3D PRINTING WORKSHOP REFERENCE POSTER

Filament Matrix · Slicing Formulas · Tolerances · G-Code & Diagnostic Guide (2026)

1. COMPREHENSIVE FILAMENT & THERMAL PARAMETER MATRIX

PRINTER & BED QUICK REFERENCE TABLE

Filament Type	Nozzle (°C)	Bed (°C)	Enclosure	Fan Speed	Build Surface / Adhesion	Drying (Moisture)	Mechanical Properties & Applications
PLA / PLA+	195 – 220	50 – 60	Open	100% (Layer 2+)	Textured / Smooth PEI, Glass (No glue needed)	45 °C / 4-6 hrs	Rigid, easy to print; rapid prototypes, decorative parts, brackets.
PETG	230 – 250	70 – 85	Open	20% – 50%	Textured PEI (Bonds to smooth PEI; use glue stick as release agent)	65 °C / 6 hrs	Impact & chemical resistance; waterproof boxes, functional brackets.
ABS / ASA	240 – 260	90 – 110	Enclosure Req.	0% – 20%	Smooth PEI + Magigoo / Slurry (Air drafts = severe cracking)	75 °C / 6 hrs	High temperature (Tg 105°C) and UV resistance; automotive, outdoor housings.
TPU (95A / 85A)	215 – 235	30 – 50	Open	50% – 80%	Blue Painter's Tape / PEI (Speed: 20-35 mm/s, Direct-Drive)	50 °C / 6-8 hrs	Flexible, wear-resistant; gaskets, vibration damping feet, protective cases.
PA-Nylon / PA-CF	255 – 285	80 – 100	Enclosure	0% – 15%	Garolite (G10) or Magigoo PA (Hardened steel nozzle required)	80 °C / 8-12 hrs	Extreme tensile strength & wear resistance; structural gears, drone arms.
PC (Polycarbonate)	265 – 300	100 – 120	Heated Encl.	0%	Specialized PC adhesive + Chamber (High thermal shrinkage)	85 °C / 8 hrs	Maximum impact strength and heat deflection (Tg 145°C); heavy engineering.
PVA (Water Soluble)	190 – 215	50 – 60	Open	50% – 100%	PEI / Glue (Dissolves entirely when submerged in warm water)	45 °C (Active drybox)	Sacrificial support material for complex internal geometries in dual toolheads.

2. NOZZLE & CALIBRATION FORMULAS

- **Layer Height Ratio Guidelines:**
  - Min Layer: 25% × Nozzle Dia (0.4mm -> 0.10mm)
  - Optimal: 50% × Nozzle Dia (0.4mm -> 0.20mm)
  - Max Layer: 75-80% × Nozzle Dia (0.4mm -> 0.32mm)
- **Line Width (Extrusion Width):**
  Maintain between **105% – 120%** of nozzle diameter. 0.45mm width for a 0.4mm nozzle yields maximum inter-layer fusion.
- **Flow Rate Calibration Formula:**

```
New Flow = Current Flow × (Target Width / Measured Width)
```

  Print a hollow calibration cube, measure with caliper.
- **E-Steps (Extruder Steps) Formula:**

```
New Steps = Current Steps × (100 mm / Measured mm)
```

  Mark 120mm on filament, extrude 100mm, measure remnant.
- **Nozzle Material Selection:**
  - `Brass` : Fast conductivity, low cost; PLA/PETG/ABS only.
  - `Hardened Steel` : Required for CF/GF/wood (+5°C needed).
  - `Bi-Metal` : Copper body + hardened tip (Best balance).

3. SLICING & STRUCTURAL RULES

- **Golden Structural Rule:**
  Over 80% of part rigidity stems from **Perimeter (Wall)** count, not infill density.
  4 Walls + 20% Infill > 2 Walls + 60% Infill
- **Optimal Infill Patterns:**
  - `Gyroid` : Uniform isotropic strength, zero nozzle dragging, smooth high-speed motion.
  - `Grid / Tri-Hex` : Fast, but nozzle scrapes across layer intersections at high speeds.
  - `Lightning` : Hollows interior, supports roofs only (Ultra-fast decorative prints).
- **Solid Roof & Floor Thickness:**
  Ensure total top solid shell thickness is **≥ 0.8 mm – 1.0 mm** (4-5 layers at 0.2mm) to prevent pillowing.
- **Scarf Joint Seam (OrcaSlicer):**
  Tapers layer starts at 45° to seamlessly blend the Z-seam into perimeter geometry.
- **Pressure Advance / Linear Advance:**
  Eliminates corner bulging. Direct-drive: 0.02-0.04; Bowden: 0.20-0.45.

4. ESSENTIAL G-CODE & KLIPPER COMMANDS

- `G28` : Home all physical axes (X, Y, Z)
- `G29` : Initiate automated bed mesh calibration
- `M104 S[T]` : Set nozzle temperature (non-blocking)
- `M109 S[T]` : Set nozzle temperature and WAIT until reached
- `M140 S[T]` : Set bed temperature (non-blocking)
- `M190 S[T]` : Set bed temperature and WAIT until reached
- `M106 S[0-255]` : Set part fan speed (255 = 100%) / `M107`: Fan Off
- `G92 E0` : Reset extruder coordinate position
- `M83` : Set extruder to relative motion mode
- `M500` : Save current configuration to EEPROM
- **Klipper Terminal Macros:**
  - `BED_MESH_CALIBRATE`: Run multi-point mesh survey
  - `SHAPER_CALIBRATE`: ADXL345 resonance frequency test
  - `PID_CALIBRATE HEATER=extruder TARGET=210`

5. 8 CRITICAL 3D PRINTING FAILURES & IMMEDIATE WORKSHOP REMEDIES

DIAGNOSTIC CHEAT-SHEET

Issue / Symptom	Root Cause (Why it happens)	Workshop Remedy (How to fix it)	Key Parameter
1. First Layer Not Sticking	Nozzle Z-height is too high (insufficient squish) or bed surface contaminated with grease/dust.	Clean bed with 99% Isopropyl Alcohol (IPA) or warm dish soap. While printing initial skirt/brim, adjust Z-BabyStep by 0.02mm steps until beads squish flat.	`Z-Offset` / Initial Layer 120% Width
2. Warping & Corner Lifting	Thermal shrinkage of cooling plastic (especially ABS/PETG) caused by room drafts and uneven cooling.	Increase bed temperature by +5°C. Close enclosure doors or eliminate drafts. Add a 5-8 mm outer Brim in your slicer to anchor sharp corners.	`Brim Width` / Bed Temperature
3. Stringing / Oozing Hair	Nozzle temperature too high, insufficient retraction distance/speed, or wet filament.	Lower printing temperature by 5°C. Increase retraction distance by 0.2mm. Dry the spool in a heated drybox (hissing or crackling sounds indicate moisture).	`Retraction Dist/Speed` / Temp Tower
4. Extruder Clogging / Grinding	Debris in nozzle, heat creep expanding filament in heatbreak, or inadequate hotend cooling.	Perform Cold Pull: heat to 230°C, cool to 90°C, pull hard in one swift motion. Verify hotend heatsink fan runs at full 100% RPM continuously.	`Cold Pull` / Heatsink Fan RPM
5. Layer Shifting (Step Loss)	Loose drive belts, nozzle colliding with curled overhangs, or overheated stepper motor driver.	Tighten belts to low bass frequency tone when plucked. Enable Z-Hop (0.2mm) during retraction. Check stepper driver V-Ref voltage and cooling fan.	`Z-Hop on Retraction` / Belt Tension
6. Z-Banding (Horizontal Ribs)	Bent Z lead screw, dirty threads, loose motor coupling, or bed temperature cycling (bang-bang).	Clean and lubricate Z lead screw with PTFE grease. Tighten coupler grub screws. Run PID autotune (`M303`) on heated bed to stabilize temperature.	`PID Autotune` / Lead Screw Lube
7. Ghosting / Ringing Ripples	Mechanical frame flex and excessive acceleration causing inertial resonance at sharp corners.	Mount printer on heavy mass (concrete paver + foam pad). Reduce acceleration/jerk or tune Klipper Input Shaping with an ADXL345 accelerometer.	`Input Shaping` / Reduce Acceleration
8. Popping & Surface Pits	Hydroscopic moisture absorption (PETG, TPU, and Nylon absorb atmospheric moisture within hours).	Water vapor turns to steam inside nozzle, exploding outwards and creating voids while reducing strength by 50%. Bake spool in drybox at 50-75°C for 6-8 hrs.	`Active Drying` / Sealed Drybox Storage

6. MECHANICAL CLEARANCE TOLERANCES

- **Press / Interference Fit:**
  - Clearance: **0.10 – 0.15 mm**
  Bearings, dowel pins, snap-fit lids.
- **Sliding / Rotating Joint:**
  - Clearance: **0.25 – 0.35 mm**
  Shafts, hinges, moving linkages.
- **Print-in-Place Mechanisms:**
  - Clearance: **0.30 – 0.40 mm**
  Pre-assembled gears and captive joints.
- **Loose Bolt Clearance:**
  - Clearance: **0.40 – 0.50 mm** (Through-holes).

7. BRASS HEAT-SET INSERT HOLE MATRIX

Thread Size	Hole Diameter	Hole Depth	Lead-in Chamfer
M2 Insert	3.2 – 3.3 mm	4.5 mm	+0.2 mm
M3 (Voron Std)	4.0 – 4.2 mm	5.5 mm	+0.3 mm
M4 Insert	5.6 – 5.8 mm	7.5 mm	+0.4 mm
M5 Insert	6.8 – 7.0 mm	9.0 mm	+0.5 mm

**Set soldering iron to 220°C and press vertically.*

8. ATOMIC COLD PULL & SPOOL YIELD

- **Step-by-Step Cold Pull Protocol:**
  1. Heat nozzle to 230°C, push Nylon/PLA firmly into hotend.
  2. Turn off heater, allow nozzle to cool to 90°C (PETG: 110°C, Nylon: 130°C).
  3. Release extruder lever, pull filament upwards firmly in one smooth motion. Inspect tip.
- **Filament Yield Per 1 Kg Spool (1.75 mm):**
  - `PLA` : ~335 m | • `PETG` : ~325 m
  - `ABS` : ~400 m | • `TPU` : ~340 m