**Maximum Volumetric Flow Measurement**

**STOP!** Before doing this experiment, properly calibrate extruder steps first.

**This is Free Air method using extruded length measurement.**

1. Set Extruder temperature to normal printing temperature of the given filament type, normally I try middle of the ground temperature from manufacture given range.
   1. ABS – 235
   2. PLA – 205
   3. PETG – 235
2. Mark the filament length of 120mm from known reference point
3. Switch to relative extrusion mode using following gcode (this step needed if we want to use console as primary way of controlling extrusion)

Issue following gcode on console: M83

1. Extrude 100mm of filament in given speed, best starting point is 5mm/s for 1.75mm filament.

Either use Fluid / Mainsail and extrude the filament or

Issue following gcode in console G1 E100 F300

1. After extrusion complete measure the remaining length and see we extruded exact amount of filament, if we measure <100mm extruded then we already reached maximum MVS and choose previous value.

MVS = extruder speed in mm/s \* cross section of filament

Cross section of filament = π \* (r2)

Cross section of 1.75mm filament = π \* (0.875)2 = 2.40528

MVS = 5 \* 2.40528 = 12.0264

**Determining Max Volumetric Flow Rate**

**Background**

As mentioned at the beginning, this probably isn't necessary if you can find a "safe" value that others are using for your particular hotend. If you have a different setup affecting flow, such as a CHT nozzle or unlisted hotend, or if you just want to take the scientific approach, here is the process.

Remember - this is a rough calculation. Maximum volumetric flow rate can change with a number of factors, like temperatures, material, and nozzle type. You should set your limit slightly lower in the slicer for margin of safety, and to avoid having to tune for different filaments that don't flow as nicely.

**Formulas\***

Volumetric flow is expressed in mm3/sec (cubic millimeters per second)

* **volume = mm / 0.416**

Or, inversely,

* **mm = volume \* 0.416**

For example, if you extrude at **5mm/sec**, that comes out to **~12mm3/sec.** (5mm / 0.416)

\* *For 2.85mm filament, use 0.157 instead of 0.416.*  
\* *These formulas are simplified versions of the cylinder volume equation (V=πr2h) given r and h or V, rounded to 3 significant figures. This is more than enough accuracy for our purposes (down to the thousandths).*[*Calculator*](https://www.calculatorsoup.com/calculators/geometry-solids/cylinder.php)

**Method**

You will follow a similar process to extruder calibration.

**1)** Heat your hotend.  
**2)** Extrude a little bit to ensure your E motor is energized and holding.  
**3)** Mark a 120mm length of filament going into your extruder.  
**4)** Extrude at increasing speeds. At each interval, measure to ensure that exactly 100mm entered the extruder.

For example, the gcode to extrude at 5mm/sec is:

M83; Relative extrusion mode

G1 E100 F300; Extrude 100mm at 5mm/sec

Remember the F speed is in mm/min, **not** mm/sec, so multiply your desired speed by 60.

**5)** Keep going until it starts dropping below 100mm. This is your max flow rate.  
**6)** Convert your extrusion speed to volumetric speed using the above formulas.  
**7)** Enter a slightly lower volumetric speed into the slicer.

**How Volumetric Flow Rate Relates to Print Speed**

Working out how quickly you can print at a given volumetric flow rate is quite simple:

* **speed = volumetric flow / layer height / line width**

Or, inversely,

* **volumetric flow = speed \* line width \* layer height**

For example, if your hotend is capable of 24mm3/sec, and you are printing with 0.4mm line width, at 0.2mm layer height:

* **24 / 0.4 / 0.2 = Maximum print speed of 300mm/sec**

# Basic 3D Printer Filament Calculations

In the world of 3D printing filament there are three different factors that are commonly used as measurement: weight, volume and length. While weight is perhaps the most common measurement, the others do appear from time to time, and it can be a bit confusing to compare them.

All are used to measure quantities of 3D printer filament. This is required certainly when purchasing 3D printer filament, but it’s also useful when estimating how much filament is to be used on a given print job, or estimating the weight or volume of a printed object.

The question is, how do you convert between them?

Filament length and volume are the easiest to convert between, and its simple geometry.

# Length To Volume

Volume = Length \* π \* (Radius^2)

To convert length to volume, you need to compute the cross-sectional area of the filament and then multiply by the length. Be sure to use consistent units. Let’s do an example, using Smit’s question from above.

1 meter of filament is equal to 100cm

The radius of the filament is (close to) 1.75mm / 2 = 0.875mm or 0.0875cm

The cross-sectional area is equal to π \* radius squared, in this case π \* (0.875) ^2 = 0.024sqcm

Multiplying by the length, we get 100 \* 0.024 = 2.405 cubic cm

Easy, right?

# Volume To Length

Length = Volume / (π \* (Radius^2))

To convert volume to length we simply do this backwards. Suppose we have 11.4cc of volume and we want to determine the corresponding length of 2.85mm filament:

Compute the cross-sectional area as (0.285/2) ^2 \* π

Divide the volume 11.4cc by the cross-sectional area to find 178.7cm of filament as the length.

# Weight to Volume

Weight / Density

Things get a lot more complex when dealing with weight, simply because each type of material has different densities.

The first thing you need to know is the precise density for a given material. An excellent resource for this is Simplify3D’s filament properties table, found here:

[**https://www.simplify3d.com/support/materials-guide/properties-table/**](https://www.simplify3d.com/support/materials-guide/properties-table/)

There we can see some common material density factors:

ABS: 1.04 grams per cubic centimeter

PLA: 1.24 gr/cc

PETG: 1.23 gr/cc

ASA: 1.07 gr/cc

And there are many others on the table. Note that some materials are a bit tricky. Nylon, for example, comes in many types and has a range of 1.06-1.14gr/cc on Simplify3D’s table. You’ll have to know the specific material involved. There are further resources on the Internet for practically any known material.

Once you know the density, it’s straightforward to convert weight to volume by dividing weight by the density. For example, if we have a 224gr 3D printed object made in PLA, its likely volume would be 224 / 1.24 = 180cc.

# Volume to Weight

Volume \* Density

The reverse, converting a volume to a weight, is even easier to calculate. Simply look up the material density and multiply.

For example, if we have a 317cc object made from ASA, we would multiply 317cc \* 1.07gr to find the object weighs 339gr.

If you’re looking for a very rough estimate, it’s sometimes useful to assume the density is 1.0 and go with that.

# Weight to Length

Converting weight to length is a bit more complex as you essentially need to do two steps from above in sequence. Again, you need to know the material and density.

As an example, let’s figure out the length of 1.75mm PETG filament we need to produce a 178gr object.

First convert the weight to a volume. Using the formula above 178gr of PETG equals 166.35cc of material. Then convert this volume into a length, as per the above formula and in this case, we find it should be about 69m of material.

# Length to Weight

Again, we need to combine formulas here. First convert the length into a volume, then compute the weight of that volume in a specific material.

For example, if we have 10m of 2.85mm ABS filament, we first compute the volume to be 63.8cc. Then with ABS’s typical density of 1.04gr/cc, we have a computed weight of 66.35gr.

# Tips

The most important thing to remember is to use consistent units. Here we’ve tried to use centimeters and grams in the formulas. You can use whatever measurement you want, but just be consistent otherwise it won’t work.

Also don’t forget that your radius is half the diameter. So don’t use 1.75mm, use 0.0875cm. Don’t use 2.85mm, use 0.1425cm. Some shortcuts:

* 2.85mm cross sectional area = 0.06379sqcm
* 1.75mm cross sectional area = 0.02405sqcm