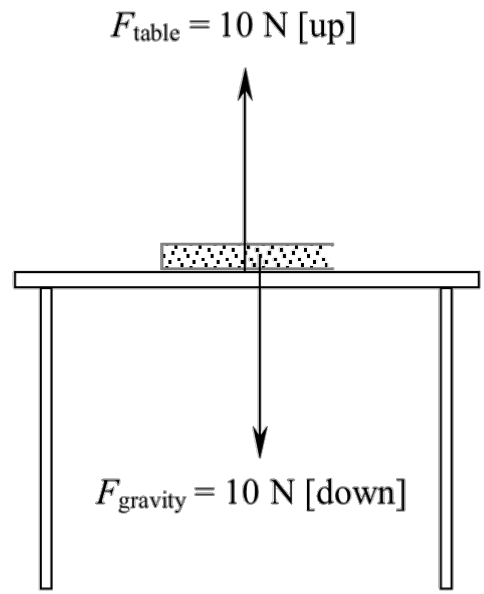
Force

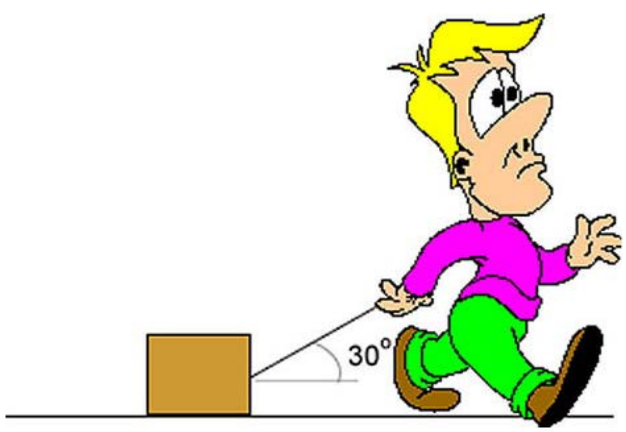
- a push or pull acting on an object
- a vector quantity (has magnitude and direction)

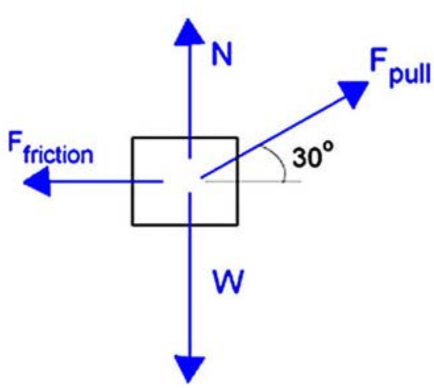
Free-body diagram—a diagram that shows all the forces acting on an object.



Net force—The total force acting on an object (a.k.a. unbalanced force).

What is the net force acting on the book?

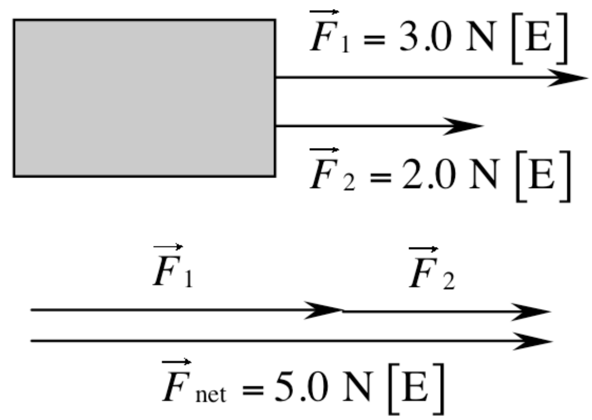




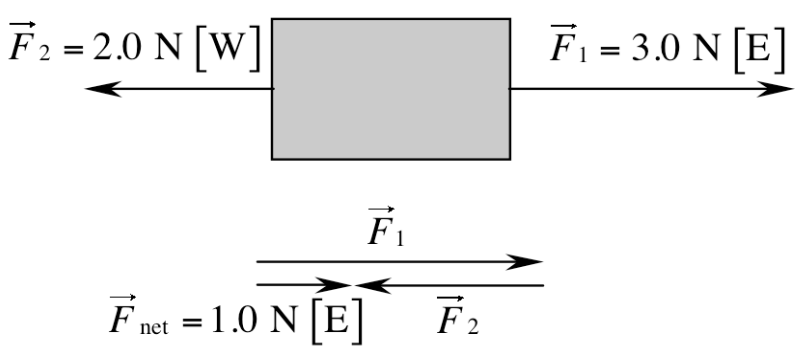
A free-body diagram showing all the forces acting on the box.

Scale: 1 cm = 1 N

$$\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2$$
$$= +3.0\text{ N} + (+2.0\text{ N})$$
$$= +5.0\text{ N}$$
$$= 5.0\text{ N [E]}$$

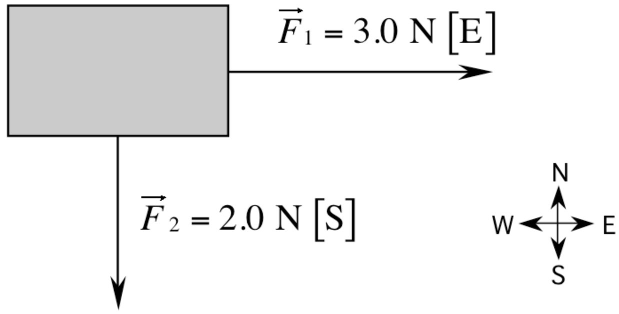


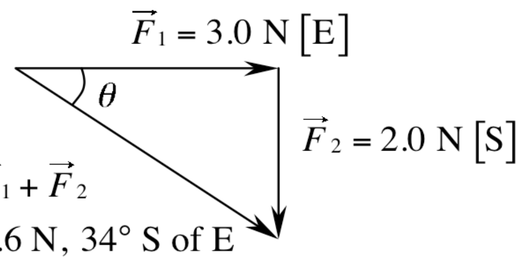
Scale: 1 cm = 1 N



$$\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2$$
$$= +3.0\text{ N} + (-2.0\text{ N})$$
$$= +1.0\text{ N}$$
$$= 1.0\text{ N [E]}$$

Adding Two Vectors





$$\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 = 3.6\ \text{N},\ 34^\circ\ \text{S of E}$$

$$(F_{\text{net}})^2 = (3.0\ \text{N})^2 + (2.0\ \text{N})^2$$

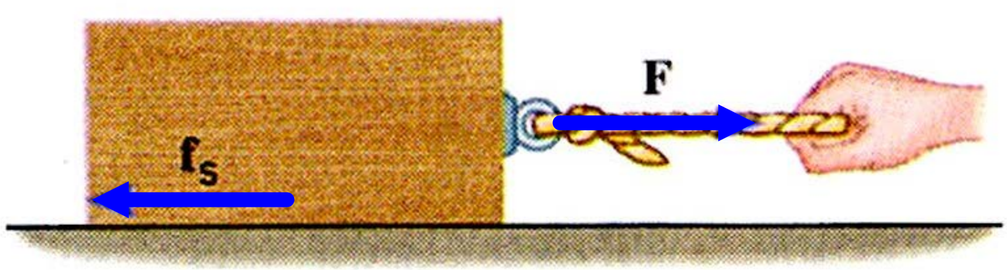
$$F_{\text{net}} = \sqrt{(3.0\ \text{N})^2 + (2.0\ \text{N})^2}$$

$$F_{\text{net}} = 3.6\ \text{N}$$

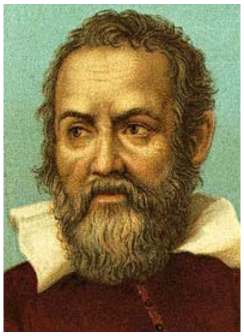
$$\tan\theta = \frac{2.0\ \text{N}}{3.0\ \text{N}}$$

$$\theta = 34^\circ$$

Friction—a force between objects or substances that opposes motion.

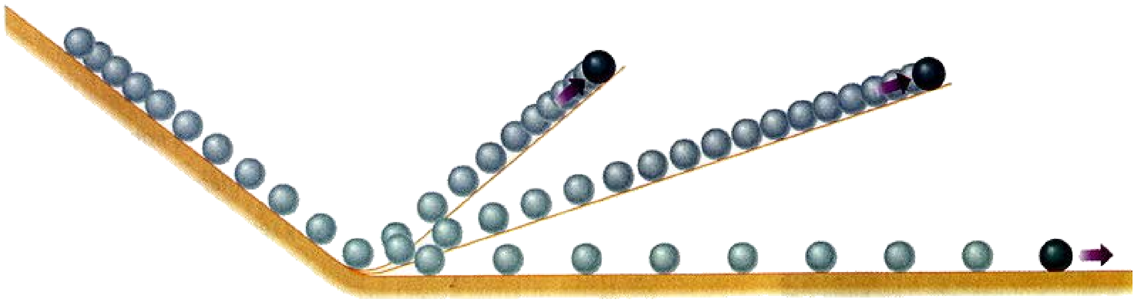


Ideal conditions—simplifying assumption that conditions are frictionless.

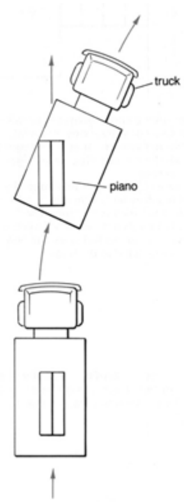


Newton's First Law of Motion (a.k.a. Galileo's Law of Inertia)

When no external, unbalanced force acts on an object, its velocity remains constant.

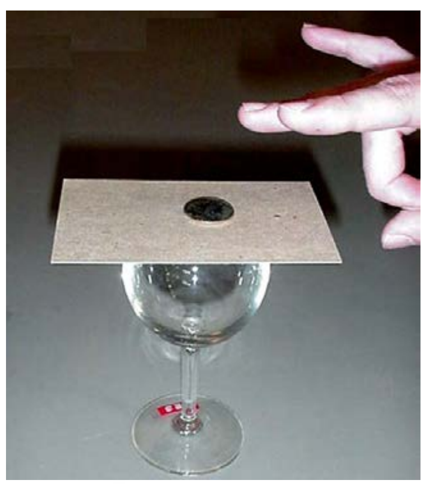


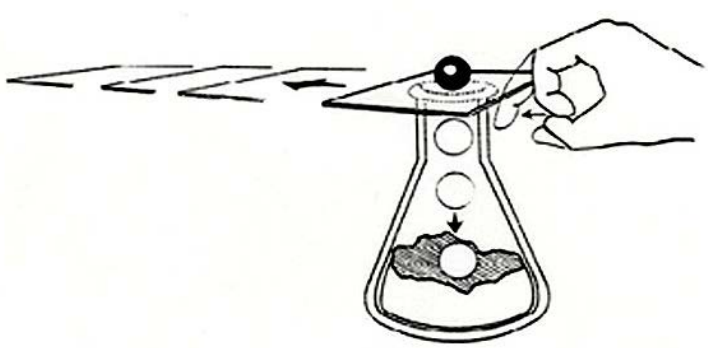
Inertia—the tendency of an object to resist changes in its state of motion.



Inertia—the tendency of an object to resist changes in its state of motion.

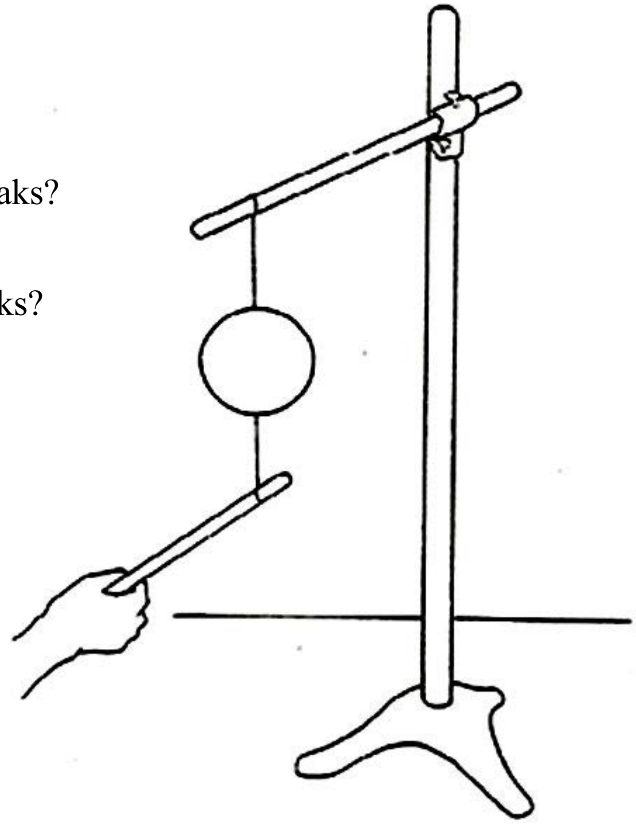
The magician's tablecloth trick.

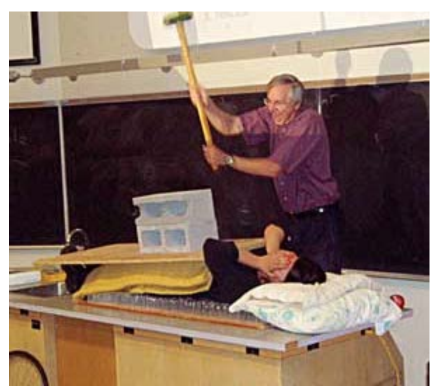


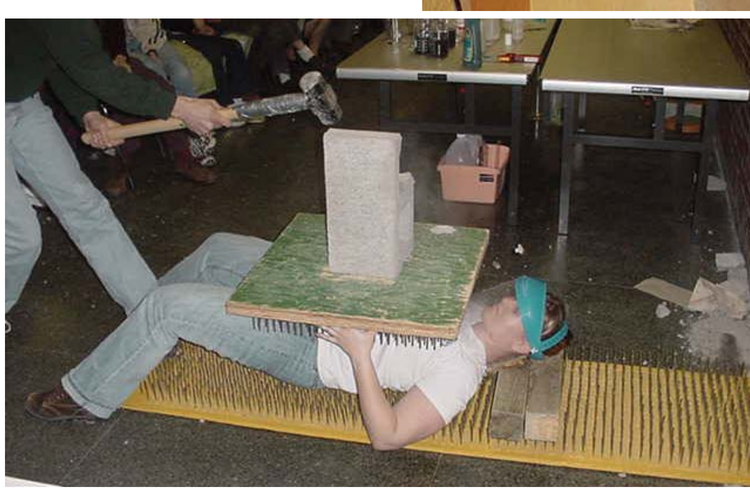


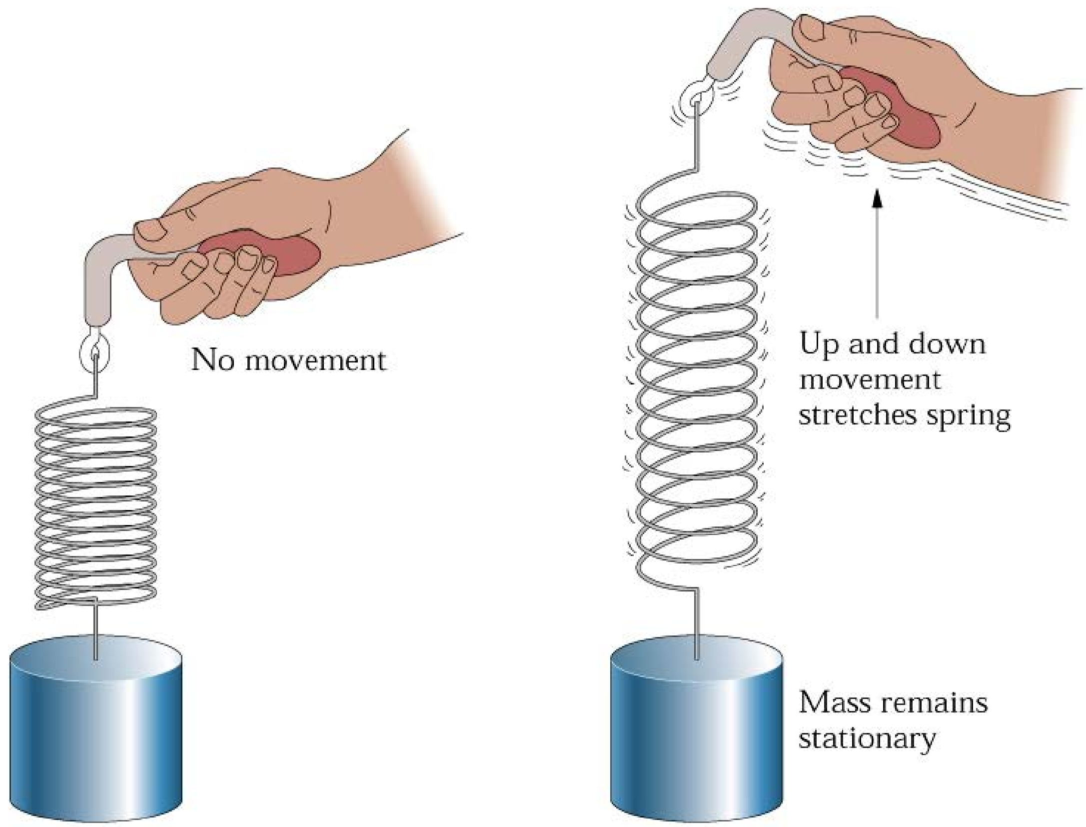
Pull quickly. Which string breaks?

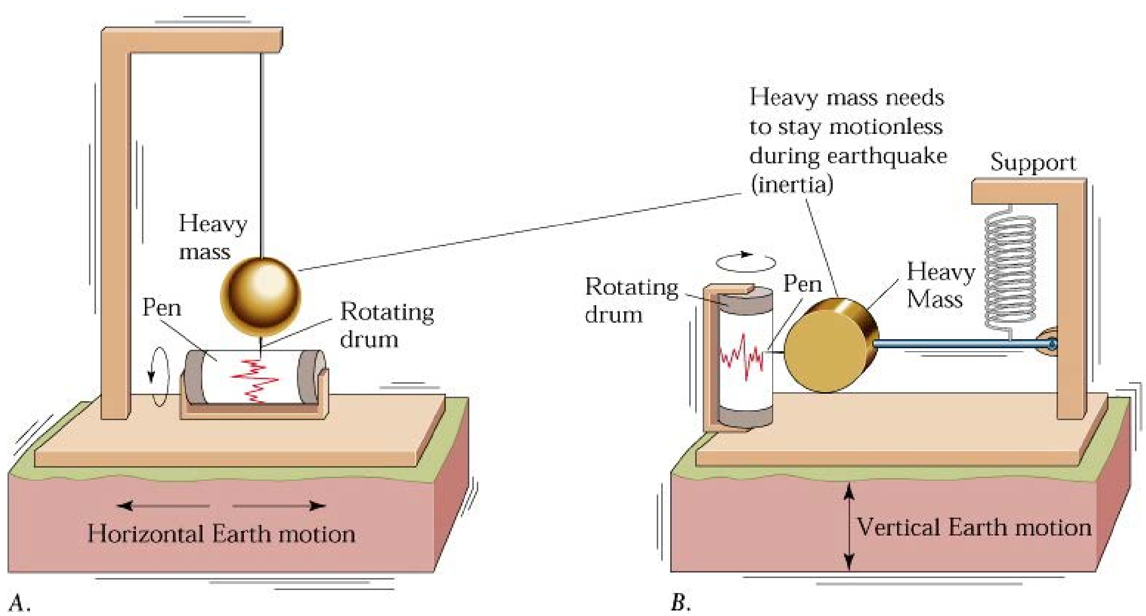
Pull slowly. Which string breaks?

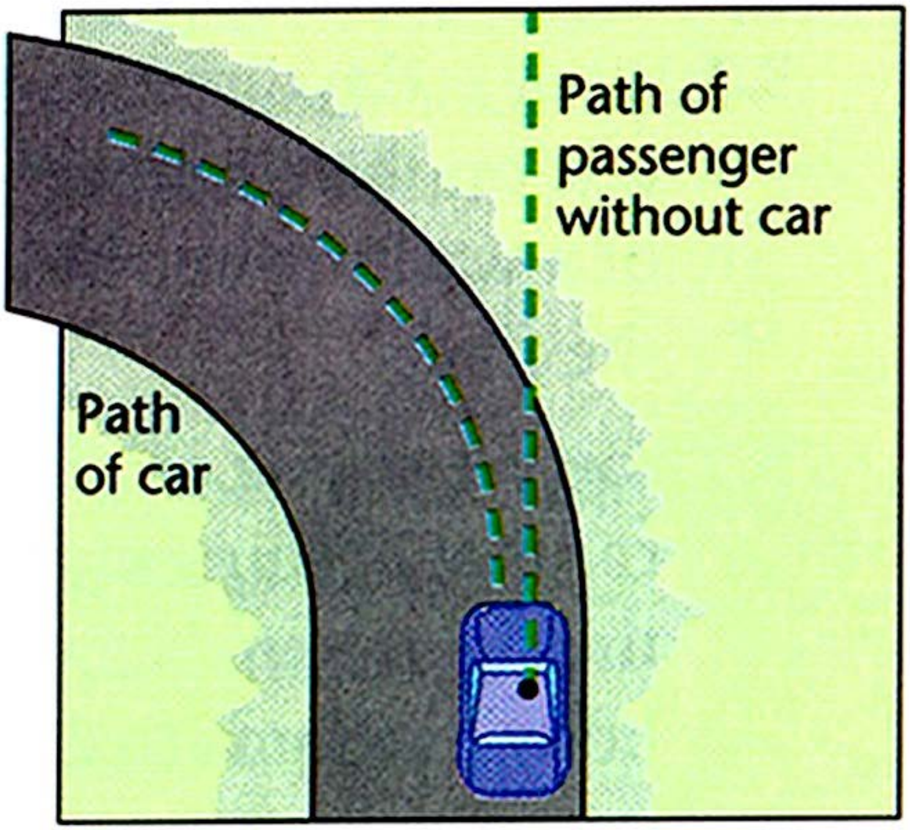




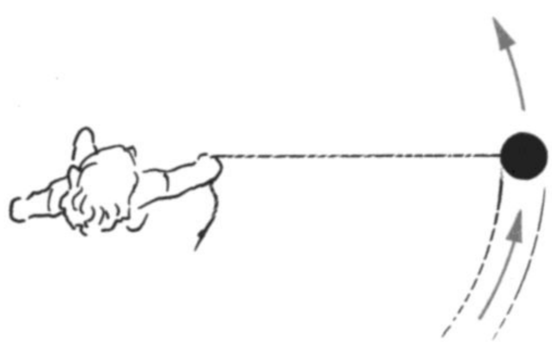



No movement
Up and down movement stretches spring
Mass remains stationary


Heavy mass
Pen
Rotating drum
Horizontal Earth motion
A.
Heavy mass needs to stay motionless during earthquake (inertia)
Support
Rotating drum
Pen
Heavy Mass
Vertical Earth motion
B.



String Break



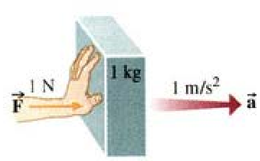
Car and Curve Speed and Curves Foucalt Pendulum 01 Foucalt Pendulum 02

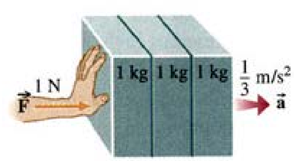
Newton's Second Law of Motion

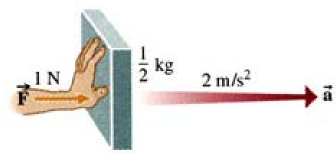
$$\vec{a} \propto \vec{F}_{\text{net}} \qquad \vec{a} \propto \frac{1}{m}$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

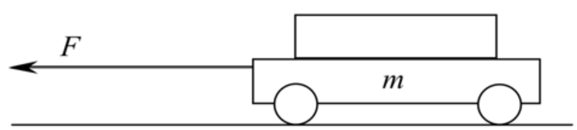
$$1\ \text{N} = 1\frac{\text{kg} \cdot \text{m}}{\text{s}^2}$$



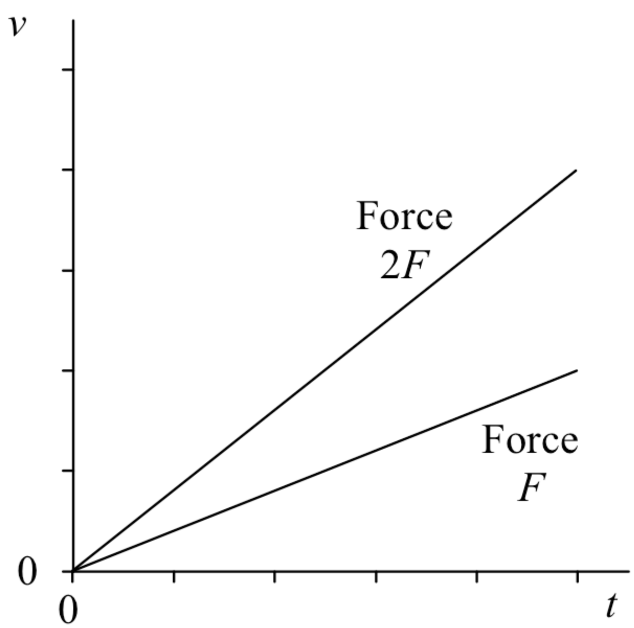




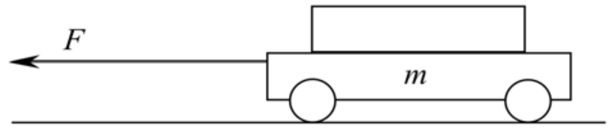
The cart shown at the right has a total mass *m* and is being pulled along a frictionless surface by a force *F*. Sketch a velocity-time graph showing the theoretical motion of the object. Show how the graph would differ if the cart were pulled with a force 2*F*.



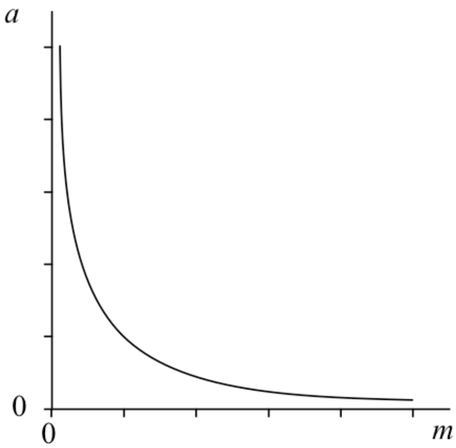
$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$$

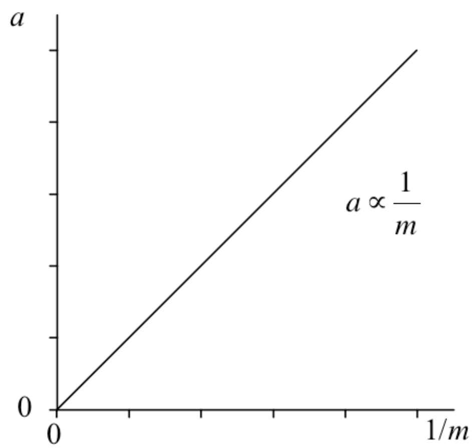


The cart shown at the right has a total mass m and is being pulled along a frictionless surface by a force F. Sketch an acceleration-mass graph showing how the acceleration of the car would vary if mass were gradually increased in consecutive experimental trials. Show how this nonlinear graph would appear if acceleration were plotted versus the reciprocal of mass.



$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$$





What is the acceleration of a 60 kg skater acted upon by a horizontal force of 150 N [W]?

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$$

$$= \frac{150 \text{ N [W]}}{60 \text{ kg}}$$

$$= 2.5 \text{ m/s}^2 \text{ [W]}$$

A worker applies a horizontal force of 400 N [E] to a 50 kg box located on a level floor. If frictional resistance amounts to 300 N, what is the resulting acceleration of the trunk?

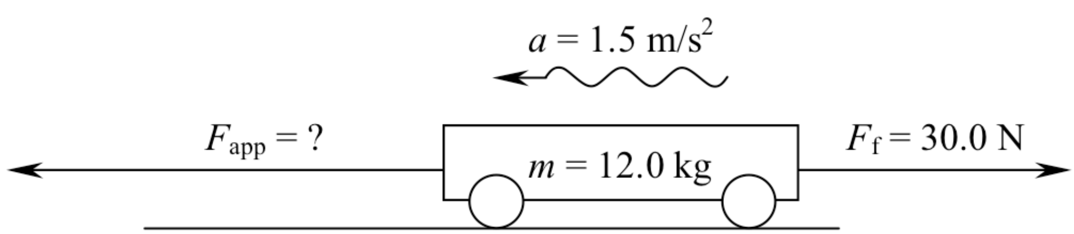
$$\begin{aligned} \vec{F}_{net} &= 400\text{ N [E]} + 300\text{ N [W]} \\ &= +400\text{ N} + (-300\text{ N}) \\ &= +100\text{ N} \\ &= 100\text{ N [E]} \end{aligned}$$

$$\begin{aligned} \vec{a} &= \frac{\vec{F}_{net}}{m} \\ &= \frac{100\text{ N [E]}}{50\text{ kg}} \\ &= 2.0\text{ m/s}^2\text{ [E]} \end{aligned}$$

W $- \longleftrightarrow +$ **E**

A boy pushes horizontally toward the west against a 12 kg wagon causing it to accelerate at 1.5 m/s^2 [W]. If the total frictional force is 30 N, what force is the boy applying?

W $- \longleftrightarrow +$ **E**



$$\begin{aligned} \vec{F}_{net} &= m\vec{a} \\ &= (12.0\text{ kg})(-1.5\text{ m/s}^2) \\ &= -18\text{ N} \end{aligned}$$

$$\begin{aligned} \vec{F}_{net} &= \vec{F}_{app} + \vec{F}_{f} \\ -18\text{ N} &= \vec{F}_{app} + (+30.0\text{ N}) \\ \vec{F}_{app} &= -48\text{ N} \\ \vec{F}_{app} &= 48\text{ N [W]} \end{aligned}$$

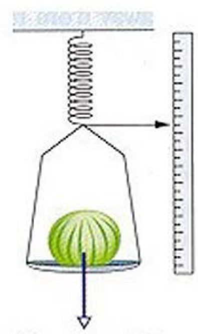
Newton's First and Second Laws Game

Mass

- Mass is a property related to how much matter an object has and how much inertia it has.
- The base unit of mass is the kg.
- Mass is measured with a balance.
- The mass of an object remains the same when the object is moved to other places in the universe.

Weight

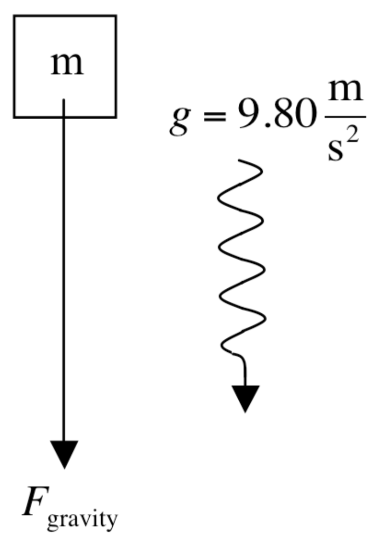
- Weight is the force of gravity acting on an object.
- Weight is measured in N.
- Weight is measured with a Newton spring scale.
- The weight of an object changes as the object is moved to other places in the universe.

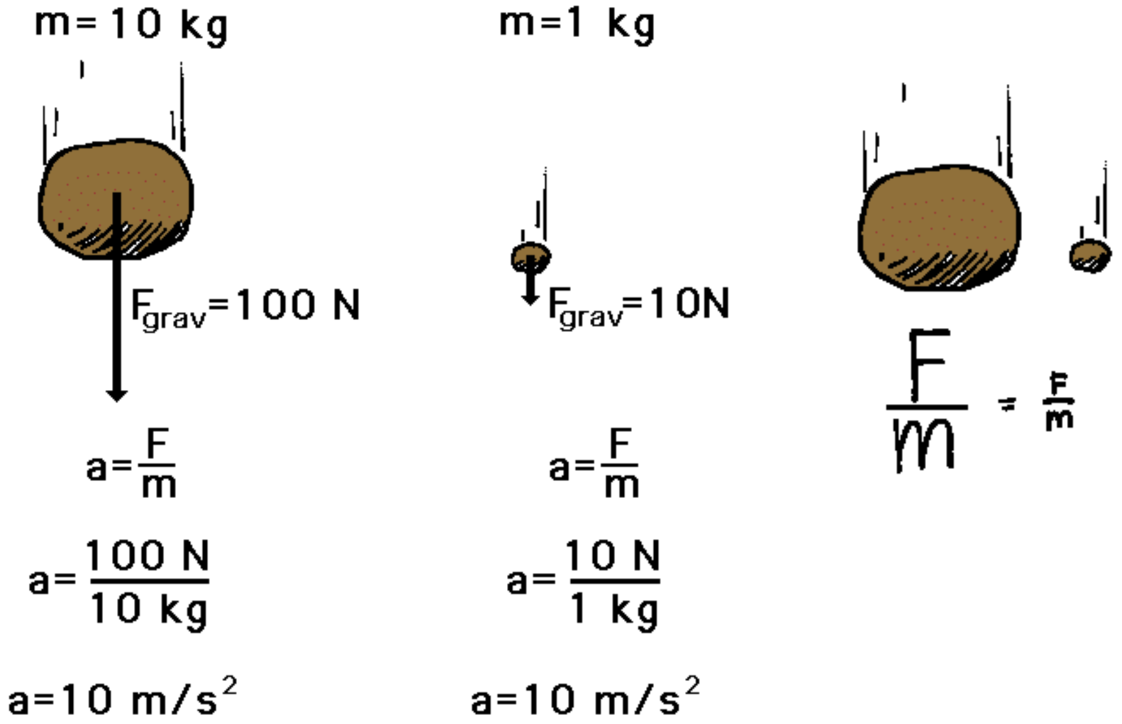


$$\vec{F}_{\text{net}} = m\vec{a}$$

$$\vec{F}_{\text{gravity}} = m\vec{g}$$

$$\text{weight} = m\vec{g}$$



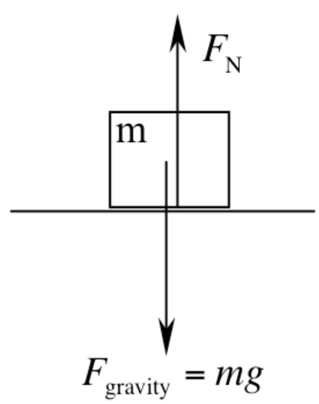


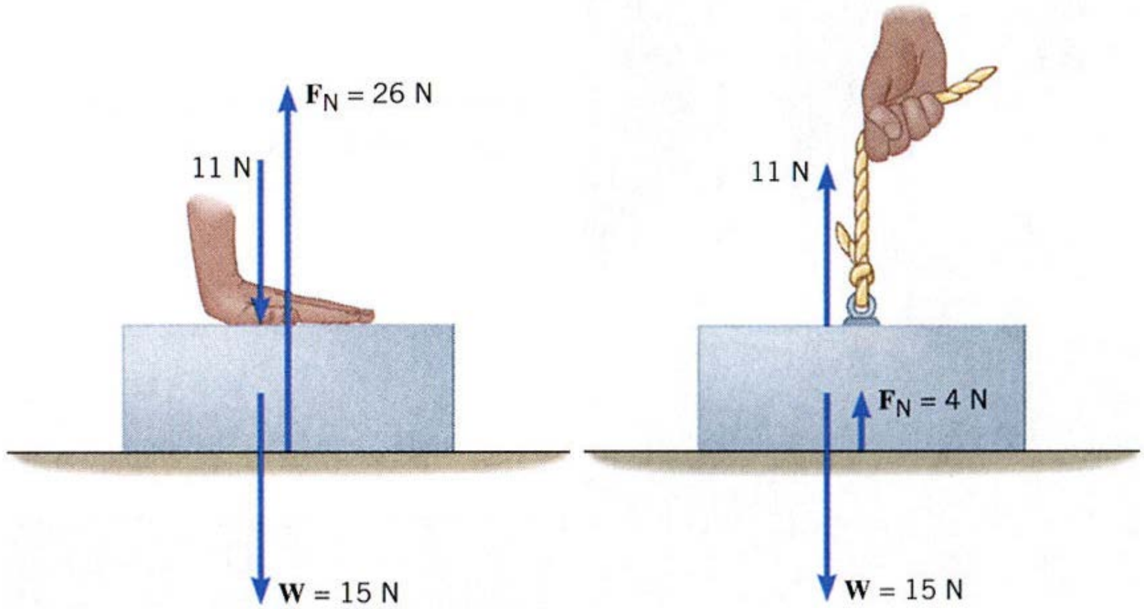
Normal force (F_N) is defined as a force that supports an object and acts perpendicular to the surface against which an object rests.

Example: Make a free-body diagram for an object that is at rest on a horizontal surface. Use Newton's second law, along with the fact that the acceleration of the object is zero, to prove that $F_N = -mg$.

$$F_{net} = ma, \text{ but } a = 0$$
$$\therefore F_{net} = 0$$

$$F_{net} = mg + F_N$$
$$0 = mg + F_N$$
$$F_N = -mg$$





The normal force acting on an object may vary, depending on other forces.

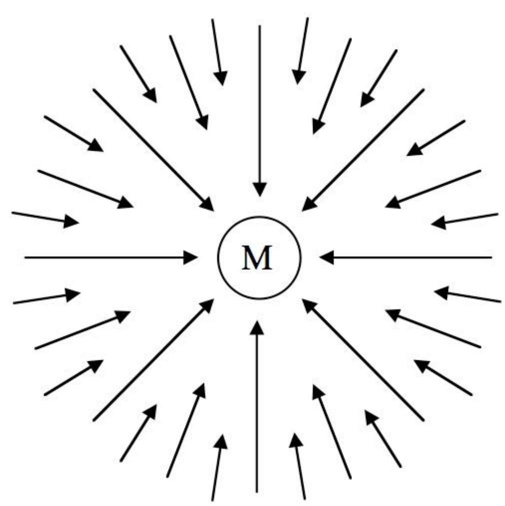
Gravitational field strength (g) is the amount of force exerted on 1 kg of mass by a gravitational field.

$$F = mg$$

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

Units:

$$g = \frac{\mathrm{N}}{\mathrm{kg}}$$



A student measures the weight of a 454 gram mass and finds it to be 4.46 N. What is the local gravitational field strength?

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

$$= \frac{4.46\ \text{N}}{0.454\ \text{kg}}$$

$$= 9.82\ \text{N/kg}$$