Newton's First Law of Motion (inertia)

Galileo (Copernicus) *vs.* Aristotle

(Earth moves in circular motion? Inertia? 5 min video from the "Mechanical Universe")

Every object continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it.

A system is at equilibrium (either at rest or in motion with constant velocity) in the absence of external force.

Mass m

is the intrinsic quantity of matter in an object. It is a measure of the inertia that an object exhibits in response to an effort to change its state of motion.

Units –

kg – in mks (meter-kilogram-second) system

slug – in British (foot-pound-second) system

1 sulg = 14.6 kg

Linear momentum $p = mv$

Newton's Second Law

The acceleration of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and is inversely proportional to the mass of the object, i.e.,

$$F_{net} = ma \quad \text{or} \quad a = F_{net} / m.$$

The rate of change of the linear momentum equals to the net force acting on an object, i.e.,

$$F_{net} = \Delta p / \Delta t = (m\Delta v)/\Delta t = m\,(\Delta v/\Delta t) = ma.$$

(The velocity changes by Δv in a time Δt.)

Weight W

Weight is the net force acting on a mass m due to gravity. Near the surface of the earth, weight

$W = mg.$

Units

N (Newton= kg-m/s^2) in mks system

lb (pound=slug-ft/s^2) in British system

1 kg is equivalent (but NOT equal) to 2.20 lb.

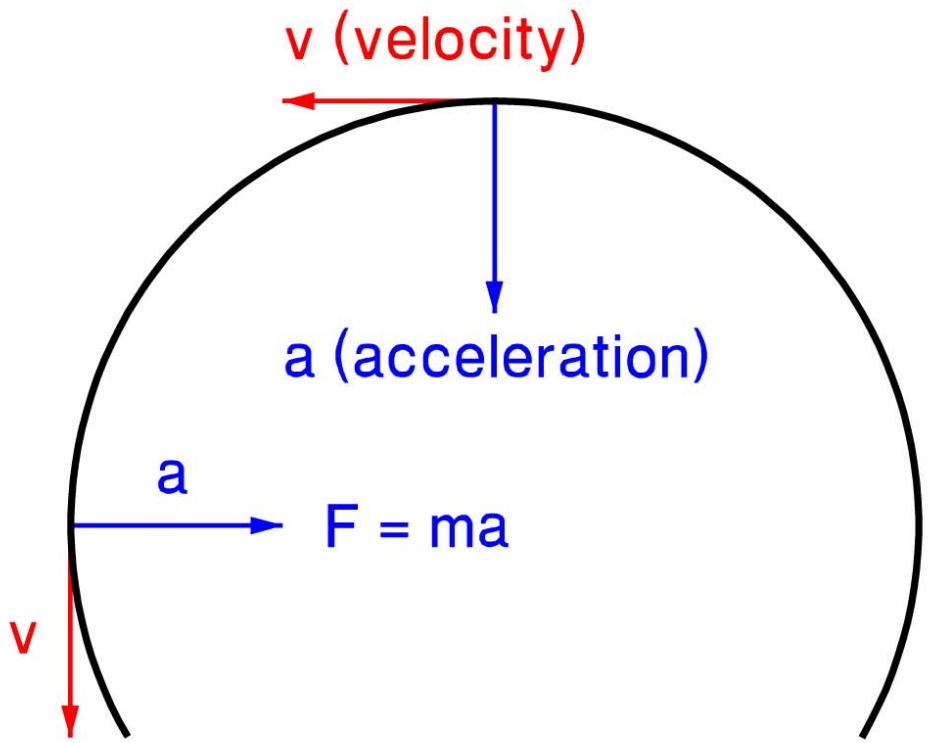
Near the surface of the earth,

$m = 60$ kg, $W = mg = 60 \times 10 = 600$ N.

Near the surface of the moon,

$g_{moon} = g_{earth}/6$ and $W_{moon} = W_{earth} / 6$.

Uniform circular motion



The acceleration (due to force F) only change the direction of the velocity, but, no the speed

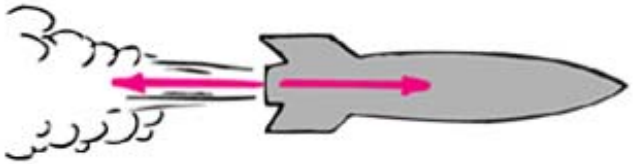
Free Fall due to gravity

Acceleration ($g = 10\ m/s^2$ or $32\ ft/s^2$) due to gravity has the same value for all objects independent of the mass of the object.

Newton's Third Law (action-reaction)

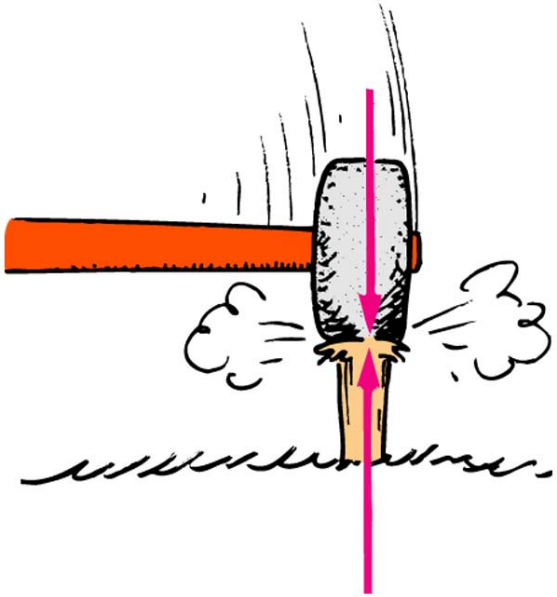
Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object.

Action: tire pushes on road Reaction: road pushes on tire



Action: rocket pushes on gas Reaction: gas pushes on rocket

Action: man pulls on spring Reaction: spring pulls on man



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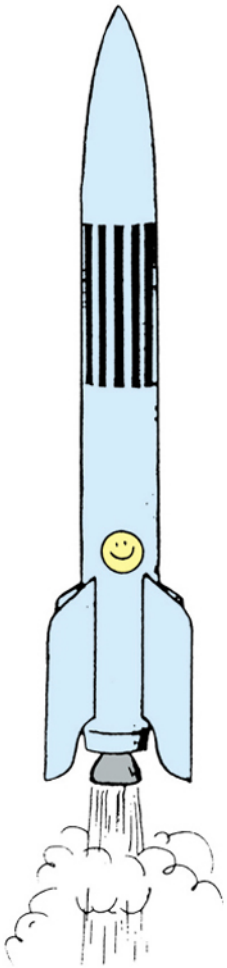

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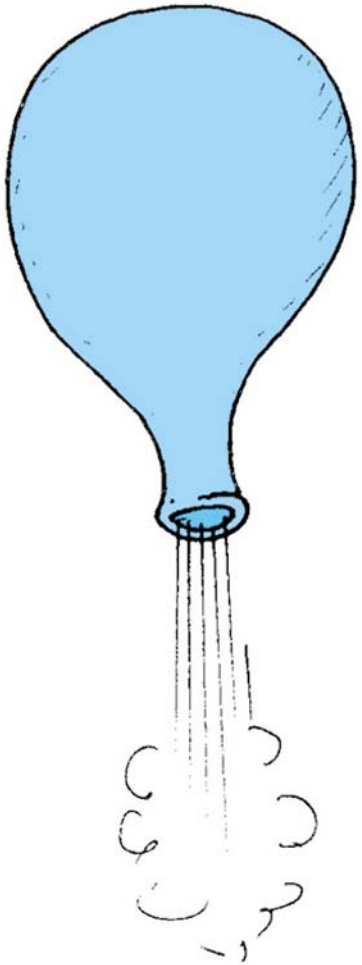

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Friction

Static friction

Keep the object from moving

Could be small or large (action-reaction)

Dynamic (sliding) friction

When in relative motion between two surfaces

Depending on the roughness (or smoothness) of the surface in terms of its frictional coefficient and the normal (perpendicular) force (action-reaction) between the two surfaces

Air resistance R (friction)

In the presence of air resistance, the free falling object is subject to a smaller acceleration "a" due to gravity.

$$ma = mg - R, \quad \text{or} \quad a = g - R/m$$

The air resistance is approximately proportional to the speed. As speed increases, the air resistance increases. If R = mg, the acceleration a = 0 and speed stays constant (terminal speed).

Chapter 3, example #2

A plane flies 800 km to city B from city A at 200 km/hr, then flies back from city A to city B at 160 km/hr. What is its average speed?

Ans: 178 km/hr.

Chapter 3, example #3

Estimate the height of a cliff if a stone initially at rest is dropped and a splash sound of the stone hitting the ground at the bottom of the cliff is heard after 4 sec.

Ans: Less that 80 m (it takes slightly over 0.5 sec. for the sound wave to travel back to the top of the cliff, otherwise, it would be 80 m.)

Chapter 3, example #4

How long it takes for a bullet to come back to the ground after it was fired vertically into the air with a muzzle speed of 800 m/sec.? What would be the speed of the bullet when it hits the ground?

Ans: About 160 sec. at the same speed, i.e., 800 m/sec.