Kinematics and Dynamics

Units

- Base Units: standard units around which a system is designed
- Derived Units: created by combining base units.
- Angostroms are 10^{-10} m.
- **Only need to know SI system for memory.**

Vectors and Scalars

Vector Addition

- Sum or difference is called **resultant of vectors**.
- Tip to Tail method: for A + B join the tip of A to the tail of B
- Subtraction is simply flipping the sign of the vector]
- Multiplication by a constant: only changes magnitude or can make direction antiparallel

Multiplying Vectors by Other Vectors

- **Dot Product** used for two vectors multiplying to get a scalar: $\boldsymbol{A} \circ \boldsymbol{B} = (\mathrm{A})(\mathrm{B})\cos\theta$
- **Cross Product:** for two vectors multiplied to get another vector: $\boldsymbol{A}\mathrm{x}\boldsymbol{B} = (\mathrm{A})(\mathrm{B})\sin\theta$
    - **Right Hand Rule** can be used to determine the direction

Displacement and Velocity

- Displacement is a vector that is a straight line from point A to point B. Does not take into account the pathway taken
- Velocity is also a vector and is defined as the rate of change of displacement in a given unit of time.
- Speed is the rate of actual distance travelled in a given unit of time
- Instantaneous speed will always equal to the magnitude of the instantaneous velocity

Forces and Acceleration

- Force is a vector quantity that is experienced as pushing or pulling on objects.
    - Gravity is an attractive force felt by all matter. Do not have much significance on a smaller scale, but are significant on the planetary scale.

$$F_g = \frac{Gm_1m_2}{r^2} \qquad G = 6.67x10^{-11}\,\frac{\mathrm{Nm}^2}{\mathrm{kg}^2}$$

    - Friction is a force that opposes movement of objects. This always forces an object to slow down
        - Static Friction (f_s): stationary object and surface it rests on

$$0 \leq f_s \leq \mu_s$$

        - Kinetic Friction: sliding object and surface it slides over.

$$f_k = \mu_k\, x\, N$$

        - Value of static coefficient is always larger than that of kinetic.
- Mass is a measure of a body inertia – the amount of matter in the object (scalar).
- Weight is a gravitational force so it is a vector quantity. $F_g = m\boldsymbol{g}$

    - Can be thought of as being applied to a single point (center of gravity) $x_{cm} = \sum_i \frac{m_i x_i}{m_i}$
- Acceleration is the rate of change of velocity that an object experiences as a result of some applied force.

Newton's Laws

- First law states that a body at rest or in motion with a constant velocity will remain that way unless a force is acted upon it. Net force is equal to zero when acceleration is 0.
- Second law states that $\boldsymbol{F_{net} = ma}$
- Third Law states that for every action there is an equal and opposite reaction.

Motion with Constant Acceleration

- A ball falling from the sky can be considered linear motion if air resistance is neglected. **Terminal Velocity** is not reached and the ball is in free fall. Most common format of linear constant acceleration motion.

$$\left.\begin{aligned} v_x &= v_{0x} + a_x t, \\ x &= \frac{1}{2}(v_x + v_{0x})t, \\ x &= v_{0x}t + \frac{1}{2}a_x t^2, \\ v_x^2 &= v_{0x}^2 + 2a_x x. \end{aligned}\right\} \quad x_0 = 0 \text{ m}, \quad t_0 = 0 \text{ s}.$$

- If air resistance is not neglected, it will oppose the motion of the object. Resistance increases as velocity increases and the object is subject to higher **drag forces**. When the drag force is equal to the weight of the object, the object stops accelerating since the net force is zero. This velocity is the **terminal velocity**.

Circular Motion

- In uniform circular motion the instantaneous velocity vector is always tangent to the circular path. The inertia of the object wants it to continue going straight, but this is stopped by the **centripetal force**, which is always pointed radially inwards.
    - Can resolve components into radial and tangential components. Tangential force is zero in uniform circular motion.

$$F_c = \frac{mv^2}{r} \; is\; the\; magnitude\; of\; the\; centripital\; force$$

Mechanical Equilibrium

- Always draw FBD's to start a force question
- Translation equilibrium is when the force causes an object to move without causing any rotation.
    - Only exists when the vector sum of all forces acting on an object are zero (**first condition of equilibrium)**.
- Rotational equilibrium occurs when forces are applied against an object so that the object rotates around a pivot point (**fulcrum)**.

- Generates a **torque** or the **moment of force**. **Lever arm** is the distance between the applied force and the fulcrum.

$$\tau = r \; x \; \boldsymbol{F} = rFsin\theta$$

Rotational equilibrium only occurs when the second condition of equilibrium is met. The vector sum of all torques acting on an object must be zero.