Newton's Laws of Motion

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Formula Name / Topic	Formula(e)	Conditions / Usage
Newton's Second Law (General)	$\vec{F}_{ext} = \frac{d\vec{p}}{dt}$	Valid for all systems (even variable mass).
Newton's Second Law (Constant Mass)	$\vec{F}_{net} = m\vec{a}$	Valid only when mass m is constant and in an Inertial Frame.
Linear Momentum	$\vec{p} = m\vec{v}$	Quantity of motion contained in a body.
Impulse (J)	$\vec{J} = \int_{t_1}^{t_2} \vec{F}_{ext} dt = \Delta\vec{p}$ $\vec{J} = \vec{F}_{avg} \cdot \Delta t$	Used when a large force acts for a short time. $\Delta\vec{p} = \vec{p}_f - \vec{p}_i$.
Impulse-Momentum Theorem	$\text{Area under } F - t \text{ graph} = \Delta p$	Used to find change in momentum from a Force-Time graph.
Equilibrium of Forces	$\sum \vec{F} = 0 \implies \vec{a} = 0$	Body is at rest or moving with constant velocity.
Lami's Theorem	$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$	Valid for 3 coplanar, concurrent forces in equilibrium.
Third Law (Action-Reaction)	$\vec{F}_{AB} = -\vec{F}_{BA}$	Action and reaction act on different bodies simultaneously.
Apparent Weight in Lift (Moving Up)	$N = m(g + a)$	Lift accelerating upwards with acceleration a.
Apparent Weight in Lift (Moving Down)	$N = m(g - a)$	Lift accelerating downwards with acceleration a ($a < g$).

Apparent Weight (Free Fall)	$N = 0$	Lift cable breaks ($a = g$). Weightlessness.
Conservation of Linear Momentum	$\vec{p}_{initial} = \vec{p}_{final}$ $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$	Valid if net external force on the system is zero ($\vec{F}_{ext} = 0$).
Rocket Propulsion (Thrust & Accel)	$F_{thrust} = u_{rel}\left(-\frac{dm}{dt}\right)$ $a = \frac{u_{rel}}{m}\left(-\frac{dm}{dt}\right) - g$	u_{rel} is exhaust speed relative to rocket. $-\frac{dm}{dt}$ is rate of fuel consumption.
Rocket Velocity (at time t)	$v = u_{rel}\ln\left(\frac{m_0}{m_t}\right) - gt$	m_0: initial mass, m_t: mass at time t. Neglecting initial velocity v_0.
Force by Liquid Jet (Thrust on Pipe)	$F = v\frac{dm}{dt} = \rho A v^2$	Reaction force on a pipe ejecting liquid of density ρ through area A.
Force by Liquid Jet (Striking Wall)	$F = \rho A v^2$ (Stops) $F = 2\rho A v^2$ (Reflects)	Force exerted by a jet striking a vertical wall normally.
Connected Bodies (Atwood Machine)	$a = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)g$ $T = \left(\frac{2m_1m_2}{m_1 + m_2}\right)g$	Massless, frictionless pulley and string. $m_2 > m_1$.

Block on Smooth Inclined Plane	$a = g \sin\theta$ $N = mg\cos\theta$	Sliding down a frictionless incline of angle θ.
Static Friction (f_s)	$f_s \le \mu_s N$ $f_{s,max} = \mu_s N$ (Limiting Friction)	Self-adjusting force. Prevents relative motion. N is Normal reaction.
Kinetic Friction (f_k)	$f_k = \mu_k N$	Opposes relative motion when bodies are actually sliding.
Angle of Friction (λ)	$\tan\lambda = \mu_s$	Angle between Normal reaction and Resultant of contact forces.
Angle of Repose (α)	$\tan\alpha = \mu_s$	Min angle of incline at which block starts sliding. ($\alpha = \lambda$).
Acceleration on Rough Incline (Down)	$a = g(\sin\theta - \mu_k \cos\theta)$	Block sliding down a rough inclined plane.
Acceleration on Rough Incline (Up)	$a = g(\sin\theta + \mu_k \cos\theta)$	Block pushed up a rough inclined plane (retardation).
Centripetal Force	$F_c = \frac{mv^2}{r} = m\omega^2 r$	Net radial force required for circular motion directed towards center.
Safe Turn on Level Road	$v_{max} = \sqrt{\mu_s r g}$	Vehicle turning on a flat horizontal road. Friction provides centripetal force.
Banking of Roads (Smooth)	$\tan\theta = \frac{v^2}{rg}$	Friction ignored. Ideal banking angle.
Banking of Roads (With Friction)	$v_{max} = \sqrt{rg\left(\frac{\mu_s + \tan\theta}{1 - \mu_s \tan\theta}\right)}$	Maximum safe speed on a banked rough road.

Bending of Cyclist	$$\tan\theta = \frac{v^2}{rg}$$	Cyclist leans inward to provide necessary centripetal force.
Pseudo Force	$\rightarrow$	Applied to an object when observing