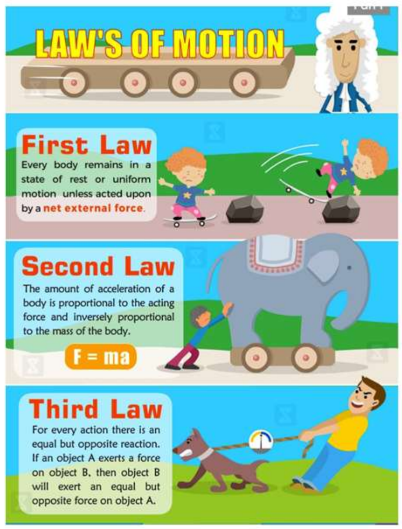
Lecture 4 – Motion and Newton's Laws



Clicker Question

An ancient Egyptian notices that an object dropped into a deep well falls a distance of 20 cubits during 2 swings of his pendulum. How many cubits did the object fall during the first swing of the pendulum?

A. 1 cubits
B. 2.5 cubits
C. 5 cubits
D. 10 cubits
E. None of the other answers.

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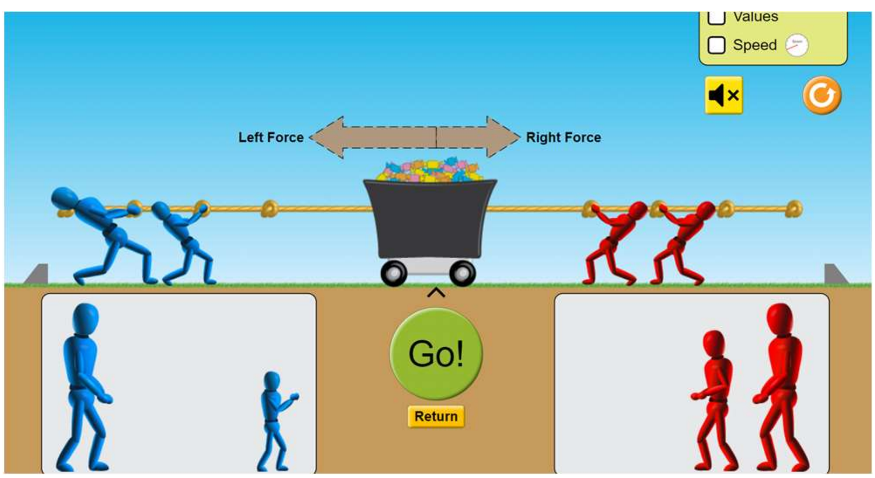
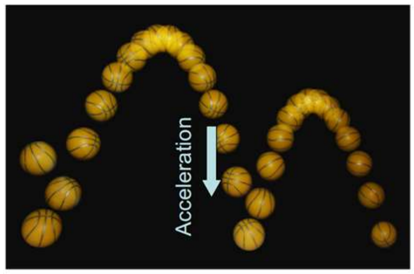
Distance Fallen: $y = \frac{1}{2}gt^2$

Phet Simulation



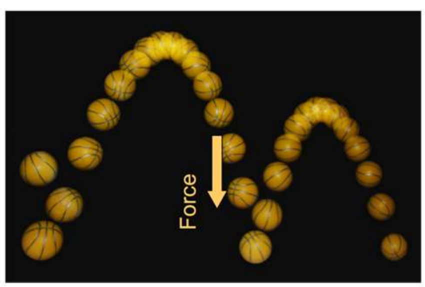
Falling motion



What is the ball's acceleration?

a = g

Falling motion



What force is acting on the ball?

F = W (weight)

F = m a becomes W = m g

Force of Gravity: Weight

<u>Mass</u> (m):
Amount of matter in an object (kg)

<u>Weight</u> (W):
Downward force of gravity acting on an object (Newtons)

<u>Relation between them</u>:

$$W = m\,g$$

g = 10 m/s^2 on surface of Earth
g = 1.6 m/s^2 on surface of moon
g = 3.7 m/s^2 on surface of Mars

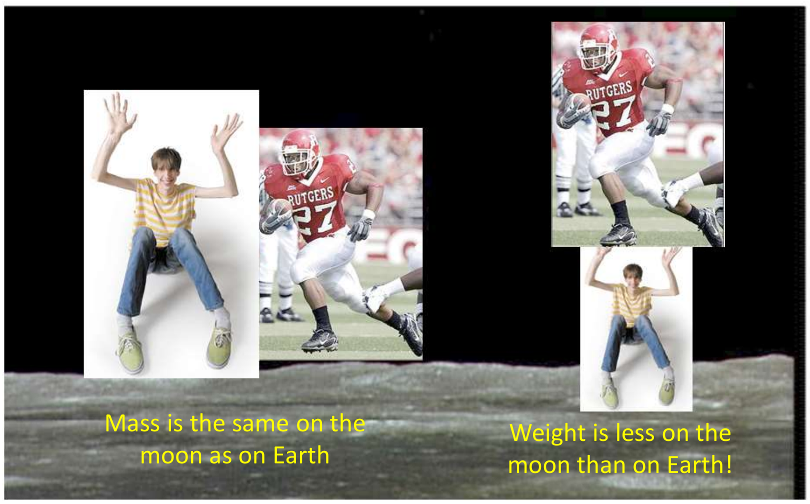
Mass vs. weight

Block on earth

Lift on earth

Mass vs. weight

Block on the moon Lift on the moon



Clicker Question

Charlie, whose mass is 100 kg, jumps off a diving board. While he is flying through the air, what is Charlie's weight (in Newtons)?

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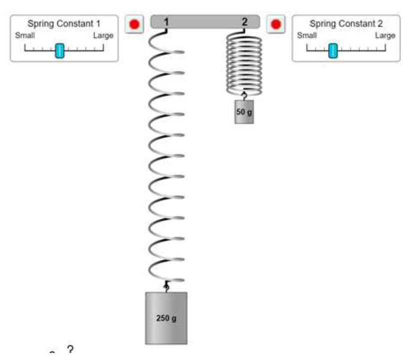
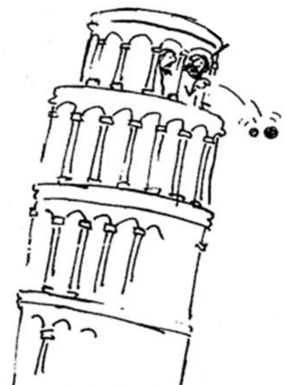
$W = mg = 100\,kg \cdot 10\,\frac{m}{s^2} = \underline{1000\,N}$

Spring Forces – Masses and Springs

- Hooke's Law
- Masses and Springs





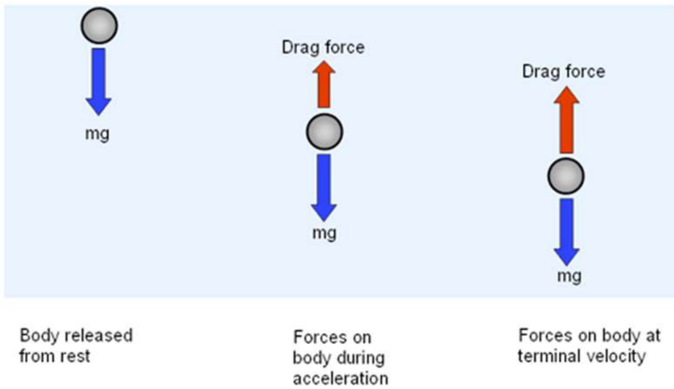
This is Galileo's law of falling: All objects fall at the same rate!

(Unless air resistance comes into play…)

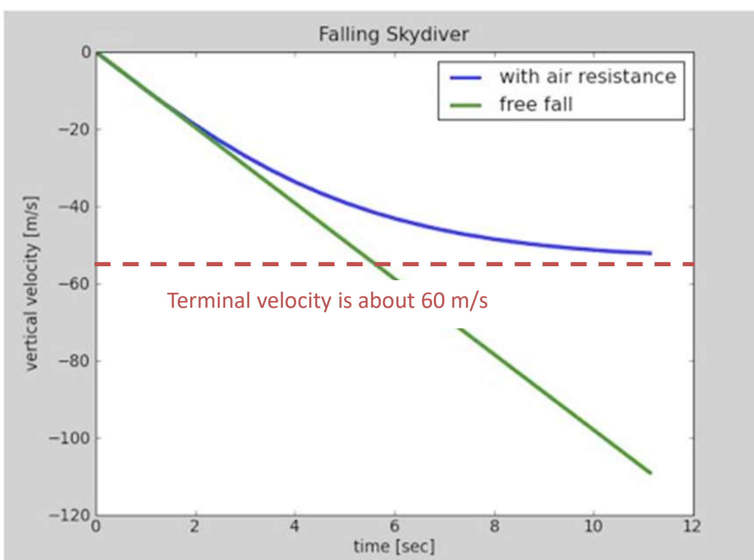
Terminal Velocity

The highest velocity attainable by an object as it falls through a fluid (like air).

Terminal velocity



The forces acting on the body balance each other more and more closely as the terminal velocity is approached



(1 m/s ≈ 2.3 mph)

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Falling in Air: Skydiving

http://www.batesville.k12.in.us/physics/PhyNet/Mechanics/Newton2/falling_in_air.htm

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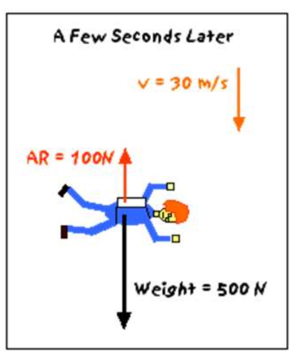
Falling in Air: Skydiving



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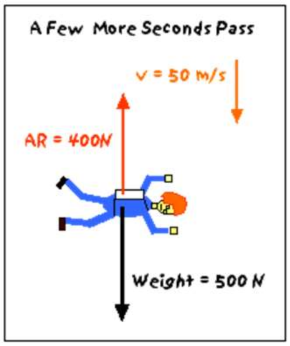

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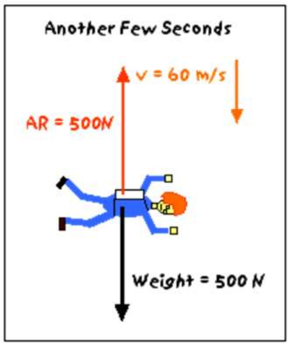
Falling in Air: Skydiving



Terminal Velocity
~130 mph (~60m/s)

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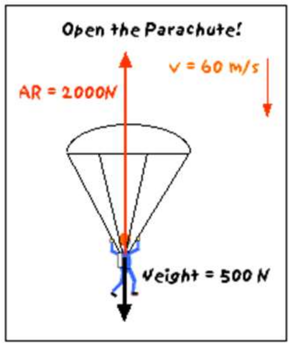
Falling in Air: Skydiving



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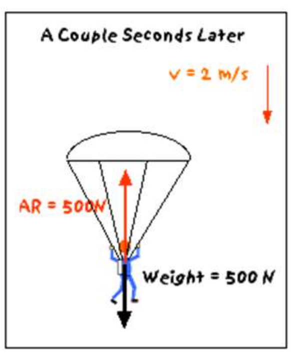
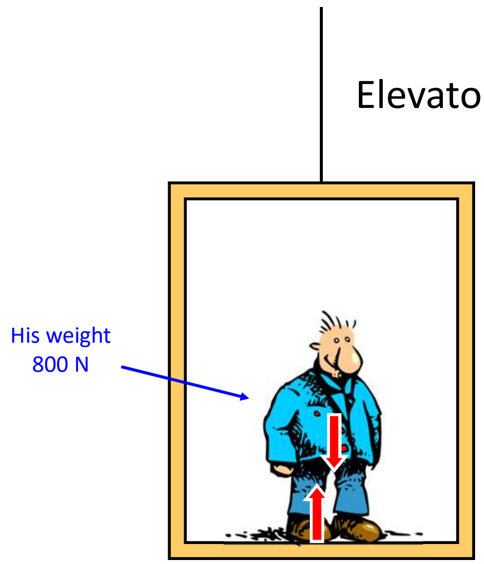
Falling in Air: Skydiving



Terminal velocity ~10 mph (~5m/s)

http://www.batesville.k12.in.us/physics/PhyNet/Mechanics/Newton2/falling_in_air.htm

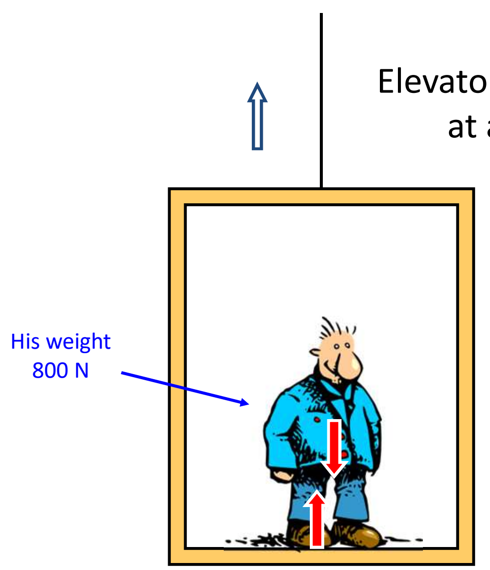
Elevator is stationary



What are forces?

Net force = 0

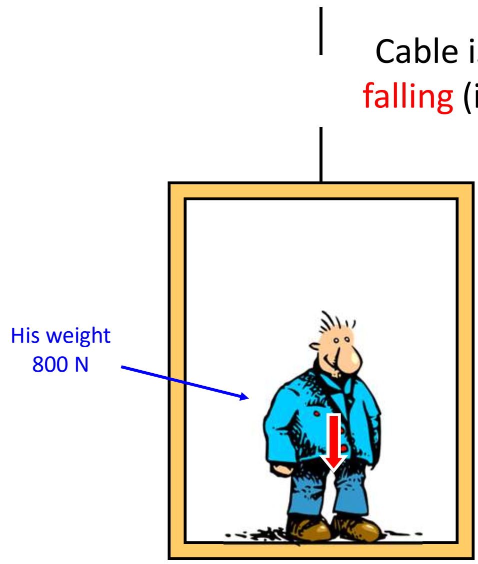
Elevator is moving upward
at a steady 3 m/s



What are forces?

Net force = 0

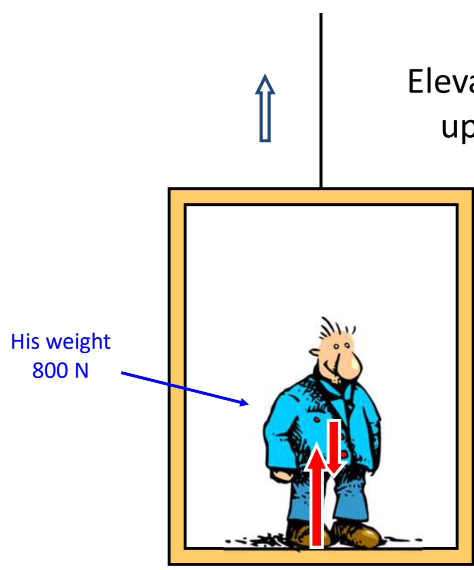
Cable is cut and elevator is falling (ignore air resistance)



What are forces?

Net force = weight = 800 N (downward)

Elevator is accelerating upward at 10 m/s^2



What are forces?

Net force = m a = 80 kg * 10 m/s = 800 N (up)

Normal force = 1600 N (up)

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Clicker Question

Bob is standing in an elevator that is accelerating downward at 3 m/s^2. Bob's mass is 100 kg. What is the normal force that the elevator floor exerts on Bob's shoes?

A. 700 N down
B. 700 N up
C. 300 N down
D. 300 N up
E. 1300 N down
F. 1300 N up

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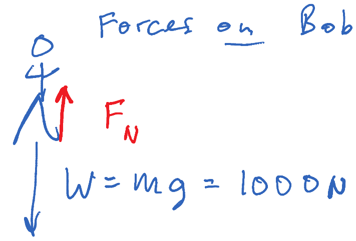
Forces on Bob



Newton's 2nd Law: $F = ma$

$F_N - W = ma = -300\ N$

$F_N = W - 300N = 700\ N$

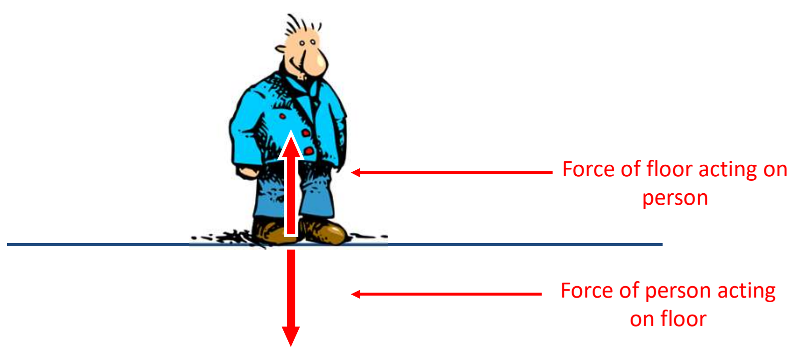
Newton's Law of Force Pairs

Newton's 3rd Law

If object A exerts a force on object B, then object B exerts an equal and opposite force on object A.

- Force pairs are sometimes called "action & reaction".
- There is no difference in principle between the two.
- So no way to decide which is "action" and which "reaction".
- Note that action/reaction force pairs always act on different bodies!

Example: Normal forces



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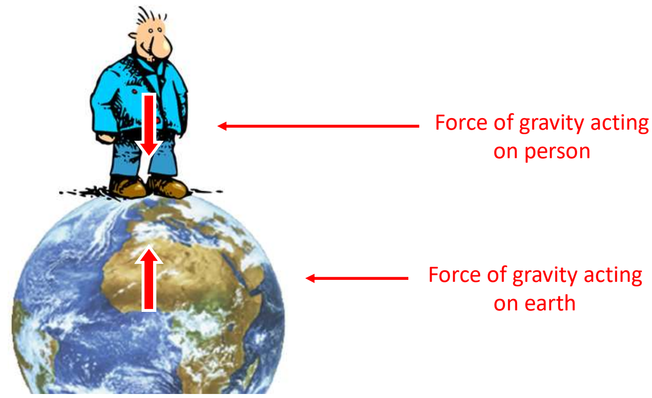
Example: Gravitational forces



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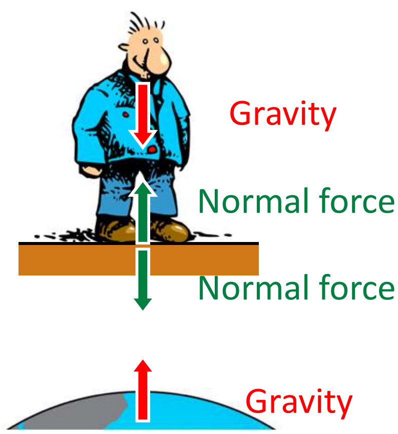
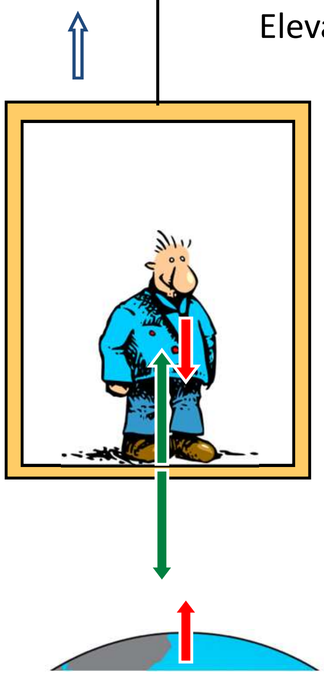
Comment on force pairs

Not all equal-and-opposite forces are force pairs!



Elevator is accelerating upward at 10 m/s^2



Clicker Question

Alice pushes horizontally on a filing cabinet standing in the middle of a room, and notes that the cabinet does not move. Why doesn't it move?

A. The force of gravity pushes downward on the cabinet, and this cancels the pushing force.
B. The cabinet exerts a force on Alice, and this force is equal and opposite to the pushing force.
C. The cabinet pushes back on Alice with a force that is even greater than the pushing force.
D. A frictional force is also exerted by the floor on the cabinet, and this force is equal and opposite to the pushing force.
E. Very massive objects such as filing cabinets are difficult to set into motion because of their large inertia.

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A skydiver is falling at terminal velocity. The Newton 3rd law (action/reaction) partner to the **skydiver's weight** is given by:

A. The force of gravity pulling up on the Earth.
B. The force of air resistance pushing up on the skydiver.
C. The skydiver's body pushing down on the air via air resistance.
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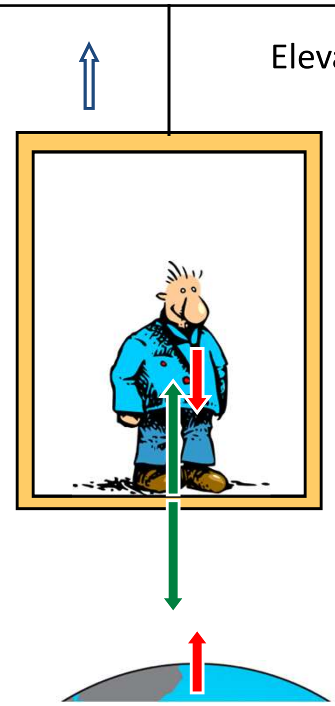

800 N of gravitational force (weight): Earth pulling person down

Normal force of 1600 N: floor pushing up on person

Normal force of 1600 N: person pushing down on floor

800 N of gravitational force: person pulling Earth up

Rocket Cart Demo