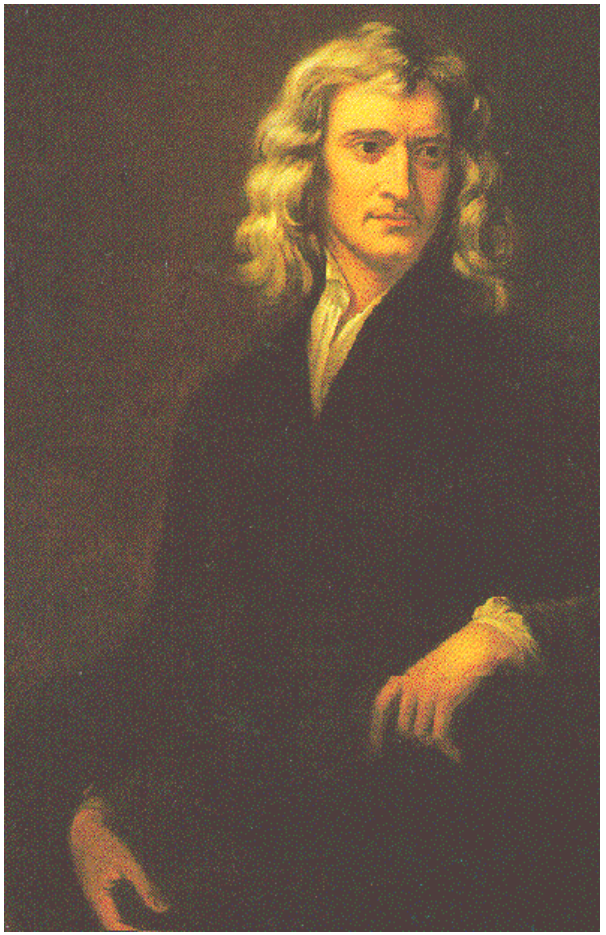
Newton's Laws of Motion

& Forces



Forces

- Forces are vectors, magnitude and direction are important
- unit of force in SI is the newton (symbol N)

- in basic units, $newton = kg \bullet \frac{m}{s^2}$

- to measure forces in newtons, mass **must** be in kg, acceleration in m/s^2

- weight is force acting on a mass due to gravity
- g = acceleration due to gravity

$$\vec{F}_g = m\vec{g}$$

In newtons

In kg

Example

- Determine the weight of a 451 g object.

$$\vec{F}_g = m\vec{g}$$

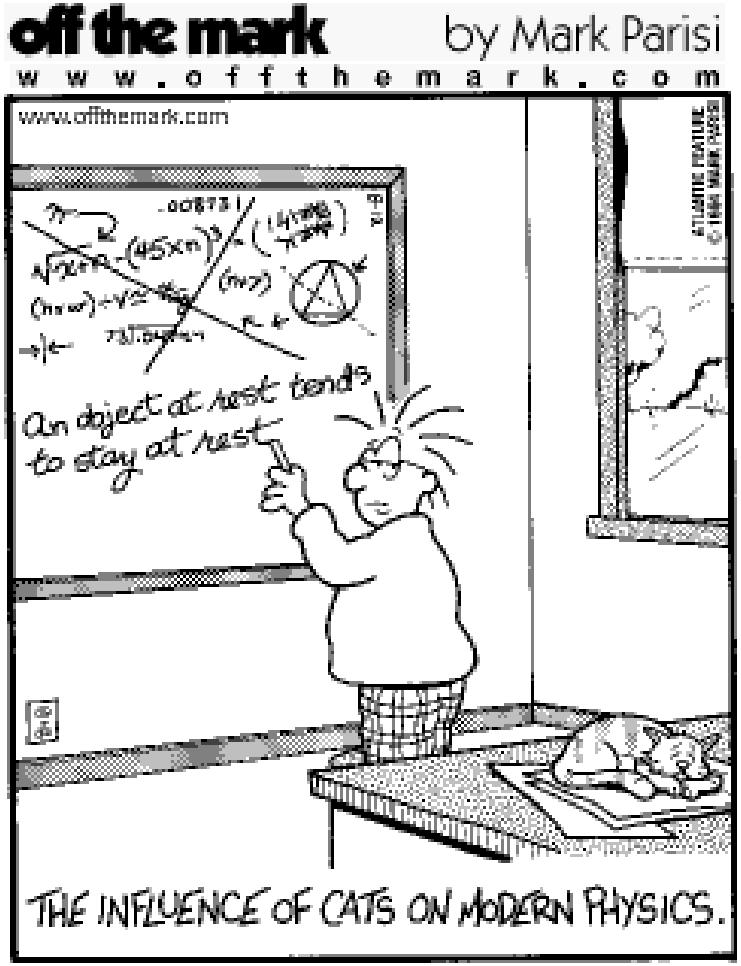
$$= 0.451 \text{ kg } (9.81 \text{ m/s}^2)$$

$$= 4.42 \text{ N}$$

Newton's Laws of Motion

- 1st Law: An object will remain in uniform motion (or at rest) unless an unbalanced force acts upon it.

- if the forces are balanced (cancel each other), the object will not change its motion (it will remain at rest or continue moving in a straight line at the same speed)



- Inertia is the tendency of an object to resist a change in its motion. Inertia and mass are closely related.

- The more mass an object has the more inertia it has so the harder it is to change the object's motion.

Example

- How much force is needed to lift a 1.0 kg object straight up at uniform motion?
- Weight of object = 9.8 N
- Uniform motion means forces are balanced so the lifting force = 9.8 N

- What unbalanced forces act on the moving object?

2nd Law:

- the acceleration of an object is directly proportional to the unbalanced force acting on it
- the larger the force acting on an object, the larger the acceleration

- F_{net} is the unbalanced force on the object

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

In newtons

In kg

In m/s^2

Example

- A net force of 3.99 N acts on a 6.00 kg object. What is its acceleration?

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

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

$$\vec{a} = 0.665 m/s^2$$

- the net force is the vector sum of forces acting on an object.

$$\vec{F}_{net} = \vec{F}_A + \vec{F}_{friction}$$

Example

- What net force is needed to accelerate a 3.00 kg object at 4.50 m/s^2 to the right?

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

$F = 3.00\ kg(4.50\ m/s^2)$

$F = 13.5\ kg \cdot m/s^2 = 13.5\ N$ right

Example

A train has a mass of 1.50×10^7 kg. If the locomotive can exert a net force of 7.50×10^5 N on the train, how much time is required for the train to reach a speed of 80.0 km/h, if the train begins from rest?

Summarize the data

- m = 1.50 x 10^7 kg
- F_{net} = 7.50 x 10^5 N
- t = ?
- v_i = 0 m/s
- v_f = 80.0 km/h
  = 22.222 m/s
- a = ?

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

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

$$\vec{a} = 0.0500 m/s^2$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

$$\Delta t = \frac{22.222 m/s - 0 m/s}{0.0500 m/s^2}$$

$$\Delta t = \frac{\vec{v}_f - \vec{v}_i}{\vec{a}}$$

t = 444 s

Example

- A force of 100 N is applied horizontally to a 30.0 kg object at rest on a horizontal surface. The object accelerates at 2.65 m/s^2. What is the magnitude of the force of friction?

$$\vec{F}_{net} = \vec{F}_{applied} + \vec{F}_{friction}$$

$$\vec{F}_{friction} = \vec{F}_{net} - \vec{F}_{applied}$$

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

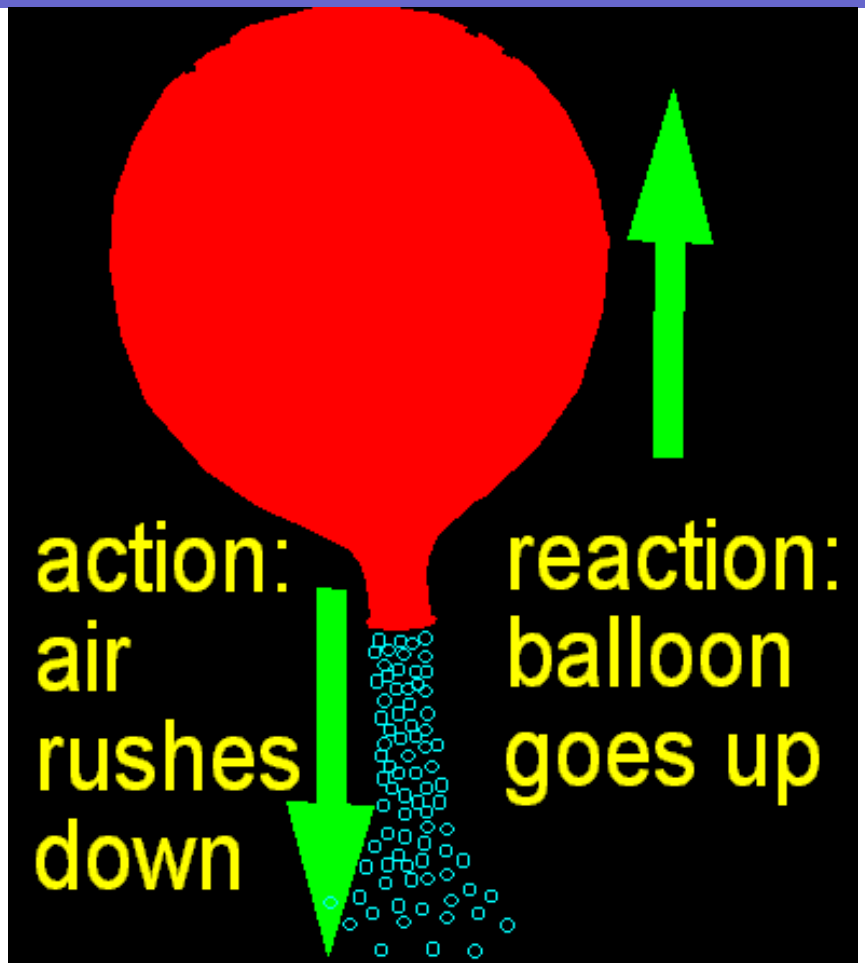
$F_{friction}$ = (30.0 kg x 2.65 m/s^2) - 100 N

$F_{friction}$ = -20.5 N

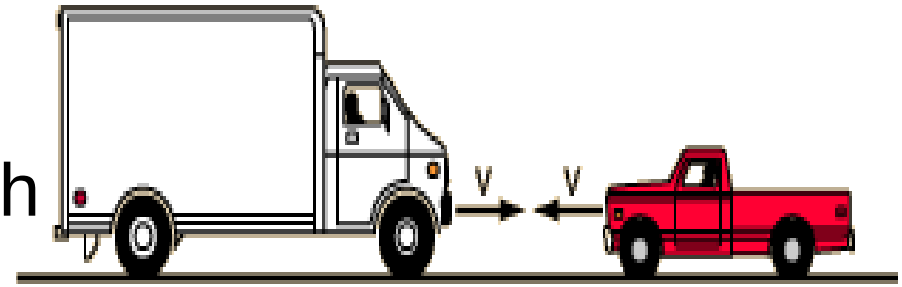
= 20.5 N

3rd Law

- For every action there is an equal and opposite reaction


action:
air
rushes
down
reaction:
balloon
goes up

- When two objects collide, they exert equal forces on each other
- Forces are equal, but the accelerations don't have to be
- The smaller mass will have larger acceleration

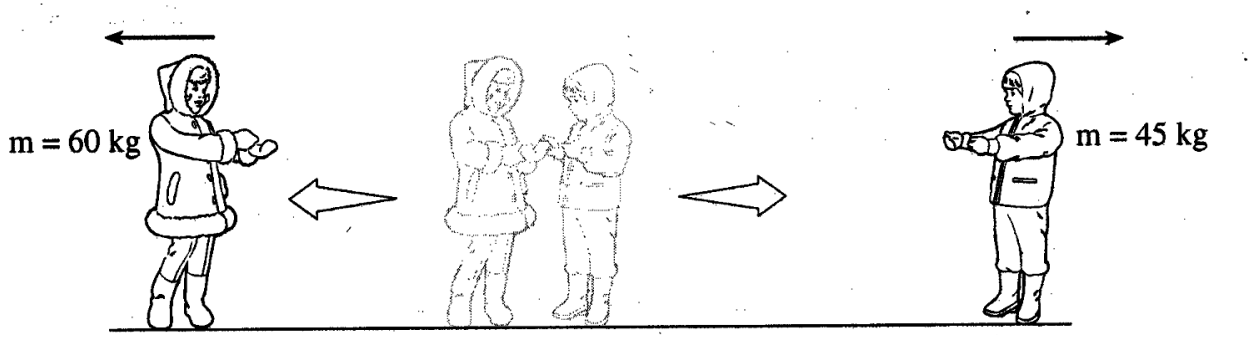


$$F_{big\ \text{truck}} = F_{little\ \text{truck}}$$

$$m_a = m_a$$

Example

- Two skaters are on ice. The 45 kg boy pushes the 60 kg girl skater who moves away with an acceleration of 1.2 m/s^2. Determine the magnitude of the boy's acceleration.



- The net force on each kid is equal in magnitude
- $F_{net\ boy} = F_{net\ girl}$
- $m_{boy}a_{boy} = m_{girl}a_{girl}$

$$a_{boy} = \frac{m_{girl}a_{girl}}{m_{boy}}$$

$$a_{boy} = \frac{60\ \text{kg}\left(1.2\ \text{m/s}^2\right)}{45\ \text{kg}}$$

$$a_{boy} = 1.6 m/s^2$$