Types of Forces

Unit: Forces in One Dimension

NGSS Standards/MA Curriculum Frameworks (2016): HS-PS2-10(MA)

AP® Physics 1 Learning Objectives/Essential Knowledge (2024): 2.2.A, 2.2.A.1, 2.2.A.2, 2.3.A, 2.3.A.1, 2.3.A.3, 2.6.A, 2.6.A.2, 2.6.A.3, 2.7.A, 2.7.A.1, 2.7.B.1

Mastery Objective(s): (Students will be able to…)

- Identify the forces acting on an object.

Success Criteria:

- Students correctly identify all forces, including contact forces such as friction, tension and the normal force.

Language Objectives:

- Identify and describe the forces acting on an object.

Tier 2 Vocabulary: force, tension, normal

Labs, Activities & Demonstrations:

- Tie a rope to a chair or stool and pull it.

Notes:

force: ($\vec{F}$, vector quantity) a push or pull on an object.

reaction force: a force that is created in reaction to the action of another force, as described by Newton's Third Law. Examples include friction and the normal force. Tension is both an applied force and a reaction force.

opposing force: a force in the opposite direction of another force, which reduces the effect of the original force. Examples include friction, the normal force, and the spring force (the force exerted by a spring).

contact force: a force that is caused directly by the action of another force, and exists *only* while the objects are in contact and the other force is in effect. Contact forces are generally reaction forces and also opposing forces. Examples include friction and the normal force.

net force: the amount of force that remains on an object after the effects of all opposing forces cancel.

Note that if an object is not accelerating (either at rest or moving at constant velocity), there is no net force on the object *in any direction*; this means that forces in all opposing directions must cancel.

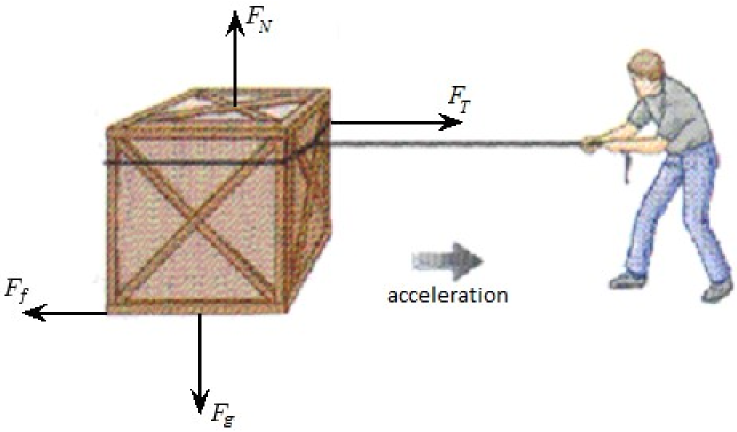
If an object is accelerating, there is uncancelled force *in the direction of the acceleration*; the forces in all other directions still cancel.

Use this space for summary and/or additional notes:

You can think of forces as the participants in a tug-of-war:

The net force is the amount of force that is not canceled by the other forces. It determines which direction the object will move, and with how much force.

An object can have several forces acting on it at once:



On the box in the above diagram, the forces are gravity ($\vec{F}_g$), the normal force ($\vec{F}_N$), the tension in the rope ($\vec{F}_T$), and friction ($\vec{F}_f$). Notice that in this problem, the arrow for tension is longer than the arrow for friction, because the force of tension is stronger than the force of friction.

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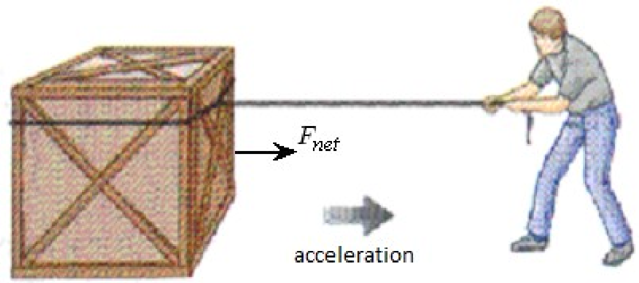
In the situation with the box above (after canceling out gravity and the normal force, and subtracting friction from the tension) the net force would be:



Because there is a ***net force*** to the right, the box will ***accelerate*** to the right as a result of the force.

Forces are what cause acceleration. If a net force acts on an object, the object will speed up, slow down or change direction. Remember that *if the object's velocity is not changing, there is no net force, which means all of the forces on the object must cancel.*

Physics problems are sometimes classified in the following categories:

statics: situations in which there is no net force on an object. (*I.e.,* the object is not accelerating.)

dynamics: situations in which there is a net force on an object. (*I.e.,* the object is accelerating.)

In the MKS system, the unit of force is the newton (N). One newton is defined as the amount of force that it would take to cause a 1 kg object to accelerate at a rate of $1\,\frac{\text{m}}{\text{s}^2}$.

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

Because the acceleration due to gravity on Earth is approximately $10\,\frac{\text{m}}{\text{s}^2}$, $\vec{\boldsymbol{F}} = m\vec{\boldsymbol{a}}$ becomes $\vec{\boldsymbol{F}}_g = m\vec{\boldsymbol{g}}$, which indicates that a 1 kg mass on Earth has a weight of approximately 10 N.

In more familiar units, one newton is approximately 3.6 ounces, which happens to be the weight of an average-sized apple. One pound is approximately 4.5 N.

Use this space for summary and/or additional notes:

Types of Forces

Weight ($\vec{F}_g, \vec{F}_w$)

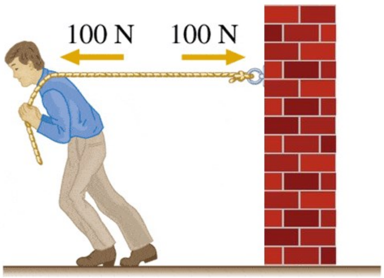
Weight ($\vec{F}_g, \vec{w}, m\vec{g}$) is what we call the action of the gravitational force. It is the downward force on an object that has mass, caused by the gravitational attraction between the object and another massive object, such as the Earth. The direction (assuming Earth) is always toward the center of the Earth.

In physics, we represent weight as the vector $\vec{F}_g$. The force of gravity is the mass of the object times the strength of the Earth's gravitational field, $\vec{g}$, which is $10\,\frac{\text{N}}{\text{kg}}$ Note that from Newton's second law, $\vec{F}_{net} = m\vec{a}$. This means that if an object is in free fall, the net force is equal to the gravitational force, and its acceleration is therefore $10\,\frac{\text{m}}{\text{s}^2}$.

Tension ($\vec{F}_T$)

Tension ($\vec{F}_T, \vec{T}$) is the pulling force on a rope, string, chain, cable, *etc.* Tension is its own reaction force; ***tension always applies in both directions at once***. The direction of any tension force is along the rope, chain, *etc.*

For example, in the following picture the person pulls on the rope with a force of 100 N. The rope transmits the force to the wall, which causes a reaction force (also tension) of 100 N in the opposite direction. The reaction force pulls on the person. The two tension forces cancel, which means there is no net force. (This is evident, because neither the person nor the wall is accelerating.)



Thrust ($\vec{F}_t$)

Thrust is any kind of pushing force, which can be anything from a person pushing on a cart to the engine of an airplane pushing the plane forward. The direction is the direction of the push.

Spring Force ($\vec{F}_s$)

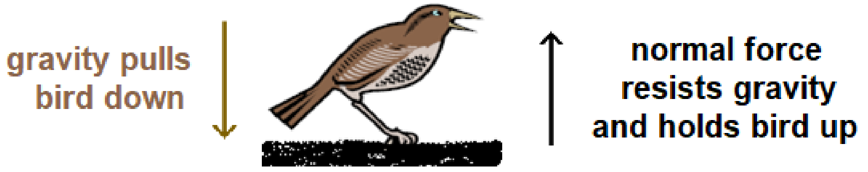
The spring force is an elastic force exerted by a spring, elastic (rubber band), *etc.* The spring force is a *reaction* force and a *restorative* force; if you pull or push a spring away from its equilibrium (rest) position, it will exert a force that attempts to return itself to that position. The direction is toward the equilibrium point.

Use this space for summary and/or additional notes:

Normal Force ($\vec{F}_N$)

The normal force ($\vec{F}_N$, $\vec{N}$) is a force exerted by a surface (such as the ground or a wall) that resists a force exerted on that surface. The normal force is always perpendicular to the surface. (This use of the word "normal" comes from mathematics and means "perpendicular".) The normal force is both a *contact* force and a *reaction* force.

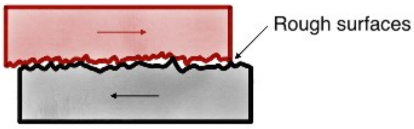
For example, if you push on a wall with a force of 10 N and the wall doesn't move, that means the force you apply causes the wall to apply a normal force of 10 N pushing back. The normal force is created by your pushing force, and it continues for as long as you continue pushing.



Friction ($\vec{F}_f$)

Friction ($\vec{F}_f$, $\vec{f}$) is a force that opposes sliding (or attempted sliding) of one surface along another. Friction is both a *contact* force and a *reaction* force. Friction is always parallel to the interface between the two surfaces.

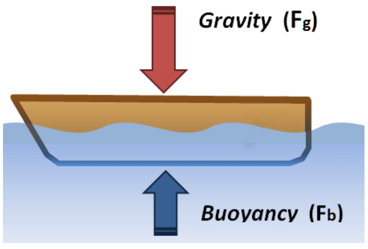
Friction is caused by the roughness of the materials in contact, deformations in the materials, and/or molecular attraction between materials. Frictional forces are parallel to the plane of contact between two surfaces, and opposite to the direction of motion or applied force.



Friction is discussed in more detail in the Friction section, starting on page 313.

Buoyancy ($\vec{F}_b$)

Buoyancy, or the buoyant force, is an upward force exerted by a fluid. The buoyant force is both a *contact force* and a *reaction force*, and causes (or attempts to cause) objects to float. The buoyant force is caused when an object displaces a fluid (pushes it out of the way), causing the fluid level to rise. Gravity pulls down on the fluid, and the weight of the fluid attempting to displace the object causes a lifting force on the object. The direction of the buoyant force is always opposite to gravity. Buoyancy is discussed in detail starting on page 531, as part of the *Fluids* unit.



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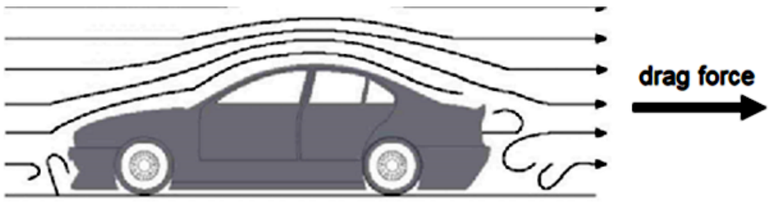
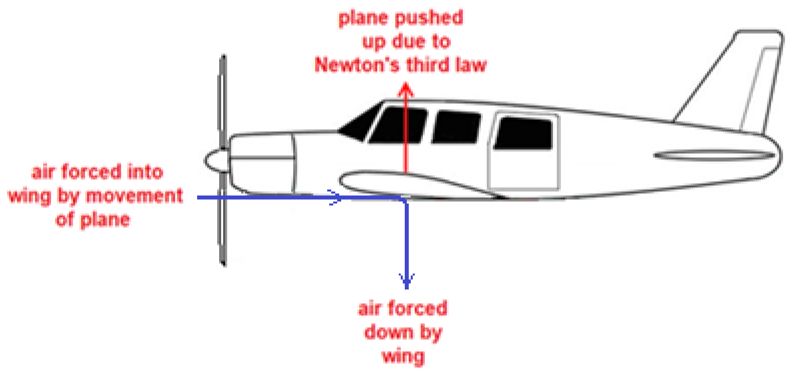
Drag ($\vec{F}_D$)

Drag is the opposing force from the particles of a fluid (liquid or gas) as an object moves through it. Drag is similar to friction; it is a contact force and a reaction force because it is caused by the relative motion of the object through the fluid, and it opposes the motion of the object. The direction is therefore opposite to the direction of motion of the object relative to the fluid. An object at rest does not push through any particles and therefore does not create drag. The drag force is described in more detail in the Drag section starting on page 322.



Lift ($\vec{F}_L$)

Lift is a reaction force caused by an object moving through a fluid at an angle. The object pushes the fluid downward, which causes a reaction force pushing the object upward. The term is most commonly used to describe the upward force on an airplane wing.



Electrostatic Force ($\vec{F}_e$)

The electrostatic force is a force of attraction or repulsion between objects that have an electrical charge. Like charges repel and opposite charges attract. The electrostatic force is studied in physics 2.

Magnetic Force ($\vec{F}_B$)

The magnetic force is a force of attraction or repulsion between objects that have the property of magnetism. Magnetism is caused by the "spin" property of electrons. Like magnetic poles repel and opposite magnetic poles attract. Magnetism is studied in physics 2.

Use this space for summary and/or additional notes:

Summary of Common Forces

Force	Symbol	Definition	Direction
weight (gravitational force)	$\vec{F}_g$, $\vec{F}_w$	pull by the Earth (or some other very large object) on an object with mass	toward the ground (or center of mass of the large object)
tension	$\vec{F}_T$	pull by a rope/string/cable	along the string/rope/cable
thrust	$\vec{F}_t$	push that accelerates objects such as rockets, planes & cars	in the direction of the push
spring	$\vec{F}_s$	push or pull reaction force exerted by a spring	opposite to the displacement from equilibrium
normal (perpendicular)	$\vec{F}_N$	contact/reaction force by a surface on an object	perpendicular to and away from surface
friction	$\vec{F}_f$	contact/reaction force that opposes sliding between surfaces	parallel to surface; opposite to direction of motion or applied force
buoyancy	$\vec{F}_b$	upward reaction force by a fluid on partially/completely submerged objects	opposite to gravity
drag (air/water resistance)	$\vec{F}_D$	reaction force caused by the molecules of a gas or liquid as an object moves through it	opposite to direction of motion
lift	$\vec{F}_L$	upward reaction force by a fluid (liquid or gas) on an object (such as an airplane wing) moving through it very fast at an angle	opposite to gravity
electrostatic force	$\vec{F}_e$	attractive or repulsive force between objects with electric charge	like charges repel; opposite charges attract
magnetic force	$\vec{F}_B$	attractive or repulsive force between objects with magnetism	like magnetic poles repel; opposite poles attract

CP1 & honors (not AP®)

Extension

The rate of change of force with respect to time is called "yank": $\vec{Y} = \frac{\Delta \vec{F}}{\Delta t}$. Just as $\vec{F} = m\vec{a}$, yank is the product of mass times jerk: $\vec{Y} = m\vec{j}$.

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