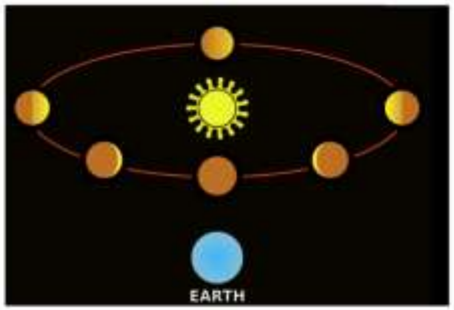
Lecture 3
Newton’s Laws of Motion

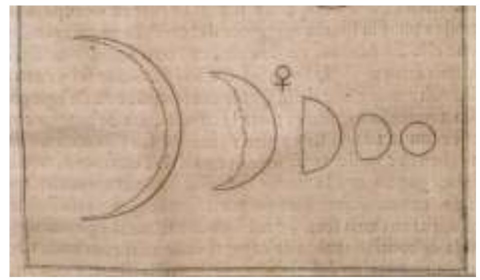
Review Question: The phases of Venus

Copernican prediction regarding phases of Venus

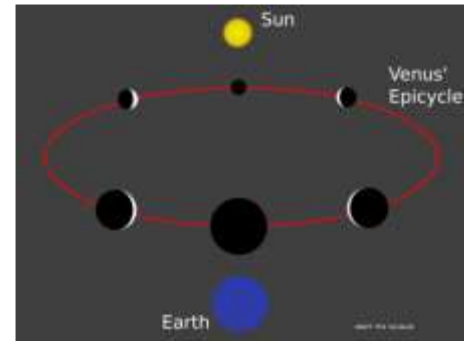


Prediction: All phases are possible

Galileo's observations:



Ptolemy's Geocentric Model



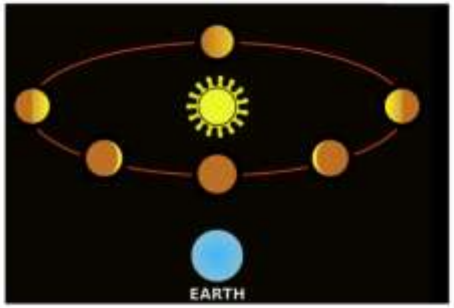
Prediction: Only crescent phases visible

Galileo studied Venus with his telescope. He observed all phases, like those of the Moon. This was a monumental discovery because it allowed him to conclude that:

A. In its orbit, Venus only moves in the space between the Sun and the Earth, thus Ptolemy's geocentric world picture is correct.
B. In its orbit, Venus only moves in the space between the Sun and the Earth, thus Copernicus' heliocentric picture is correct.
C. In its orbit, Venus passes behind the sun and then between the Earth and the sun. Consequently, the Copernican heliocentric picture is correct.
D. Venus orbits around the Sun, thus Ptolemy's geocentric picture is correct.

Review Question: The phases of Venus

Copernican prediction regarding phases of Venus



Prediction: All phases are possible

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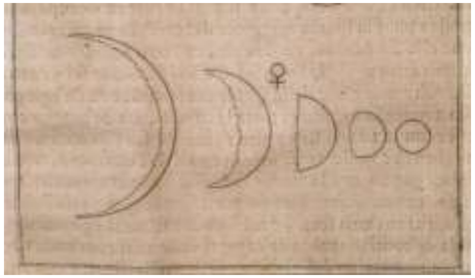

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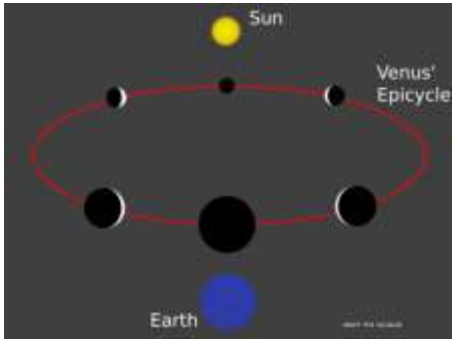

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D. Venus orbits around the Sun, thus Ptolemy's geocentric picture is correct.

Review question

A **scientific theory** is

A. The same as fact.
B. Very speculative.
C. A framework of ideas that help explain and understand observations.
D. Always true.
E. A hypothesis that has been confirmed by experiment.

Review question

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Review question

What is a picosecond?

A. 0.000 000 000 001 second
B. 0.000 000 001 second
C. 1 000 000 000 seconds
D. 1 000 000 000 000 seconds
E. The amount of time it takes light to travel one picometer.

Review question

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REVIEW:

Speed

The rate of motion of a body.

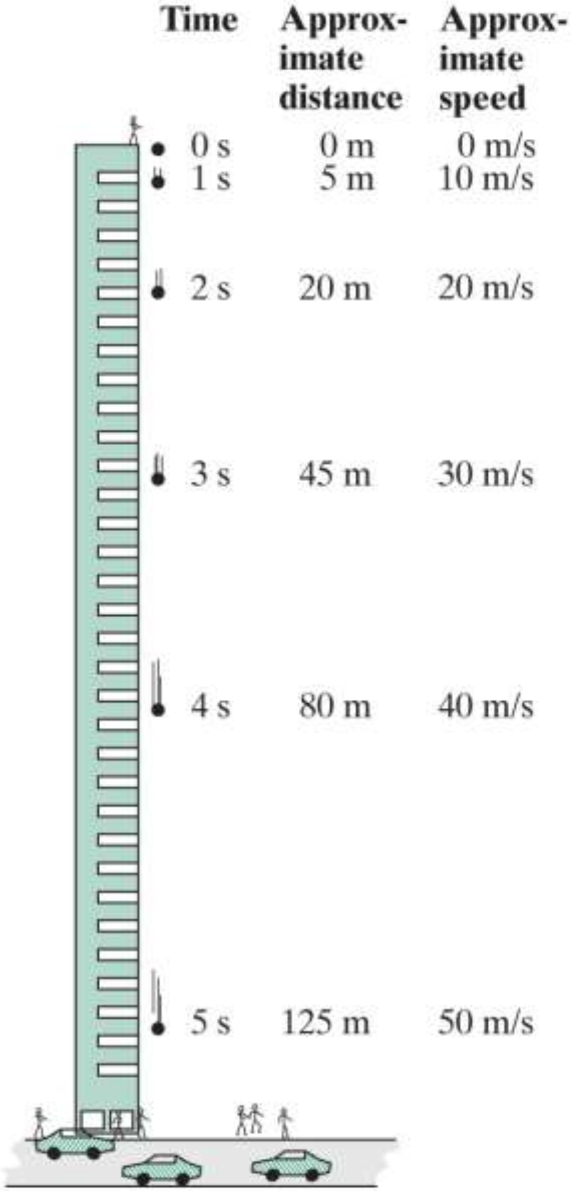
Velocity

The combination of *speed* and *direction.*

Acceleration

Any change of velocity.

Falling object, dropped from rest:



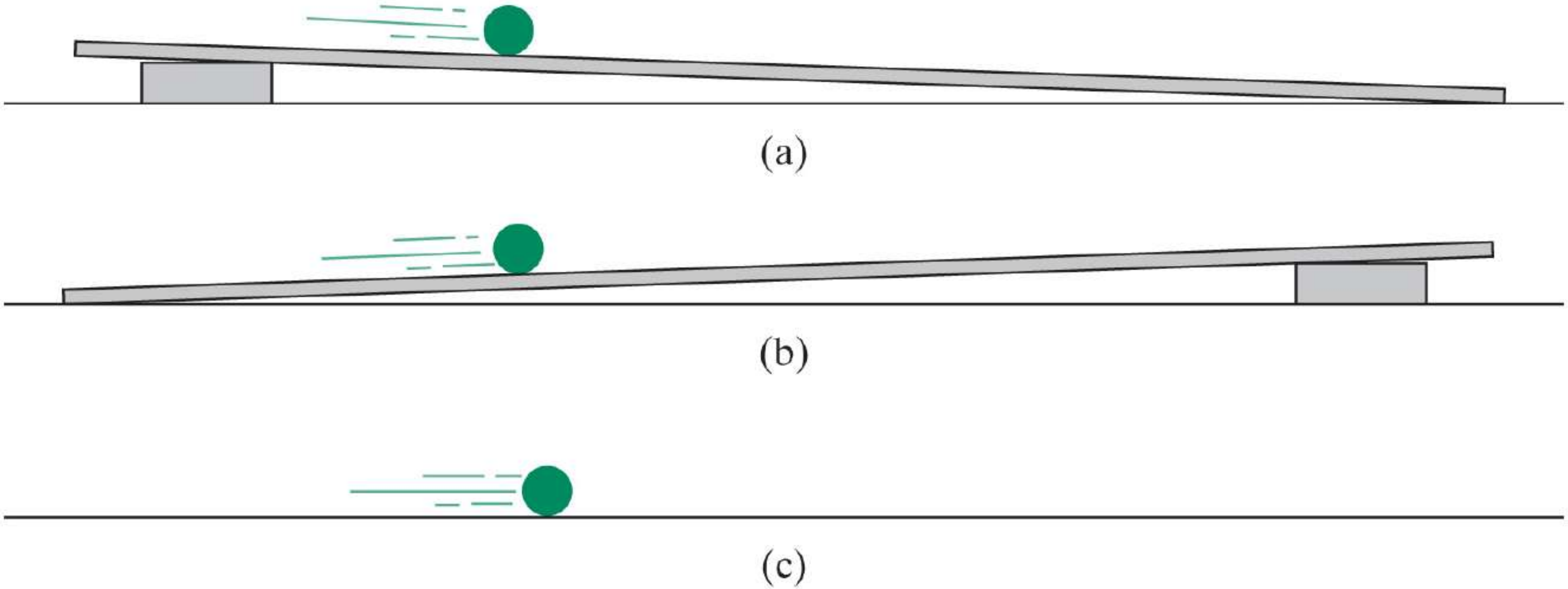
Distance Fallen: $y = \frac{1}{2}gt^2$

Height: $h = h_0 - \frac{1}{2}gt^2$

Velocity: $v = -gt$

Acceleration: $a = -g$

$$g = 10\,\frac{\mathrm{m}}{\mathrm{s}^2}$$



In which cases is there acceleration?

In which direction is the acceleration?

Clicker Question

Which situation corresponds to an object that is accelerating?

A. All of the other answers.
B. An object that is slowing down.
C. An object that is speeding up.
D. An object that is falling without air resistance.
E. An object in orbit around the Earth.
F. An object that is changing its direction of motion.

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Clicker Question

An object is released from rest on a certain planet. After 2 seconds, it has fallen a distance of 2 meters. What is this planet's acceleration of gravity?

A. 1 m/s^2
B. 2 m/s^2
C. 3 m/s^2
D. 4 m/s^2
E. Cannot be answered without knowing the object's mass.

Clicker Question

An object is released from rest on a certain planet. After 2 seconds, it has fallen a distance of 2 meters. What is this planet's acceleration of gravity?

A. $\boxed{1\ m/s^2}$
B. $2\ m/s^2$
C. $3\ m/s^2$
D. $4\ m/s^2$
E. Cannot be answered without knowing the object's mass.

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

Clicker Question

An object is released from rest on a certain planet. After 2 seconds, it has fallen a distance of 2 meters. After 4 seconds, it has fallen a distance of

A. 4 meters
B. 8 meters
C. 16 meters
D. None of the other answers.
E. Cannot be answered without knowing the planet’s acceleration of gravity.

Clicker Question

An object is released from rest on a certain planet. After 2 seconds, it has fallen a distance of 2 meters. After 4 seconds, it has fallen a distance of

A. 4 meters

B. 8 meters

C. 16 meters

D. None of the other answers.

E. Cannot be answered without knowing the planet's acceleration of gravity.

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

Clicker Question

An object is released from rest on a certain planet. After 2 seconds, it has fallen a distance of 2 meters. At that time, its speed is

A. 1 m/s
B. 2 m/s
C. 4 m/s
D. None of the other answers.
E. Cannot be answered without being given the planet's acceleration of gravity.

Clicker Question

An object is released from rest on a certain planet. After 2 seconds, it has fallen a distance of 2 meters. At that time, its speed is

A. 1 m/s
B. 2 m/s
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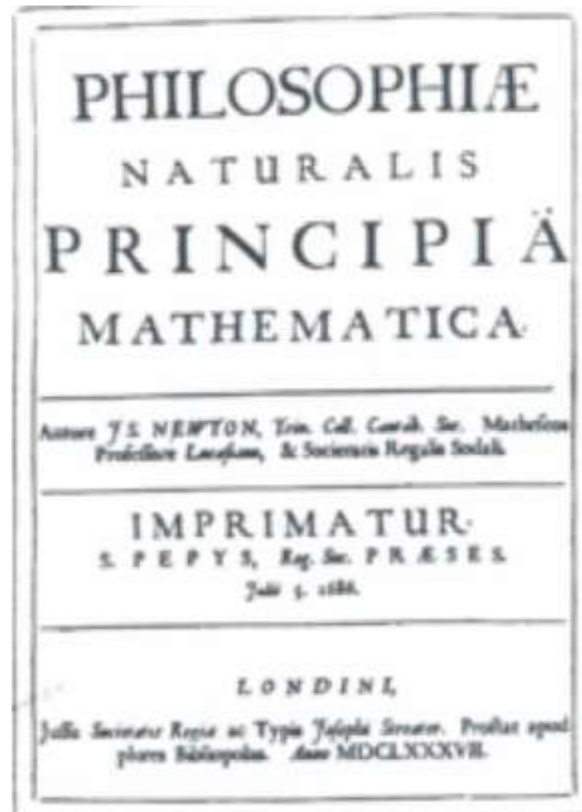
Velocity: $v = -gt$

Isaac Newton (1643-1726)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LONDINI,

Newton's Laws of Motion:

1. Law of Inertia
2. Law of Motion
3. Law of Force Pairs

Inertia

The tendency of all bodies to keep moving in a straight line at a constant speed unless acted on by external forces.

What keeps the ball rolling?

Law of inertia

For a body that is subjected to no external influences (also called external forces):

- **If initially at rest, it will stay at rest!**
- **If initially moving, it will keep moving along a straight line at an unchanging speed!**

Demo video

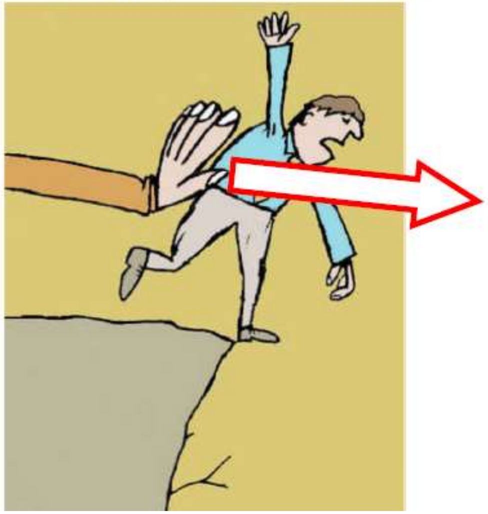
Restatement:

A body that is subject to **no external forces** will maintain a constant velocity

Force

A push or pull acting on a body.

Force has magnitude and direction, so it is another example of a vector.



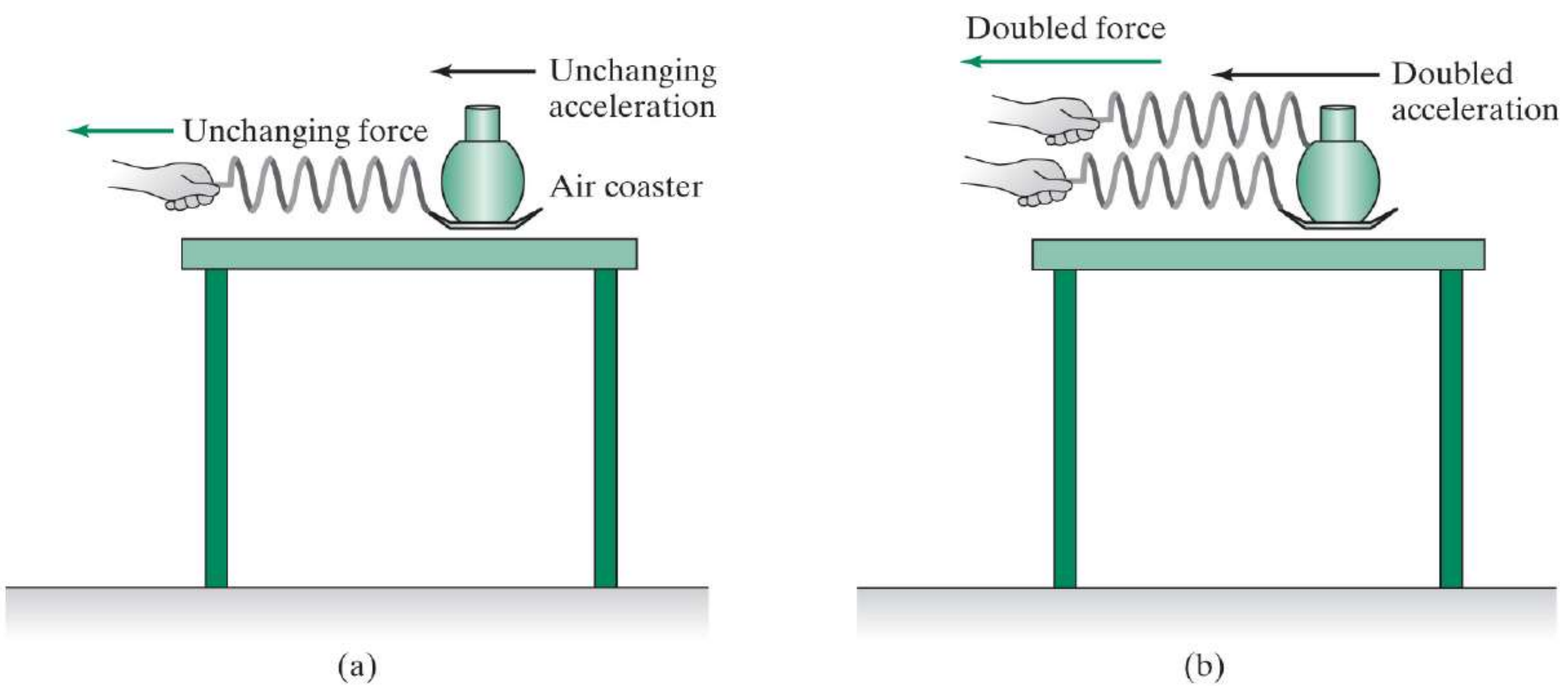
Examples of forces

- Contact forces
  - Push (normal force)
  - Pull
  - Tapping or bouncing
  - Wind
  - Friction
- Gravity
- Electrical and magnetic forces

Newton's Law of Motion (2^{nd} Law)

Through experimentation, we see that the acceleration is proportional to the force:

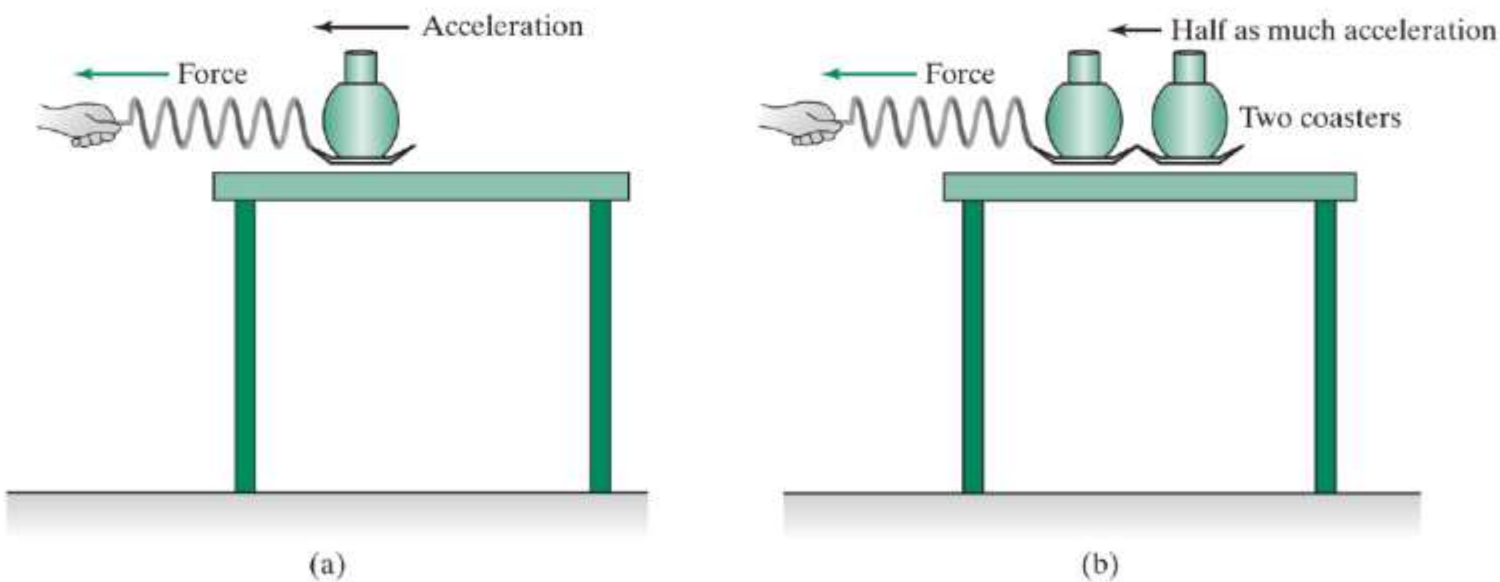
$$a \propto F$$



Newton's Law of Motion (2nd Law)

Through experimentation, we see that the same force produces a smaller acceleration of a greater mass. Acceleration is inversely proportional to mass:

$$a \propto 1/m.$$



Newton's Law of Motion

$$\text{Acceleration} = \frac{\text{Force}}{\text{Mass}}$$

Mass in kilograms (kg)

Force in newtons (N) $N = kg\ m/s^2$

Acceleration in m/s^2

Newton's Law of Motion (2^{nd} Law)

[Space Station Demo]

Amy places a lead block and an iron block on the table, and hits both of them with the same force. The lead block is twice as massive as the iron block. The acceleration of the lead block is

A) Four times that of the iron block

B) Two times that of the iron block

C) The same as that of the iron block

D) Half that of the iron block

E) One fourth that of the iron block

Amy places a lead block and an iron block on the table, and hits both of them with the same force. The lead block is twice as massive as the iron block. The acceleration of the lead block is

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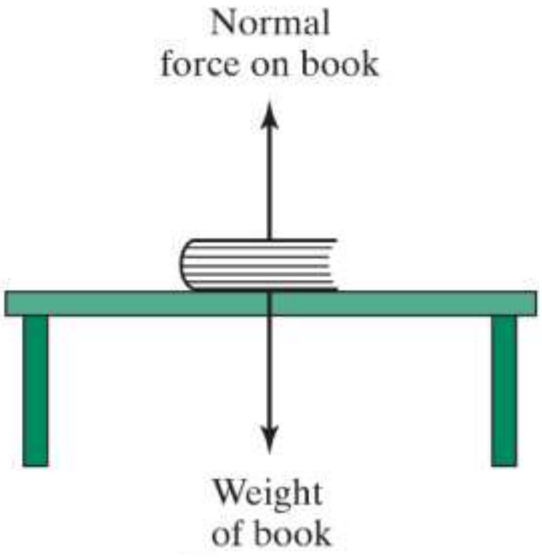
$$\boxed{\text{Acceleration} = \frac{\text{Force}}{\text{Mass}}}$$

Normal Force

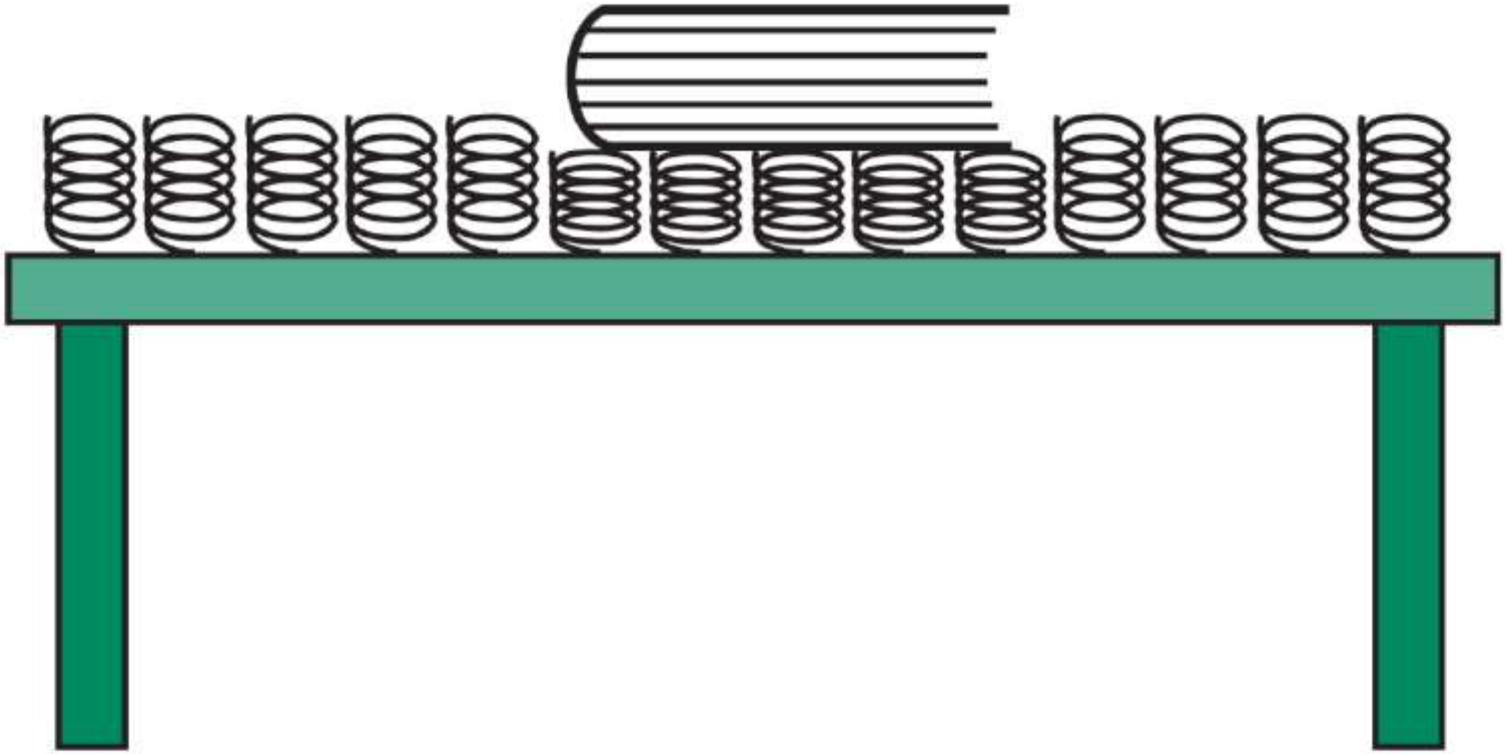
Consider a book sitting on a table. It isn't moving, so the net force on it must be zero. Gravity is pulling it down; what holds it up?

What's holding it up is a force exerted by the surface it's sitting on; this is called the normal force.

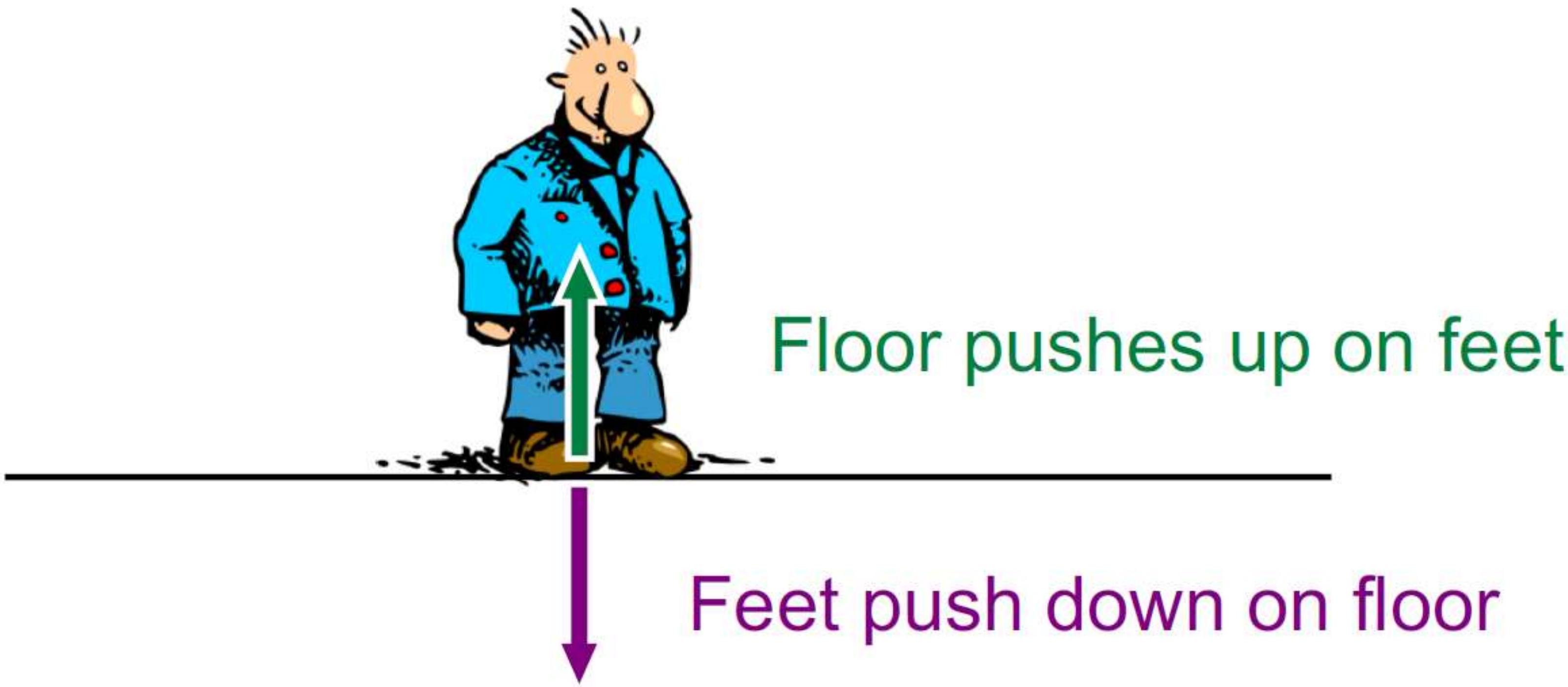


Normal Force

To visualize the normal force, imagine that the table top is covered with springs:



Normal forces



Clicker Question

An elevator moves upward at a constant speed of 7 m/s. The net force on a 50 kg woman inside the elevator is

A. zero
B. 500 N
C. -500 N
D. None of the other answers.
E. 350 N

Clicker Question

An elevator moves upward at a constant speed of 7 m/s. The net force on a 50 kg woman inside the elevator is

A. zero

B. 500 N

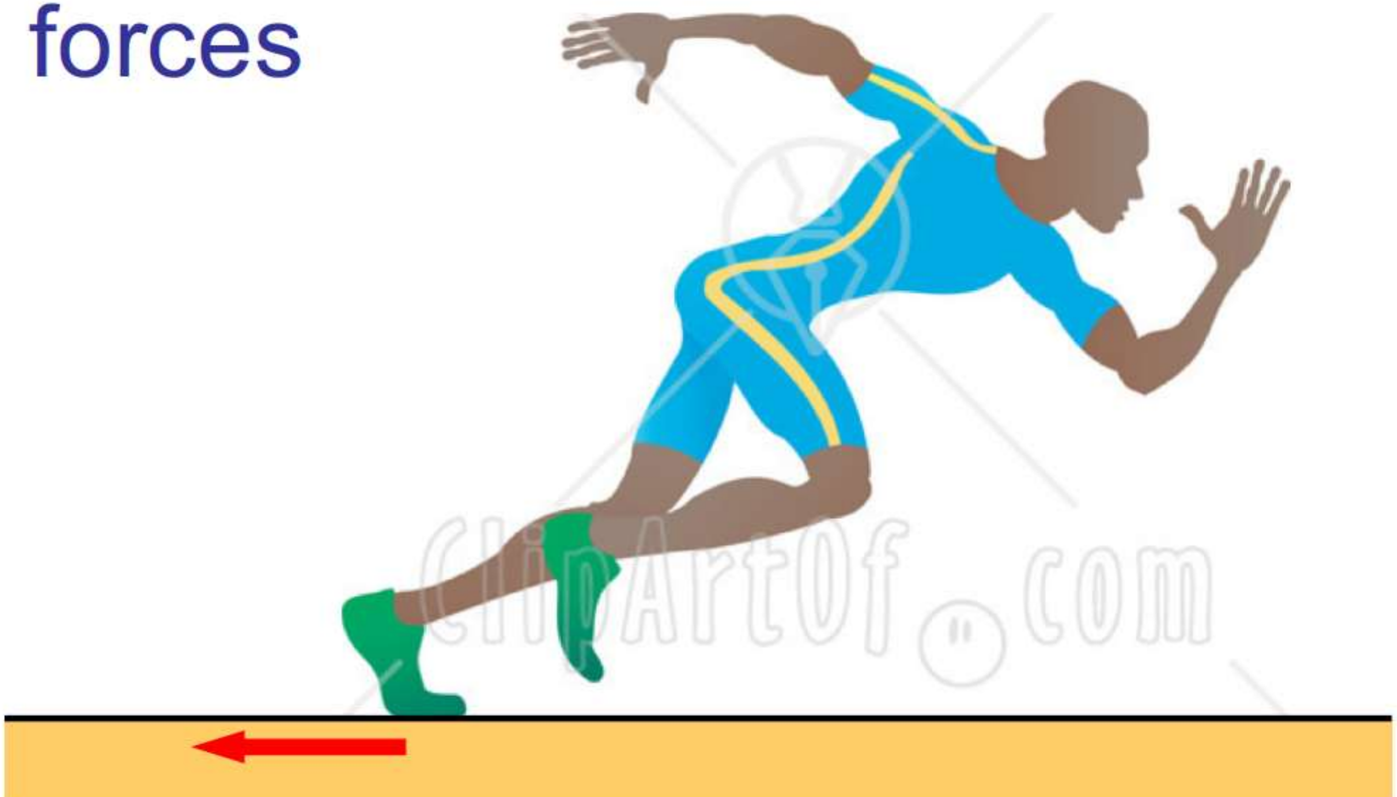
C. -500 N

D. None of the other answers.

E. 350 N

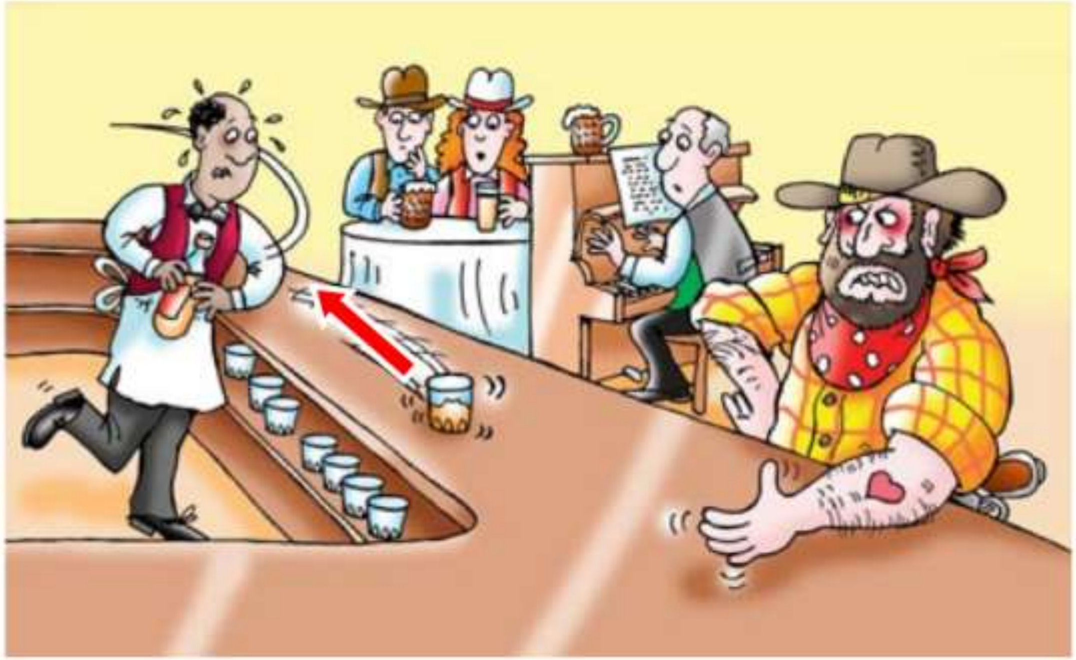
Force = mass x acceleration

Static frictional forces

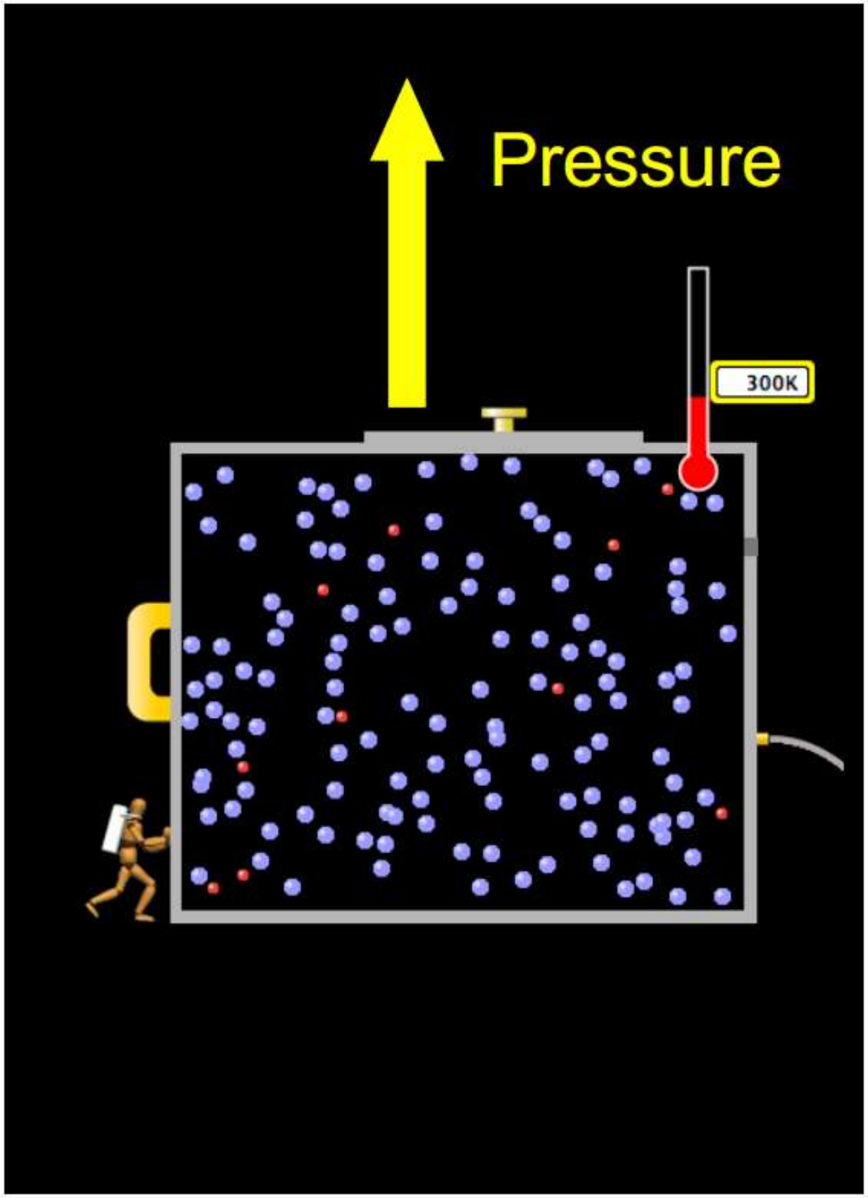


Foot pushes back on floor

Sliding frictional forces



Pull of
spring
Weight
of dog



Force exerted by pressure

Speed

The rate of motion of a body.

Velocity

The combination of *speed* and *direction.*

Acceleration

Any change of velocity.

Purely for description of motion

Force

A push or pull acting on an object.

Cause of motion

Newton's Law of Motion (2^{nd} Law)

" $F = m\,a$ "

$$\boxed{\text{Acceleration} = \frac{\text{Force}}{\text{Mass}}} \qquad a = \frac{F}{m}$$

Expresses causality better

$$\Downarrow$$

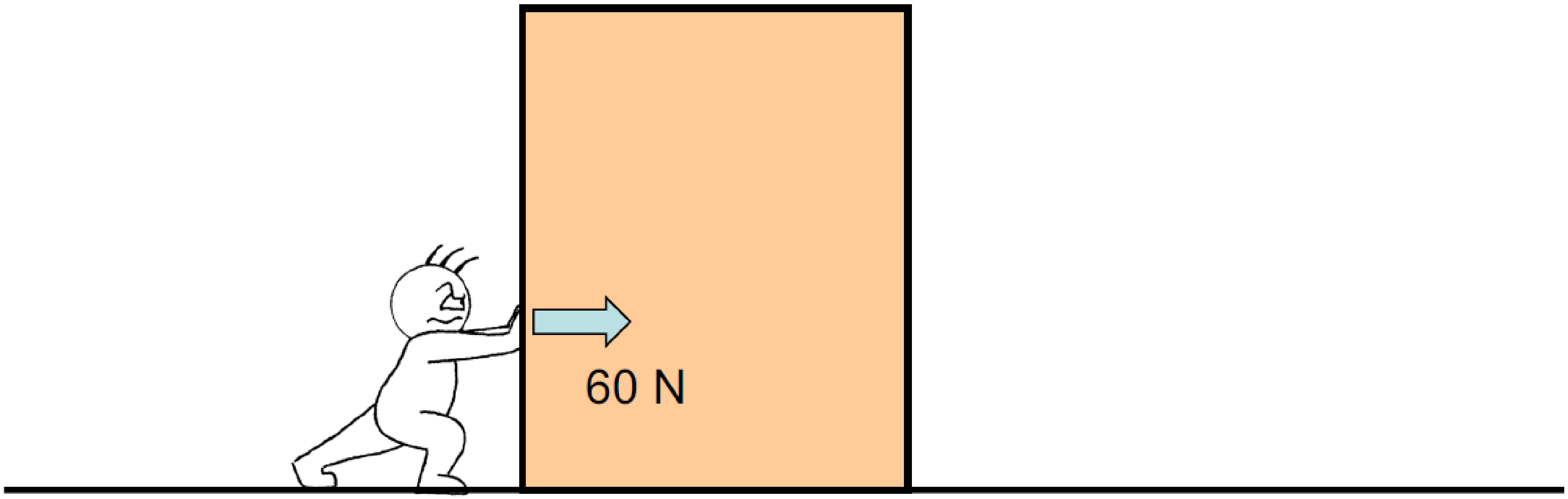
$$\boxed{\text{Force} = \text{Mass} \times \text{Acceleration}} \qquad F = m\,a$$

Newton’s Law of Motion

“Total” or “net” force

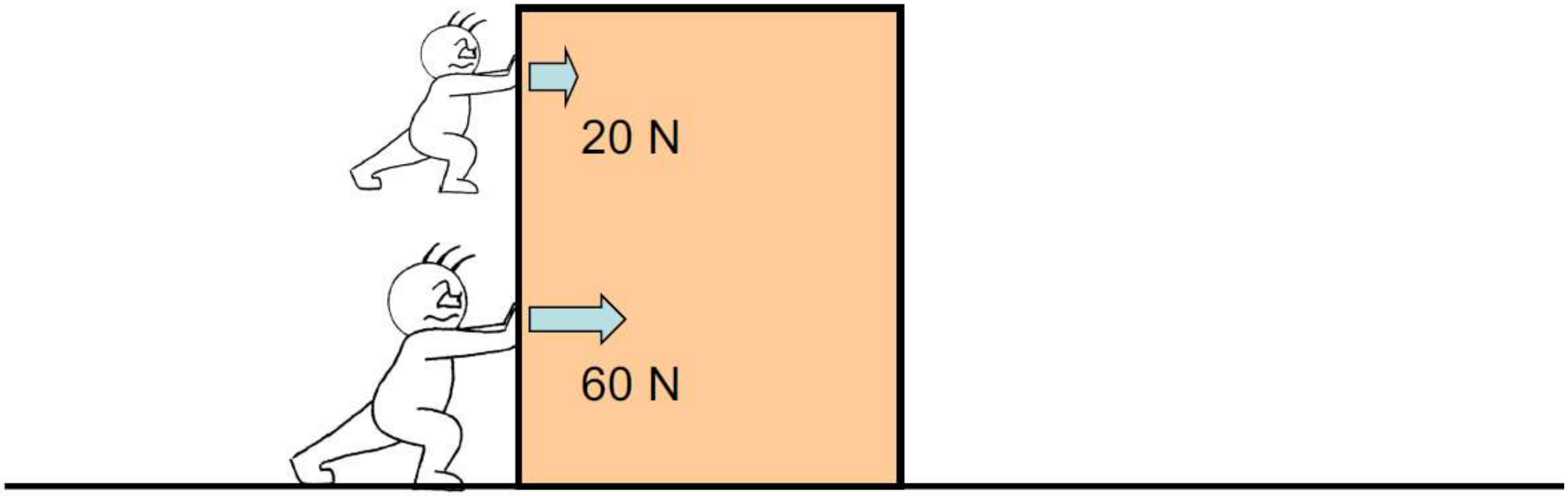
(these terms are synonymous)

$$\text{Acceleration} = \frac{\text{Force}}{\text{Mass}}$$



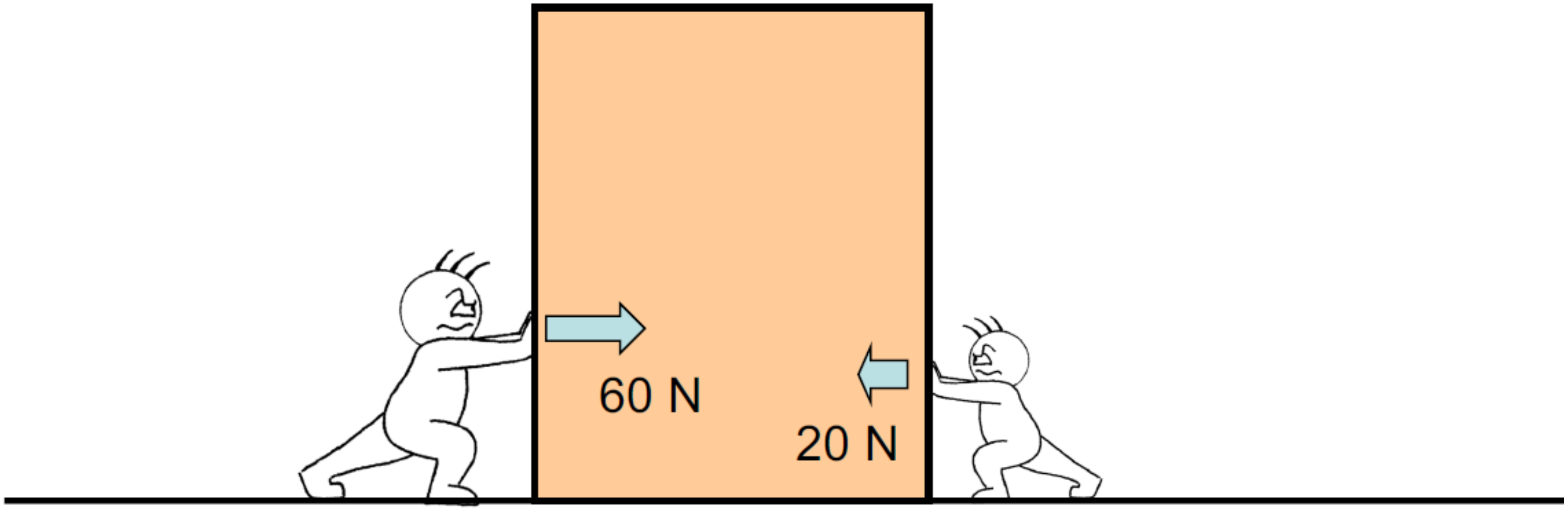
What is the total (or net) force?

60 N to the right



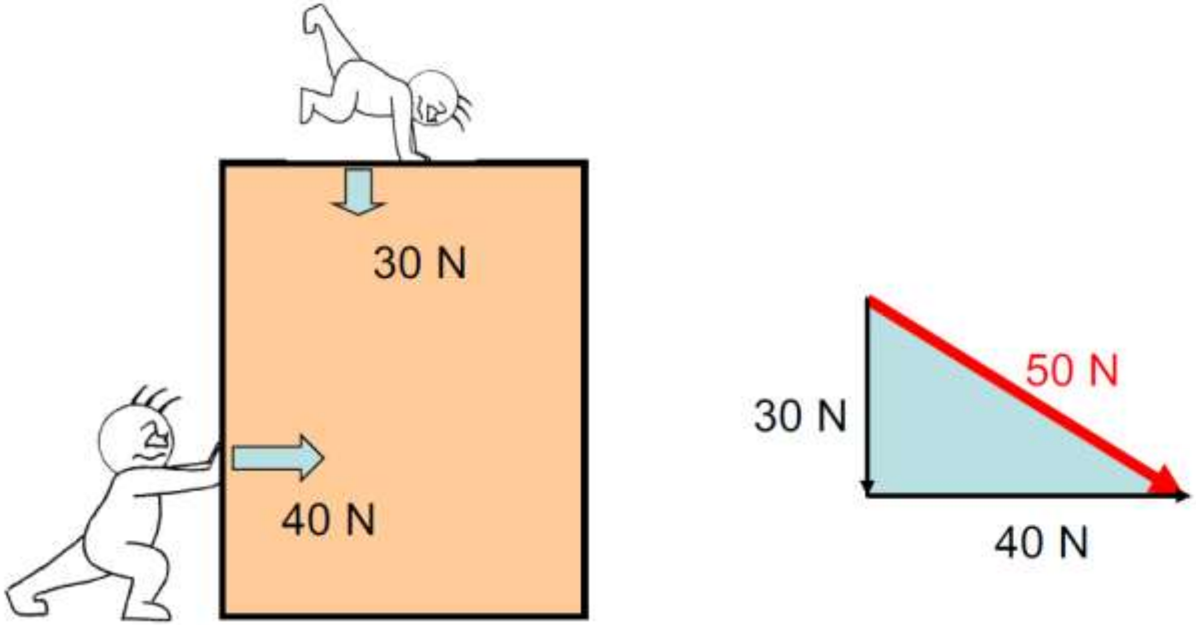
What is the total (or net) force?

80 N to the right



What is the total (or net) force?

40 N to the right



What is the total (or net) force?

50 N at a funny angle

What is the car’s acceleration?
What is the net force acting on the car?
What is the acceleration if the car coasts to a stop?
What is the net force in this case?