Chapter 5

The Laws of Motion

Force

- Force is something that affects object's motion
  - force reflects interaction between objects
  - force causes (or may cause) acceleration
- Force is a vector (has magnitude and direction)

Newton's First Law of Motion

- First law of motion (a.k.a. the law of inertia): if an object does not interact with other objects, its velocity doesn't change (i.e. its acceleration is 0)
  - This may not be true for all possible reference frames
  - First law postulates existence of at least one reference frame where it's true (inertial reference frame, IRF)
  - As soon as one IRF is found, other IRFs can be obtained from it by shifting the origin, rotating, and applying Galilean transformations
- Existence of IRFs means that the space is homogeneous, isotropic, and time independent

Mass

- Mass is a measure of how much the motion of an object changes under certain force
- If two objects have masses m_1 and m_2, the same force acting on these objects produces accelerations a_1 and a_2 such that

$$\frac{m_1}{m_2} = \frac{a_2}{a_1}$$

Newton's Second Law of Motion

- Net force F on an object of mass m causes acceleration

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

  - net force = the vector sum of all forces acting on an object
- Second law is only valid in IRFs
- Force unit: Newton [N]=[kg][m/s^2]

Weight

- Weight = magnitude of gravitational force

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

  - unlike mass, weight depends on place where it is measured
- Mass in this equation reflects the interaction between the object and the Earth, it's not inertial mass
  - however, the two masses are known to be equivalent ("weak equivalence principle,"proved experimentally to 10^{-12})
  - "strong equivalence principle": gravitation can be simulated by a constant acceleration (basis of general relativity)

Newton's Third Law of Motion

- If two objects interact, force F_{12} exerted by object 1 on object 2 is equal in magnitude and opposite in direction to force F_{21} exerted by object 2 on object 1

$$\vec{F}_{12} = -\vec{F}_{21}$$

  - the two forces act on different objects, so they don't cancel each other

Force of Friction

- Force of friction F_s between two objects is directed along the surface of their contact opposite the intended direction of motion
- If N is the magnitude of the normal force exerted by one surface on the other,

$$F_s \leq \mu_s N$$

  - μ_s is the coefficient of static friction
  - inequality becomes equality on the verge of slipping
- When the object begins to accelerate, force of friction becomes

$$F_k = \mu_k N$$

  - μ_k is the coefficient of kinetic friction