CBSE CLASS 9 SCIENCE

Chapter 8: Force and Laws of Motion

Complete Concept & Question Bank

EXAM BOOSTER EDITION

SECTION 1: Chapter Overview

What is Force?

Force is a push or pull on an object that can cause it to change its state of rest or motion, or change its shape or size. It is a vector quantity, meaning it possesses both magnitude and direction dynamically.

Importance of Force in Daily Life

Fundamental movements like walking, running, and jumping are entirely possible due to contact and reaction forces. Vehicles navigate roads safely because of balanced friction and mechanical forces generated by engines. Every mechanical manipulation in our surroundings involves the application of a force vector.

Learning Outcomes

By the end of this chapter, you will be able to:

- Understand the absolute concept of force and its mechanical effects.
- Differentiate systematically between balanced and unbalanced force vectors.
- Apply Newton's three profound laws of motion to diverse daily scenarios.
- Understand the concepts of inertia, linear momentum, and their operational limits.
- Solve core mathematical numerical parameters based on force, mass, acceleration, and momentum.

Chapter Summary

- **Force:** Push or pull vectors modifying states of rest, uniform motion, or geometry.
- **Balanced Forces:** Net resultant force $\Sigma F = 0$; causes no change in the state of dynamic motion.
- **Unbalanced Forces:** Net resultant force $\Sigma F \neq 0$; triggers linear acceleration.
- **First Law (Inertia):** Objects naturally resist modifications to their instantaneous velocity states; mass serves as the fundamental scalar measure of inertia.
- **Second Law:** $F = ma$; the rate of change of momentum is directly proportional to the applied unbalanced force vector.
- **Third Law:** Forces always arise in pairs; action and reaction are completely equal in magnitude, opposite in direction, and operate on two distinct bodies.
- **Conservation of Momentum:** The total vector momentum of an isolated system remains fundamentally constant over time.

SECTION 2: Important Concepts

1. Balanced vs Unbalanced Forces

Balanced Forces: When the vector sum of all forces operating on an object equals zero, the forces are balanced. The body maintains its existing state of rest or uniform straight-line velocity (e.g., a static book experiencing balanced gravity and surface normal force values).

Unbalanced Forces: When the resultant net force vector is non-zero, an acceleration is generated in the direction of the net vector force, modifying speed, path, or both.

[Image of Balanced vs Unbalanced Forces]

Figure 8.1: Vector diagram comparing Balanced Forces (Net F = 0) vs Unbalanced Forces (Net F ≠ 0 causing acceleration).

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

An object persists in its current state of rest or uniform motion along a straight path unless compelled to change that state by an external unbalanced force vector applied to it.

The Three Facets of Inertia:

- **Inertia of Rest:** Inherent resistance to leaving a static state (e.g., dust separating when a heavy carpet is beaten).
- **Inertia of Motion:** Inherent resistance to changing constant velocity (e.g., passengers jerking forward during sudden braking).
- **Inertia of Direction:** Inherent resistance to altering a path vector (e.g., being thrown outwards when a vehicle rounds a sharp curve).

3. Linear Momentum & Newton's Second Law

Momentum (p): The product vector of an object's mass and its instantaneous velocity. $p = mv$ (SI Unit: kg·m/s).

Newton's Second Law: States that the applied force vector is directly proportional to the time rate of change of its linear momentum vector.

Derivation: $F \propto (mv - mu)/t \rightarrow F \propto m(v - u)/t \rightarrow F = ma$ (where the constant of proportionality $k = 1$).

4. Newton's Third Law & Action-Reaction Pairs

To every action force vector, there exists an equal and opposite reaction force vector. Crucially, these paired forces act on two entirely distinct physical bodies simultaneously, meaning they never cancel each other out within the system framework.

5. Law of Conservation of Momentum

In the absolute absence of an external unbalanced force vector acting on a multi-body system, the total vector linear momentum of the system remains perfectly preserved.

$$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$

SECTION 3: Important Formula Sheet

Formula	Physical Description	Standard SI Unit
$F = ma$	Newton's Second Law of Motion	Newton (N) or kg·m/s²
$p = mv$	Linear Momentum Formula	kg·m/s
$F = \Delta p / \Delta t$	Force as rate of momentum change	Newton (N)
$m_A u_A + m_B u_B = m_A v_A + m_B v_B$	Total Conservation of Linear Momentum	kg·m/s

Definition of One Newton (1 N)

One Newton represents the exact amount of unbalanced force required to accelerate a absolute 1 kg scalar mass at a rate of precisely 1 m/s² in the direction of the force vector. (1 N = 1 kg·m/s²).

SECTION 4: Top 30 Frequently Repeated Questions

Very Short Answer Type (1 Mark)

Q1. Define momentum.

Ans: Momentum is the physical vector quantity defined as the product of an object's mass and its velocity vector ($p = mv$).

Q2. What is the measure of inertia?

Ans: Mass is the quantitative scalar measure of an object's inertia. Greater mass implies higher inertia.

Q3. Why do passengers fall backward when a bus suddenly accelerates from rest?

Ans: Due to the inertia of rest, the upper body seeks to maintain its static position while the lower body moves forward with the bus floor.

Q4. What is the net acceleration of an object experiencing perfectly balanced forces?

Ans: Zero, since the net resultant force vector $\Sigma F = 0$.

Short Answer Type (2-3 Marks)

Q15. Why does a cricket fielder pull his hands backward while catching a fast moving cricket ball?

Ans: By moving the hands backward along the trajectory, the fielder extends the time interval (t) required to bring the momentum to zero. According to $F = \Delta p/t$, an increased time interval drastically minimizes the rate of change of momentum, reducing the impact force felt on the hands.

Q16. Explain why it is difficult for a fireman to hold a hose pipe ejecting water at high velocity.

Ans: As water is forced forward out of the nozzle with immense momentum (Action), an equal and opposite reaction force pushes the hose pipe backward (Newton's Third Law), making stability difficult.

SECTION 5: Top 20 Most Expected Questions

Q2. Prove mathematically that F = ma using Newton's second law of motion.

Ans: Consider a body of mass m changing velocity from initial value u to final value v in time t.

Initial momentum $p_1 = mu$, Final momentum $p_2 = mv$.

Change in momentum $\Delta p = mv - mu = m(v - u)$.

Rate of change of momentum = $m(v - u)/t$.

Since $(v - u)/t = a$ (acceleration), the rate becomes ma.

By Newton's Second Law, $F \propto ma \rightarrow F = kma$. With SI units set to give $k = 1$, we arrive at $F = ma$.

Q4. A bullet of mass 10 g is fired from a gun of mass 4 kg with a velocity of 50 m/s. Find the recoil velocity of the gun.

Ans: Given: $m_1 = 10\ g = 0.01\ kg$, $v_1 = 50\ m/s$, $m_2 = 4\ kg$.

By Conservation of Momentum: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$.

Initially at rest, total initial momentum = 0.

$0 = (0.01 \times 50) + (4 \times v_2) \rightarrow 0 = 0.5 + 4v_2 \rightarrow 4v_2 = -0.5$.

$v_2 = -0.125\ m/s$. The negative sign denotes backward recoil direction.

SECTION 10: Common Mistakes Students Make

Common Misconception	Correct Conceptual Fact
Believing Action/Reaction pairs cancel each other out.	They can never cancel because they act on **different physical objects**, not the same one.
Confusing Inertia with an applied active force.	Inertia is an intrinsic property relating to mass; it is not an active force vector.
Forgetting to convert mass values to kg in F=ma.	Always convert mass given in grams into standard kilograms ($1\ kg = 1000\ g$) prior to computing force.

SECTION 14: One-Day Before Exam Revision

Quick Memory Tricks

- **First Law:** Inertia acts like a stubborn resistor—it hates changes to current motion states!
- **Second Law: F = ma**—Applied force determines exactly how fast a mass changes its velocity.
- **Third Law:** Forces are twins—always equal and facing opposite ways, but living on different objects!