Forces

How do we get an object at rest to move?

force: a push or pull of one body on another which tends to change the state of motion or shape of an object
> shape change; ex; push on wall ----> imperceptible shape change.

Forces which act on bodies are of two families:

1) contact - physical contact exists between bodies [ex; friction]
2) field - bodies disconnected from each other are moved by a "force-field" [*a.k.a.* "action at a distance"]
[ex.'s; gravitation, magnetic, electric]

> The types of forces are;

> tensile - a force which tends to elongate a substance
> compressional - a force which tends to shorten a substance
> shearing - a force which tends to force one part of a substance to slide over an adjacent part
> torsional - a force which tends to twist a substance
∗ transverse - a force which tends to bend a substance [combination of tension & compression: bend a bar]

What forces are acting on an object at rest?

gravity, normal, friction?

*When forces are **balanced**, there will be no change in motion. [ex; person standing on floor.]
An objects' motion (speed or direction) will change only when "**unbalanced**" force(s) are acting on it.

friction (f): a force of resistance which opposes all efforts to slide or roll one body over another
Note that friction does not appear unless there is an unbalanced force acting on the body.

mechanics: the science which treats the motion of bodies [Rest being a special case of motion!]

How can we explain the behavior of objects in motion?

Dynamics is the study of the motion of matter under the influence of forces.

In Galileo's "Dialogue on the New Sciences" he puts forth some ideas which would be translated by Newton.

1) *If no force acts on a body it will continue to move uniformly both in speed and direction.*

2) *When a force acts, the motion changes either in speed or direction or both, at a pace proportional to the magnitude of the force, and in the same direction as that in which the force acts.*

Isaac Newton (1642-1727)

In 1684 Edmund Halley asks Newton to prove Kepler's laws mathematically (at Halley's expense). The result was the *Philosophiane naturalis principia mathematica* (Mathematical principles of natural philosophy), or commonly just called the "***Principia***." Published in 1687, it contains his philosophy on the **3 laws of motion** & **gravitation**. *a.k.a.* "fundamental laws of dynamics"

1st law (inertia): "A body (S-L-G) tends to remain at rest (or remain in "straight-line" motion) unless it is acted on by an unbalanced force."
"**A body by itself is not capable of changing its condition of rest or motion**."
Any change in motion (even in a vacuum) requires a force.

Inertia is the tendency of a body to preserve its state of motion.

-Inertia is a property of mass, and is the resistance that mass offers to any change in its motion.

*The more mass a body has, the more inertia it has, and is better at resisting attempts to change its motion (ex; earth!) **Mass is also defined as a measure of an object's inertia!**

> Aristotle correctly believed that an object would only keep moving as long as a force was applied to it (otherwise motion ceased). *How did he explain how a discus kept moving once it left the throwers hand?*

-Air that was plowed backward would rush around discus filling the void, thus pushing the discus forward.

> Galileo was the first known to reason that no force was required to keep an object in motion. He proposed that the natural tendency for a moving object is to continue moving at a uniform speed in a straight line (when unaffected by an outside force). The concept "inertia" was later formalized Newton.

> In Galileo's Dialogue on Two New Sciences, he puts forth ideas which would be translated later by Newton such as; "*If no force acts on a body it will continue to move uniformly both in speed and direction*."

ex.'s; train quickly starts moving while a passenger is standing still / pull tablecloth / auto & plane accidents

* In a head-on auto accident, there is a 50% of death without wearing a seatbelt when moving at 30 mph!, headrests, skiing accidents ----> ~ 35 deaths/yr.
* A telescope dropped from the crow's nest of moving ship....object retains the motion of the ship immediately before its release. It has a **memory** (inertia) of the boat's forward motion and lands directly beneath where it was dropped.
* Early philosophers believed the earth to be motionless because a rock thrown upward did not fall backward.
* An astronaut pushes hard on a satellite in orbit, but having less inertia than the satellite, he is the one moved.
* Shake a very heavy anvil in outer space and it will shake you!

2nd law (acceleration): "*When an unbalanced force acts on a body, the body will accelerate in the direction of the force, and its acceleration is proportional to the force*." [F = ma]

*In Galileo's Dialogue on Two New Sciences; "*When a force acts, the motion changes either in speed, direction or both, at a pace proportional to the magnitude of the force, and in the same direction as that in which the force acts*."

What force is needed to accelerate a 1.0 kg by 1.0 m/s^2? **1.0 N** = 1.0 kg x 1.0 m/s^2

The Newton (N) is the standard unit of force in the MKS system.

In the CGS system: **1.0 dyne** = 1.0 gcm/s^2 = 10^{-5}N

1.0 N ~ 0.25 (0.225) lb, and **ironically is also equal to the attractional force between an apple and earth!**

> "*Aristotle says that an iron ball of one hundred pounds falling from a height of one hundred cubits reaches the ground before a one-pound ball has fallen a single cubit. I say they arrive at the same time*." Galileo ~ 1612

Why do objects of different masses accelerate at the same rate?

> If the force is doubled, then the acceleration is also doubled, but if the mass is doubled, the acceleration will not change because the inertia will also double, and a doubling of the force acting on the object will be required, thus all masses fall at the same rate!

$$a = F/m \quad \& \quad a = 2F/2m$$

How do you calculate your weight in Newtons?

Use second law: F = ma.

mass (m) -----> "quantity of matter in a body"

weight (W) ------> "force (pull) of gravity acting on mass" **W = m x g**

To convert pounds (lb) to kilograms (kg), where 1.0 kg = 2.2 lb, then multiply times (g) 9.8 m/s^2.

ex; 190 lb = 86.3 kg x 9.8 m/s^2 = 847 N

Are we "massless" in interstellar space?

3rd law (interaction): "*For every acting force in nature, there will be another force of equal magnitude and opposite direction opposing it*." [ex.'s; punch a wall, auto & skiing accidents, etc..]

-**Forces always occur in pairs (action - reaction) that are equal in magnitude, and opposite in direction**.
[ex's; walking, propeller, lawn sprinklers, gun recoil, helicopter height limitations - thin air & little reaction]

***A force can not be applied without <u>two</u> or more bodies interacting**.

-This implies a mutual **action - reaction** of bodies since one body can not exert a force on another unless there is a "**resistance**" upon it.

<u>resistance</u> ----> The reaction to an action.

How does your weight change in a moving elevator?

Due to one's inertia;

when the elevator is moving up more force is exerted on the floor.

when the elevator is moving down less force is exerted on the floor.

when the elevator is in free-fall no force is exerted on the floor. [weightless!]

How do astronauts get prepared for weightlessness?

>Discuss NASA's "vomit comet" - KC135 cargo plane ("weightless wonder") rises to 25,000 feet and dives for about 30 seconds, which generates a <u>micro</u>-gravity environment in free-fall.

At bottom ----> approximately 2g's, then another 45˚ climb (plane does about 40 parabolas).

The odds of a first-timer vomiting is one in three!