FREE NOTES · NCERT + JEE/NEET LEVEL

Laws of Motion

Newton ke teen laws se lekar friction, pulley aur banked road tak, simple Hinglish me. Har topic ke saath formula box, diagram, solved numericals aur common mistakes.

01 Force kya hai?
02 Inertia & Newton's 1st law
03 Momentum & Newton's 2nd law
04 Impulse
05 Newton's 3rd law
06 Conservation of linear momentum
07 Equilibrium & Lami's theorem
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18 Quick revision: exam se pehle 5 minute

01 Force kya hai?

Force wo push ya pull hai jo kisi body ki **speed, direction ya shape** badal sakta hai (ya badalne ki koshish karta hai). SI unit: **newton (N)**. 1 N = 1 kg·m/s².

- **Contact forces:** jab do cheezein touch karti hain, jaise normal force, friction, tension, push.
- **Non-contact (field) forces:** bina touch ke, jaise gravity, magnetic force, electric force.

Force ek **vector** hai, isliye do forces ko seedha jodte nahi. Unka **vector sum** lete hain.

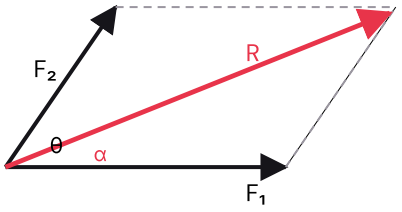
FORMULA: DO FORCES KA RESULTANT

$$R = \sqrt{(F_1^2 + F_2^2 + 2F_1F_2 \cos\theta)}$$

$$\tan\alpha = F_2 \sin\theta / (F_1 + F_2 \cos\theta)$$

θ = dono forces ke beech ka angle, α = resultant ka F_1 se angle.

Special case $F_1 = F_2 = F$: $R = 2F\cos(\theta/2)$, α = θ/2.



Parallelogram law: R diagonal hai

02 Inertia & Newton's 1st law

NCERT: ARISTOTLE KI GALTI VS GALILEO

Aristotle ka kehna tha ki body ko chalte rehne ke liye force lagta rehna chahiye. **Galileo** ne inclined plane ke experiment se dikhaya: ek slope se neeche aayi ball doosre slope pe *lagbhag utni hi height* tak chadhti hai. Doosra slope jitna flat karo, ball utna aage jaati hai. Bilkul flat aur smooth surface pe wo **hamesha chalti rehti**. Ball rukti hai sirf friction ki wajah se. Yahin se inertia ka idea aaya.

Inertia = body ka apni state (rest ya uniform motion) ko **khud se na badal paane** ka gun. **Jitna zyada mass, utna zyada inertia.** Inertia sirf mass pe depend karta hai, shape ya speed pe nahi.

NEWTON'S 1ST LAW (LAW OF INERTIA)

Agar body pe **net external force zero** hai, toh rest wali body rest me rahegi aur moving body **same velocity** (same speed, same direction) se chalti rahegi.

Type of inertia	Matlab	Roz ki zindagi ka example
Inertia of rest	Rest wali body khud se move nahi kar sakti	Bus achanak chale toh hum peeche ki taraf girte hain; dari ko jhatka do toh dhool alag ho jaati hai
Inertia of motion	Moving body khud se ruk nahi sakti	Bus achanak ruke toh hum aage girte hain; long jump se pehle athlete daud ke aata hai
Inertia of direction	Body khud se direction nahi badal sakti	Bus mude toh hum bahar ki taraf jhukte hain; ghoomte pahiye se keechad tangent ki direction me udta hai

YAAD RAKHO

1st law force ko *define* karta hai (force wahi jo state badle). Force kitna hai, ye 2nd law batata hai.

03 Momentum & Newton's 2nd law

Linear momentum $p = m\,v$: kisi chalti body me "kitni motion bhari hai". Vector hai, direction velocity wali. Unit: kg·m/s.

NEWTON'S 2ND LAW

Momentum ke change hone ki rate, lagaaye gaye **net external force** ke barabar hoti hai, aur force ki direction me hoti hai.

FORMULAS

$$F = dp/dt = d(mv)/dt$$

Situation	Force
Mass constant, velocity badle (zyada tar sawaal)	$F = m\,(dv/dt) = m\,a$
Velocity constant, mass badle (conveyor belt pe ret girna)	$F = v\,(dm/dt)$
Dono badlein (rocket)	$F = m\,a + v\,(dm/dt)$
Rocket ka thrust (gas relative speed u se nikle)	$F_{thrust} = u\,(dm/dt)$

COMMON GALTI

$F = ma$ sirf tab jab mass constant ho. Rocket ya conveyor ke sawaal me dm/dt wala term mat bhoolo.

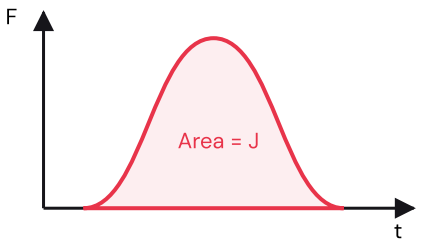
04 Impulse

Jab bada force bahut thodi der ke liye lage (bat se ball, hathoda), toh force aur time ka product dekhte hain. Ise **impulse (J)** kehte hain.

IMPULSE–MOMENTUM THEOREM

$$J = F_{avg} \cdot \Delta t = \Delta p = m\,v - m\,u$$

F–t graph ke neeche ka area = impulse. Unit: N·s (= kg·m/s)



Force–time graph

REAL LIFE ME

- Catch lete waqt cricketer haath **peeche kheenchta** hai: Δt badha toh force kam, haath ko chot kam.
- Gaddi ya ret pe koodne se chot kam lagti hai: rukne ka time zyada.
- Car me **airbag aur crumple zone** isi principle pe kaam karte hain.

05 Newton's 3rd law

STATEMENT

Har action ka **barabar aur ulta reaction** hota hai. Agar A, B pe force lagaye toh B bhi A pe utna hi force ulti direction me lagata hai: $F_{AB} = -F_{BA}$

- Action aur reaction **alag-alag bodies** pe lagte hain, isliye ek dusre ko cancel nahi karte.
- Dono ek saath paida hote hain, pehle-baad wala koi nahi.
- Examples: chalte waqt pair zameen ko peeche dhakelta hai, zameen humein aage. Rocket gas ko neeche phenkta hai, gas rocket ko upar. Tairte waqt paani ko peeche dhakelte hain.

COMMON GALTI: "TABLE PE RAKHI KITAAB"

Kitaab ka weight (Earth ka kheench) aur table ka normal force **action-reaction pair NAHI** hain. Dono ek hi body (kitaab) pe lagte hain. Weight ka reaction = kitaab ka Earth ko upar kheenchna. Normal force ka reaction = kitaab ka table ko neeche dabana.

06 Conservation of linear momentum

Agar kisi system pe **net external force zero** ho, toh system ka total momentum constant rehta hai. Ye 2nd aur 3rd law se hi nikalta hai: andar ke forces pairs me cancel ho jaate hain.

FORMULA

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Gun recoil: pehle sab rest pe, toh $0 = m_bv_b + M_gV_g \Rightarrow V_g = -m_bv_b/M_g$ (minus = ulti direction)

Applications: gun ka recoil, bomb ka phatna (tukdon ka total momentum = 0), naav se kinare pe koodna, rocket.

07 Equilibrium & Lami's theorem

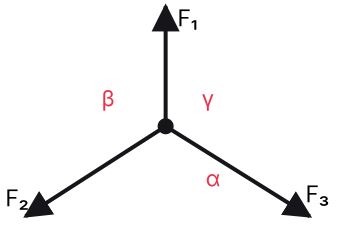
Body **equilibrium** me hai jab us pe net force zero ho: $\Sigma F_x = 0$, $\Sigma F_y = 0$. Body ya toh rest me hai ya constant velocity se chal rahi hai.

LAMI'S THEOREM

Teen forces ek point pe mil rahe hon aur body equilibrium me ho:

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

Har angle us force ke **saamne** wala angle hai (baaki do forces ke beech).

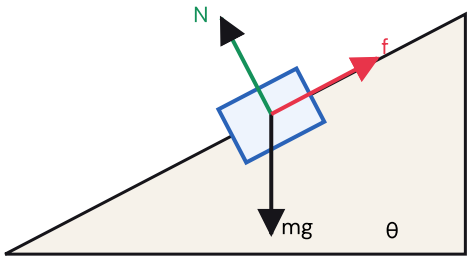


α = F_2 aur F_3 ke beech ka angle (F_1 ke saamne)

08 Free Body Diagram (FBD): har sawaal ki chaabi

Laws of Motion ka 80% sawaal sahi FBD se solve ho jaata hai. Steps:

1. Jis body ka sawaal hai, use **alag** se ek dot ya box ki tarah draw karo.
2. Us body pe lagne wale **saare forces** lagao: weight mg (neeche), normal N (surface ke perpendicular), tension T (rassi ki taraf), friction f (motion ke khilaaf), applied force.
3. Body jo forces *doosron* pe lagati hai, wo mat lagao.
4. Convenient axes chuno (incline pe: slope ke along aur perpendicular).
5. Har axis pe likho: $\Sigma F = m\,a$ (equilibrium me 0).



Incline pe block: mg, N, friction f (upar ki taraf, kyunki block neeche sarakna chahta hai)

INCLINE PE COMPONENTS

Slope ke along: $mg \sin\theta$

Slope ke perpendicular: $mg \cos\theta$

$N = mg \cos\theta$

Smooth incline pe: $a = g \sin\theta$

Friction ke saath (neeche sarakte hue): $a = g(\sin\theta - \mu_k \cos\theta)$

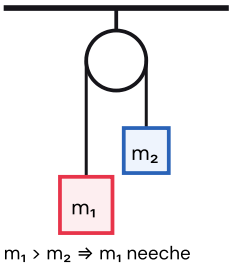
Common forces ek nazar me

Force	Direction	Kab lagta hai
Weight mg	Hamesha seedha neeche	Har body pe
Normal N	Surface ke perpendicular, body se door	Jab body surface ko dabaaye. Hamesha mg ke barabar nahi hota!
Tension T	Rassi ke along, body se door (kheenchta hai)	Light rassi me har jagah same tension
Friction f	Relative motion (ya uski koshish) ke khilaaf	Rough surface pe
Spring force	Natural length ki taraf wapas	$F = -k\,x$

09 Connected bodies & pulley

Trick: pehle **poore system** ko ek body maan ke acceleration nikalo, phir kisi ek body ka FBD bana ke tension ya contact force nikalo.

(a) Atwood machine

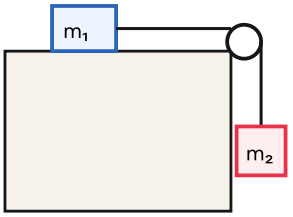


$m_1 > m_2 \Rightarrow m_1$ neeche

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

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

(b) Table pe block + latakta block



Smooth table:

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

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

Friction μ ho toh: $a = (m_2 - \mu\, m_1)\, g \,/\, (m_1 + m_2)$

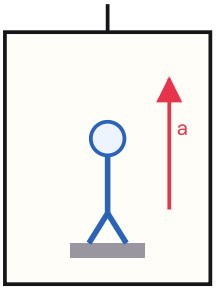
(c) Do blocks touch karte hue, peeche se force F

$$a = F \,/\, (m_1 + m_2) \quad \text{contact force on } m_2 = m_2\, F \,/\, (m_1 + m_2)$$

10 Lift me apparent weight

Weighing machine hamesha **normal force N** padhti hai, asli weight nahi. Lift me N badal jaata hai:

Lift ki state	Machine reading N
Rest ya constant velocity	$N = mg$
Upar accelerate (a)	$N = m\,(g + a)$
Neeche accelerate (a)	$N = m\,(g - a)$
Free fall (rassi toot gayi, a = g)	$N = 0$ (weightless)



Upar accelerate karti lift me aap "bhaari" mehsoos karte ho

11 Friction

Friction wo force hai jo do surfaces ke beech **relative motion (ya uski koshish) ka virodh** karta hai. Ye surface ki ruggedness aur molecular attraction se aata hai.

Type	Kab	Value
Static friction	Body abhi tak hili nahi	Self-adjusting: 0 se $f_{s,max} = \mu_s N$ tak, jitna zaroori ho utna
Kinetic friction	Body sarak rahi hai	$f_k = \mu_k N$ (lagbhag constant)
Rolling friction	Pahiya ludhak raha hai	Sabse kam: isliye pahiye aur ball bearings

ORDER YAAD RAKHO

$\mu_{rolling} < \mu_k < \mu_s$

Isliye bhaari almari ko hilana (shuru karna) mushkil hai, hilne ke baad aasaan.

Laws of friction

- Limiting friction normal force ke proportional hai: $f \propto N$.
- Contact area pe (lagbhag) depend nahi karta.
- Surfaces ke nature (material, roughness) pe depend karta hai.

ANGLE OF FRICTION (Λ)

$$\tan \lambda = \mu_s$$

Resultant of N aur f_{max} ka N se angle.

ANGLE OF REPOSE (Θ_R)

$$\tan \theta_r = \mu_s$$

Incline ka wo angle jahan block bas sarakne wala ho. $\lambda = \theta_r$.

COMMON GALTI

Static friction hamesha $\mu_s N$ nahi hota! Agar 10 N ki limit hai aur aap 4 N se dhakelo toh friction sirf 4 N hoga, body hilegi nahi.

FRICTION ZAROORI BHI HAI

Chalna, gaadi ka brake, pen se likhna, sab friction se hota hai. Kam karne ke tareeke: lubricant (oil), ball bearings, polishing, streamlined shape.

12 Circular motion: level road & banked road

Circle me ghoomne ke liye centre ki taraf ek force chahiye, **centripetal force**: $F_c = m v^2/r$. Ye koi naya force nahi; tension, friction, normal ya gravity me se koi ye kaam karta hai.

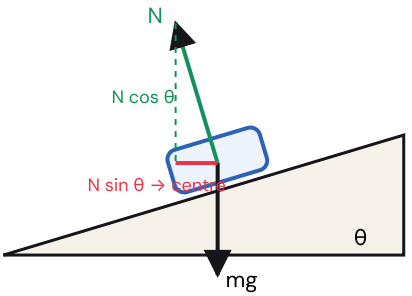
(a) Level (flat) road pe car

Centripetal force sirf **friction** deta hai:

$$m\,v^2/r \le \mu_s\, m\, g$$

$$v_{max} = \sqrt{(\mu_s\, r\, g)}$$

Mass pe depend nahi karta.



N cos θ = mg, N sin θ = mv²/r ⇒ tan θ = v²/rg

(b) Banked road

Road ko angle θ pe jhuka dete hain taaki normal force ka horizontal hissa centripetal force de.

Bina friction ke (ideal speed):

$$\tan\theta = v^2 / (r\, g)$$

Friction μ ke saath max speed:

$$v_{max} = \sqrt{(\, r\, g\, (\mu + \tan\theta) / (1 - \mu \tan\theta)\,)}$$

Cyclist mod pe andar ki taraf jhukta hai: angle $\tan\theta = v^2/(r\, g)$, same logic.

13 JEE Extra + Tricks

JEE LEVEL

- Atwood machine: $a = (m_1 - m_2)g/(m_1 + m_2)$, $T = 2m_1m_2g/(m_1 + m_2)$.
- Non-inertial frame: **pseudo force** $-ma$ jodo (frame ke acceleration ka ulta). Lift upar tez: apparent weight $m(g + a)$; free fall: weightless.
- Angle of repose: $\tan\theta = \mu_s$. $\tan\theta > \mu$ ho to block phisalta.
- Banked road: $\tan\theta = v^2/(rg)$ (bina friction); friction ke saath $v_{max}^2 = rg(\mu + \tan\theta)/(1 - \mu\tan\theta)$.
- Constraint trick: dori ki lambai constant $\Rightarrow$ (displacement $\times$ dori ke hisse) ka jod = 0.
- Spring ko n barabar hisson me kaato: har ek $k' = nk$.

14 Solved numericals (g = 10 m/s²)

Q1. 3 N aur 4 N ke do forces ek doosre ke perpendicular hain. Resultant kitna hai aur 3 N wale force se kis angle pe?
R = √(3² + 4² + 2·3·4·cos 90°) = √25 = 5 N. tan α = 4/3 ⇒ α ≈ 53°. **Ans: 5 N, 53°**

Q2. 150 g ki ball 30 m/s se bat pe aati hai aur 20 m/s se ulti direction me wapas jaati hai. Contact time 0.01 s hai. Bat ka average force?
Ulti direction ko negative lo: Δp = m(v − u) = 0.15 × (20 − (−30)) = 0.15 × 50 = 7.5 N·s. F = Δp/Δt = 7.5/0.01. **Ans: 750 N**

Q3. 4 kg ki gun se 20 g ki goli 400 m/s se chalti hai. Gun ki recoil velocity?
Momentum conservation: 0 = 0.02 × 400 + 4 × V ⇒ V = −8/4 = −2 m/s. **Ans: 2 m/s, goli ki ulti direction me**

Q4. Atwood machine me 5 kg aur 3 kg ke blocks hain. Acceleration aur tension?
a = (5 − 3) × 10 / (5 + 3) = 2.5 m/s². T = 2 × 5 × 3 × 10 / 8 = 37.5 N. **Ans: 2.5 m/s², 37.5 N**

Q5. 60 kg ka student lift me weighing machine pe khada hai. Lift (i) 2 m/s² se upar, (ii) 2 m/s² se neeche accelerate kar rahi hai, (iii) free fall me hai. Reading?
(i) N = 60(10 + 2) = 720 N, (ii) N = 60(10 − 2) = 480 N, (iii) N = 0. **Ans: 720 N, 480 N, 0**

Q6. 30° ke incline pe block neeche sarak raha hai, μ_k = 0.2. Acceleration?
a = g(sin 30° − μ cos 30°) = 10(0.5 − 0.2 × 0.866) = 10 × 0.327. **Ans: ≈ 3.27 m/s²**

Q7. Smooth table pe 4 kg ka block, rassi se pulley ke upar 1 kg latakta block. a aur T?
a = 1 × 10 / (4 + 1) = 2 m/s². T = m_1a = 4 × 2 = 8 N (check: 1×10 − 8 = 1×2 ✓). **Ans: 2 m/s², 8 N**

Q8. Flat road pe mod ki radius 50 m hai, μ_s = 0.5. Car ki max safe speed?
v = √(μ r g) = √(0.5 × 50 × 10) = √250 ≈ 15.8 m/s ≈ 57 km/h. **Ans: ≈ 15.8 m/s**

Q9. 100 m radius ke mod pe 20 m/s ki speed ke liye road ko kitna bank karein (bina friction)?
tan θ = v²/(r g) = 400/1000 = 0.4 ⇒ θ ≈ 21.8°. **Ans: ≈ 22°**

Q10. Smooth floor pe 2 kg aur 3 kg ke blocks touch kar rahe hain. 2 kg wale ko 20 N se dhakela. 3 kg pe contact force?
a = 20/5 = 4 m/s². Contact force = 3 × 4 = 12 N. **Ans: 12 N**

15 Common mistakes (exam me marks yahin katte hain)

- **N = mg hamesha nahi**: incline pe $mg\cos\theta$, lift me $m(g \pm a)$, upar se dhakelo toh zyada.
- Action-reaction ko ek hi body pe laga dena. Ye hamesha alag bodies pe hote hain.
- Static friction ko seedha $\mu_s N$ le lena, jabki wo sirf utna hota hai jitna zaroori ho.
- Impulse ke sawaal me direction ka sign bhool jaana (wapas aayi ball me velocity ka sign ulta).
- Centripetal force ko FBD me alag force ki tarah jod dena. Wo kisi existing force ka hi kaam hai.
- Units mix karna: grams ko kg aur km/h ko m/s me badalna mat bhoolo (km/h × 5/18 = m/s).

16 One-page formula sheet

Resultant of two forces	$R = \sqrt{(F_1^2 + F_2^2 + 2F_1F_2 \cos\theta)}$
Momentum	$p = m\,v$
Newton's 2nd law	$F = dp/dt = m\,a$ (mass constant)
Variable mass / conveyor	$F = v\,(dm/dt)$
Rocket thrust	$F = u\,(dm/dt)$
Impulse	$J = F\,\Delta t = \Delta p = m(v - u)$
Momentum conservation	$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
Gun recoil	$V = -\,m\,v\,/\,M$
Lami's theorem	$F_1/\sin\alpha = F_2/\sin\beta = F_3/\sin\gamma$
Smooth incline	$a = g\sin\theta$, $N = mg\cos\theta$
Rough incline (sliding down)	$a = g(\sin\theta - \mu_k\cos\theta)$
Atwood machine	$a = (m_1-m_2)g/(m_1+m_2)$, $T = 2m_1m_2g/(m_1+m_2)$
Block on table + hanging block	$a = m_2g/(m_1+m_2)$, $T = m_1m_2g/(m_1+m_2)$
Lift (apparent weight)	$N = m(g + a)$ up, $m(g - a)$ down, 0 free fall
Static / kinetic friction	$f_s \le \mu_sN$, $f_k = \mu_kN$
Angle of repose / friction	$\tan\theta_r = \tan\lambda = \mu_s$
Centripetal force	$F = m\,v^2/r$
Max speed, level road	$v = \sqrt{(\mu\,r\,g)}$
Banked road (no friction)	$\tan\theta = v^2/(r\,g)$
Banked road, max speed	$v = \sqrt{(rg(\mu + \tan\theta)/(1 - \mu\tan\theta))}$
Cyclist bending	$\tan\theta = v^2/(r\,g)$

17 Practice questions (khud try karo)

1. 2 kg ki body ki velocity 3 s me 4 m/s se 10 m/s ho jaati hai. Lagaaya gaya force?
2. 10 kg ke block ko floor pe hilaane ke liye kam se kam kitna horizontal force chahiye? (μ_s = 0.4)
3. Rocket se gas 500 m/s ki relative speed se 2 kg/s ki rate se nikal rahi hai. Thrust?
4. 1000 kg ki car 20 m radius ke mod pe 10 m/s se ghoom rahi hai. Kitna friction force chahiye?

5. Ghoda gaadi ko kheenchta hai aur gaadi ghode ko utna hi peeche kheenchti hai (3rd law). Phir bhi system aage kaise badhta hai?
6. Lift neeche g acceleration se gir rahi hai. 50 kg ke aadmi ka apparent weight?

ANSWERS

1) 4 N · 2) 40 N · 3) 1000 N · 4) 5000 N · 6) 0

5) Ghode pe gaadi ka peeche ka force aur ghode ke pairon pe zameen ka aage ka force alag hain. Ghoda zameen ko peeche dhakelta hai, zameen ka reaction (friction) system ko aage dhakelta hai. Jab ye zameen wala force gaadi ke friction se zyada ho, system aage badhta hai.

18 Quick revision: exam se pehle 5 minute

NEWTON KE LAWS

- 1st law: net force 0 ⇒ velocity constant. Inertia ∝ mass.
- 2nd law: F = dp/dt; mass constant ⇒ F = ma.
- 3rd law: action = - reaction, **alag bodies** pe.
- Impulse = FΔt = Δp. Δt badhao ⇒ force kam.
- Net external force 0 ⇒ total momentum conserved.

FORCES & FBD

- Ek body, uske saare forces, phir ΣF = ma har axis pe.
- Incline: N = mg cos θ, along slope mg sin θ.
- Lift: N = m(g ± a); free fall me N = 0.
- Light rassi: har jagah same T.
- Lami: F/sin(saamne ka angle) same.

FRICTION

- Static: 0 se $\mu_s N$ tak (self-adjusting).
- Kinetic: $\mu_k N$. Order: rolling < kinetic < static.
- tan(angle of repose) = μ_s.
- Area pe depend nahi karta.

CIRCULAR MOTION

- Centripetal = mv^2/r, koi naya force nahi.
- Level road: $v_{max} = \sqrt{(\mu rg)}$.
- Banked, bina friction: $\tan\theta = v^2/rg$.
- Cyclist ka jhukav: $\tan\theta = v^2/rg$.

Top 5 exam traps	Sahi soch
Weight aur normal = action-reaction	Nahi, dono ek hi body pe hain
N = mg hamesha	Sirf flat surface pe, bina extra vertical force ke
Static friction = $\mu_s N$	Ye sirf maximum value hai
Wapas aati ball ka Δp = m(v - u) seedha	Direction ka sign lagao: Δp = m(v + u)
Uniform circular motion me acceleration 0	Nahi, v^2/r centre ki taraf hota hai

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka 30-question mock test do.