AL- Mustaqpal University

Science College

Dep. Medical Biotechnology

Second Stage

Lec 4

Application of Newton's Laws in Solving Physical Problems

م . م علي سـلمان حمادي

Introduction

Newton's laws of motion are fundamental principles in classical mechanics that describe the relationship between an object's motion and the forces acting upon it. These laws form the basis for understanding a wide range of physical phenomena, from the motion of planets to the behavior of everyday objects.

Newton's Laws

* **First Law of Motion** (Law of Inertia): An object at rest will remain at rest, and an object in motion will continue to move in a straight line at a constant speed unless acted upon by an unbalanced force.

* **Second Law of Motion**: The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. Mathematically, this is represented by the equation: **$F = ma$**

* where F is the net force, m is the mass, and a is the acceleration.

* **Third Law of Motion** (Law of Action and Reaction): For every action, there is an equal and opposite reaction.

Applications of Newton's Laws

1 .**Static Equilibrium:**

* Objects at rest are in static equilibrium when the net force acting on them is zero.
* This principle is used in the design of structures, bridges, and buildings to ensure stability.

2 .**Dynamics of Motion:**

* Newton's second law can be used to analyze the motion of objects under the influence of forces.

* Examples include calculating the acceleration of a falling object, the tension in a rope, or the force required to move an object.

3 .**Circular Motion**:

* Objects moving in a circle experience a centripetal force that keeps them on their path.
* This force is calculated using Newton's second law, and its magnitude depends on the mass of the object, its speed, and the radius of the circle.

4 .**Projectile Motion**:

* The motion of a projectile can be decomposed into horizontal and vertical components

The horizontal component is unaffected by gravity, while the vertical component is influenced by gravity.

* Newton's laws can be used to calculate the projectile's trajectory, maximum height, and range.

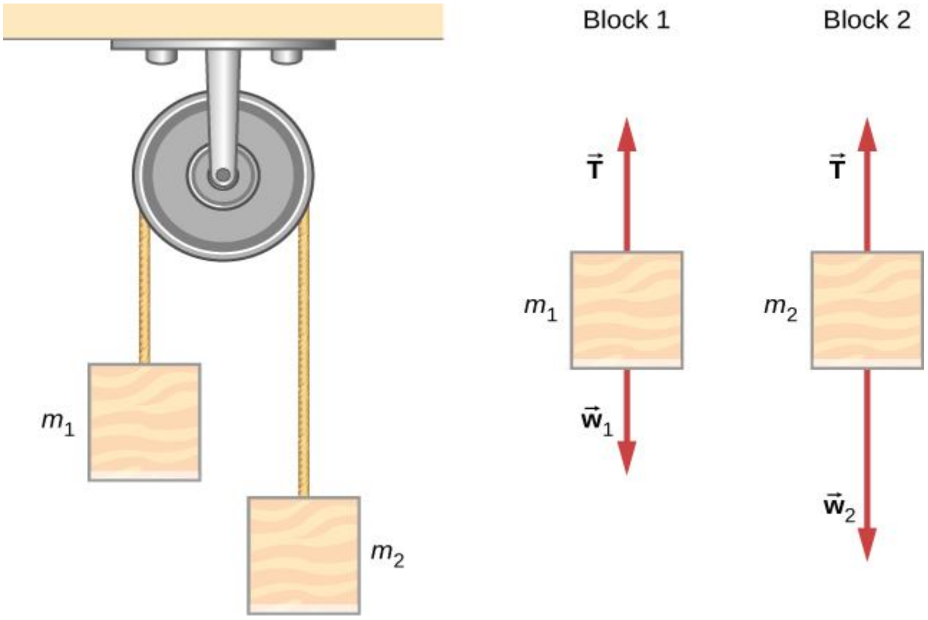
5 **.Simple Machines**:

* Simple machines, such as levers, pulleys, and inclined planes, can be analyzed using Newton's laws to determine their mechanical advantage.
* Mechanical advantage is the ratio of the output force to the input force.

Newton's laws of motion provide a powerful framework for understanding the dynamics of physical systems. By applying these laws, we can solve a wide range of problems in fields such as engineering, physics, and everyday life. Success in problem solving is necessary to understand and apply physical principles. We developed a pattern of analyzing and setting up the solutions to problems involving Newton’s laws in Newton’s Laws of Motion; in this chapter, we continue to discuss these strategies and apply a step-by-step process.

Atwood Machine

A classic problem in physics, similar to the one we just solved, is that of the Atwood machine, which consists of a rope running over a pulley, with two objects of different mass attached. It is particularly useful in understanding the connection between force and motion.



Example 1

In the figure above

m_1 = 2.00kg and **m_2 = 4.00kg**. Consider the pulley to be frictionless.

(a) If m_1 m_2 is released, what will its acceleration be ?

(b) What is the tension in the string ?

Solution

For m_1, $\sum F_y = T - m_1 g = m_1 a.$

For m_2, $\sum F_y = T - m_2 g = -m_2 a.$

(The negative sign in front of m_2a indicates that m_2 accelerates downward; both blocks accelerate at the same rate, but in opposite directions.)

Solve the two equations simultaneously (subtract them) and the result is :

$$(m_2 - m_1)g = (m_1 + m_2)a$$

Solving for *a*:

$$\boldsymbol{a = \frac{m2 - m1}{m2 + m1}\, g}$$

$$= \frac{4-2}{4+2} \times 9.8 = 3.27 \text{ m/s}^2$$

Observing the first block, we see that

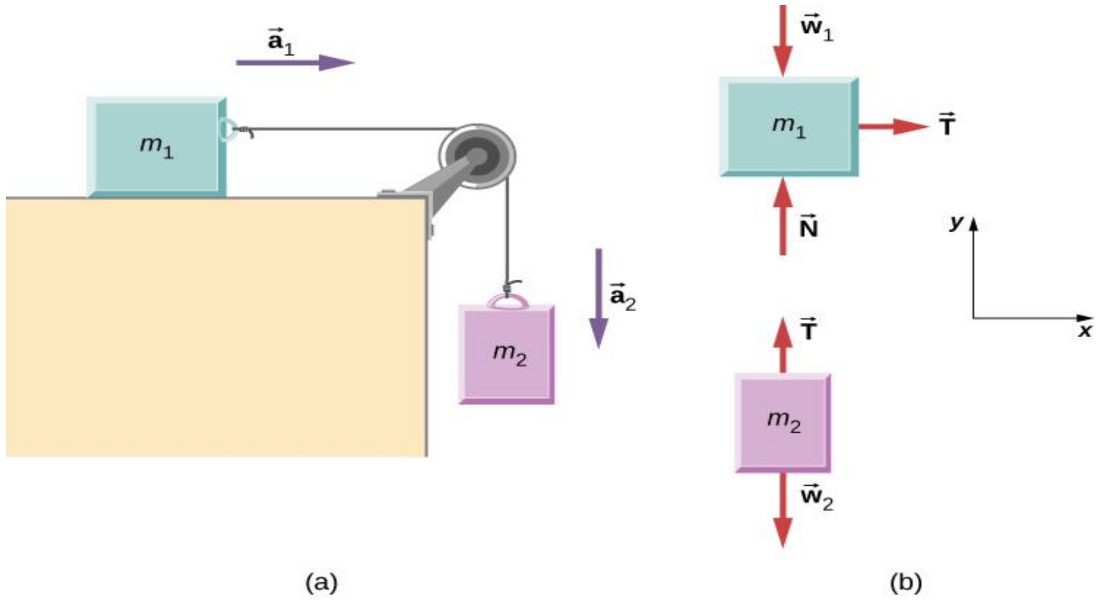
$$T - m_1 g = m_1 a$$

$$T = m_1(g+a)$$

$$= (2)(9.8 + 3.27) = 26.1 \text{ N.}$$

Example 2

Shows a block of mass m_1= 2 kg on a frictionless, horizontal surface. It is pulled by a light string that passes over a frictionless and massless pulley. The other end of the string is connected to a block of mass m_2 = 4 kg Find the acceleration of the blocks and the tension in the string ?



We draw a free-body diagram for each mass separately, as shown in Figure. Then we analyze each one to find the required unknowns. The forces on block 1 are the gravitational force, the contact force of the surface, and the tension in the string. Block 2 is subjected to the gravitational force and the string tension. Newton's second law applies to each, so we write two vector equations:

For m₁ $\sum F\chi = T$

$$m_1 a = T$$

For m₂ $\sum Fy = m_2 g - T$

$$m_2 a = m_2 g - T$$

Solving for *a*:

$$a = \frac{m2}{m2 + m1}\ g$$

$$a = \frac{4}{4+2} \times 9.8 \quad = 6.533 \ m/s^2$$

Observing the first block, we see that :

$$T = m_1 a$$

$$T = 2 \times 6.533$$

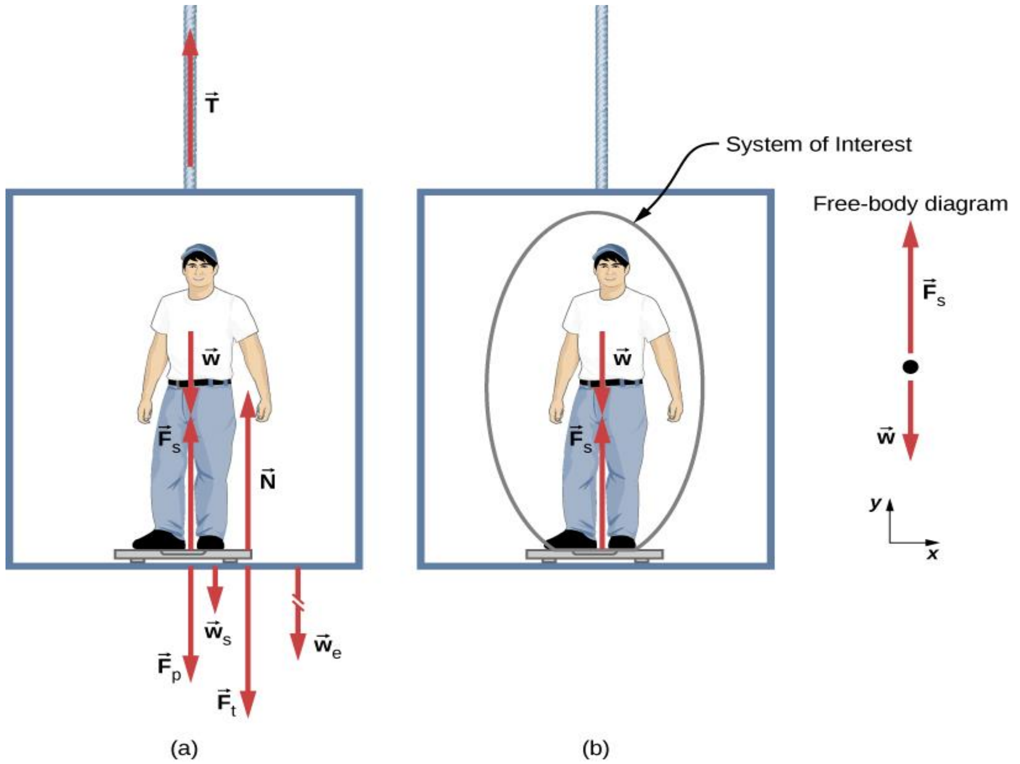
$$= 13.066 \ N$$

Example 3

Figure below shows a 75.0-kg man standing on a bathroom scale in an elevator. Calculate the scale reading:

(a) If the elevator accelerates upward at a rate of 1.20 m/s^2.

(b) If the elevator moves upward at a constant speed of 1 m/s.



Solving for *a* :

$$F_{net} = F_s - mg$$ Where Fs is the upward force of the scale

$$ma = F_s - mg$$

$$75 \times 1.2 = F_s - 75 \times 9.8$$

$$90 = F_s - 735 \quad \leftrightarrow \quad F_s = 825 \text{ N}$$

Solving for b :

Now, what happens when the elevator reaches a constant upward velocity ? Will the scale still read more than his weight? For any constant velocity—up, down, or stationary—acceleration is zero

$$F_{net} = F_s - mg$$

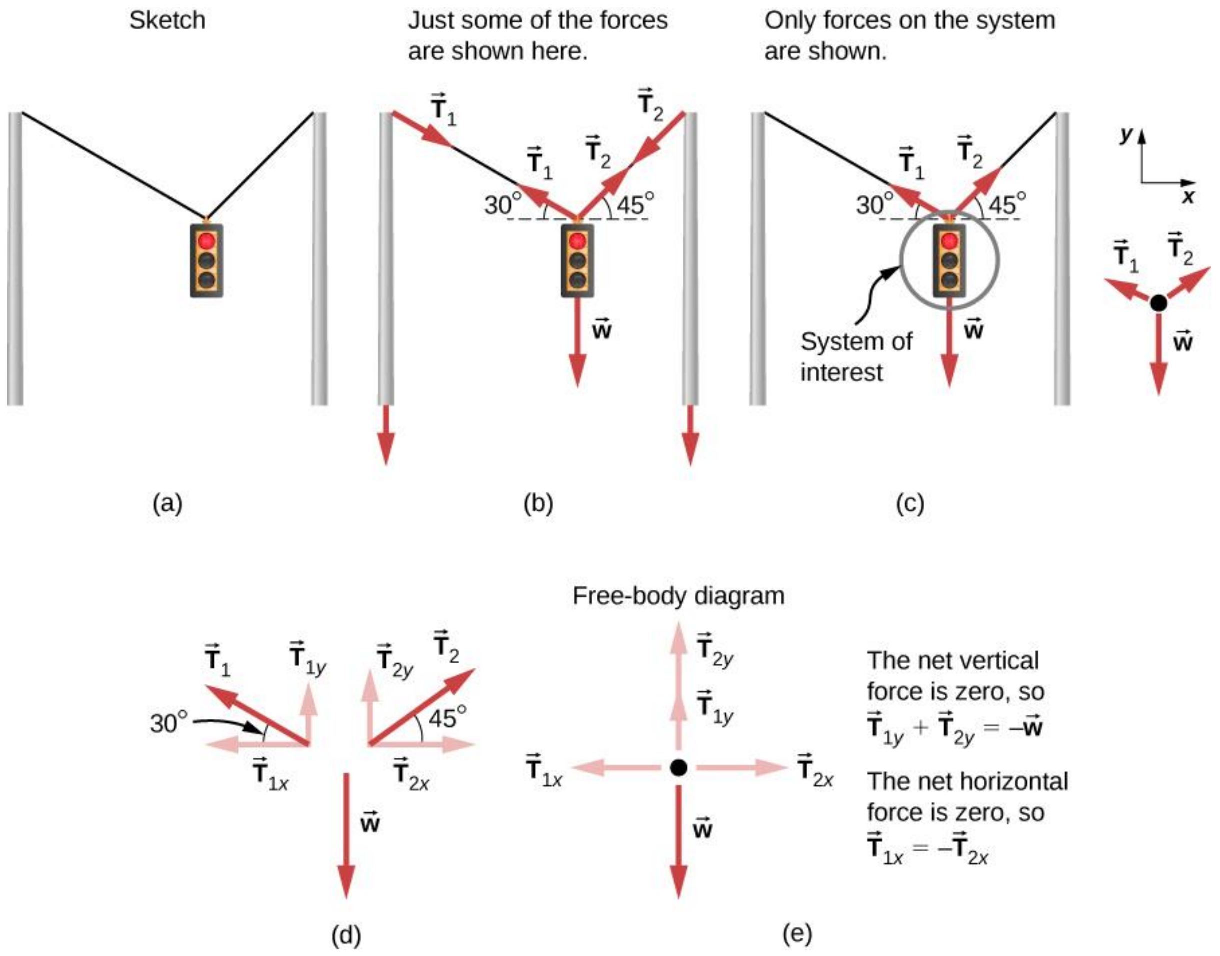
$$ma = F_s - mg$$

$$75 \times 0 = F_s - 75 \times 9.8$$

$$0 = F_s - 735 \quad \leftrightarrow \quad F_s = 735 \text{ N}$$

Example 4

Consider the traffic light (mass of 15.0 kg) suspended from two wires as shown in Figure . Find the tension in each wire, neglecting the masses of the wires.



Particle Equilibrium

Recall that a particle in equilibrium is one for which the external forces are balanced. Static equilibrium involves objects at rest, and dynamic equilibrium involves objects in motion without acceleration, but it is important to remember that these conditions are relative. For example, an object may be at rest when viewed from our frame of reference, but the same object would appear to be in motion when viewed by someone moving at a constant velocity. We now make use of the knowledge attained in Newton's Laws of Motion, regarding the different types of forces and the use of free-body diagrams, to solve additional problems in particle equilibrium.

Discussion

1. What does Newton's First Law of Motion state?

- An object at rest will remain at rest.

2. What is the equation associated with Newton's Second Law of Motion?

$$F = ma$$

3. In which situation can Newton's laws be applied to analyze static equilibrium?

- When the net force acting on an object is zero

4. What type of force keeps objects moving in circular motion according to Newton's laws?

- Centripetal force

5. What happens to the horizontal component of a projectile's motion under Newton's laws?

- It remains constant.

6. How is mechanical advantage defined in simple machines?

- Ratio of output force to input force

7. In the Atwood machine scenario described, what promotes understanding of the connection between force and motion?

1. The acceleration of the lighter mass
2. The tension in the connecting rope
3. The difference in mass between the two objects

8. When a block is on a frictionless, horizontal surface pulled by a string, what forces act on it?

- Tension and normal force

9. What must be true when the elevator moves at a constant speed in relation to forces acting on a man standing on a scale?

- The scale reading equals the gravitational force on the man.

10. In the example with the traffic light suspended from two wires, what is neglected in analyzing the tension in the wires?

- The mass of the wires