NEWTON'S LAWS OF MOTION

NEET Physics — Class 11 — Complete Revision Sheet

1. FUNDAMENTAL CONCEPTS

Newton's First Law (Law of Inertia)

- Object at rest stays at rest; moving object stays moving in straight line unless external force acts
- Condition: $\sum \vec{F} = 0$ (equilibrium)
- No net force $\Rightarrow$ No acceleration

Newton's Second Law

- Force = Rate of change of momentum
- $\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$
- Direction of force = Direction of acceleration

Newton's Third Law

- Action = Reaction (equal, opposite, on different bodies)
- $F_{AB} = -F_{BA}$
- Never cancel (act on different objects)

Types of Inertia

- **Inertia of Rest:** Resistance to change from rest to motion
- **Inertia of Motion:** Resistance to change in velocity
- **Inertia of Direction:** Resistance to change in direction

2. KEY FORMULAS

Force

$\boxed{F = ma}$ (SI: N = kg·m/s^2)

$\boxed{\vec{F} = \frac{d\vec{p}}{dt}}$ (Force = rate of change of momentum)

Momentum

$\boxed{p = mv}$ (SI: kg·m/s, Dimension: [MLT^{-1}])

- Vector quantity (direction = velocity direction)
- $\Delta p = m\Delta v = m(v_f - v_i)$

Impulse

$\boxed{J = F\Delta t = \Delta p}$

- SI: N·s or kg·m/s
- From graph: Area under F-t curve
- Average force: $F_{avg} = \frac{\Delta p}{\Delta t}$

Weight

$\boxed{W = mg}$ (Force, SI: N, Direction: Downward)

- Varies with g (location dependent)
- Mass always constant

Apparent Weight in Elevators

Moving up with acceleration a: $\boxed{N = m(g + a)}$

Moving down with acceleration a: $\boxed{N = m(g - a)}$

Free fall ($a = g$): $\boxed{N = 0}$ (Weightlessness)

3. FREE BODY DIAGRAM (FBD)

Steps to Draw FBD

1. Isolate the object (imagine as point particle)
2. Draw all forces as vectors from center
3. Label each force with magnitude and direction
4. Include: weight (down), normal (perpendicular), tension (along string), friction (opposing motion)
5. Choose coordinate system (x, y axes)

Common Forces in FBD

- **Weight (mg):** Always downward
- **Normal (N):** Perpendicular to surface, pushing outward
- **Tension (T):** Along string, pulling
- **Friction (f):** Parallel to surface, opposes motion
- **Applied Force (F):** External push/pull

KEY: Draw FBD FIRST in every problem. It clarifies what forces act.

4. FRICTION

Static Friction (f_s)

$\boxed{0 \leq f_s \leq \mu_s N}$ (Self-adjusting)

- Acts when object is at rest
- Value depends on applied force
- Maximum = Limiting friction

Limiting Friction

$\boxed{f_{limit} = \mu_s N}$ (Just before object moves)

Kinetic Friction (f_k)

$\boxed{f_k = \mu_k N}$ (Always constant when moving)

- Acts when object is moving
- Always opposes motion
- $\mu_k < \mu_s$ (always!)

Angle of Friction (λ)

$$\boxed{\tan\lambda = \mu_s}$$

- When force applied at angle λ: friction = force component perpendicular
- λ = angle of repose for inclined plane

Angle of Repose (θ_0)

$\boxed{\tan\theta_0 = \mu_s}$ (Angle when object just starts to slide)

COMMON MISTAKE: Confusing static and kinetic friction coefficients!

5. INCLINED PLANE

Forces on Incline (angle θ)

- Parallel to plane: $mg\sin\theta$ (down)
- Perpendicular to plane: $mg\cos\theta$ (into)
- Normal reaction: $N = mg\cos\theta$
- Friction: $f = \mu N = \mu mg\cos\theta$

Acceleration Down Incline

No friction: $\boxed{a = g\sin\theta}$

With friction: $\boxed{a = g(\sin\theta - \mu\cos\theta)}$

- Slides down if: $\tan\theta > \mu_s$
- Doesn't slide if: $\tan\theta \leq \mu_s$

6. CIRCULAR MOTION

Centripetal Force

$$\boxed{F_c = \frac{mv^2}{r} = m\omega^2 r}$$ (Towards center)

- Always perpendicular to velocity
- Changes direction, not speed
- Net inward force required

Vertical Circular Motion

At bottom: $\boxed{N - mg = \frac{mv^2}{r}} \Rightarrow N = mg + \frac{mv^2}{r}$

At top: $\boxed{N + mg = \frac{mv^2}{r}} \Rightarrow N = \frac{mv^2}{r} - mg$

Banking of Roads

$$\boxed{\tan\theta = \frac{v^2}{rg}}$$ (Safe speed)

- No friction needed at this speed
- Banking angle depends on safe velocity

NEET TIP: At highest point of vertical circle, minimum speed is $v = \sqrt{gr}$ (when $N = 0$).

7. SYSTEMS & CONSTRAINTS

Two Bodies Connected

$\boxed{F = (m_1 + m_2)a}$ (Same acceleration)

Pulley System (Light String)

$$\boxed{a = \frac{(m_1 - m_2)g}{m_1 + m_2}}$$ (Assuming $m_1 > m_2$)

$$\boxed{T = \frac{2m_1 m_2 g}{m_1 + m_2}}$$ (Tension)

- Assumptions: Massless string, frictionless pulley
- Same tension throughout string
- Both blocks have same acceleration magnitude

8. CONSERVATION OF MOMENTUM

Principle If net external force = 0, momentum is conserved.

$$\boxed{p_{initial} = p_{final}} \text{ or } m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

Applications

- Collisions (internal forces cancel)
- Explosions (momentum before = after)
- Isolated systems (no external forces)

WARNING: Kinetic energy NOT conserved in inelastic collisions!

9. IMPORTANT GRAPHS

Force vs Time (F-t) Graph

- Area under curve = Impulse ($J = \int F\,dt$)
- Slope = ? (No direct meaning)
- Constant F $\Rightarrow$ Uniform impulse delivery

Momentum vs Time (p-t) Graph

- Slope = Force ($\frac{dp}{dt} = F$)
- Straight line = Constant force
- Vertical jump = Impulsive force

10. UNITS & DIMENSIONS

Quantity	Symbol	SI Unit	Dimension
Force	F	N (Newton)	$[MLT^{-2}]$
Momentum	p	kg·m/s	$[MLT^{-1}]$
Impulse	J	N·s	$[MLT^{-1}]$
Mass	m	kg	[M]
Weight	W	N	$[MLT^{-2}]$
Friction	f	N	$[MLT^{-2}]$
Normal	N	N	$[MLT^{-2}]$

11. QUICK TRICKS & COMMON MISTAKES

Action-Reaction Pairs

MISTAKE: Thinking action and reaction cancel each other.

CORRECT: They act on DIFFERENT bodies, never cancel on same body.

Mass vs Weight

MISTAKE: Using $m = W/9.8$ everywhere (g varies!)

CORRECT: Mass is constant. Weight varies: $W = mg$ at that location.

Friction Direction

MISTAKE: Friction acts in direction of applied force.

CORRECT: Friction OPPOSES relative motion (or potential motion).

Static vs Kinetic

MISTAKE: Using f_k for object at rest.

CORRECT: At rest $\Rightarrow f_s \leq \mu_s N$. Moving $\Rightarrow f_k = \mu_k N$.

Tension in String

MISTAKE: Different tensions on both sides of massless string.

CORRECT: For ideal string: $T_1 = T_2$ (same throughout).

Normal Reaction

MISTAKE: N always equals mg.

CORRECT: $N = mg$ only on horizontal surface. On incline: $N = mg\cos\theta$.

Centripetal Direction

MISTAKE: Centripetal force acts outward.

CORRECT: Centripetal ALWAYS acts toward center (inward).

12. NEET EXAM CHECKLIST

- ✓Draw FBD carefully (includes ALL forces)
- ✓Identify if object in equilibrium ($\sum F = 0$) or accelerating
- ✓Check: Is it moving? If YES, use $f_k = \mu_k N$. If NO, check $f_s \leq \mu_s N$
- ✓Choose correct formula: $F = ma$ or impulse-momentum
- ✓For systems: Same tension? Same acceleration?
- ✓In circular motion: Force toward center?
- ✓Momentum conserved? Check external forces (gravity counts!)
- ✓Verify units and dimensions
- ✓Check limiting cases (e.g., $g \to 0$, $\mu \to 0$)

13. MASTER FORMULA REFERENCE

Core Formulas:

$$F = ma \quad ; \quad p = mv \quad ; \quad J = F\Delta t = \Delta p$$

$$W = mg \quad ; \quad f_s \leq \mu_s N \quad ; \quad f_k = \mu_k N$$

$$F_c = \frac{mv^2}{r} \quad ; \quad \tan\theta = \frac{v^2}{rg}$$

SUMMARY: Newton's 2nd Law ($F = ma$) is the KEY to all dynamics problems!