Gravitation - the complete formula card

Topic	Formula	Remember
Escape velocity	v_e = sqrt(2GM/R) = sqrt(2gR)	from the surface; mass of projectile never matters; Earth 11.2 km/s, Moon 2.4
Orbit velocity	v_o = sqrt(GM/r) = sqrt(gR)	r = R+h always; higher = slower; v_e = sqrt(2) x v_o (11.2 / 7.9)
Kepler's third law	T^2 = 4*pi^2*r^3/GM	same central body only; ratio trick: x4 -> x8, x9 -> x27; M = 4*pi^2*r^3/GT^2
Angular momentum	L = mvr = I*omega (constant if torque = 0)	gravity pulls but cannot twist; closer = faster; Kepler's 2nd law = L/2m
Gravitational PE	U = -GMm/r	U = 0 at infinity; negative = bound/trapped; V = -GM/r is per kg
Orbit energies	KE = GMm/2r, PE = -GMm/r, E = -GMm/2r	ratio PE:KE:E = -2:+1:-1; escape costs your current KE
g with height	g' = gR^2/(R+h)^2 ~ g(1-2h/R)	shortcut only for tiny h; at h=R exact answer is g/4
g with depth	g' = g(1 - d/R)	rock above cancels itself; g = 0 at centre (but PE deepest: -1.5GMm/R)
g with latitude	g' = g - omega^2 R cos^2(lambda)	equator discount ~0.34%; poles unaffected; 9.780 to 9.832 m/s^2
Field & potential	E = GM/r^2 = -dV/dr	field exists without a test mass; inside a shell E = 0 exactly
Geostationary	T = 24 h forces r = 42,300 km	h = 36,000 km, over the equator, circular, ~3.1 km/s
Schwarzschild radius	R_s = 2GM/c^2	black hole = escape velocity crossing light speed; Earth = 9 mm, Sun = 3 km

Full series with letter-by-letter explanations, solved examples and memory tricks: hmmnm.in/physics-series

Rotational Motion - the complete formula card

Topic	Formula	Remember
Centre of mass	x_com = sum(m_i x_i)/M	inside forces never move it; cut-outs = negative mass; may lie outside body
Torque	tau = F d sin(angle)	through the pivot = zero; pick pivots where unknown forces act
Moment of inertia	I = sum(m r^2)	ring MR^2, disc MR^2/2, rod ML^2/12 (mid) ML^2/3 (end), sphere 2MR^2/5, shell 2MR^2/3
Axis theorems	I = I_com + Md^2 (parallel); I_z = I_x + I_y (flat bodies)	balance-point axis always smallest
Rotational Newton	tau_net = I*alpha	fixed axis or balance-point axis; bridges: s = r*theta, v = r*omega, a = r*alpha
Angular momentum	L = I*omega = mvr sin(theta)	no outside twist = locked; sticking collisions: L survives, KE dies
Rolling	v_com = R*omega; KE = (1/2)Mv^2(1 + I/MR^2)	shape factors: sphere 1.4, disc 1.5, ring 2.0; race: sphere > disc > ring
Ramp acceleration	a = g sin(theta)/(1 + I/MR^2)	mass and radius cancel; skid-to-roll sphere: final speed = 5/7 of launch
Rotational energy	KE = (1/2)I omega^2; W = tau*theta; P = tau*omega	rpm x 2*pi/60 = rad/s FIRST; 1 hp = 746 W
Equilibrium	sum F = 0 AND sum tau = 0	tip when the balance-point line exits the base; topple at tan(theta) = b/h vs slide at mu

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Work, Energy & Power - the complete formula card

Topic	Formula	Remember
Work	W = F d cos(angle)	perpendicular = zero (carry a bag, push a wall); against motion = negative
Kinetic energy	KE = (1/2) m v^2	double speed = 4x energy; stopping distance grows as v^2
Work-energy theorem	W_total = change in KE	before/after only - the path never matters
Height PE	PE = mgh	choose ONE zero level; conservative = path-free
Spring PE	PE = (1/2) k x^2	stretch SQUARED, always metres; Hooke's force F = kx
Energy conservation	KE + PE = constant (gravity/springs)	friction leak = F x distance -> heat; drop speed v = sqrt(2gh), no mass
Vertical circle	v_top(min) = sqrt(gR); v_bottom(min) = sqrt(5gR); h = 2.5R	gravity helps at the top, opposes at the bottom
Power	P = W/t = F v	watts; lifting: mgh/t; fixed power -> more force = less speed; 1 kWh = 3.6 MJ
Efficiency	useful out / total in	always < 100%; input = useful / efficiency
Collisions	momentum ALWAYS survives	elastic: KE too; sticking: max KE loss; equal-mass elastic = velocity swap
Variable force	work = area under force-distance graph	spring's 1/2 k x^2 is exactly the triangle under F = kx
PE curves	valley = stable, hill = unstable	slope = force; valley wobble = SHM

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