CHAPTER NOTES

Laws of Motion Class 11 Notes | CBSE Physics Chapter 4

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CHAPTER SUMMARY

Laws of Motion builds on Newton's three laws to explain why objects start, stop, speed up, or change direction, linking force to momentum through F = ma and F = dp/dt. It also covers friction, impulse, equilibrium, and conservation of momentum, the ideas behind everyday recoil, collisions, and motio...

... see more

CHAPTER NOTES

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Key Concepts

1. Force and Inertia

A **force** is a push or a pull that can change the state of rest or of uniform motion of a body, or change its shape. **SI unit:** newton (N). Force is a vector quantity.

Inertia is the natural tendency of a body to resist any change in its state of rest or of uniform motion. A heavier body has more inertia — that is why it is harder to push a loaded trolley than an empty one.

Three Types of Inertia

- **Inertia of rest:** a body at rest stays at rest (dust falls off a carpet when you beat it).
- **Inertia of motion:** a moving body keeps moving (a passenger lurches forward when a bus brakes suddenly).
- **Inertia of direction:** a body resists change in its direction of motion (mud flies off tangentially from a spinning wheel).

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

A body continues in its state of rest or of uniform motion in a straight line unless acted upon by an external **unbalanced** force.

The first law gives us the qualitative definition of force (force is what changes a body's state of motion) and defines inertia. If the net force is zero, acceleration is zero — the body is in equilibrium.

Key idea: No net force is needed to keep a body moving at constant velocity — only to change its velocity.

3. Linear Momentum

Linear momentum (p) is the quantity of motion contained in a body. It is the product of mass and velocity.

p = mv

- **SI unit:** kg·m/s (or N·s)
- It is a **vector quantity**, in the direction of velocity.

- A heavy slow truck and a light fast bullet can have the same momentum.

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4. Newton's Second Law of Motion

The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction of the force.

$F = dp/dt = d(mv)/dt = ma$ (for constant mass)

- This is the quantitative definition of force.
- 1 newton = the force that gives a 1 kg mass an acceleration of 1 m/s².
- Acceleration is along the direction of the net force.

The second law contains the first law as a special case: if F = 0, then a = 0, so velocity is constant.

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5. Impulse

Impulse is the product of a force and the time for which it acts. It equals the change in momentum of the body (the impulse-momentum theorem).

Impulse $J = F \times \Delta t = \Delta p = m(v - u)$

- **SI unit:** N·s or kg·m/s
- It is a vector quantity.
- This is why cricketers pull their hands back while catching a ball — increasing Δt reduces the force F felt for the same change in momentum.

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6. Newton's Third Law of Motion

To every action there is an equal and opposite reaction. Action and reaction act on **two different bodies**, are equal in magnitude, opposite in direction, and act simultaneously.

- A gun recoils when a bullet is fired.
- A swimmer pushes water backward; water pushes the swimmer forward.
- A rocket expels gas downward; the gas pushes the rocket upward.

Important: Action and reaction never cancel out because they act on different bodies.

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7. Law of Conservation of Linear Momentum

If the net external force on a system is zero, the total linear momentum of the system remains constant.

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

This law is a direct consequence of Newton's second and third laws. It is the principle behind recoil of a gun, rocket propulsion, and collisions.

Recoil of a Gun

If a gun of mass M fires a bullet of mass m with velocity v, the recoil velocity V of the gun is:

$V = -mv/M$ (negative sign shows the gun moves opposite to the bullet)

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8. Free-Body Diagrams (FBD)

A **free-body diagram** is a sketch showing a single body isolated from its surroundings with all the external forces acting on it drawn as arrows.

[DIAGRAM: A block on a table — weight mg downward, normal reaction N upward, applied force F horizontal, friction f opposite to motion.]

Common Forces in an FBD

- **Weight (W = mg):** always acts vertically downward.
- **Normal reaction (N):** perpendicular to the surface of contact.
- **Tension (T):** along a string, pulling away from the body.

- **Friction (f):** along the surface, opposing relative motion.

Method: Isolate the body → draw all forces → choose axes → apply $\Sigma F_x = ma_x$ and $\Sigma F\_y = ma\_y$.

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9. Equilibrium of Concurrent Forces

A body is in equilibrium when the net force on it is zero, so it has zero acceleration (either at rest or moving with constant velocity).

Condition: $\Sigma F_x = 0$ and $\Sigma F\_y = 0$

For three concurrent forces in equilibrium, the **Lami's theorem** applies:

$$F_1/\sin\alpha = F_2/\sin\beta = F_3/\sin\gamma$$

where α, β, γ are the angles opposite to forces F_1, F_2, F_3 respectively.

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10. Friction

Friction is the force that opposes relative motion (or tendency of motion) between two surfaces in contact. It acts along the surfaces, opposite to the direction of motion.

Types of Friction

Type	Description	Relation
Static friction (f_s)	Acts when the body is at rest; self-adjusting up to a maximum	$f_s \le \mu_s N$
Limiting friction (f_{max})	Maximum static friction, just before motion begins	$f_{max} = \mu_s N$
Kinetic friction (f_k)	Acts when the body is in motion	$f\_k = \mu\_k N$

Note: $\mu_s > \mu\_k$, which is why it is harder to start sliding an object than to keep it sliding.

Laws of Friction

- Friction is independent of the area of contact.
- Friction is proportional to the normal reaction N.
- Kinetic friction is nearly independent of speed.

Angle of Friction and Angle of Repose

- **Angle of friction (ϕ):** $\tan\phi = \mu$ — the angle between the resultant of N and limiting friction, and the normal.
- **Angle of repose (θ):** the minimum angle of an inclined plane at which a body just begins to slide. $\tan\theta = \mu_s$. For a plane inclined at angle θ, the angle of repose equals the angle of friction.

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11. Motion on an Inclined Plane

For a body of mass m on a frictionless incline of angle θ, gravity splits into two components.

- **Along the incline (down):** $mg\sin\theta$ → causes acceleration $a = g\sin\theta$
- **Perpendicular to incline:** $mg\cos\theta$ → balanced by normal reaction $N = mg\cos\theta$

With friction (body sliding down): $a = g(\sin\theta - \mu\cos\theta)$.

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12. Dynamics of Circular Motion

When a body moves in a circle, its direction keeps changing, so it is accelerating even at constant speed. The acceleration points towards the centre — this is **centripetal acceleration**.

$$a\_c = v^2/r = \omega^2 r$$

The net inward force causing this is the **centripetal force**:

$$F\_c = mv^2/r = m\omega^2 r$$

Important: Centripetal force is not a new kind of force — it is provided by tension, gravity, friction, or normal reaction depending on the situation.

Banking of Roads

On a curved road, banking (tilting the road inward) provides the centripetal force without relying entirely on friction.

- **Ignoring friction:** $\tan\theta = v^2/(rg)$, so the safe speed is $\mathbf{v = \sqrt{(rg \tan \theta)}}$.
- **With friction (maximum speed):** $v_{max} = \sqrt{[rg(\tan\theta + \mu)/(1 - \mu \tan\theta)]}$

Vehicle on a Level Curved Road

Here friction alone supplies the centripetal force, so the maximum safe speed is $\mathbf{v_{max} = \sqrt{(\mu rg)}}$.

Read the rest of the chapter →

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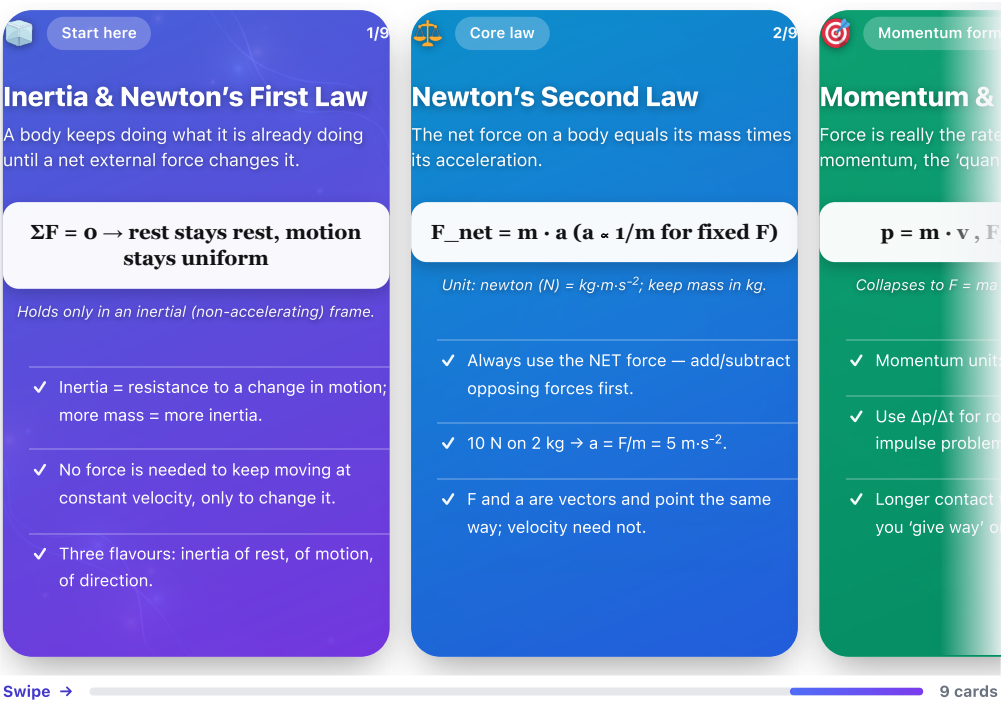

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Q1 NEET 2020

A truck is stationary and has a bob suspended by a light string, in a frame attached to the truck. The truck suddenly moves to the right with an acceleration of a. The pendulum will tilt

A to the left, angle with vertical = $\sin^{-1}(g/a)$

B to the left, angle with vertical = $\tan^{-1}(a/g)$

C to the left, angle with vertical = $\sin^{-1}(a/g)$

D to the left, angle with vertical = $\tan^{-1}(g/a)$

Q2 NEET 2020

Two bodies of mass 4 kg and 6 kg are tied to the ends of a massless string. The string passes over a pulley which is frictionless. The acceleration of the system in terms of acceleration due to gravity g is

A g/2

B g/5

C g/10

D g

Q3 NEET 2020

Calculate the acceleration of the block and trolly system shown in the figure. The coefficient of kinetic friction between the trolly (10 kg) and the surface is 0.05. The hanging block is 2 kg. (g = 10 m/s², mass of the string is negligible and no other friction exists)

A 1.25 m/s²

B 1.50 m/s²

C 1.66 m/s²

D 1.00 m/s²

Q4 NEET 2019

A particle moving with velocity v is acted upon by three forces shown by the vector triangle PQR. The velocity of the particle will

A decrease

B remain constant

C change according to the smallest force QR

D increase

Q5 NEET 2019

A body of mass m is kept on a rough horizontal surface (coefficient of friction = μ). Horizontal force is applied on the body, but it does not move. The resultant of normal reaction and the frictional force acting on the object is given by F, where F is

A $|F| = mg + \mu mg$

B $|F| = \mu mg$

C $|F| \leq mg\sqrt{(1+\mu^2)}$

D $|F| = mg$

Q6 NEET 2018

A block of mass m is placed on a smooth inclined wedge ABC of inclination θ. The wedge is given an acceleration a towards the right. The relation between a and θ for the block to remain stationary on the wedge is

A a = g cosθ

B a = g/sinθ

C a = g/cosecθ

D a = g tanθ

Q7 NEET 2017

Two blocks A and B of masses 3m and m respectively are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in figure. The magnitudes of acceleration of A and B immediately after the string is cut are respectively

A g, g/3

B g/3, g

C g, g

D g/3, g/3

Q8 NEET 2013

Three blocks with masses m, 2m and 3m are connected by strings, as shown in the figure. After an upward force F is applied on block m, the masses move upward at constant speed v. What is the net force on the block of mass 2m? (g is the acceleration due to gravity)

A Zero

B 2mg

C 3mg

D 6mg

Q9 NEET 2010

A man of 50 kg mass is standing in a gravity free space at a height of 10 m above the floor. He throws a stone of 0.5 kg mass downwards with a speed 2 m/s. When the stone reaches the floor, the distance of the man above the floor will be

A 9.9 m

B 10.1 m

C 10 m

D 20 m

Q10 NEET 1995

If the force on a rocket moving with a velocity of 300 m/s is 345 N, then the rate of combustion of the fuel is

A 0.55 kg/s

B 0.75 kg/s

C 1.15 kg/s

D 2.25 kg/s

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Frequently Asked Questions

What is Newton's first law of motion?

Newton's first law states that a body stays at rest, or keeps moving in a straight line at constant speed, unless a net external force acts on it. This tendency to resist any change in its state of motion is called inertia, and a body with more mass has more inertia.

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What is the formula for Newton's second law and what does it mean?

Newton's second law is F_net = m times a, meaning the net force on a body equals its mass times its acceleration. More generally force is the rate of change of momentum, F = dp/dt, and the unit of force is the newton (N), equal to kg times m per second squared.

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Is Laws of Motion important for NEET?

Yes, Laws of Motion is part of the NEET physics syllabus and is a high-yield mechanics chapter. It is tested directly and its force-balance and free-body-diagram skills carry over into work-energy, circular motion, and many other numerical problems, so it gives strong returns for the effort.

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What is the difference between static and kinetic friction?

Static friction acts before sliding begins and self-adjusts up to a maximum of mu_s times N, balancing the applied force until that limit. Kinetic friction acts while the surfaces are sliding and stays fixed at mu_k times N opposite to the motion, and since mu_s is greater than mu_k it takes more force to sta...

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Why are the weight of a book and the normal force from the table not an action-reaction pair?

A Newton's third law action-reaction pair must act on two different bodies, but the book's weight and the table's normal force both act on the book itself, so they are not a pair. The true reaction to Earth pulling the book down is the book pulling Earth up.

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