CLASS 9 SCIENCE

Chapter 6 Notes

How Forces Affect Motion

Chapter focus
This chapter explains force, net force, friction and Newton's three laws of motion. It connects force with acceleration and mass, introduces momentum and applies the laws to familiar situations such as catching a ball, airbags, rowing, rockets and connected objects.

1. The Concept of Force

- A force can set an object at rest into motion, change the speed or direction of a moving object, or change its shape.
- Force has both magnitude and direction.
- The SI unit of force is newton (N).
- The magnitude of a force tells us its strength.
- Changing either the magnitude or direction of a force can change its effect.
- A spring balance can be used to measure the magnitude of a force, including the weight of an object.

2. Balanced and Unbalanced Forces

Balanced forces	Unbalanced forces
Equal and opposite forces give zero net force.	Forces give a non-zero net force.
They do not change the velocity of an object.	They produce acceleration and change velocity.
Example: equal pulls in tug of war.	Example: one team pulls harder in tug of war.

- For two opposite unequal forces, net force = larger force − smaller force, in the direction of the larger force.
- For forces acting in the same direction, their magnitudes are added.

Important
An object's motion depends on the net force acting on it, even when several individual forces are present.

3. Force of Friction

- Friction acts opposite to the direction of motion or attempted motion.
- A stationary box starts moving only when the applied force becomes large enough to overcome friction.
- For a box on a horizontal surface, weight acts downward and normal force acts upward; these may balance each other.
- Air also exerts friction on moving objects, though it may be small enough to neglect in some situations.
- If the applied force is removed, friction can reduce the velocity of a moving object and finally bring it to rest.
- The force of friction depends on the nature of the surfaces in contact.
- Smaller friction allows an object to travel farther before coming to rest.
- A spring balance can provide an approximate measure of friction while pulling a block.

Galileo's idea
If all impediments such as friction were removed, an object moving on a horizontal plane would continue moving indefinitely.

4. Newton's First Law of Motion

Statement
An object at rest remains at rest and an object in motion continues to move with a constant velocity, unless a net force acts upon the object.

- If net force = 0, acceleration = 0.
- An object at rest remains at rest when the net force is zero.
- A moving object continues with constant velocity when the net force is zero.
- Constant velocity means no change in either the magnitude or direction of velocity.
- Inertia is the tendency of an object to resist a change in its state of rest or uniform motion.
- If friction were zero, no force would be required to maintain constant velocity; force would be required only to change velocity or stop the object.

5. Newton's Second Law of Motion

Statement
When a net force acts on an object, the object accelerates in the direction of the net force. The magnitude of acceleration is proportional to the net force and inversely proportional to the mass of the object.

- For a fixed mass: larger net force → larger acceleration.
- For a fixed force: larger mass → smaller acceleration.
- Mathematically: $a = F/m$ or $F = ma$.
- The direction of acceleration is the same as the direction of the net force.
- One newton is the force that produces an acceleration of 1 m s^{-2} in a mass of 1 kg.

Quantity	Symbol	SI unit
Force	F	newton (N)
Mass	m	kilogram (kg)
Acceleration	a	m s^{-2}

6. Weight and Acceleration Due to Gravity

- Weight is the gravitational force exerted by the Earth on an object.
- Weight: $F = mg$.
- Near Earth's surface, $g \approx 9.8$ m s^{-2}; for quick estimates, $g \approx 10$ m s^{-2} may be used.
- The acceleration due to Earth's gravitational force does not depend on the mass of the falling object.

7. Momentum

- Momentum is the product of mass and velocity: $p = mv$.
- The direction of momentum is the same as the direction of velocity.
- The more complete form of Newton's second law relates net force to the rate of change of momentum.
- This momentum form is useful even in situations where the mass of an object is not constant.

8. Everyday Applications of Newton's Second Law

- A cricket fielder pulls the hands backward while catching a fast ball. This increases the stopping time, reduces acceleration and therefore reduces the required force.
- Vehicle airbags increase the time over which a passenger comes to rest during a collision, reducing acceleration and force and lowering the risk of injury.
- Bubble wrap, hay and landing mats protect objects or people for a similar reason: they increase the stopping time and reduce the force during impact.

9. Newton's Third Law of Motion

Statement
Whenever one object exerts a force on a second object, the second object simultaneously exerts an equal and opposite force on the first object.

- Forces always occur in pairs.
- The two forces are equal in magnitude and opposite in direction.
- Most importantly, the two forces act on two different objects, so they do not cancel each other.
- Two connected spring balances show equal readings, illustrating equal and opposite interaction forces.

10. Applications of Newton's Third Law

Situation	Action–reaction explanation
Walking / climbing	The person pushes the ground or trunk; it pushes the person in the opposite direction.
Rowing a canoe	Paddle pushes water backward; water pushes paddle and canoe forward.
Balloon	Air is expelled in one direction; the balloon moves in the opposite direction.
Rocket	Engine expels gases downward; gases exert an equal and opposite force upward on the rocket.
Jumping from a boat	Person pushes the boat backward while moving forward; boat moves backward.

- The rocket motion to the same principle and notes that reverse firing can slow a spacecraft.

11. Forces Acting on a System of Objects

- Connected objects can often be treated as a single system.
- Forces between parts of the system are internal forces; forces from outside are external forces.
- For two boxes of masses m_1 and m_2 connected by a string on a frictionless surface and pulled by external force F, the system behaves like a single object of mass $m_1 + m_2$.
- Acceleration of the system: $a = F/(m_1 + m_2)$.
- Tension in the connecting string is an internal force when both boxes and the string are treated as one system.
- The downward gravitational force on the system is balanced by the upward normal force when there is no vertical acceleration.

12. Important Formulae

Concept	Formula / relation
Net force, same direction	$F_{net} = F_1 + F_2$
Net force, opposite directions	Fnet = larger force − smaller force
Newton's second law	F = ma
Acceleration	a = F/m
Weight	W = mg
Momentum	p = mv
Connected system	$a = F/(m_1 + m_2)$

13. Common Conceptual Points

- A moving object does not necessarily require a net force. If it moves with constant velocity, the net force is zero.
- A net force is required to change velocity-its speed, direction or both.
- Balanced forces do not mean that no forces are acting; they mean that the net force is zero.
- Action and reaction forces do not balance because they act on different objects.
- Equal and opposite forces acting on the same object can balance each other.
- Friction is the main reason everyday moving objects usually slow down when no driving force is applied.
- A negative acceleration or force sign in a one-dimensional calculation indicates direction opposite to the chosen positive direction.

14. Quick Numerical Examples

Example 1: Net force
Forces 10 N and 6 N in the same direction: Fnet = 10 + 6 = 16 N. If they act oppositely, Fnet = 10 − 6 = 4 N toward the 10 N force.

Example 2: Force from mass and acceleration
For a 1500 kg car accelerating at 2 m s^{-2}: F = ma = 1500 × 2 = 3000 N.

Example 3: Weight
For a 30 kg object: $W = mg = 30 \times 9.8 = 294$ N.

Example 4: Balanced applied force and friction
If a stationary block is pushed with 50 N while maximum opposing friction is 50 N, net force is zero and the block remains stationary.

15. Key Terms

Term	Meaning
Force	A push or pull capable of changing motion or shape.
Net force	Combined effect of all forces acting on an object.
Balanced forces	Forces whose combined net force is zero.
Unbalanced forces	Forces producing a non-zero net force.
Friction	Force opposing relative motion between surfaces.
Normal force	Force exerted by a surface perpendicular to itself.
Inertia	Tendency to resist a change in rest or uniform motion.
Acceleration	Rate of change of velocity.
Momentum	Product of mass and velocity.
Tension	Pulling force transmitted through a string or similar connector.
Internal force	Force between parts of a chosen system.
External force	Force on the system from outside it.

16. Newton's Three Laws - One Table Revision

Law	Core idea	Key result
First Law	No net force → no change in velocity.	Rest stays rest; uniform motion continues.
Second Law	Net force produces acceleration.	$F = ma$; acceleration is along net force.
Third Law	Interactions produce force pairs.	Equal and opposite forces act on different objects.

17. Exam-Oriented Self-Check Questions

1. Define force. Why must both magnitude and direction be specified?
2. Differentiate between balanced and unbalanced forces.
3. How is net force found when two forces act in the same direction? What if they act oppositely?
4. Why does a moving ball eventually stop on the ground?
5. State Newton's first law of motion and explain inertia.
6. Can an object move when the net force on it is zero? Explain.
7. State Newton's second law of motion.
8. Write the relation between force, mass and acceleration and define one newton.
9. What is weight? Write its relation with mass and g.
10. Define momentum and state its direction.
11. Why does a cricket fielder move the hands backward while catching a fast ball?
12. Why are airbags useful during a collision?
13. State Newton's third law of motion.

14. Why do action and reaction forces not cancel each other?
15. Explain the motion of a canoe using Newton's third law.
16. Explain how a rocket lifts off using Newton's third law.
17. Why does a boat move backward when a sailor jumps forward from it?
18. What are internal and external forces in a system?
19. Two connected masses m_1 and m_2 are pulled by force F on a frictionless surface. Write the acceleration of the system.
20. Explain why constant velocity implies zero net force.

One-Minute Chapter Summary

Quick revision

Force has magnitude and direction and is measured in newtons. The motion of an object depends on net force. Balanced forces give zero net force, while unbalanced forces produce acceleration. Friction opposes motion. Newton's first law explains motion when net force is zero; the second law relates force, mass and acceleration through F = ma; and the third law states that interacting objects exert equal and opposite forces on each other. Momentum is p = mv, weight is W = mg and connected objects can often be analysed conveniently as a single system.

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