WEEK 4

Physics of Engineer

Chapter 4: Newton's Laws of Motion

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Outline

- Unraveling the Mysteries of Motion
- Introduction to Force
- Newton's First Law of Motion
- Applications of Newton's First Law of Motion
- Newton's Second Law of Motion
- Applications of Newton's Second Law
- Newton's Third Law of Motion
- Everyday Examples of the Third Law
- Summary and Conclusion

Unraveling the Mysteries of Motion: Newton's Laws

Introduction to Force: What is Force?

Definition: Force is any interaction that can change an object's state of motion (rest or moving).

Unit: Measured in Newtons (N), representing the amount of force needed to accelerate a 1-kilogram mass by 1 meter per second squared.

Introduction to Force: What is Force?

Types:

- **Contact Forces:** Direct physical interaction between two objects.
- **Field Forces:** Act at a distance without direct contact.
- **Normal Force:** The force exerted by a surface perpendicular to an object in contact with it.
- **Friction:** Force opposing the relative motion of two surfaces in contact.

Newton's First Law of Motion

Law of Inertia

An object at rest stays at rest, and an object in motion stays in motion with the same speed and direction unless acted upon by an unbalanced force.

Inertia: The tendency of an object to resist changes in its motion. (Measured in kg)

Newton's First Law of Motion

Mathematically, inertia is related to momentum (p):

$$p = mv,$$

where:

p is momentum (measured in kg m/s)

m is the object's mass (measured in kg)

v is the object's velocity (speed and direction, measured in m/s)

Newton's First Law of Motion

- **Mathematically**, Newton's First Law essentially states that in the absence of an unbalanced force, momentum remains constant:

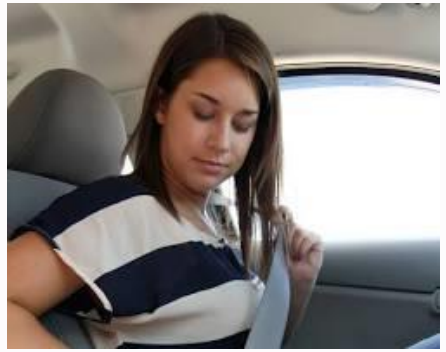
$\Sigma F = 0$ (sum of all forces equals zero)

where:

F is force (measured in N or kg m/s^2)

Newton's First Law of Motion

The Law in Action: Everyday and Beyond



Transportation:

- **Seatbelts and airbags in cars**: When a car stops suddenly, the inertia of the passenger keeps them moving forward until the belt/airbag applies an equal and opposite force, preventing injuries.
- **Bicycle helmets**: Protect the head from impact during a fall by absorbing the force and reducing its effect on the brain.
- **Roller coasters**: Riders experience thrills as their bodies resist changes in motion during drops and turns.

Newton's First Law of Motion

The Law in Action: Everyday and Beyond

Sports:

- **Javelin throwers:** Use their body mechanics to transfer energy efficiently to the javelin, maximizing its launch distance.
- **Gymnasts:** Defy gravity by performing flips and twists, relying on their initial momentum and proper body control.
- **Track runners:** Overcome inertia at the starting line and maintain momentum throughout the race.

Newton's First Law of Motion

The Law in Action: Everyday and Beyond

Everyday Life:

- **Walking and running**: We push off the ground (applying force), and the ground exerts an equal and opposite force, propelling us forward.
- **Carrying groceries**: Our arms experience an upward force from the ground to counteract the downward weight of the groceries.
- **Opening a door**: We push the door, and it pushes back on our hand with an equal force, causing it to swing open.

Newton's Second Law of Motion

The Force-Acceleration Connection

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

Net force: The sum of all forces acting on an object. (Unit: N)

Newton's Second Law of Motion

The Force-Acceleration Connection

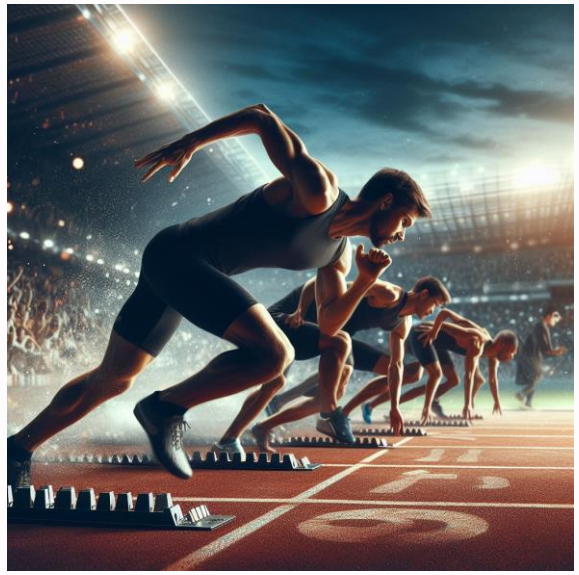
Acceleration: The rate of change of an object's velocity (speed and direction). (Unit: m/s^2)

Expressed by the equation:

$$\Sigma F = ma$$

(Sum of Force = mass x acceleration)

Newton's Second Law of Motion



Putting the Law to Work

Explains how rockets reach space, why skydivers fall with constant acceleration, and how cars brake effectively.

Helps design roller coasters, amusement park rides, and sports equipment.

Newton's Third Law of Motion

Every Action Has an Equal and Opposite Reaction

For every action force, there is an equal and opposite reaction force. Forces always act in pairs on different objects.

Explains why rockets fly, birds can take off, and swimmers move forward in water.

Newton's Third Law of Motion

Every Action Has an Equal and Opposite Reaction

Parameters and Definitions:

Action Force: The force exerted by one object on another object. Measured in Newtons (N).

Reaction Force: The force exerted by the second object back on the first object. Equal in magnitude and opposite in direction to the action force. (N)

Newton's Third Law of Motion

Every Action Has an Equal and Opposite Reaction

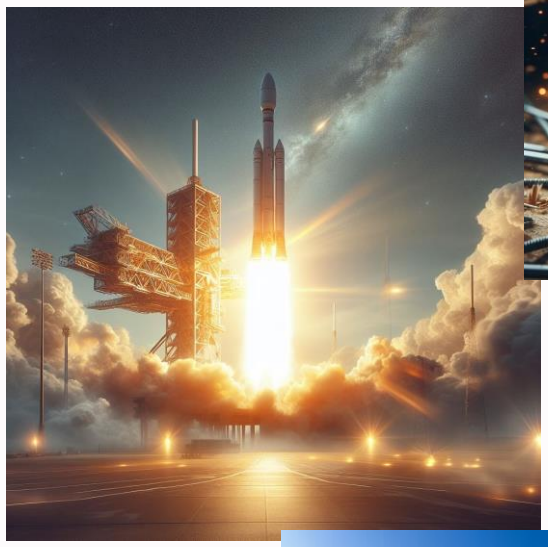
Mathematical Equation:

Action Force = Reaction Force

$$F_{action} = -F_{reaction}$$

Alternatively, using momentum:

$$\Delta p_{action} = -\Delta p_{reaction}$$



Newton's Third Law of Motion

The Law in Action All Around Us

Explains why balloons fly when released, how magnets attract and repel, and how airplanes stay aloft.

Crucial for understanding forces in sports, games, and even nature.

Conclusion and Summary

A Recap of Newton's Laws

- ✓ Newton's First Law (Law of Inertia): Objects resist changes in motion (stay at rest or maintain motion) unless acted upon by an unbalanced force. Inertia depends on mass. (Equation: $\Sigma F = 0$)
- ✓ Newton's Second Law (Force-Acceleration Law): The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. (Equation: $\Sigma F = ma$)

Conclusion and Summary

A Recap of Newton's Laws

- ✓ Newton's Third Law (Action-Reaction Law): For every action force, there is an equal and opposite reaction force. Forces always act in pairs on different objects.

  (Equation: $F_{action} = -F_{reaction}$)

Conclusion and Summary

A Recap of Newton's Laws

Impact and Applications:

- ✓ These fundamental laws provide a framework for understanding various physical phenomena:
  - Rocket launches, car crashes, sports mechanics, object interactions in everyday life.
- ✓ Crucial in various fields: physics, engineering, sports, design, and more

Reference and Additional Resources

General Physics Resources:

1. Serway, R. A., & Jewett, J. W. (2018). Principles of physics: A textbook with access (5th ed.). Cengage Learning.
2. Hewitt, P. G. (2013). Conceptual physics (11th ed.). Pearson.
3. Giancoli, S. C. (2014). Physics: Principles with applications (7th ed.). Pearson.
4. Khan Academy. (n.d.). Newton's laws of motion. Retrieved from [[invalid URL removed]]([invalid URL removed])
5. Crash Course. (n.d.). Newton's laws of motion: Crash course physics #1. Retrieved from [[invalid URL removed]]([invalid URL removed])

Reference and Additional Resources

Specific Topics:

1. NASA Glenn Research Center. (n.d.). Newton's laws of motion. Retrieved from [[invalid URL removed]]([invalid URL removed]) (Information on force and Newton's Second Law)
2. National Geographic. (n.d.). Momentum. Retrieved from [[invalid URL removed]]([invalid URL removed]) (Information on momentum and its relation to Newton's Laws)
3. The Physics Classroom. (n.d.). Action and reaction forces. Retrieved from [[invalid URL removed]]([invalid URL removed]) (Detailed explanation of Newton's Third Law)

Additional Resources:

1. Interactive simulations and activities can be found on various educational websites like PhET Interactive Simulations (https://phet.colorado.edu/).
2. Historical context and biographies of Isaac Newton can be found on websites like Britannica (https://www.britannica.com/biography/Isaac-Newton).

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