Linear Forces

Unit: Dynamics (Forces) & Gravitation

NGSS Standards: HS-PS2-1

MA Curriculum Frameworks (2006): 1.5

AP Physics 1 Learning Objectives: 3.A.2.1, 3.A.4.1, 3.C.4.1, 3.C.4.2, 4.A.2.2

Knowledge/Understanding Goals:

- what force is
- net force
- types of forces

Skills:

- identify the forces acting on an object

Language Objectives:

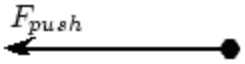
- Understand and correctly use the terms "force," "normal force," "contact force," "opposing force," and "weight."
- Accurately describe and apply the concepts described in this section using appropriate academic language.

Labs, Activities & Demonstrations:

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

Notes:

force: (vector) a push or pull on an object.



weight: the force of gravity pulling an object downward. In physics, we represent weight as the vector $\vec{F}_g$. Note that from Newton's second law, $\vec{F}_g = m\vec{g}$, which means on Earth, $\vec{F}_g = m(10)$.

opposing force: a force in the opposite direction of another force that reduces the effect of the original force.

net force: the overall force on an object after opposing forces cancel out.

contact force: a opposing force that exists only while another force is acting on an object. Examples include friction and the normal force.

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normal force: a force exerted by a surface (such as the ground or a wall) that resists the force of gravity on an object.

Because force is a vector, two forces in opposite directions counteract each other; if the magnitudes are equal, the forces completely cancel. For example, in the following picture:

the forces acting on the bird are:

- gravity, which is pulling the bird down, and
- the force from the ground, which is pushing the bird up.

The force from the ground is called the ***normal*** force. (The term "normal" is borrowed from math and means "perpendicular".)

The normal force is the force exerted by a surface (such as the ground, a table, or a wall) that counteracts another force on the object. The normal force is called a ***contact force***, because it is caused by the action of another force, and it exists *only* while the objects are in contact. The normal force is also an ***opposing force*** because it acts in the opposite direction from the applied force, and acts to lessen or diminish the applied 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 to the wall causes a normal force of 10 N pushing back from the wall. This normal force continues for as long as you continue pushing.

friction: Like the normal force, friction is also both a contact force (caused by the action of another force) and an opposing force. The direction of friction is parallel to the surfaces that are in contact, and opposite to the direction of motion.

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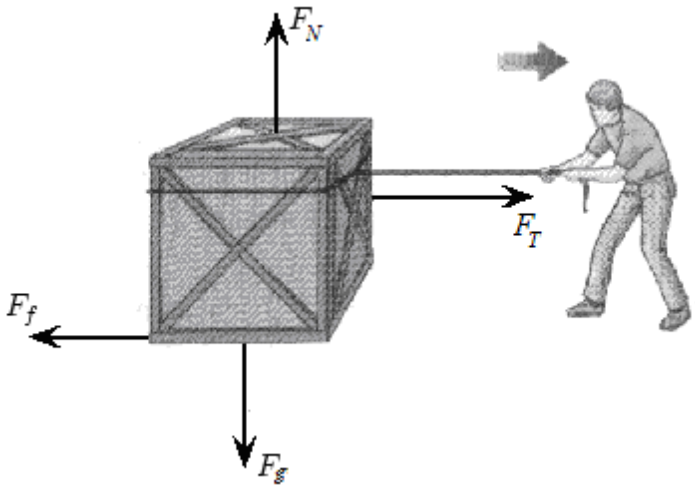
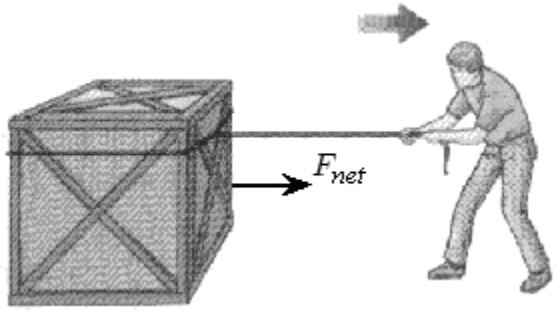
An object can have several forces acting on it at once:



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.

net force: the remaining force on an object after canceling opposing forces. The net force on the box (after canceling out gravity and the normal force, and subtracting friction from the tension) would be represented as:



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

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

In the above situation, the net force is in the direction that the ropes will move.

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 cancel.*

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 $1\,\frac{m}{s^2}$.

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

Because the acceleration due to gravity on Earth is approximately $10\,\frac{m}{s^2}$, $\vec{F} = m\vec{a}$ indicates that a 1 kg mass on Earth would have a weight of approximately 10 N.

In more familiar terms, one newton is approximately 3.6 ounces, which is the weight of a medium-sized apple. One pound is approximately 4.5 N.

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Common Types of Forces

Force	Symbol	Definition	Direction
gravity (weight)	$\vec{F}_g$, $\vec{w}$, $m\vec{g}$	pull of gravity by the Earth (or some other celestial body) on an object with mass	toward the ground (or center of mass of the celestial body)
tension	$\vec{F}_T$, $\vec{T}$	pull exerted by a rope/string/cable	away from the object in the direction of the string/rope/cable
normal	$\vec{F}_N$, $\vec{N}$	contact force by a surface on an object	perpendicular to and away from surface
friction	$\vec{F}_f$, $\vec{f}$	contact force that opposes sliding between surfaces	parallel to surface; opposite to direction of applied force
thrust	$\vec{F}_t$	push that accelerates objects such as rockets, planes & cars	in the same direction as acceleration
spring	$\vec{F}_s$	the push or pull exerted by a spring	opposite the displacement of the object
buoyancy	$\vec{F}_B$	the upward force by a fluid on objects less dense than the fluid	opposite to gravity
drag	$\vec{F}_D$	friction caused by the molecules of a fluid as an object moves through it	opposite to the direction of motion
lift	$\vec{F}_\ell$	the upward push (reaction force) by a fluid on an object (such as an airplane wing) moving through it at an "angle of attack"	opposite to gravity.

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Force	Symbol	Definition	Direction
electrostatic	$\vec{F}_e$	the attraction or repulsion between two objects with an electric charge	like charges repel; opposite charges attract
magnetic	$\vec{F}_B$, $\vec{F}_M$	the magnetic attraction or repulsion between two objects	like magnetic poles repel; opposite poles attract

You may have noticed that both buoyancy and magnetic force can use the same subscript ($\vec{F}_B$). This should not cause too much confusion, because there are very few situations in which both forces would be applied to the same object. If that were to happen, we would use $\vec{F}_B$ for the buoyant force and $\vec{F}_M$ for the magnetic force.

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: $\vec{Y} = m\vec{j}$. Problems involving yank have not been see on the AP exam.

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