CLASS 11 PHYSICS — FORMULA SHEET

Chapter 4 : Laws of Motion (NCERT)

4.1 Newton's Three Laws of Motion

Law	Statement / Formula
First law (inertia)	A body stays at rest or in uniform motion unless acted on by a net external force. Defines inertia & force.
Inertia	Tendency to resist change in state of rest/motion; measured by mass
Second law	$F = dp/dt = ma$ (net force = rate of change of momentum)
Linear momentum	$p = mv$ (vector; unit kg m/s)
Third law	Every action has an equal and opposite reaction ($F_{AB} = -F_{BA}$)
Action-reaction note	Act on DIFFERENT bodies, so they never cancel each other

4.2 Force, Momentum & Impulse

Quantity	Formula
Net force	$F_{net} = ma$ (vector sum of all forces)
Impulse	$J = F \times \Delta t = \Delta p = m(v - u)$
Impulse–momentum theorem	Impulse = change in momentum
Impulsive force	Large force acting for a very short time (e.g. bat hitting ball)
Area under F–t graph	= Impulse
Conservation of momentum	If $F_{ext} = 0$, total momentum p = constant
Recoil of gun	$m_{gun}v_{gun} = -m_{bullet}v_{bullet}$; $v_{gun} = -(m_b v_b)/m_g$

4.3 Equilibrium & Common Forces

Concept	Detail / Formula
Equilibrium of particle	Net force = 0 → $\Sigma F_x = 0$ and $\Sigma F_y = 0$
Weight	$W = mg$ (acts vertically downward)
Normal reaction (N)	Perpendicular contact force from a surface
Tension (T)	Pull along a string; same throughout a massless string
Spring force (Hooke's law)	$F = -kx$ (k = spring constant, x = extension/compression)
Apparent weight in lift (up, accel a)	$N = m(g + a)$
Apparent weight in lift (down, accel a)	$N = m(g - a)$
Free fall in lift (a = g)	N = 0 (weightlessness)

4.4 Friction

Type	Formula / Detail
Static friction	$f_s \le \mu_s N$ (self-adjusting up to a maximum)
Limiting friction	$f_{s,max} = \mu_s N$ (just before motion begins)
Kinetic friction	$f_k = \mu_k N$ (during motion; $\mu_k < \mu_s$)
Coefficient of friction	$\mu = f \div N$ (dimensionless)
Angle of friction (λ)	$\tan\lambda = \mu_s$
Angle of repose (α)	$\tan\alpha = \mu_s$ (angle at which body just slides on incline) $\rightarrow \alpha = \lambda$
Body on incline (no friction)	$a = g \sin\theta$ (down the slope)
Body on incline (with friction)	$a = g(\sin\theta - \mu\cos\theta)$ when sliding down

4.5 Connected Bodies & Pulleys

System	Formula
Two masses on smooth table (pull F)	$a = F \div (m_1 + m_2)$; tension $T = m_2 a$
Atwood machine ($m_1 > m_2$)	$a = (m_1 - m_2)g \div (m_1 + m_2)$
Atwood tension	$T = 2m_1m_2g \div (m_1 + m_2)$
Mass on table + hanging mass	$a = m_2g \div (m_1 + m_2)$; $T = m_1m_2g \div (m_1 + m_2)$
General method	Draw free-body diagram for each mass; apply F = ma along motion

4.6 Circular Motion Dynamics

Situation	Formula
Centripetal force	$F_c = mv^2/r = m\omega^2 r$ (directed toward centre)
Level circular road (max speed)	$v_{max} = \sqrt{(\mu_s r g)}$
Banked road (no friction)	$\tan\theta = v^2 \div (r g) \rightarrow v = \sqrt{(r g \tan\theta)}$
Banked road (with friction, v_{max})	$v_{max} = \sqrt{[r g (\mu + \tan\theta) \div (1 - \mu\tan\theta)]}$
Conical pendulum	$\tan\theta = v^2 \div (r g)$; $T_{period} = 2\pi\sqrt{(L\cos\theta \div g)}$
Vertical circle (top)	$v_{top} \ge \sqrt{(gr)}$ for the string to stay taut
Vertical circle (bottom)	$v_{bottom} \ge \sqrt{(5gr)}$ to complete the loop

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Newton's 2nd law	F = ma is the master equation — always start with a free-body diagram.
Action–reaction	Equal & opposite but on DIFFERENT bodies → they never cancel.
Impulse = Δp	J = FΔt = change in momentum = area under F–t graph.
Lift trick	Going up (or accelerating up): N = m(g+a). Down: N = m(g−a). Free fall: N = 0.
Friction order	$\mu_s > \mu_k$; static friction is self-adjusting up to $\mu_s N$.
Angle of repose	$\tan\alpha = \mu_s$; equals the angle of friction λ.
Banking (no friction)	$\tan\theta = v^2/rg$ — independent of mass.

Vertical circle speeds	Top ≥ √(gr) ; Bottom ≥ √(5gr) to complete the loop.