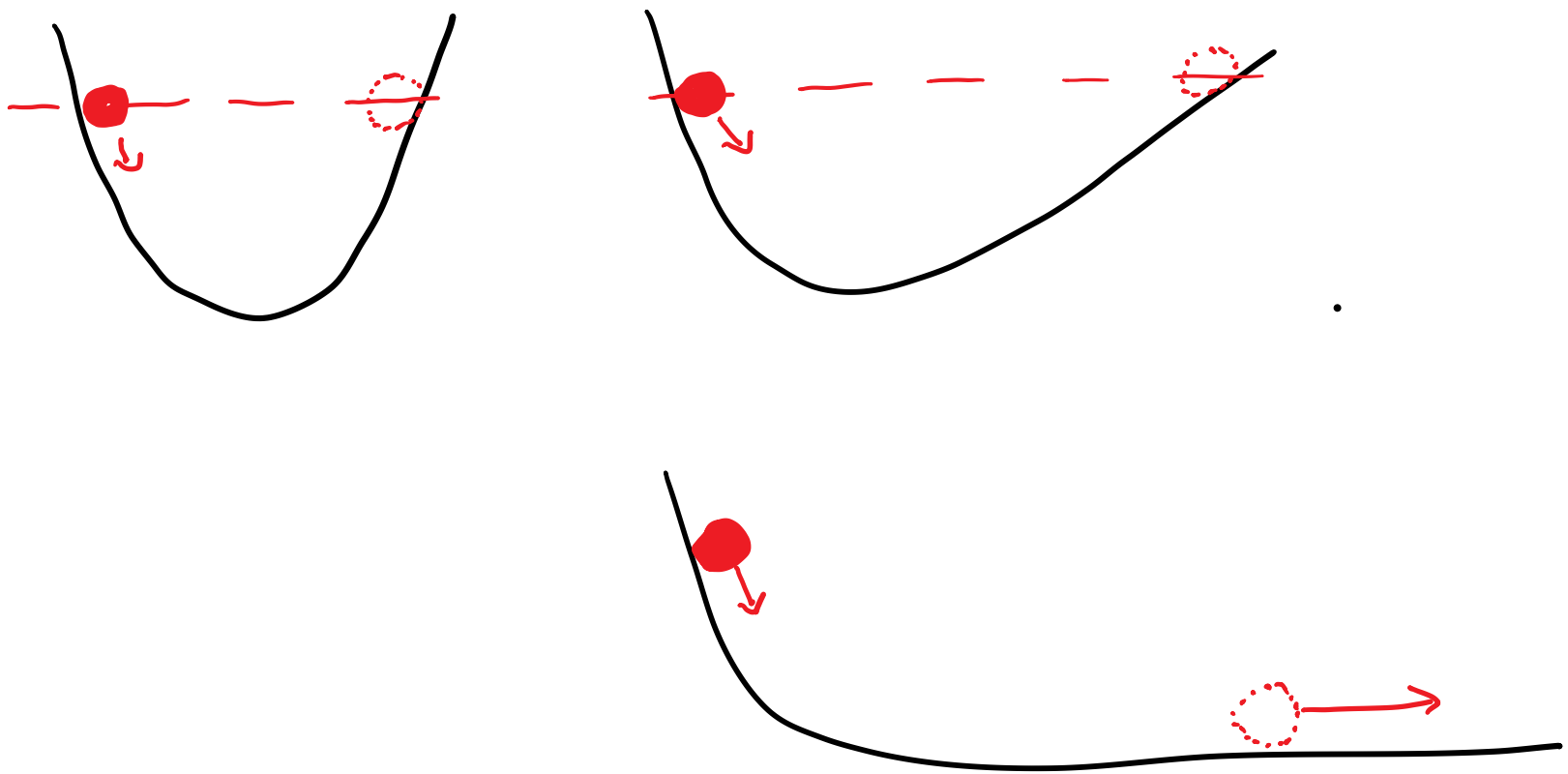
Lecture 11: Forces

- Forces
- Newton's 1st and 2nd Law
- Inertia
- Relationship between forces and acceleration
- Procedure for solving force problems

What is the “natural” state of an object left to itself?

Aristotle: to be at rest.

Galileo: to be in uniform motion with constant velocity.



Newton's 1st Law – Law of Inertia

Every body continues in its state of rest or of uniform speed in a straight line unless acted on by a nonzero force.

If no external force acts on an object, its velocity remains constant: $\Sigma\vec{F} = 0 \implies \vec{v} = constant$ *

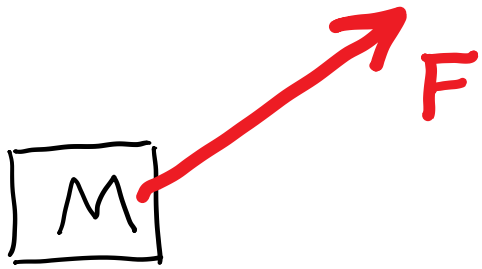
* Remember that **velocity** is a VECTOR, and has both direction and magnitude

Examples for forces

- Gravity (weight)
- Spring force
- Tension (ball held by rope)
- Friction
- Push/Pull
- Normal force

A force….

...is a push or pull
…acts on a object
…is a vector and has magnitude and direction



Stop to Think: Discussion Question

You throw a small ball straight up. Disregarding any effect of air resistance, what forces are acting on the ball until it returns to the ground?

A) a constant downward force of gravity only.

B) its weight vertically downward along with a steadily decreasing upward force.

C) a steadily decreasing upward force from the moment it leaves the hand until it reaches the highest point, beyond which there is a steadily increasing downward force of gravity.

A force….

...is a push or pull
…acts on a object
…is a vector and has magnitude and direction
…requires an agent
…is either a contact force or a long-range force (such as gravity)

Changes in velocity

If $\vec{v} = constant$ in magnitude and direction
$\Longrightarrow \vec{a} = 0$

Changes in velocity such as

- Stopping (or starting) an object
- Changing direction of motion
- Increasing/decreasing speed

require force.

Inertia

Observation:

Objects with greater weight are harder to accelerate.

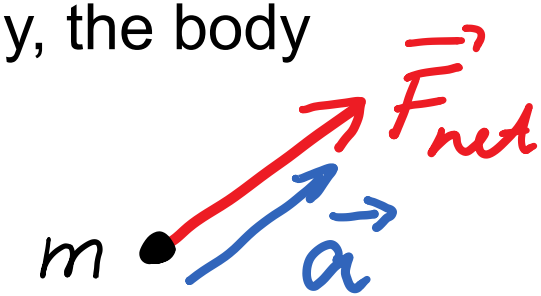
In deep space: no gravity, so no weight.
But objects still have intrinsic resistance to acceleration.

This resistance to changes in motion is called **inertia**,
and the quantity of resistance is called **mass** m.

Newton's 2nd Law

If a net external force acts on a body, the body accelerates.

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



$$\boxed{\Sigma\vec{F} = m\vec{a}}$$

*for object
with constant mass

Unit: $kg\ \frac{m}{s^2} = N$ Newton

Component version of Newton's 2nd Law

$$\vec{F}_{net} = \Sigma\vec{F} = m\vec{a} \quad *$$

*Net force also sometimes called resultant or total force

$$\Sigma F_x = ma_x$$
$$\Sigma F_y = ma_y$$

Because the axes are orthogonal, we can separately equate the *x*-components and the *y*-components.