Chapter 4

The Laws of Motion
1. Force
2. Newton’s Laws
3. Applications
4. Friction
Classical Mechanics

- What is classical Mechanics?
- Under what conditions can I use it?
Sir Isaac Newton

- 1642 – 1727
- Formulated basic concepts and laws of mechanics
- Universal Gravitation
- Calculus
- Light and optics
Forces

- What is a force?
- What are its units?
- Grouping forces
- Fundamental forces
  - How many types?
    - Strong nuclear force
    - Electromagnetic force
    - Weak nuclear force
    - Gravity
  - What Characteristics?
Newton’s First Law

- What is Newton’s first Law? An object moves with a velocity that is constant in magnitude and direction, unless acted on by a nonzero net force.
- What is an external force?
- What is an internal force?
- What is Inertia?
- How is inertia related to mass?
Newton’s Second Law

- What is Newton’s second Law? The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.
- SI unit again
- Examples of forces
Gravitational Force

- What is the gravitational force?
- How do I compute it?
- What is a Universal constant?
- What is G?
Weight and Tension

- What is weight?
- What is the difference between mass and weight?
- What is tension?
Newton’s Third Law

- What is Newton’s third law?
  If object 1 and object 2 interact, the force exerted by object 1 on object 2 is equal in magnitude but opposite in direction to the force exerted by object 2 on object 1.
Some Action-Reaction Pairs
Forces Acting on an Object
How do I Use of Newton’s Laws?

- Make Assumptions
- Draw a Free Body Diagram (FBD)
- Check for Equilibrium
- Write the necessary equations
- Solve for the required information
Free Body Diagram, Example
Free Body Diagram, Example
Equilibrium Example

1. A traffic light weighing 100 N hangs from a vertical cable tied to two other cables that are fastened to a support, as shown. The upper cable makes angles of 37.0° and 53.0° with the horizontal. Find the tension in each of the three cables.
Example-Inclined Plane and Equilibrium

1. A child holds a sled at rest on a frictionless snow-covered hill, as shown. If the sled weighs 77.0 N, find the force \( T \) exerted by the rope on the sled and the force \( n \) exerted by the hill on the sled.
Example – Uniform motion

1. A constant force acts on a particle of mass 20kg for 5s, causing it to reach a velocity of 50 m/s from rest. Find
   a) The force
   b) The acceleration this force would give a particle of mass 2000kg
   c) The distance through which the particle of mass 2000kg would move while being accelerated from rest to 44 m/s
Example – Uniform motion

1. A 5.8 g bullet leaves the muzzle of a rifle with a speed of 334 m/s. What force (assumed constant) is expected on the bullet while it is traveling down the 0.77 m long barrel of the rifle?
Example – Uniform motion

1. A person of mass 72.2 kg is standing on weigh scale in an elevator cab. Find his weight when the cab is
   a) Stationary
   b) Accelerating up with $a=3.2 \text{ m/s}^2$.
   c) Accelerating down with $a=3.2 \text{ m/s}^2$. 
Example – Uniform motion and Incline plane

1. A block of mass 8.9kg is prevented from sliding down with the help of a string. The angle $\theta$ is 60 degrees. Assume frictionless conditions.
   a) Draw a labeled free body diagram
   b) Find the tension in the cord
   c) Find the normal force acting on the block
   d) If the cord is cut, find the magnitude of the block’s acceleration.
Multiple Objects – Example

1. Two objects with masses of 3.0 kg and 5.0 kg are connected by a light string that passes over a frictionless pulley as shown. Determine
   a) The tension in the string
   b) The acceleration of each object, and
   c) The distance each object will move in the first second of the motion if both objects start from rest.
Weight Example

1. I had a dream last night. In my dream I discovered a planet and found that its mass is 3 times the mass of earth and its radius is 2 times the radius of earth. What would be my weight on this planet compared to my weight on earth?
Forces of Friction

- What if friction?
- How do I calculate it?
- What does friction depend on?
- How do I include it in Newton’s second Law?
- Two types of friction
Example - friction

1. A hockey puck struck by a hockey stick, is given an initial speed of 20.0 m/s on a frozen pond. The puck remains on the ice and slides $1.20 \times 10^2$ m, slowing down steadily until it comes to rest. Determine the coefficient of kinetic friction between the puck and the ice.
Example - friction

1. A woman at an airport is towing her 20-kg suitcase at constant speed by pulling on a strap at an angle of $\theta$ above the horizontal. She pulls on the strap with a 35 N force, and the friction force on the suitcase is 20 N.
   a) What angle does the strap make with the horizontal?
   b) What normal force does the ground exert on the suitcase?