# Summary for last week: Newton's 2nd Law + 1st Law

- $$\vec{\mathbf{F}}_{\text{resultant}} = \underbrace{\sum \vec{\mathbf{F}}_{\text{i}}}_{\substack{\text{all forces acting } \textbf{on} \text{ object} \\ \text{due to } \textbf{other} \text{ objects}}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \ldots + \vec{\mathbf{F}}_N = m\vec{\mathbf{a}}_{\text{Object}}$$

**if** we measure acceleration in an inertial coordinate system

# Newton's Third Law

- If object A exerts a force $\mathbf{F}_{AonB}$ on object B, there is an equal and opposite force
  $\mathbf{F}_{BonA} = - \mathbf{F}_{AonB}$ that B exerts on A.
- Both forces have exactly same magnitude, regardless of motion (acceleration) of either object.
- The two forces act on **different** bodies and in opposite direction. They are called a "Action-Reaction Pair".

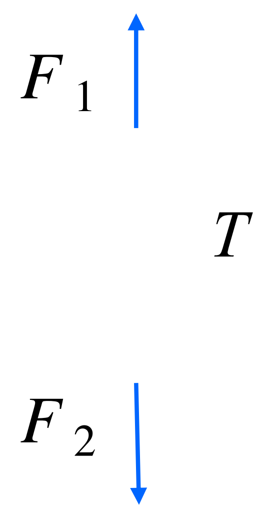
$$\Rightarrow \mathbf{F}_{Action} = - \mathbf{F}_{Reaction}$$

# Examples I

- Gravitational downwards Force $-m\mathbf{g}$ on object of mass m <=> equally strong upwards Force $+m\mathbf{g}$ on Earth
- Person pulling with force $\mathbf{F}$ on object <=> object pulls with force $-\mathbf{F}$ on person
- Person pushing object forward <=> object pushes back on person with equal force
- Weight of object $-m\mathbf{g}$ pushing down on support <=> support pushing object up with normal force $+m\mathbf{g}$ .
- Rocket “pushing out gas” - gas pushing rocket forward.

# Tension

- String, Rope, Chain etc.:
  Means of transmitting force from one point to another (even change direction using a pulley etc.)
- Forces acting at each end of string from action-reaction pair:
  - Equal in magnitude: $|\mathbf{F}_1| = |\mathbf{F}_2|$ = Tension in string*)
  - Opposite in direction
  - Tension is the same everywhere along the string
- Spring: will elongate proportional to tension
  - $T = k\Delta L$
  - Can be used to measure tension and therefore force




*) Ignoring any mass the string might have

# Important Points:

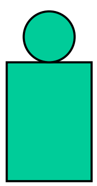
- For Newton's Second Law, use **only** forces acting **on** object to calculate $\Sigma\mathbf{F} = m\,\mathbf{a}$ , **not** reaction forces on other objects.
- No object can exert a net force on **itself** (Münchhausen trick): Force of one part on another exactly balanced by Reaction Force => total sum = zero.
- Nothing can **experience** a force without **exerting** a force
- HOWEVER: ***Effect*** of (reaction) force on **one** object may be a lot smaller than the effect of the (equal-sized) action force on the **other** object (cannon recoil…)
- Action+Reaction pair = INTERACTION (most fundamental; all forces are due to interactions)

# How can we tell that a force is acting (and how strong it is)?

- Operational definition based on Newton's Second Law.
- By looking at its effects:
  - the object (mass point) is accelerating
  - a solid is stretched or bent (spring [balance], rope, …)
- From our knowledge of Force Laws:
  - an object of mass $m$ will experience a force $F_y = -mg$ pointing downwards on the surface of Earth
  - A rope which is pulled with force of strength $|\mathbf{F}|$ at one end will exert force of same strength at its other end (in the direction of the rope) if it doesn't accelerate and its weight is negligible (Newton's 3rd Law).
  - General gravitational force law (later in semester), electromagnetism (even later in semester)…
- Through the magnitude of the reaction force

# Web of Forces and Masses

- Use Newton's 2nd and 3rd law to create relationships between known forces and masses and unknown ones:
- Masses:



SI kg

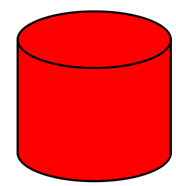
Force Laws: Gravitation

Known Forces: Springs

$\longrightarrow$

Compare accelerations (3rd Law, 2nd Law)

Balance forces (Superposition)



Unknown mass

- New Forces
  - Measure **a**, *m* (2nd Law)
  - Balance with known force (spring, pulley + weight,…)
  - Observe reaction (3rd Law)
  - Develop Force Law, apply to new situations