Geometric Intuition Cheat Sheet

Linear Algebra

- Vectors → arrows in space; addition = parallelogram rule
- Matrix multiplication → geometric transformations (rotation, scaling, shear)
- Rank → # of independent directions preserved
- Null space → directions collapsed to 0
- Row space = constraints (planes); Column space = reachable outputs

Calculus

- Derivative → slope of tangent (line/plane)
- Gradient → direction of steepest ascent (hill analogy)
- Divergence → spread of vector field
- Curl → swirling/rotation of vector field

Probability & Statistics

- Random variable → dart throw outcome
- Expectation → balance point of distribution
- Variance → spread (moment of inertia analogy)
- Central Limit Theorem → smoothing to bell curve

Differential Equations

- Solution curve → particle trajectory
- Phase plane → arrows of motion; equilibria as sinks/sources
- Eigenvalues → spiral, shrink, or grow near equilibrium

Abstract Algebra

- Groups → symmetries of shapes
- Cosets → tiling space into chunks
- Homomorphisms → shape-preserving maps

General Habits

- Ask: what does this look like in 2D/3D?
- Draw arrows, planes, surfaces
- Use physics analogies: prob ↔ balance, calc ↔ motion, LA ↔ forces
- Think in extremes (limits, collapse, infinity)