

JEE Physics

The Last-Mile Formula & Trap Sheet

Not every formula — only the ones that decide marks. Built for revision under time pressure.

A note before you start using this sheet:

This is a **deliberately curated** sheet, not a complete formula encyclopedia. A standard JEE physics formula booklet already runs to 30+ pages of small print — and in the last few days before an exam, that volume works against you: you re-read things you already know cold, and skim past the traps that actually cost marks. This sheet leaves out routine/low-yield formulas (ones you already recall instantly, or that rarely decide a question on their own) on purpose, so it stays something you can read start to finish in one sitting instead of a reference you passively scroll.

What is included is chosen for **high-frequency, high-mistake-rate** value: formulas that appear repeatedly across JEE Main/Advanced papers, paired with a **TRAP/TRICK** box per topic that flags the specific sign error, missing condition, unit slip, or wrong assumption that typically costs the mark — not the formula itself. Some entries (e.g. pseudo-force frames, sign conventions in optics, Kirchhoff's loop direction) genuinely need this extra observation to apply correctly; that is the point of the box, not an afterthought.

Use this alongside your full formula book or class notes, not instead of them. Treat this as the "final revision + error-check" layer on top of complete preparation, not as your primary or sole source. If a topic here feels thin, that is a signal to go back to the complete notes for that chapter — it is not a claim that nothing else in that chapter matters.

1. Units, Dimensions & Errors

Core Results

- Dimensional formula check: an equation is dimensionally consistent only if both sides match in every power of $[M][L][T]$
- Max % error in $Z = \frac{A^p B^q}{C^r}$: $\frac{\Delta Z}{Z} = p \frac{\Delta A}{A} + q \frac{\Delta B}{B} + r \frac{\Delta C}{C}$ (always add, never subtract, even for division)
- Significant figures: multiplication/division $\rightarrow$ result has as many sig. figs. as the least precise input; addition/subtraction $\rightarrow$ result has as many decimal places as the least precise input

⚠ TRAP / TRICK

Errors always **ADD**, even when the formula has division or subtraction — error propagation is never "subtracted out," a very common first mistake.

Dimensional analysis cannot verify dimensionless constants (like 2 in $\frac{1}{2}mv^2$) — it only checks form, not exact numerical correctness.

Fig. fig. rule differs for $+/-$ vs $\times/\div$ — mixing the two rules in a multi-step calculation is a frequent slip.

2. Kinematics

1D / 2D Motion

- $v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
- Distance in n th second: $s_n = u + \frac{a}{2}(2n - 1)$
- Relative velocity: $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$; for rain-man / river-boat problems, draw the vector triangle first
- Projectile: $T = \frac{2u \sin \theta}{g}$, $R = \frac{u^2 \sin 2\theta}{g}$, $H = \frac{u^2 \sin^2 \theta}{2g}$; max range at $\theta = 45^\circ$
- Equation of trajectory: $y = x \tan \theta - \frac{gx^2}{2u^2 \cos^2 \theta}$

⚠ TRAP / TRICK

Equations of motion assume constant acceleration — do not apply $v = u + at$ blindly if a varies; switch to calculus ($a = dv/dt$) for variable acceleration.

Same range for θ and $90^\circ - \theta$, but time of flight and max height differ — a classic MCQ distractor pairs the wrong quantity.

Sign convention: fix "up/right positive" once at the start of the problem and stick to it for every velocity, displacement, and acceleration term — switching mid-solution is the single biggest source of kinematics errors.

3. Laws of Motion & Friction

Newton's Laws, Friction

- $F = ma$ (in an inertial frame); in a non-inertial (accelerat-

ing) frame, add a pseudo-force $-m\vec{a}_0$

- Friction: $f_s \leq \mu_s N$ (static, self-adjusting), $f_k = \mu_k N$ (kinetic, fixed); usually $\mu_s > \mu_k$
- Angle of repose: $\tan \theta = \mu_s$ — the incline angle at which a block just starts to slide
- Connected bodies / pulley systems: draw free body diagrams for each mass separately, write $F = ma$ for each, then solve simultaneously
- Banking of roads: $\tan \theta = \frac{v^2}{rg}$ (no friction); with friction,

$$v_{max}^2 = rg \frac{\mu + \tan \theta}{1 - \mu \tan \theta}$$

⚠ TRAP / TRICK

Static friction is NOT always $\mu_s N$, it only reaches that value at the verge of slipping — otherwise f_s exactly balances the applied force (self-adjusting), which is a very common conceptual trap.

Pseudo-force only exists in the non-inertial (accelerating) frame — if you solve from the ground (inertial) frame, do NOT add it; mixing frames is the #1 error in pulley/wedge problems.

Normal force is not always mg — on an incline, in a lift, or under an additional applied force, N must be found from the force balance, never assumed.

4. Work, Energy & Power

Key Results

- $W = \int \vec{F} \cdot d\vec{s}$; Work-energy theorem: $W_{net} = \Delta KE$
- Conservation of energy applies only when non-conservative forces (friction, air drag) do zero work
- Spring PE: $U = \frac{1}{2}kx^2$; Power: $P = \vec{F} \cdot \vec{v}$
- Elastic collision (1D): $v'_1 = \frac{(m_1 - m_2)u_1 + 2m_2u_2}{m_1 + m_2}$ (and symmetric for v'_2); both momentum and KE conserved
- Perfectly inelastic collision: bodies stick together, only momentum conserved, KE is lost

⚠ TRAP / TRICK

Work done by friction is path-dependent — unlike gravity or spring force, you cannot use a potential energy function for friction; always compute it as $-f \times d$ along the actual path.

"Conservation of mechanical energy" fails silently if you forget an external force (friction, applied force, air resistance) is doing work — always list every force before invoking conservation.

Coefficient of restitution $e = \frac{\text{relative velocity of separation}}{\text{relative velocity of approach}}$ — students often invert this ratio; $e = 1$ elastic, $e = 0$ perfectly inelastic.

5. Circular Motion & Rotational Mechanics

Key Results

- Centripetal acceleration $= \frac{v^2}{r} = \omega^2 r$; centripetal force always points toward the centre (it is not a separate "new" force – it's the net radial force)
- Torque $\vec{\tau} = \vec{r} \times \vec{F}$; $\vec{\tau} = I\vec{\alpha}$ (rotational analogue of $F = ma$)
- Angular momentum $\vec{L} = I\vec{\omega}$; conserved when net external torque $= 0$
- Parallel axis: $I = I_{cm} + Md^2$; Perpendicular axis (planar bodies): $I_z = I_x + I_y$
- Rolling without slipping: $v_{cm} = R\omega$; total KE $= \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2 \left(1 + \frac{k^2}{R^2}\right)$

⚡ TRAP / TRICK

"Centripetal force" is not an extra force to add in a free body diagram – it is the name given to the net force already present (tension, gravity, normal, friction) that happens to point toward the centre; adding it separately double-counts forces.

Rolling without slipping requires $v_{cm} = R\omega$ at every instant – if this condition breaks (e.g. object skids), friction becomes kinetic and the relation no longer holds directly.

Angular momentum conservation needs zero NET external torque about the chosen axis – internal forces (like friction between two rotating parts of the same system) don't violate it, but check the axis choice carefully.

6. Gravitation

Key Results

- $F = \frac{Gm_1m_2}{r^2}$; gravitational PE $= -\frac{GMm}{r}$ (zero taken at infinity, hence negative)
- Orbital velocity $v_o = \sqrt{\frac{GM}{r}}$; escape velocity $v_e = \sqrt{\frac{2GM}{R}} = \sqrt{2}v_o$
- Kepler's 3rd law: $T^2 \propto r^3$
- Total energy of a satellite in circular orbit $= -\frac{GMm}{2r}$ (negative $\Rightarrow$ bound orbit)
- Variation of g : with height $g' = g \left(1 - \frac{2h}{R}\right)$ ($h \ll R$); with depth $g' = g \left(1 - \frac{d}{R}\right)$

⚡ TRAP / TRICK

PE is negative by convention (zero at infinity) – do not treat a "more negative" PE as "less energy available"; it means more tightly bound, not less energetic.

g decreases going up but also decreases going down, by DIFFERENT formulas – mixing the height and depth formulas is a common recall error.

Escape velocity is independent of launch angle and mass of the projectile – a frequent trick-question setup tests exactly this independence.

7. SHM & Waves

Simple Harmonic Motion

- $x = A \sin(\omega t + \phi)$; $v = A\omega \cos(\omega t + \phi)$; $a = -\omega^2 x$
- $T = 2\pi\sqrt{\frac{m}{k}}$ (spring); $T = 2\pi\sqrt{\frac{L}{g}}$ (simple pendulum, small angle)
- Energy in SHM: $KE = \frac{1}{2}m\omega^2(A^2 - x^2)$, $PE = \frac{1}{2}m\omega^2x^2$, total $= \frac{1}{2}m\omega^2A^2$ (constant)

Waves & Sound

- $v = f\lambda$; wave equation $y = A \sin(\omega t - kx)$; $v_{string} = \sqrt{T/\mu}$
- Doppler effect: $f' = f \left(\frac{v \pm v_o}{v \mp v_s}\right)$ – sign depends on direction of relative motion (source/observer approaching $\rightarrow$ higher f')
- Beats: $f_{beat} = |f_1 - f_2|$
- Closed pipe: only odd harmonics, $f_n = \frac{(2n-1)v}{4L}$; open pipe: all harmonics, $f_n = \frac{nv}{2L}$

⚡ TRAP / TRICK

Doppler sign convention: always take the direction from source to observer as positive, then decide each velocity's sign based on whether it moves along or against that direction – guessing the sign is the #1 Doppler error.

SHM acceleration is $-\omega^2 x$, always directed toward mean position – it is NOT constant like in projectile motion; don't reuse constant- a kinematics formulas inside SHM.

Closed pipe has NO even harmonics – forgetting this halves your harmonic list incorrectly in resonance-tube problems.

8. Elasticity, Fluid Mechanics & SHM Extras

Key Results

- Young's modulus $Y = \frac{F/A}{\Delta L/L}$; Bulk modulus $B = -V \frac{dP}{dV}$
- Bernoulli's equation: $P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$ (along a streamline, ideal incompressible flow)
- Continuity equation: $A_1 v_1 = A_2 v_2$
- Surface tension: excess pressure inside a drop $= \frac{2T}{r}$, inside a soap bubble $= \frac{4T}{r}$ (two surfaces)
- Viscosity (Stokes' law): $F = 6\pi\eta r v$; terminal velocity $v_t = \frac{2r^2(\rho - \sigma)g}{9\eta}$

⚡ TRAP / TRICK

Soap bubble has TWO surfaces (inner and outer), so its excess pressure is double that of a single liquid drop – a very frequently tested factor-of-2 trap.

Bernoulli's equation assumes ideal fluid (no viscosity) and streamline flow – it does not directly apply to viscous flow through narrow tubes (that's Poiseuille's regime instead).

Continuity equation ($A_1 v_1 = A_2 v_2$) only holds for incompressible flow – don't apply it to compressible gas flow without modification.

9. Thermal Physics

Heat & Thermodynamics

- Ideal gas law: $PV = nRT$; first law: $\Delta Q = \Delta U + \Delta W$
- Isothermal: $\Delta U = 0$, $W = nRT \ln(V_2/V_1)$; Adiabatic: $\Delta Q = 0$, $PV^\gamma = \text{const}$, $W = \frac{nR(T_1 - T_2)}{\gamma - 1}$
- $C_p - C_v = R$; $\gamma = C_p/C_v$ (monatomic 5/3, diatomic 7/5)
- Heat engine efficiency $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$ (Carnot, reversible only)
- Stefan-Boltzmann: $E = \sigma T^4$; Wien's law: $\lambda_m T = \text{constant}$

⚡ TRAP / TRICK

Carnot efficiency formula $1 - T_2/T_1$ applies ONLY to a reversible (Carnot) engine – using it for a general/real heat engine overestimates efficiency, a very common misapplication.

Sign convention for the first law ($\Delta Q = \Delta U + \Delta W$, work done BY the gas positive) must be fixed at the start – some texts use $\Delta U =$

$\Delta Q - \Delta W$; check which convention the question uses before plugging in.

Temperature in gas-law and thermodynamics formulas is always absolute (Kelvin) – forgetting to convert from Celsius is a recurring silent error.

10. Electrostatics

Key Results

- $F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$; $E = \frac{F}{q}$; $V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$; $E = -\frac{dV}{dr}$
- Gauss's law: $\oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\epsilon_0}$ – use for symmetric charge distributions (spherical, cylindrical, planar)
- Capacitor: $C = \frac{Q}{V}$; parallel plate $C = \frac{\epsilon_0 A}{d}$; series combine as $1/C$, parallel combine directly as C
- Energy stored: $U = \frac{1}{2} CV^2 = \frac{1}{2} QV = \frac{Q^2}{2C}$
- Dipole: $\tau = \vec{p} \times \vec{E}$; $PE = -\vec{p} \cdot \vec{E}$; field on axial line $= \frac{2kp}{r^3}$, on equatorial line $= \frac{kp}{r^3}$ (opposite direction to $\vec{p}$)

⚡ TRAP / TRICK

Capacitors: series/parallel rules are OPPOSITE to resistors – series capacitors combine like parallel resistors ($1/C$ adds) and vice versa; this swap is a very frequent slip under time pressure.

Gauss's law gives E only for symmetric distributions – for irregular charge shapes, you cannot pull E out of the integral; don't force-fit Gauss's law where symmetry doesn't hold.

Electric field inside a conductor in electrostatic equilibrium is always zero, and charge resides only on the surface – a foundational fact often forgotten mid-problem.

11. Current Electricity

Key Results

- $V = IR$; $R = \rho \frac{L}{A}$; resistivity increases with temperature for metals ($\rho = \rho_0(1 + \alpha \Delta T)$)
- Series: $R_{eq} = \sum R_i$ (current same); Parallel: $\frac{1}{R_{eq}} = \sum \frac{1}{R_i}$ (voltage same)
- Kirchhoff's laws: KCL ($\sum I_{in} = \sum I_{out}$ at a node), KVL ($\sum V = 0$ around a closed loop)
- Wheatstone bridge balanced: $\frac{P}{Q} = \frac{R}{S}$, galvanometer carries zero current
- Power: $P = I^2 R = VI = \frac{V^2}{R}$; internal resistance: $\epsilon = I(R + r)$

⚡ TRAP / TRICK

Assign a consistent current direction and loop-traversal direction BEFORE writing KVL – sign errors from inconsistent direction assumptions are the single biggest source of wrong answers in circuit problems.

Ammeter should have (near) zero resistance, voltmeter should have (near) infinite resistance – forgetting this when a "non-ideal" meter is specified changes the whole circuit's effective resistance.

Terminal voltage $\neq$ EMF whenever current flows through internal resistance – $V = \epsilon - Ir$ on discharge, $V = \epsilon + Ir$ on charging; mixing these signs is a classic trap.

12. Magnetism & EMI/AC

Magnetic Effects

- Biot-Savart: $dB = \frac{\mu_0}{4\pi} \frac{Id\vec{l} \times \hat{r}}{r^2}$; for a long straight wire $B = \frac{\mu_0 I}{2\pi a}$

- Force on a moving charge: $\vec{F} = q\vec{v} \times \vec{B}$; force on a current-carrying wire: $\vec{F} = I\vec{L} \times \vec{B}$
- Faraday's law: $\epsilon = -\frac{d\phi}{dt}$; Lenz's law gives the direction (opposes the change, hence the minus sign)
- Self-inductance: $\epsilon = -L \frac{dI}{dt}$; energy stored $U = \frac{1}{2} LI^2$
- AC: $X_L = \omega L$, $X_C = \frac{1}{\omega C}$; impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$; resonance at $X_L = X_C$, i.e. $\omega_0 = \frac{1}{\sqrt{LC}}$

⚡ TRAP / TRICK

Lenz's law direction is about opposing the CHANGE in flux, not the flux itself – a frequently confused distinction that flips the induced current direction if misapplied.

X_L and X_C move opposite ways with frequency ($X_L \uparrow$, $X_C \downarrow$ as $f \uparrow$) – below resonance the circuit is capacitive, above it's inductive; know which side you're on before deciding phase relations.

RMS values, not peak values, go into power formulas ($P = V_{rms} I_{rms} \cos \phi$) – plugging in peak voltage/current directly is a very common AC-circuit error.

13. Ray Optics

Key Results

- Mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$; magnification $m = -\frac{v}{u}$ (sign convention: distances measured from pole, real is negative for concave mirror facing left)
- Lens formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$; lens maker's: $\frac{1}{f} = (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$
- Combination of lenses in contact: $\frac{1}{f} = \sum \frac{1}{f_i}$; power $P = \frac{1}{f}$ (in metres), added directly
- Refraction: $n_1 \sin \theta_1 = n_2 \sin \theta_2$; critical angle $\sin \theta_c = \frac{1}{n}$ (denser to rarer)
- Prism: $\delta = (i_1 + i_2) - A$; minimum deviation: $n = \frac{\sin \frac{A + \delta_m}{2}}{\sin \frac{A}{2}}$

⚡ TRAP / TRICK

Sign convention must be fixed and applied consistently for EVERY distance in the problem (object, image, focal length, radius) – the single most common ray-optics error is applying the convention to some quantities but not others.

Mirror formula uses $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, lens formula uses $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, don't swap them under exam pressure.

Total internal reflection only occurs going from denser to rarer medium, AND only when the angle of incidence exceeds the critical angle – both conditions must hold.

14. Wave Optics

Key Results

- Young's double slit: fringe width $\beta = \frac{\lambda D}{d}$; path difference $= d \sin \theta \approx \frac{dy}{D}$
- Constructive interference: path diff. $= n\lambda$; destructive: $(n + \frac{1}{2})\lambda$
- Diffraction (single slit) minima: $a \sin \theta = n\lambda$
- Resolving power / limit of resolution: $\theta_{min} = \frac{1.22\lambda}{a}$

- **Malus's law:** $I = I_0 \cos^2 \theta$ (polarizer)

⚡ TRAP / TRICK

Single-slit diffraction minima condition looks identical in form to double-slit interference maxima – keep them mentally separate; single-slit MINIMA use $n\lambda$, double-slit MAXIMA use $n\lambda$, and they describe opposite physical outcomes.

Fringe width depends on wavelength – if white light is used, different colours have different β , causing colored fringes away from the centre; don't treat β as a single fixed number in white-light problems.

Introducing a thin film/slab in one path shifts the fringe pattern without changing β – shift = $\frac{(n-1)tD}{d}$; a frequently tested add-on to the basic YDSE setup.

15. Modern Physics

Photoelectric Effect, Atoms, Nuclei

- **Photoelectric equation:** $E = h\nu = \phi_0 + KE_{max}$; stopping potential $eV_0 = KE_{max}$
- **de Broglie wavelength:** $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mKE}}$
- **Bohr model:** $r_n \propto n^2/Z$, $E_n = -13.6 \frac{Z^2}{n^2} \text{ eV}$
- **Radioactive decay:** $N = N_0 e^{-\lambda t}$; half-life $t_{1/2} = \frac{0.693}{\lambda}$; mean life = $1/\lambda$
- **Mass-energy:** $E = \Delta mc^2$; binding energy per nucleon peaks around $A \approx 56$ (Fe)

⚡ TRAP / TRICK

Photoelectric current depends on intensity, but KE_{max} depends only on frequency, not intensity – this independence is one of the most heavily tested conceptual points in modern physics.

Below threshold frequency, NO photoelectrons are emitted regardless of intensity – a strong beam of low-frequency light still produces zero photoelectrons; don't assume "more light = more electrons" unconditionally.

Half-life and mean-life are different by a factor of $\ln 2$: $t_{1/2} = 0.693/\lambda$, mean life = $1/\lambda$ – confusing the two is a very common recall slip.

16. Semiconductors & Communication

Key Results

- **p-n junction:** forward bias reduces depletion width and barrier potential, reverse bias increases both
- **Diode as rectifier:** half-wave uses 1 diode, full-wave (bridge) uses 4, output ripple reduced by a capacitor filter
- **Zener diode:** used as a voltage regulator, operated in reverse breakdown region
- **Transistor as amplifier:** $\beta = \frac{I_C}{I_B}$ (common emitter current gain); voltage gain = $\beta \times \frac{R_C}{R_B}$ approx.
- **Modulation index (AM):** $m = \frac{A_m}{A_c}$; for undistorted signal, $m \leq 1$

⚡ TRAP / TRICK

Forward bias LOWERS the barrier potential, it does not remove it entirely – conduction starts once forward voltage exceeds the barrier potential (about 0.7 V for Si), not at any positive voltage.

Zener diodes are deliberately operated in reverse breakdown – unlike normal diodes where reverse breakdown is something to avoid, here it's the intended operating region; a common conceptual mix-up.

Modulation index $m > 1$ causes distortion (over-modulation) – a frequently tested boundary condition in communication-systems numericals.