KSQUARE CAREER INSTITUTE

LAWS OF MOTION

Class 11 Physics • Newton's 1st & 2nd Laws • NEET / JEE Notes

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Today's Targets

1. Inertia, force & free body diagram (FBD)
2. Newton's 1st law — equilibrium, inclined plane, Lami's theorem
3. Momentum & Newton's 2nd law
4. Motion of connected bodies — contact force & tension
5. Pulley (Atwood machine) systems, lifts, rope tension
6. Added: Newton's 3rd law, impulse, conservation of momentum, friction, pseudo force — formula sheet

BASICS

- **Inertia** — the inability (disability) of a body to change its state by itself. **Inertia of rest**: a passenger falls backward when a bus suddenly starts. **Inertia of motion**: a passenger falls forward when a moving bus suddenly stops.
- **Mass is the measure of inertia.**
- **Force** is a **vector** (magnitude + direction); SI unit **newton (N)**; $F_{net} = F_1 + F_2 + F_3 + \ldots$ (vector sum).

Free Body Diagram (FBD)

Draw the body alone and show **all the forces** acting on it:

1. **Field forces** — gravitational (mg), electric, magnetic
2. **Contact forces** — normal reaction (N), friction, tension
3. **External / applied force**

- Example: a 2 kg block on a table pushed by 2 N — forces: 2 N (applied), mg = 20 N (down), N = 20 N (up).

NEWTON'S FIRST LAW OF MOTION

First law (law of inertia)

"Every body continues in its state of **rest or of uniform motion along a straight line** unless and until an **external force** is applied."

Equilibrium

$$\text{If } F_{net} = F_1 + F_2 + \ldots + F_n = 0 \Rightarrow a_{net} = 0 \Rightarrow \text{velocity} = \text{constant (equilibrium)}$$

Inclined Plane

- Break all forces **along the direction of motion** and **perpendicular to it**.
- On an incline of angle θ: component along the incline = **mg sin θ**; perpendicular = **mg cos θ ⇒ N = mg cos θ** (no other perpendicular force).

Lami's Theorem

Lami's theorem

For three concurrent, coplanar forces in equilibrium:

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

(α, β, γ = angles opposite to F_1, F_2, F_3 respectively)

Practice — First Law

Q1. Three blocks m, 2m, 3m tied together move upward at constant speed v. The net force on the block of mass 2m is **[NEET 2013]**

(a) Zero
(b) 2mg
(c) 3mg
(d) 6mg

Answer: (a) — Constant velocity ⇒ a = 0 ⇒ $F_{net} = 0$.

Q2. A particle moving with velocity v is acted on by three forces represented by the sides of a closed vector triangle PQR. Its velocity will **[NEET 2019]**

(a) remain constant
(b) change according to the smallest force QR
(c) increase
(d) decrease

Answer: (a) — $F_1 + F_2 + F_3 = 0 \Rightarrow F_{net} = 0$.

Q3. A mass √2 m hangs from a string passing over two pulleys with masses m at each end; each string makes angle θ with the vertical. Find θ for equilibrium.

(a) 0°
(b) 30°
(c) 45°
(d) 60°

Answer: (c) — T = mg; 2T cos θ = √2 mg ⇒ cos θ = 1/√2.

Q4. A 2 kg block on a 30° incline is connected over a pulley to a 2 kg hanging block and to block A on the other side. Find m_a for equilibrium (g = 10).

(a) 2 kg
(b) 0.5 kg
(c) 1 kg
(d) 3 kg

Answer: (d) — $20 + mg\sin 30° = m_a g \Rightarrow 20 + 10 = 10m_a \Rightarrow m_a = 3$ kg.

MOMENTUM & NEWTON'S SECOND LAW

- **Linear momentum** p = mv (vector, along v); |p| = mv; unit **kg m s^{-1}**.

Second law

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

Second law

$$F \propto dp/dt \Rightarrow F = k\, d(mv)/dt = k\,(v\, dm/dt + m\, dv/dt)$$

With k = 1 and constant mass: $\mathbf{F = ma}$

Average force: $F = \Delta p/\Delta t = m(v_f - v_i)/t$

Q5. A player takes 0.1 s in catching a ball of mass 150 g moving at 20 m/s. The force imparted by the ball on the player's hands is

(a) 0.3 N
(b) 3 N
(c) 30 N
(d) 300 N

Answer: (c) — F = m(0 – 20)/0.1 = 0.15 × 200 = 30 N (opposing force).

MOTION OF CONNECTED BODIES

Key idea

$$a = F_{driving} / M_{total}$$

Normal (contact) force acts perpendicular to the contact surface

Blocks in Contact (F applied on m_1)

Contact forces

$$a = F/(m_1 + m_2 + m_3)$$

N_1 (between m_1 & m_2) = $(m_2 + m_3)\, a$; N_2 (between m_2 & m_3) = $m_3\, a$

Q6. Blocks A (4 kg), B (2 kg), C (1 kg) are in contact on a smooth surface; 14 N pushes A. The contact force between A and B is **[CBSE AIPMT 2015]**

(a) 2 N
(b) 6 N
(c) 8 N
(d) 18 N

Answer: (b) — a = 14/7 = 2 m/s^2; N = (2 + 1) × 2 = 6 N.

▸ Blocks Connected by Strings (F pulls m_3)

Tensions

$$a = F/(m_1 + m_2 + m_3)$$

$$T_2 \text{ (between } m_1 \& m_2) = m_1 a \; ; \quad T_1 \text{ (between } m_2 \& m_3) = (m_1 + m_2) a$$

NEET Point / PYQ Alert

In a **massless string**, the **same rope has the same tension** throughout.

Q7. Blocks 2 kg, 3 kg, 1 kg are connected by strings; 14 N pulls right on the 1 kg block and 8 N pulls left on the 2 kg block. Tension in the string between 2 kg and 3 kg is

(a) 6 N
(b) 8 N
(c) 10 N
(d) 12 N

Answer: (c) — $a = (14 - 8)/6 = 1$ m/s²; $T - 8 = 2 \times 1 \Rightarrow T = 10$ N (and the other string: $T_1 - 8 = 5 \times 1 \Rightarrow 13$ N).

PULLEY SYSTEMS (ATWOOD MACHINE)

Two masses over a pulley ($m_2 > m_1$)

$$a = (m_2 - m_1)\, g \,/\, (m_1 + m_2)$$

$$T = m_1(g + a) = 2m_1m_2g \,/\, (m_1 + m_2)$$

Q8. Masses 5 kg and 10 kg hang over a frictionless pulley. Their acceleration is

(a) g
(b) g/2
(c) g/3
(d) g/4

Answer: (c) — $a = (100 - 50)/15 = 10/3 = g/3$.

Q9. A 2 kg block on a smooth table is connected by strings over pulleys to a 5 kg block on one side and a 3 kg block on the other. Find the acceleration and the tensions (g = 10).

Answer: a = 2 m/s²; T_1 = 40 N; T_2 = 36 N — $a = (50 - 30)/10 = 2$; $50 - T_1 = 5 \times 2 \Rightarrow T_1 = 40$ N; $T_2 - 30 = 3 \times 2 \Rightarrow T_2 = 36$ N.

Q10. Two 2 kg blocks rest on smooth inclines of 37° (B) and 53° (A) connected over a pulley at the top. Tension in the string is

(a) 12 N
(b) 8 N
(c) 10 N
(d) 14 N

Answer: (d) — Driving: 20 sin 53° = 16 N; opposing 20 sin 37° = 12 N ⇒ $a = 4/4 = 1$ m/s²; $T - 12 = 2 \times 1 \Rightarrow T = 14$ N.

LIFTS & ROPES

Lift motion	Tension in cable / apparent weight
At rest or uniform velocity	T = mg
Accelerating up (a)	T = m(g + a)
Accelerating down (a)	T = m(g – a)
Free fall (a = g)	T = 0 (weightlessness)

Q11. The mass of a lift is 2000 kg. When the tension in the cable is 28000 N, its acceleration is

(a) 30 m s^{-2} down
(b) 4 m s^{-2} up
(c) 4 m s^{-2} down
(d) 14 m s^{-2} up

Answer: (b) — 28000 – 20000 = 2000a ⇒ a = 4 m s^{-2} upward.

Q12. A 60 kg person is in a lift of mass 940 kg which moves up with acceleration 1 m/s^2 (g = 10). The tension in the cable is

(a) 9680 N
(b) 11000 N
(c) 1200 N
(d) 8600 N

Answer: (b) — T = 1000(10 + 1).

Q13. A 20 kg monkey holds a vertical rope that breaks if the suspended mass exceeds 25 kg. The maximum acceleration with which the monkey can climb up is (m/s^2) **[AIPMT 2003]**

(a) 2.5
(b) 10
(c) 12
(d) 15

Answer: (a) — T_{max} = 250 N; 250 – 200 = 20a ⇒ a = 2.5 m/s^2.

Q14. A rope of length L and mass M hangs from a rigid support. The tension at distance x from the support is

(a) Mg
(b) (L – x)Mg/L
(c) LMg/(L – x)
(d) xMg/L

Answer: (b) — Tension supports the rope below: mass (M/L)(L – x).

BEYOND THE PDF (ADDITIONAL TOPICS)

Topic	Key facts / formulas
Newton's 3rd law	To every action there is an **equal and opposite reaction**; action–reaction act on **different bodies**, so they never cancel
Impulse	J = F Δt = Δp (area under the F–t graph); unit N s
Conservation of linear momentum	If F_{ext} = 0, total momentum is constant — e.g. recoil of gun: $m_b v_b = -M_g V_g$

Topic	Key facts / formulas
Static friction	$f_s \le \mu_s N$ (self-adjusting); limiting friction $f = \mu_s N$
Kinetic friction	$f_k = \mu_k N$; $\mu_k < \mu_s$; rolling friction is least
Angle of repose	$\tan\theta = \mu_s$
Block on rough incline	$a = g(\sin\theta - \mu\cos\theta)$ (sliding down)
Pseudo force	In a frame with acceleration a: $F_{pseudo} = -ma$
Banking of road	$\tan\theta = v^2/rg$ (no friction); v_{max} on level road = $\sqrt{(\mu rg)}$

FORMULA SHEET

1. First law: $F_{net} = 0 \Rightarrow v = \text{constant}$
2. Lami: $F_1/\sin\alpha = F_2/\sin\beta = F_3/\sin\gamma$
3. $p = mv$; $F = dp/dt = ma$; $F_{avg} = \Delta p/\Delta t$
4. Connected bodies: $a = F_{driving}/M_{total}$
5. Contact force on rear blocks = (mass behind) × a
6. Atwood: $a = (m_2 - m_1)g/(m_1 + m_2)$; $T = 2m_1m_2g/(m_1 + m_2)$
7. Lift: $T = m(g \pm a)$
8. Hanging rope: $T(x) = Mg(L - x)/L$

Draw the FBD first — every mechanics question gets easier!