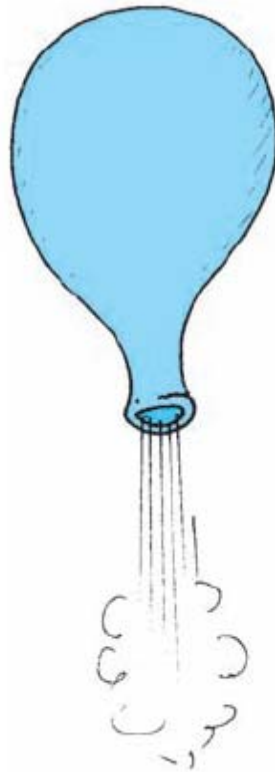
Action—reaction pairs

- Rifle has less acceleration than the bullet
- Because it has greater mass
- Forces are the same



Action—reaction pairs

- Rocket accelerates upward
- Recoil from exhaust gas



Action—reaction pairs



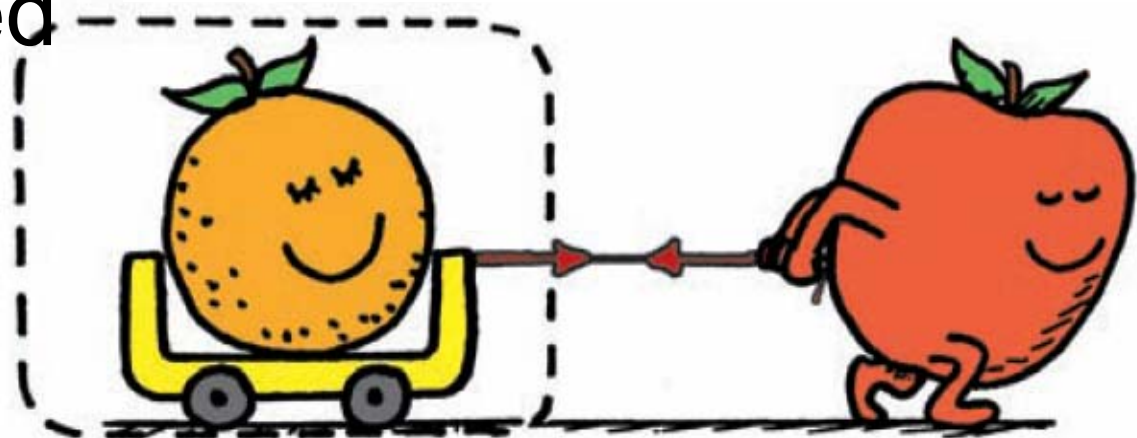
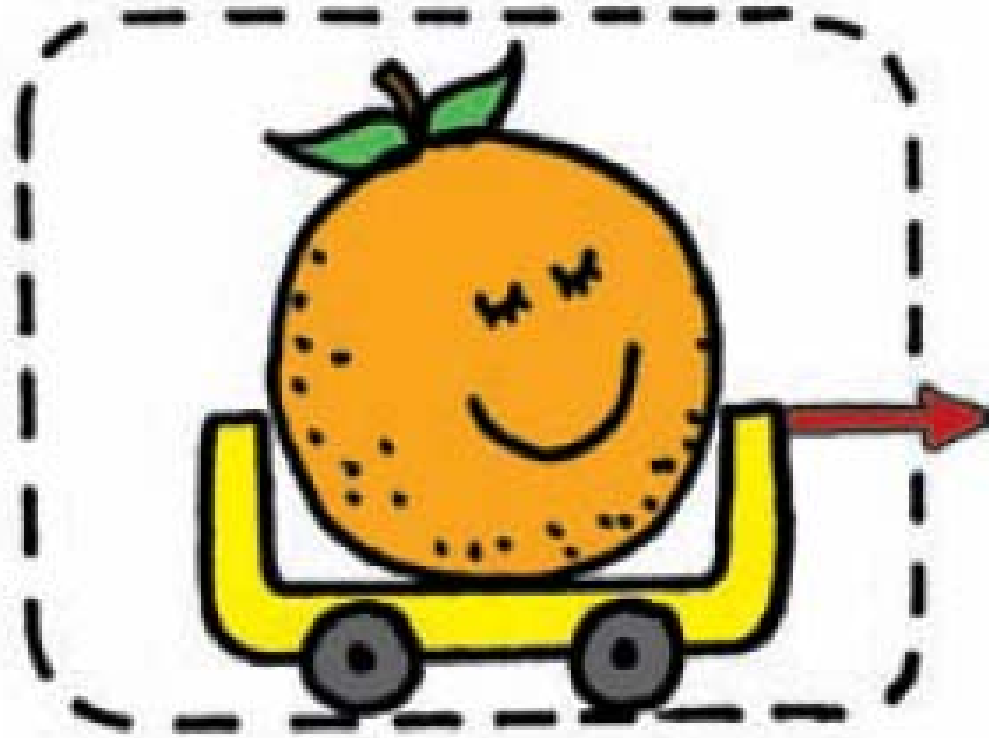
- Birds push down on air
- Air pushes up on bird



- Fish pushes backward on water
- Water pushes forward on fish

Action—reaction pairs

- Forces of atoms within objects are in action—reaction pairs
- No net acceleration due to these molecular forces
- External force needed to move object



Bug vs. Bus

- If a bug is splatted against the windshield of a bus on the freeway, is the force the bug exerts on the bus the same as the force the bus exerts on the bug?
- Justify why the deceleration of the bug is not the same as the deceleration of the bus with Newton's third law.

Summary of laws of motion

Newton's First Law of Motion

- Object at rest tends to remain at rest
- Objects in motion tend to remain moving
 - Law of Inertia
 - Function of mass of object
- Changes in motion occur due to presence of net force acting on object

Summary of laws of motion

Newton's Second Law of Motion

- Acceleration proportional to net force

$$a \approx \frac{F}{m}$$

Summary of laws of motion

Newton's Third Law of Motion

- Objects exert equal and opposite forces upon one another
- Action—reaction pairs have no net force