Al-Mustaqbal University

College of Engineering & Technology

Biomedical Engineering Department

Subject Name: Physics

1st Class, First Semester

Subject Code: [Insert Subject Code Here]

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Lecture No.:- 3

Lecture Title: [Newton's Laws of Motion]

1. Newton's First Law of Motion (Law of Inertia)

Newton’s first law states that if a body is at rest or moving at a constant speed in a straight line, it will remain at rest or keep moving in a straight line at constant speed unless it is acted upon by a force. In fact, in classical Newtonian mechanics, there is no important distinction between rest and uniform motion in a straight line; they may be regarded as the same state of motion seen by different observers, one moving at the same velocity as the particle and the other moving at constant velocity with respect to the particle. This postulate is known as the law of inertia.

Mathematical Formulation:

$$F_{\text{net}} = 0 \quad \text{implies} \quad \Delta v = 0$$

2. Newton's Second Law of Motion

Newton’s second law is a quantitative description of the changes that a force can produce on the motion of a body. It states that the time rate of change of the momentum of a body is equal in both magnitude and direction to the force imposed on it. The momentum of a body is equal to the product of its mass and its velocity. Momentum, like velocity, is a vector quantity, having both magnitude and direction. A force applied to a body can change the magnitude of the momentum or its direction or both. Newton’s second law is one of the most important in all of physics. For a body whose mass m is constant, it can be written in the form F = ma, where F (force) and a (acceleration) are both vector quantities. If a body has a net force acting on it, it is accelerated in accordance with the equation. Conversely, if a body is not accelerated, there is no net force acting on it.

Mathematical Formulation:

$$F = m \cdot a$$

Where:

- F: Net force (N)
- m: Mass of the object (kg)
- a: Acceleration (m/s²)

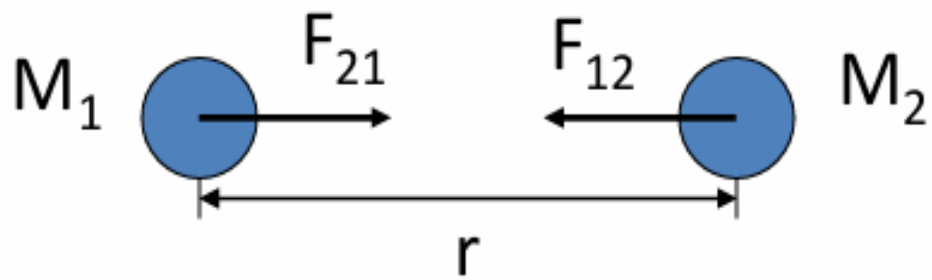
Application of Newton's Second Law of Motion 1- Weight: The magnitude of the earth's gravitational force to the body and it is measured in N and is given by the following formula:

$$\boldsymbol{W=m\ .g}$$

2- Law of Gravitation: Any two objects in the universe attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

$$F = \frac{GM_1M_2}{r^2}$$

r is the distance between the two masses M_1 and M_2 and $G = 6.67\times10^{-11}\ Nm^2/kg^2$.



$$\mathbf{F_{21} = -F_{12}}.$$

Example: A force of 50 N is applied to a 10 kg object. What is the acceleration of the object?

- **Solution:**
  - **Given:**

    Force (F) = 50 N

    Mass (m) = 10 kg

  - **Acceleration:**

    $$a = \frac{F}{m} = \frac{50}{10} = 5\,\mathrm{m/s^2}$$

Example: A person pushes a wheelchair with a total mass of 20 kg and applies a force of 40 N.What is the acceleration of the wheelchair?

- Solution:
  - Given:

    Force (F) = 40 N

    Mass (m) = 20 kg

  - Acceleration:

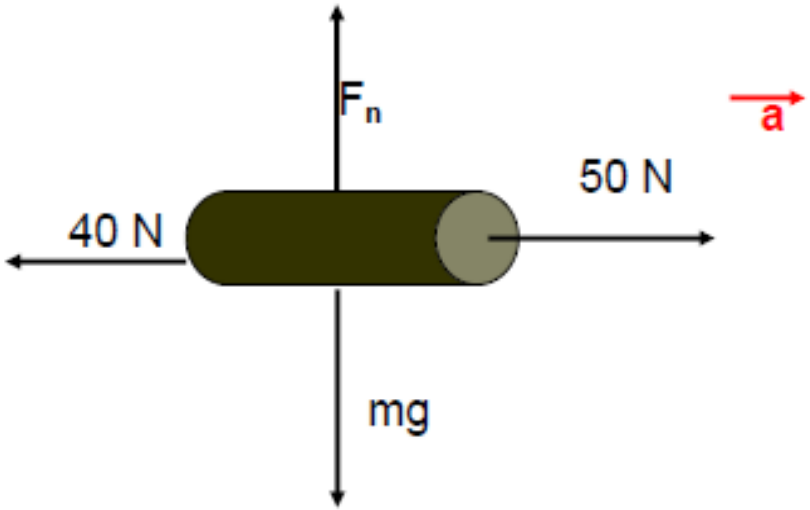
    $a = \frac{F}{m} = \frac{40}{20} = 2\,\mathrm{m/s^2}$

The wheelchair accelerates at $2\,\mathrm{m/s^2}$.

3. Newton's Third Law of Motion

Newton’s third law states that when two bodies interact, they apply forces to one another that are equal in magnitude and opposite in direction. The third law is also known as the law of action and reaction. This law is important in analyzing problems of static equilibrium, where all forces are balanced, but it also applies to bodies in uniform or accelerated motion. The forces it describes are real ones, not mere bookkeeping devices. For example, a book resting on a table applies a downward force equal to its weight on the table. According to the third law, the table applies an equal and opposite force to the book. This force occurs because the weight of the book causes the table to deform slightly so that it pushes back on the book like a coiled spring.

Example: A 50 N applied force drags an 8.16 kg log to the right across a horizontal surface. What is the acceleration of the log if the force of friction is 40.0 N?



$$F_{NET} = ma$$

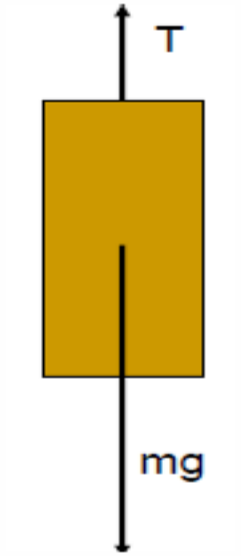
$$F_a - F_f = ma$$

$$50 - 40 = 8.16a$$

$$10 = 8.16a$$

$$a = 1.23 \text{ m/s/s}$$

- **Example: An elevator with a mass of 2000 kg rises with an acceleration of 1.0 m/s2. What is the tension in the supporting cable?**



Equation of Motion

$$F_{NET} = ma$$

$$\boxed{T - mg = ma}$$

$$T = ma + mg$$

$$T = (2000)(1) + (2000)(9.8)$$

$$T = \text{21,600 N}$$