Topics: Mass, Force, Work, Energy, Power, and Momentum

1. Introduction to Dynamics

Dynamics is the branch of mechanics that deals with the study of bodies in motion and the forces that cause or affect this motion. In engineering, these principles are essential for analyzing the behavior of moving parts in machinery and aircraft systems.

1.1 Mass and Force

• Mass (m): A fundamental property of matter that represents a body's resistance to acceleration (Inertia). It is a scalar quantity measured in Kilograms (kg).

• Force (F): A vector quantity that represents the interaction between bodies. According to Newton's Second Law, the net force acting on an object is equal to its mass multiplied by its acceleration:

$$F = m \cdot a$$

• Inertia: The tendency of an object to resist any change in its state of rest or motion.

2. Work, Energy, and Power

These concepts describe the capacity of a system to perform tasks and the rate at which energy is transformed.

2.1 Work (W)

Work is done when a force acts upon an object to cause a displacement in the direction of the force.

$$W = F \cdot d \cdot \cos(\theta)$$

• Unit: Joule (J).

2.2 Energy (E)

Energy is defined as the capacity to do work. In this module, we focus on:

• Kinetic Energy (K.E): The energy of an object due to its motion.

$$K.E = \frac{1}{2} m v^2$$

• Potential Energy (P.E): The energy stored due to an object's position (Gravitational).

$$P.E = m \cdot g \cdot h$$

• Efficiency (η): The ratio of useful work output to the total energy input, often expressed as a percentage.

2.3 Power (P)

Power is the rate at which work is performed or energy is transferred over time.

$$P = W / t$$

• Unit: Watt (W).

2.4 Heat (Q)

Heat is a form of energy transferred between systems due to a temperature difference.

Unit: Joule (J)

Heat Equations

1. Sensible Heat:

$$Q = m\, cp\, \Delta T$$

Where m is mass (kg), cp is specific heat (J/kg·°C), ΔT is temperature change (°C).

2. Latent Heat:

$$Q = m \, . \, L$$

Where L is latent heat (J/kg), used during phase change.

3. Momentum and Impulse

3.1 Linear Momentum (p)

The product of an object's mass and its velocity. It represents the "quantity of motion".

$$p = m \cdot v$$

3.2 Impulse (I)

Impulse is the change in momentum resulting from a force acting over a specific time interval.

$$I = F \cdot \Delta t = \Delta p$$

4. Solved Engineering Examples

Example 1: Work and Kinetic Energy

Problem: A component with a mass of 1200 kg is traveling at 20 m/s. If a constant braking force of 6000 N is applied, calculate the distance required to bring the component to a complete stop.

Solution:

1. Initial Kinetic Energy:

K.E =(1/2) . (1200) . $(20)^2$ = 240,000 J

2. Work-Energy Relation: The work done by the braking force must equal the kinetic energy.

W = F · d = 240,000 J

3. Calculate Distance:

d = 240,000 / 6000 = 40 m

Example 2: Conservation of Momentum

Problem: A 2 kg mass moving at 5 m/s collides and sticks to a stationary 3 kg mass. What is the final velocity of the combined system?

Solution:

Using the Law of Conservation of Momentum:

$$m_1v_1 + m_2v_2 = (m_1 + m_2)v_f$$

$$(2 \cdot 5) + (3 \cdot 0) = (2 + 3) \cdot v_f$$

$$10 = 5 \cdot v_f$$

$$v_f = 2 \text{ m/s.}$$

Example 3: Heat Transfer (Sensible Heat)

Problem: A 2 kg mass of water is heated from 25°C to 75°C. Given Cp= 4180 J/kg·°C, calculate the heat added.

Solution:

$$\Delta T = 50°C$$

$$Q = m\ c\ \Delta T = 2 \times 4180 \times 50 = 418000\ J$$

Final Answer: Q = 4.18 × 10^5 J

Example 4: Latent Heat

Problem: Calculate the heat required to convert 1 kg of ice at 0°C to water at 0°C.

Given L = 334,000 J/kg.

Solution:

Q = m L = 1 × 334000 = 334000 J

Final Answer: Q = 3.34 × 10^5 J

5. Summary of Key Formulas

F = m · a

W = F · d · cos(θ)

K.E = ½ m v²

P.E = m · g · h

P = W / t

p = m · v

I = F · Δt = Δp

References

1. Serway & Jewett – Physics for Scientists and Engineers

2. Hibbeler – Mechanics of Materials

3. Gere & Timoshenko – Strength of Materials

Sameer.Saad.Raheem@uomus.edu.iq