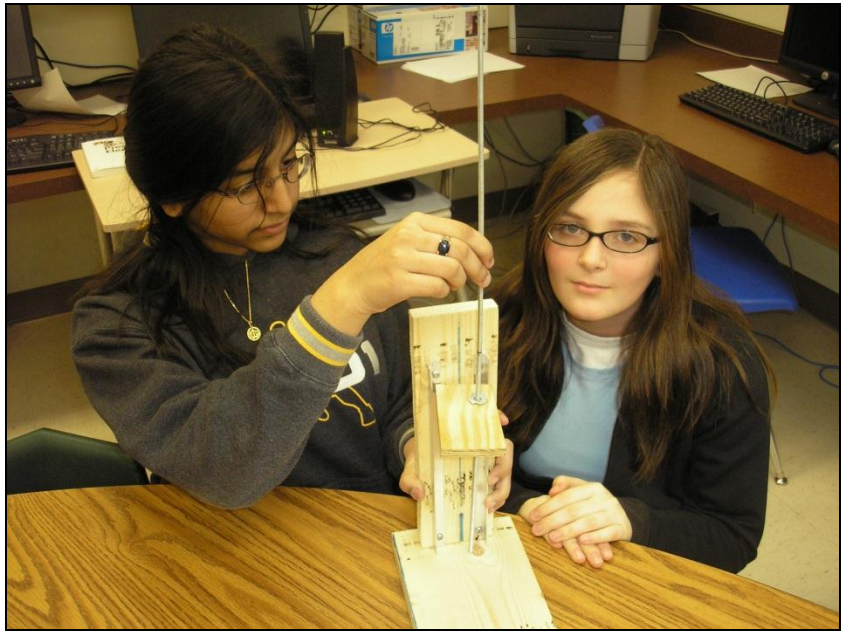
Center for Nanoscale
Chemical-Electrical-Mechanical
Manufacturing Systems

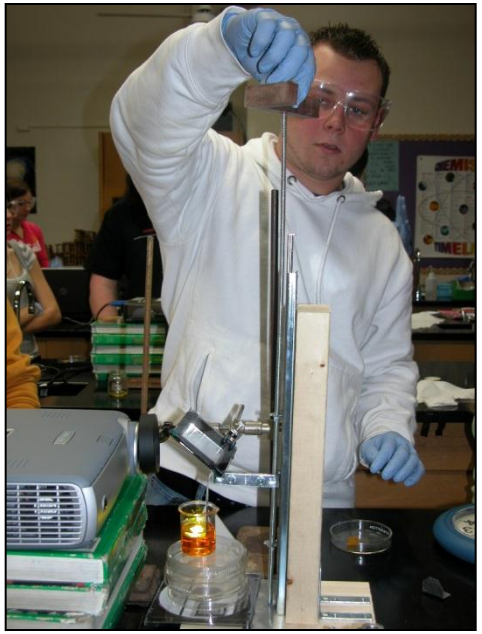
3D Printing in the Classroom

Last modified 2/10/12

Today

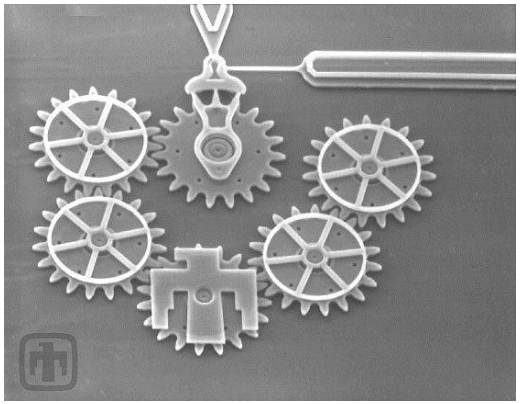
- Learn about creating nano-sized 3-D objects
- Learn about polymerization and how it can be initiated by light
- Learn how to use this technology to create 3-D objects





Micromanufacturing

- Current micromanufacturing methods make relatively flat objects.
  - Alignment of layers hard to achieve
  - Process very complex and expensive
- Flat objects called 2-D or 2.5-D



Example of 2.5D objects

The Challenge: Lack truly 3-D microfabrication methods

The Solution: *Microstereo Lithography*

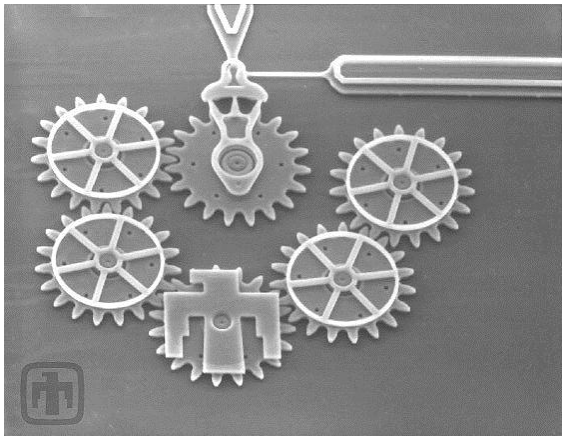
Micromanufacturing

- Micromanufacturing refers to methods used to create structures of micrometer sizes or smaller.

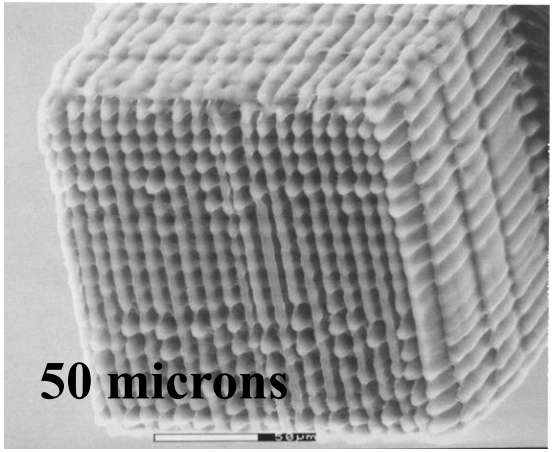
A Micron-Size Dust Particle on a Pin Head

One micrometer, or micron, is one-millionth of a meter ($1.0x10^{-6}m$)

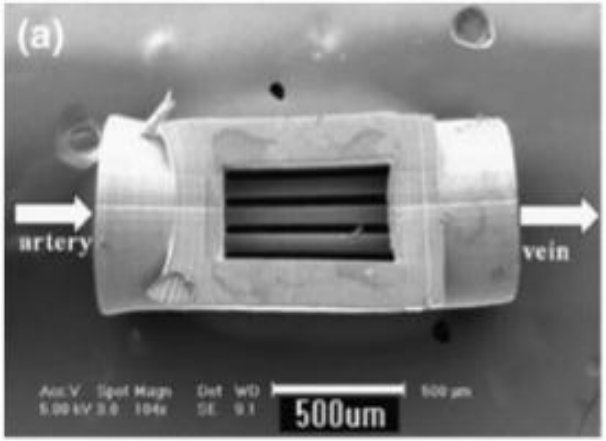
One nanometer is one-billionth of a meter ($1.0x10^{-9}m$)



Micro Gears



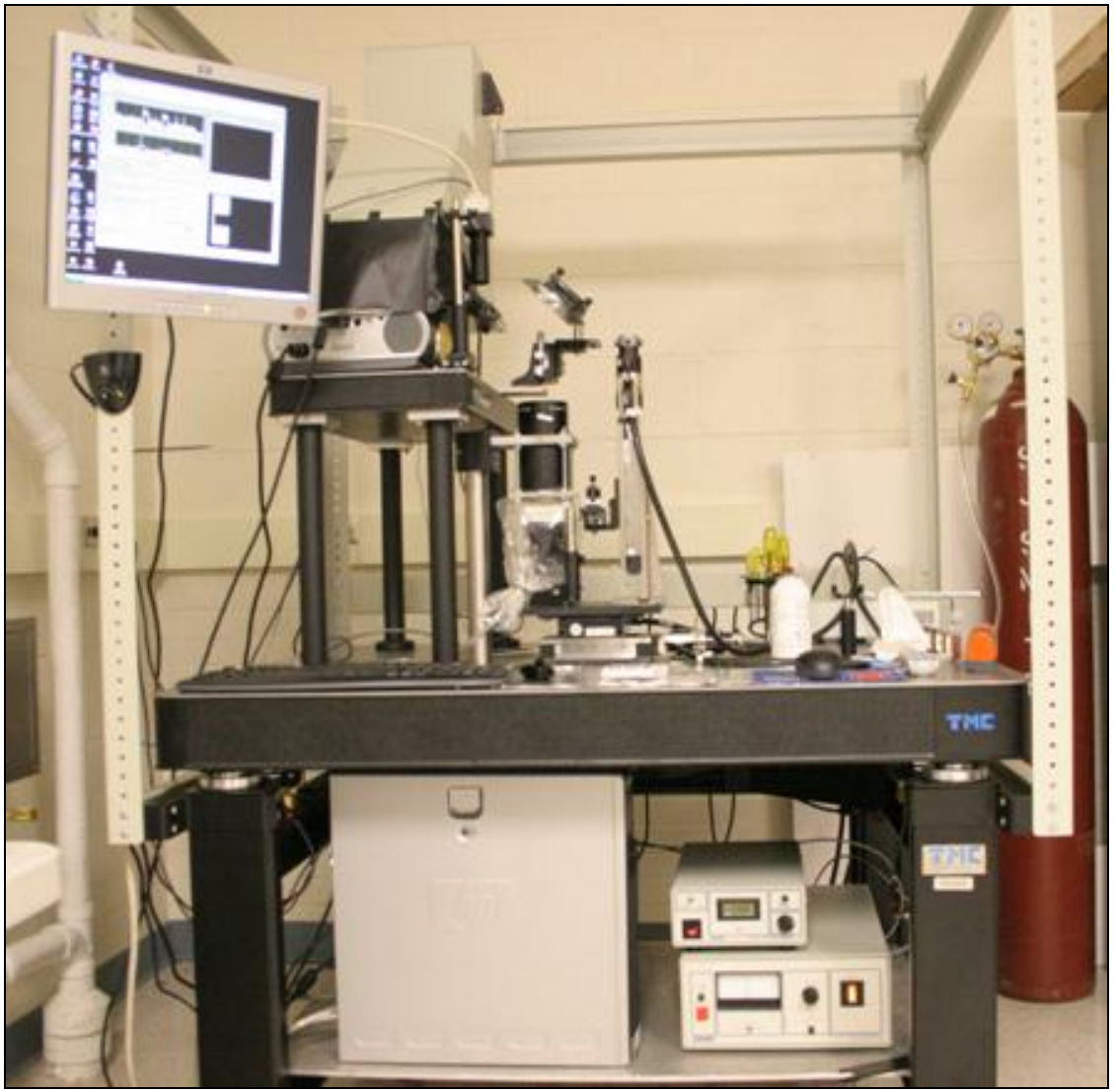
Photonic Crystal



Bioreactor

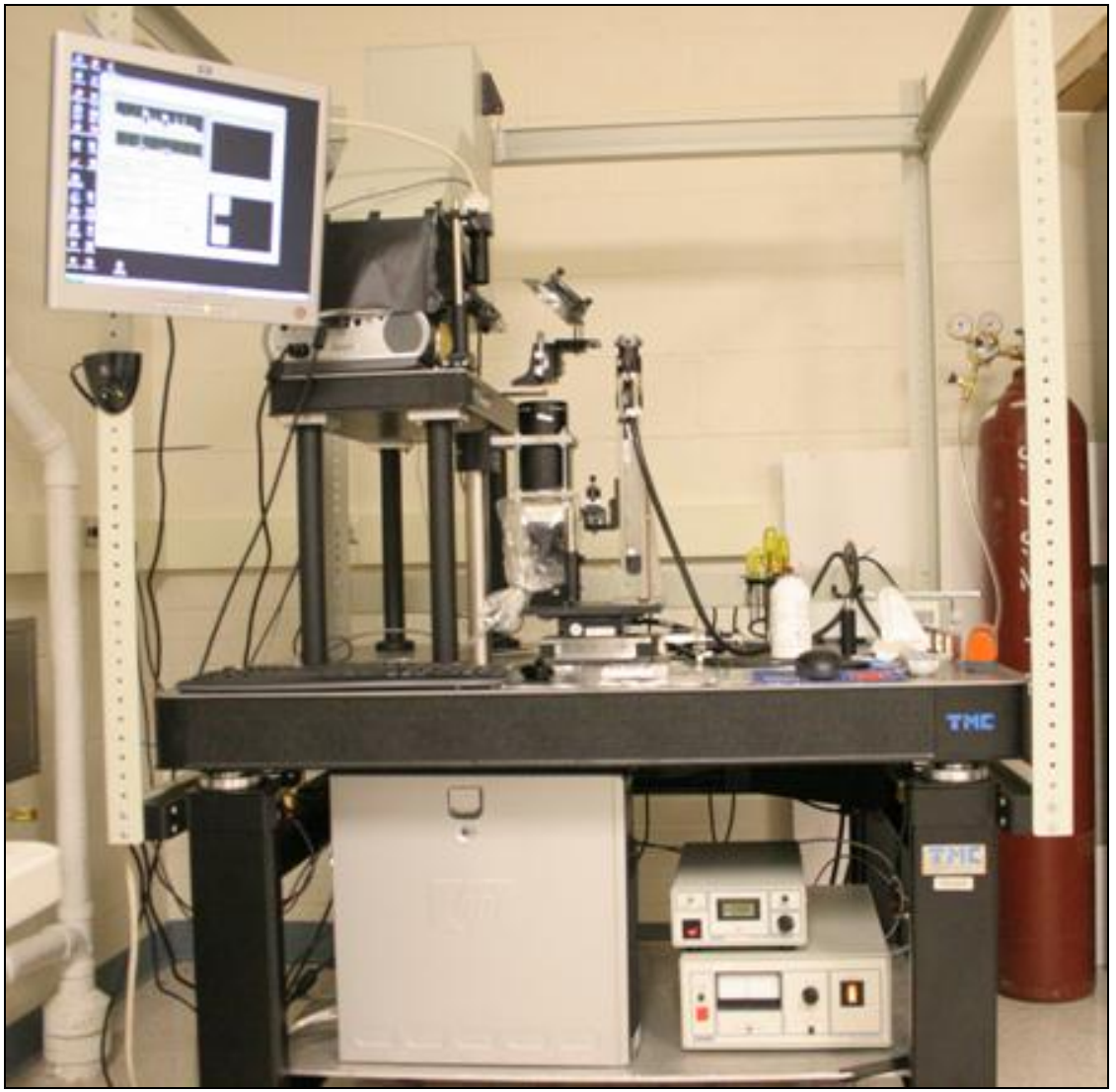
3-Dimensional Printing

- Work of Professor Nicholas Fang in nanoscale optical imaging
- Idea is to mimic a complicated and expensive lab setup in an inexpensive way.
- Uses equipment normally found in a school classroom.

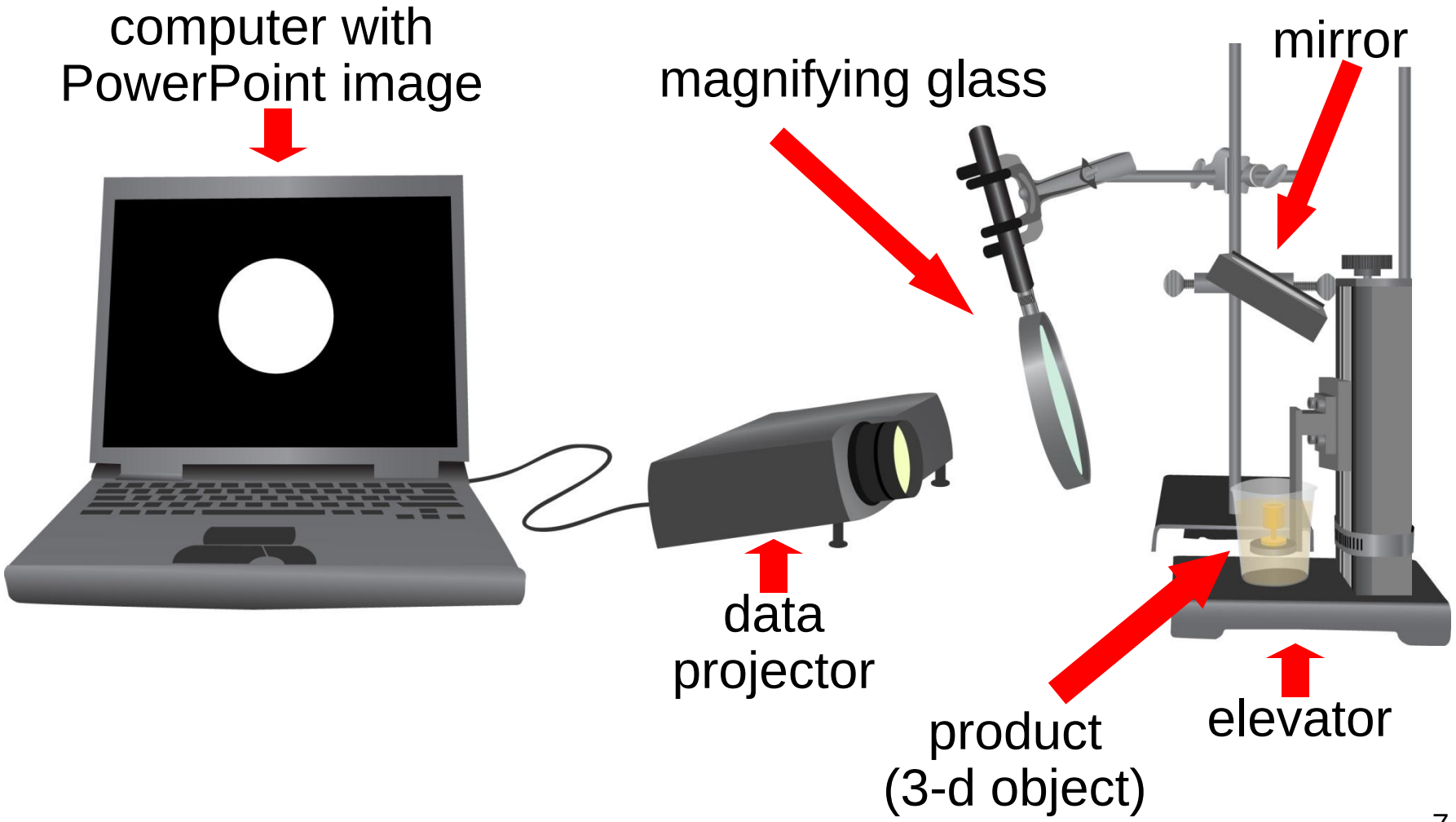


3-Dimensional Printing

- So, can't take $ 500,000 machine into classroom – what can students do?

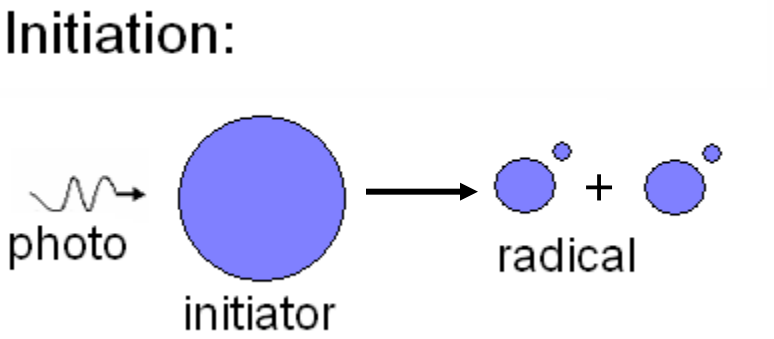


3-Dimensional Printing



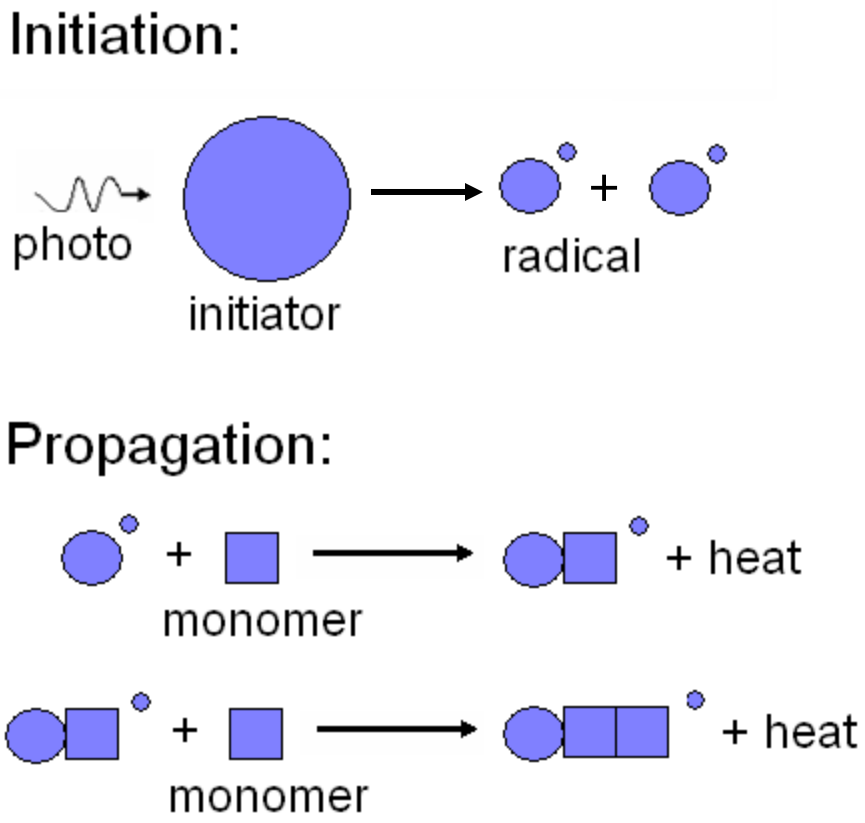
Light-Activated Polymer

- uv light reacts with initiator to create two radicals.
- Radicals each have single free electron.



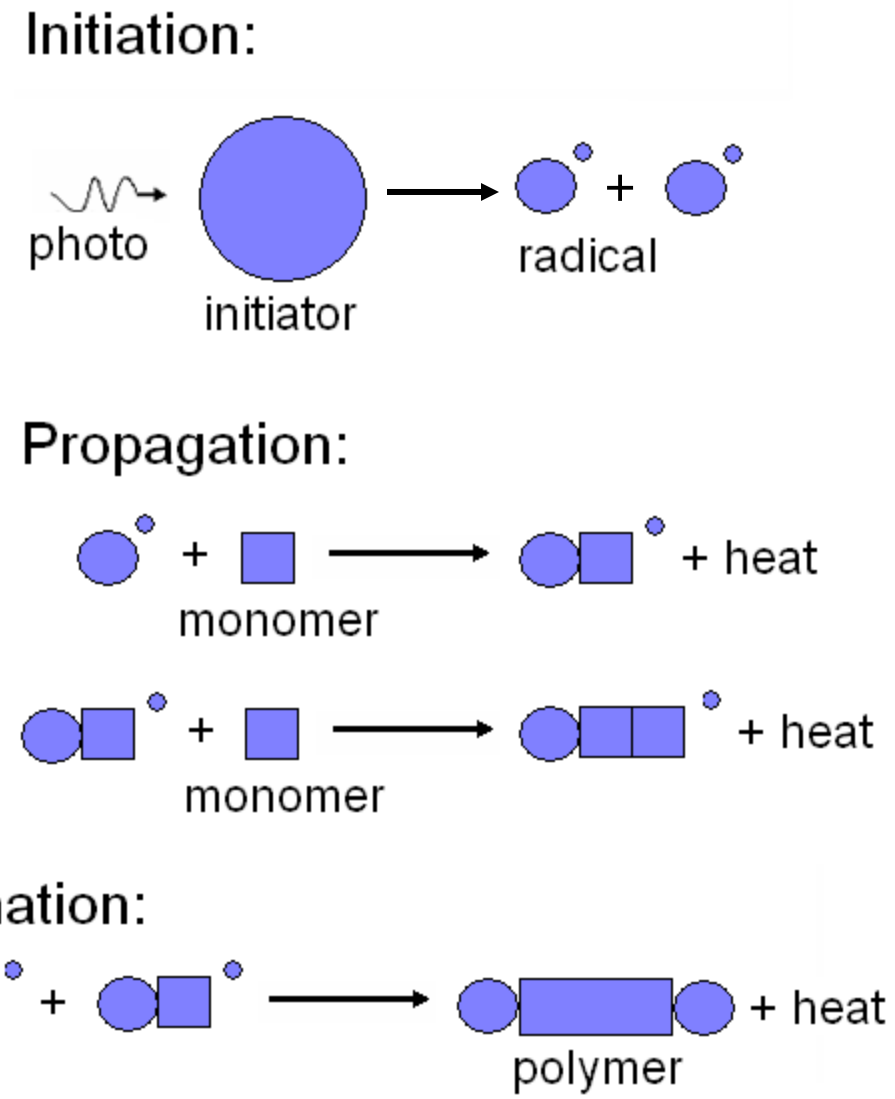
Light Activated Polymer

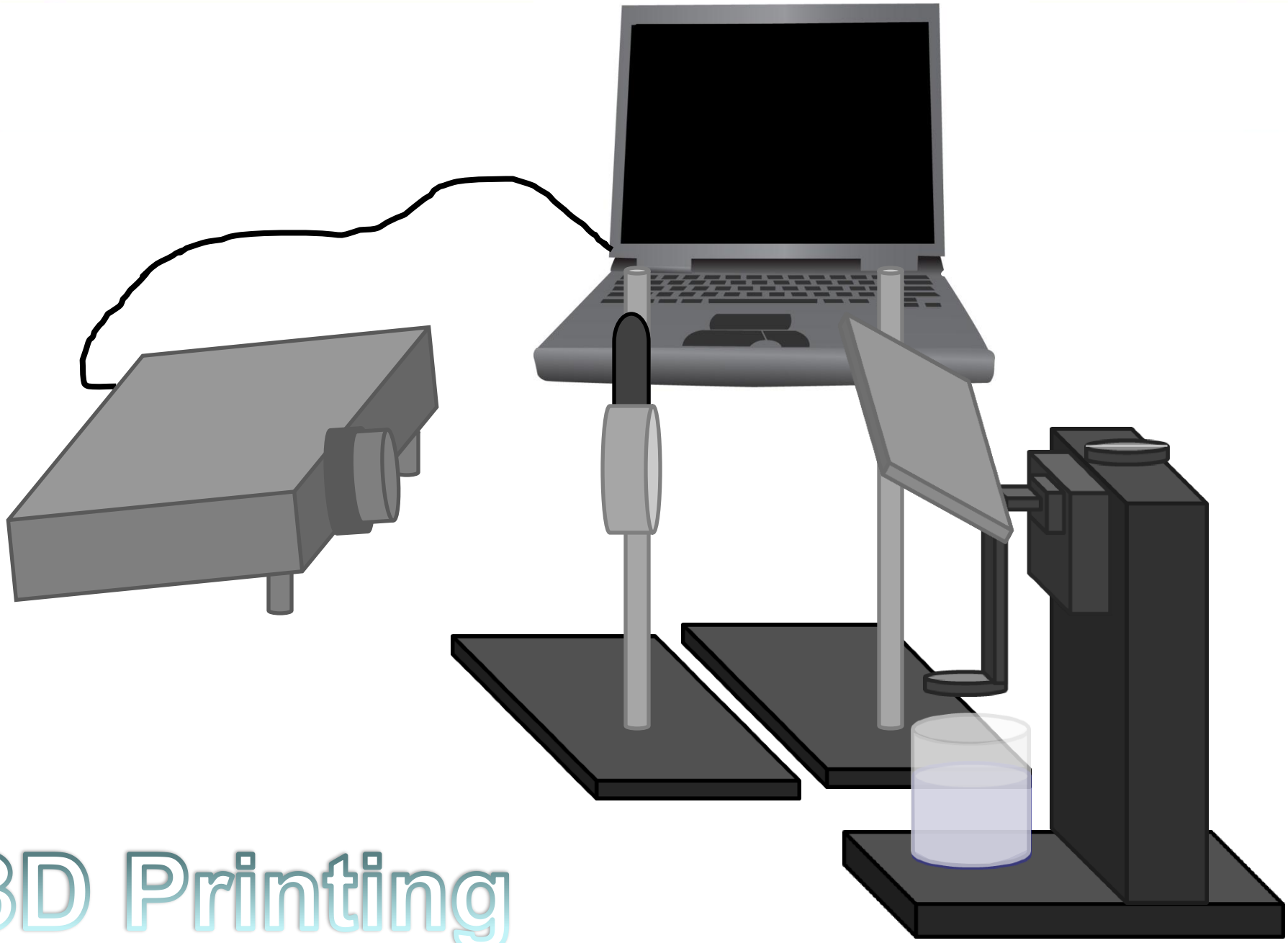
- Radical bonds with monomer.
- Now single free electron at end of chain



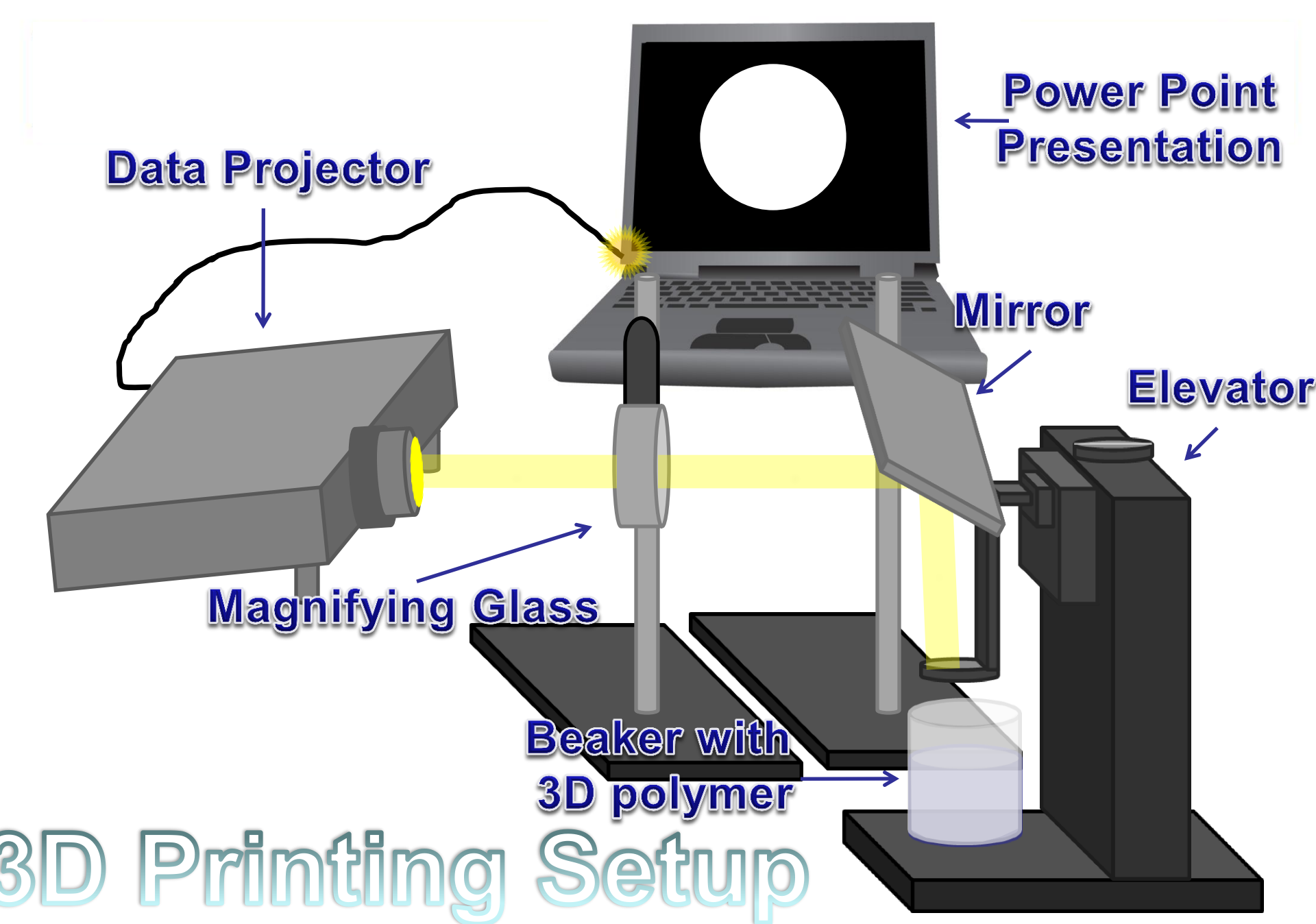
Light Activated Polymer

- Repeats until two ends with free electrons interact and bond.

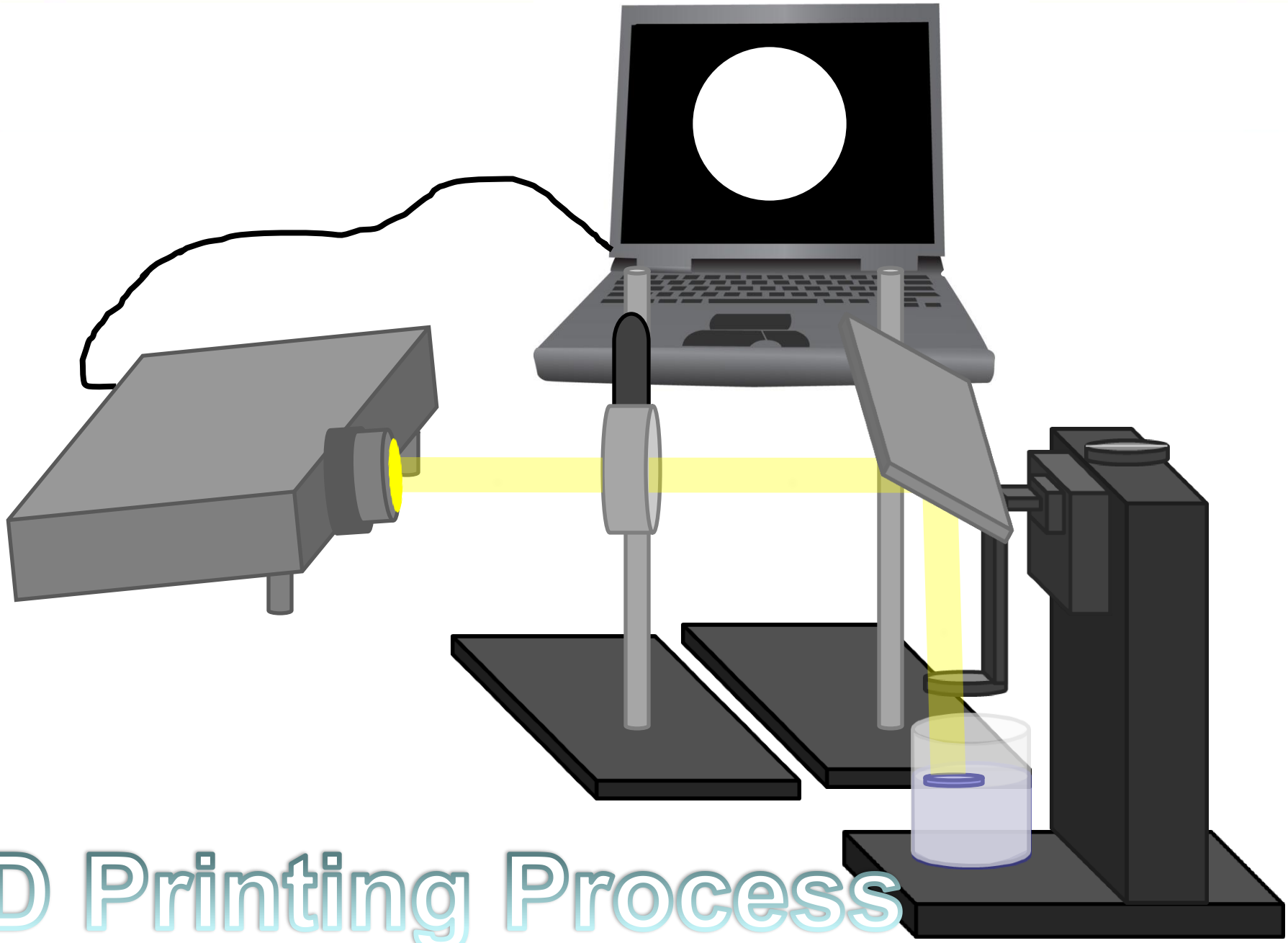




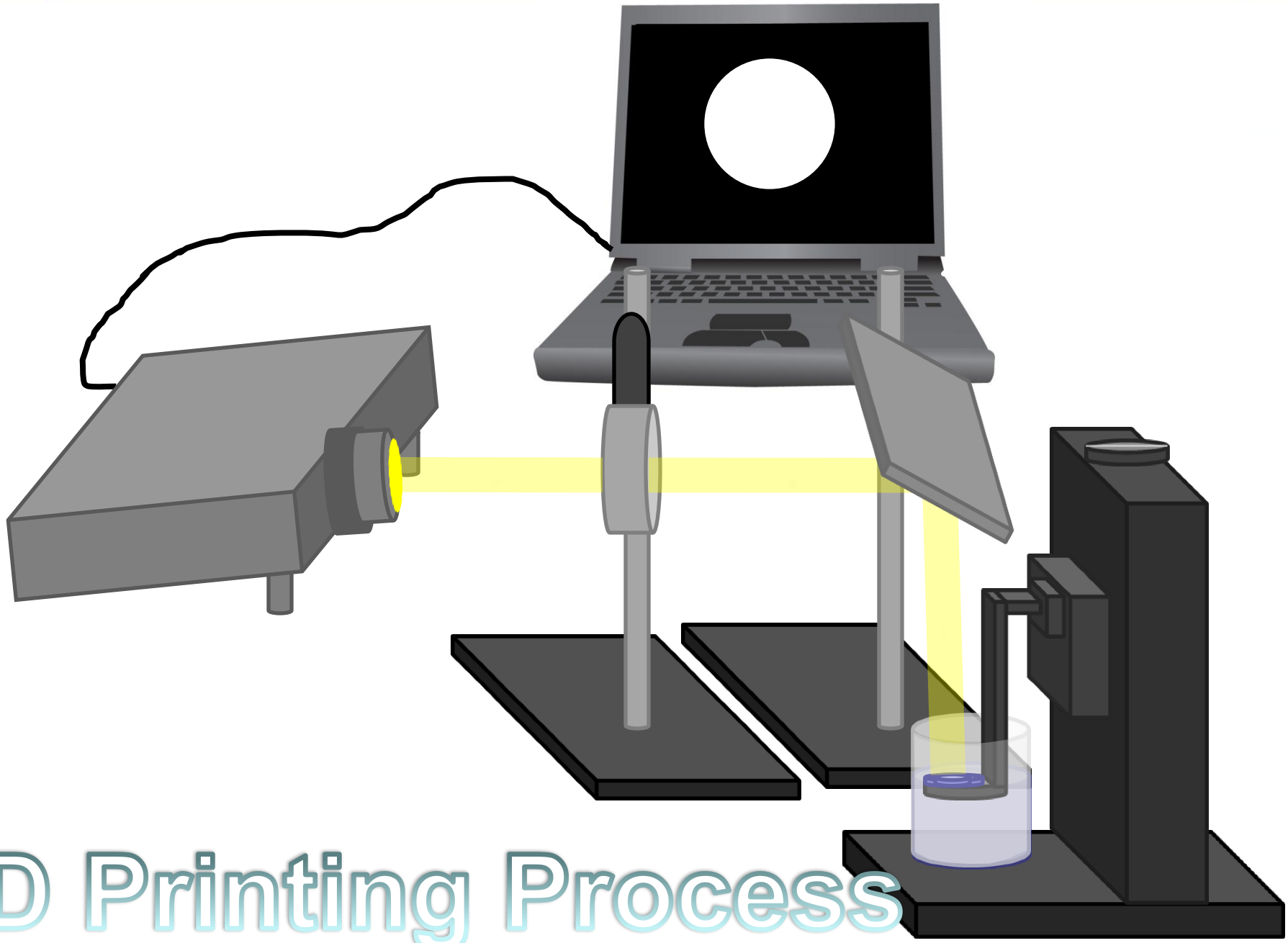
3D Printing



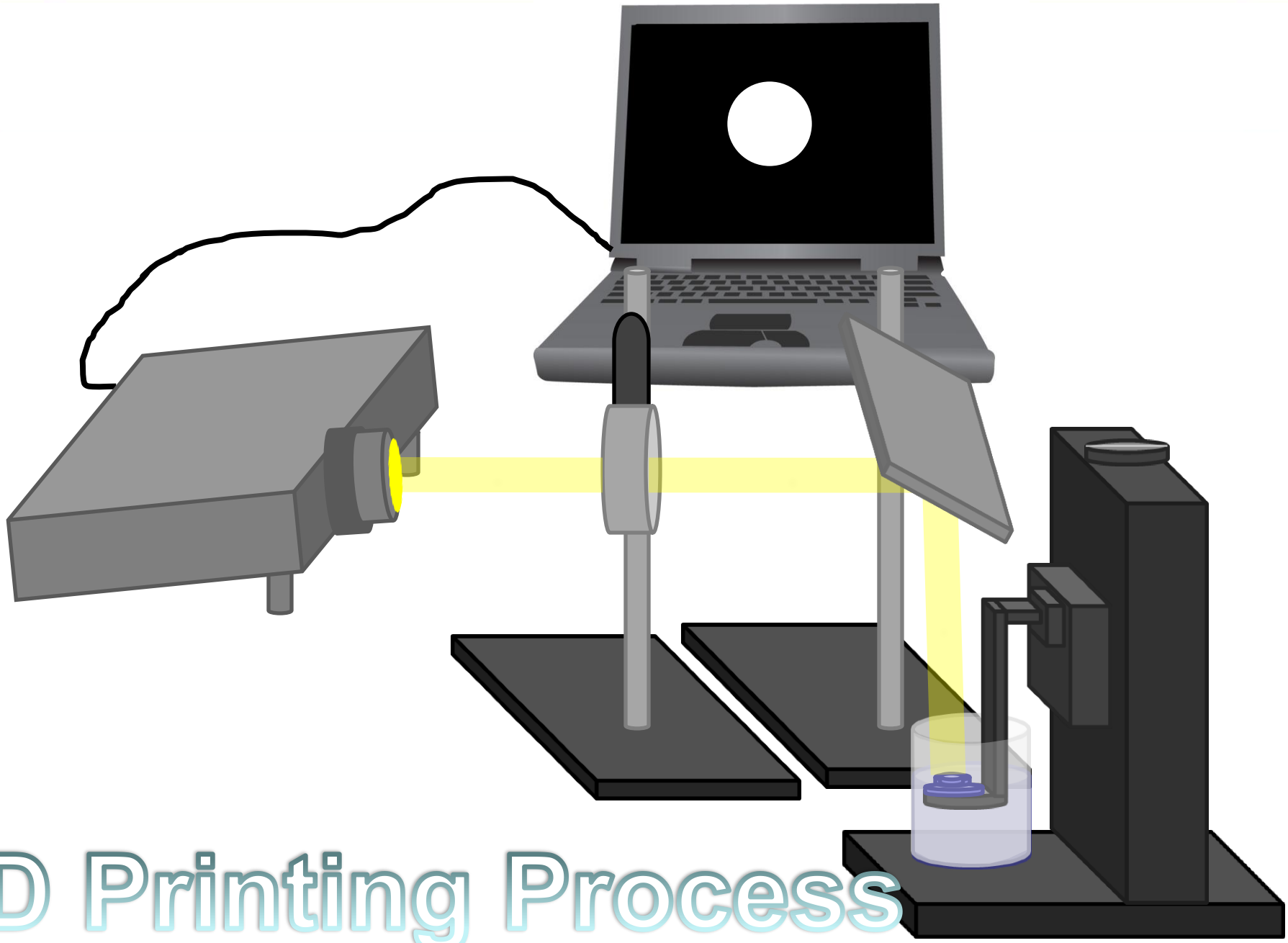
3D Printing Setup



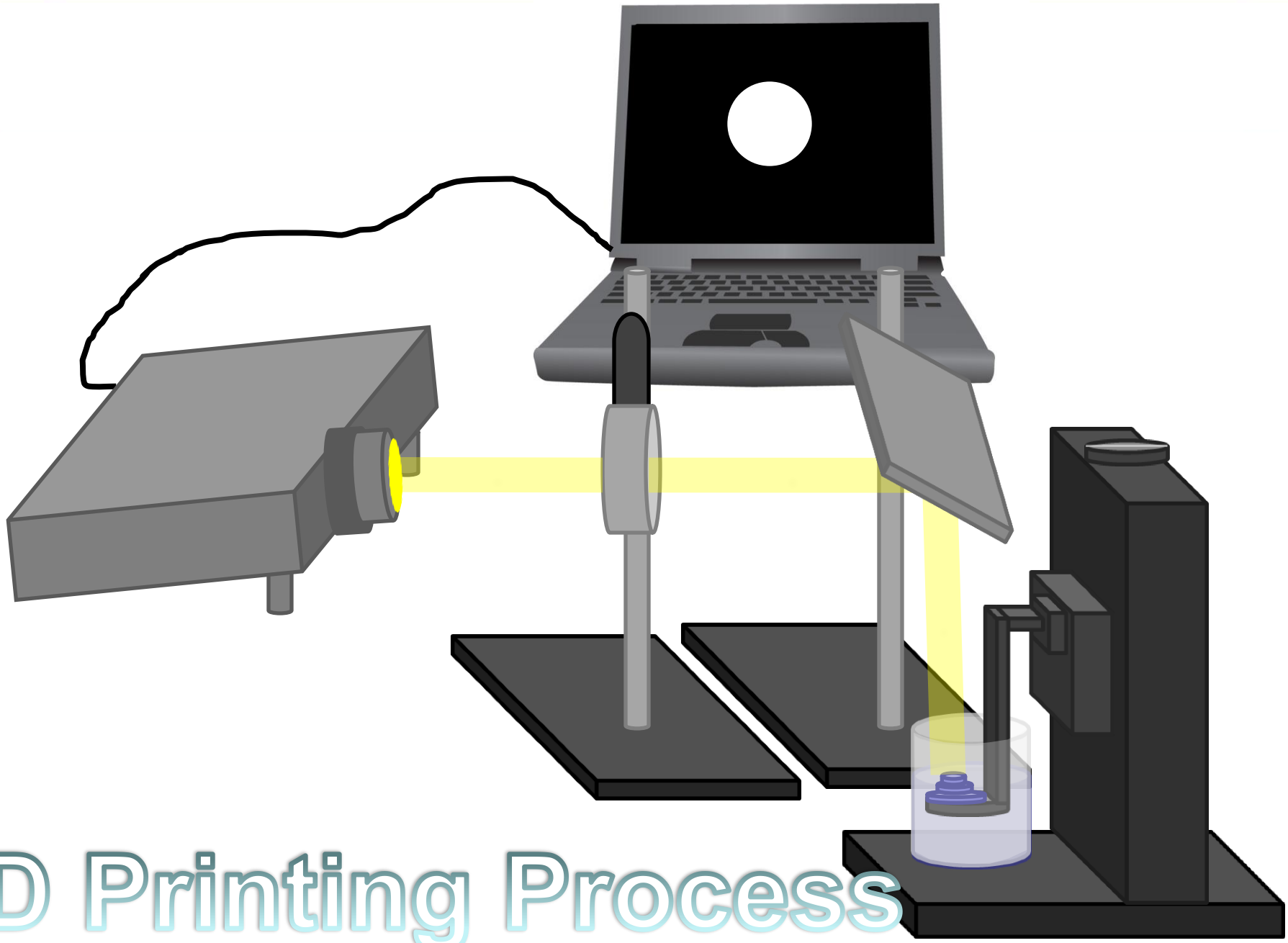
3D Printing Process



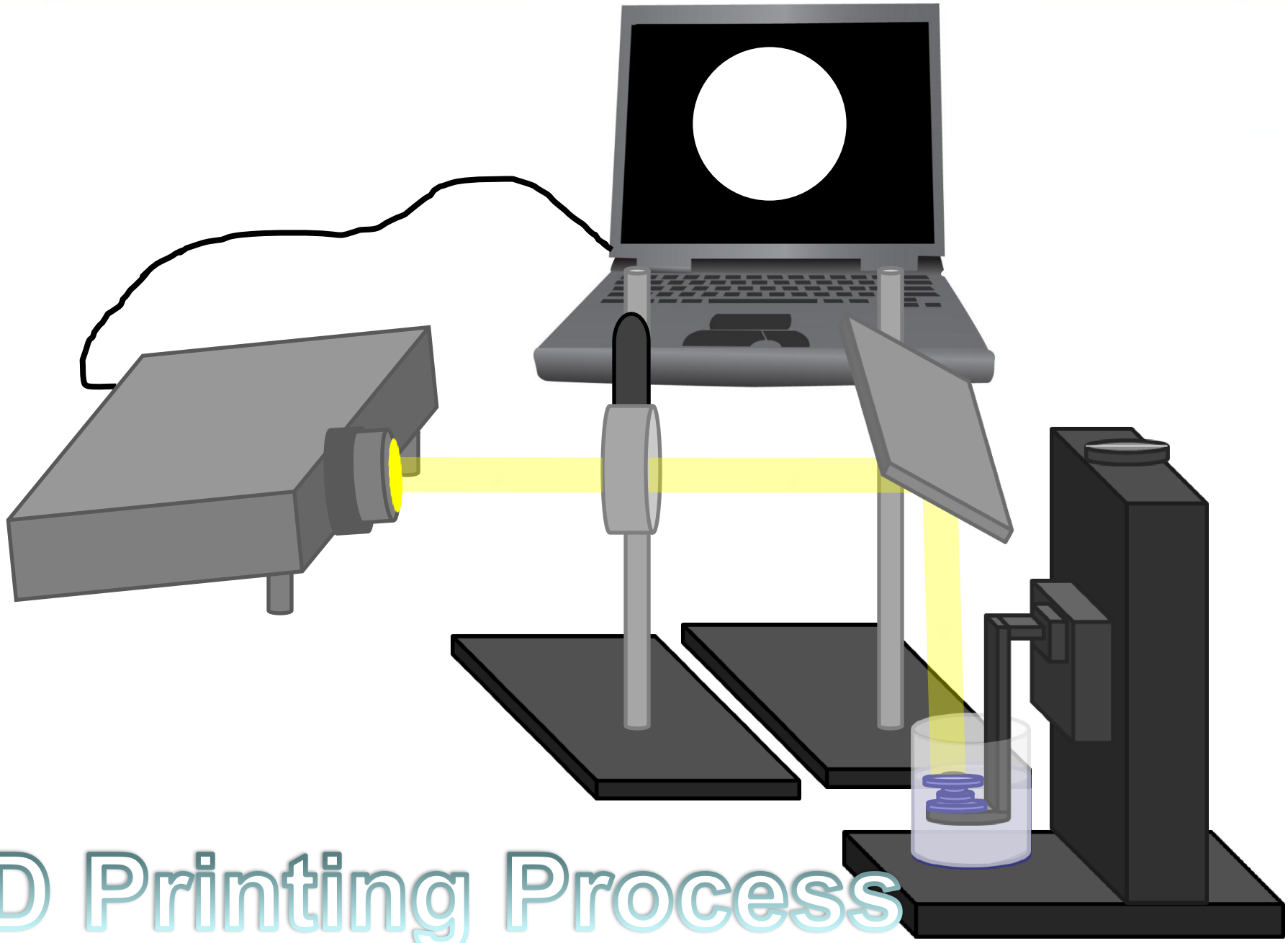
3D Printing Process



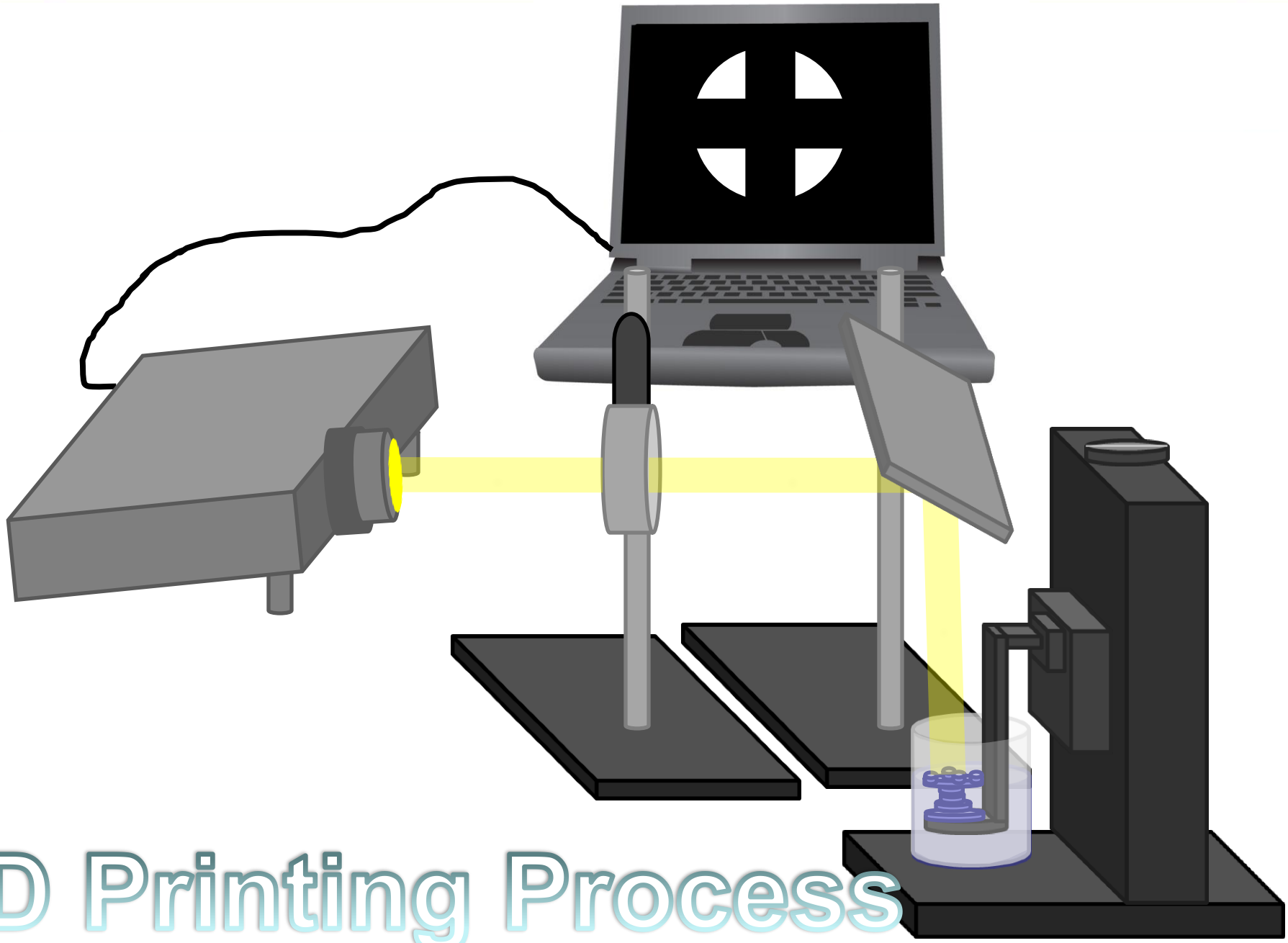
3D Printing Process



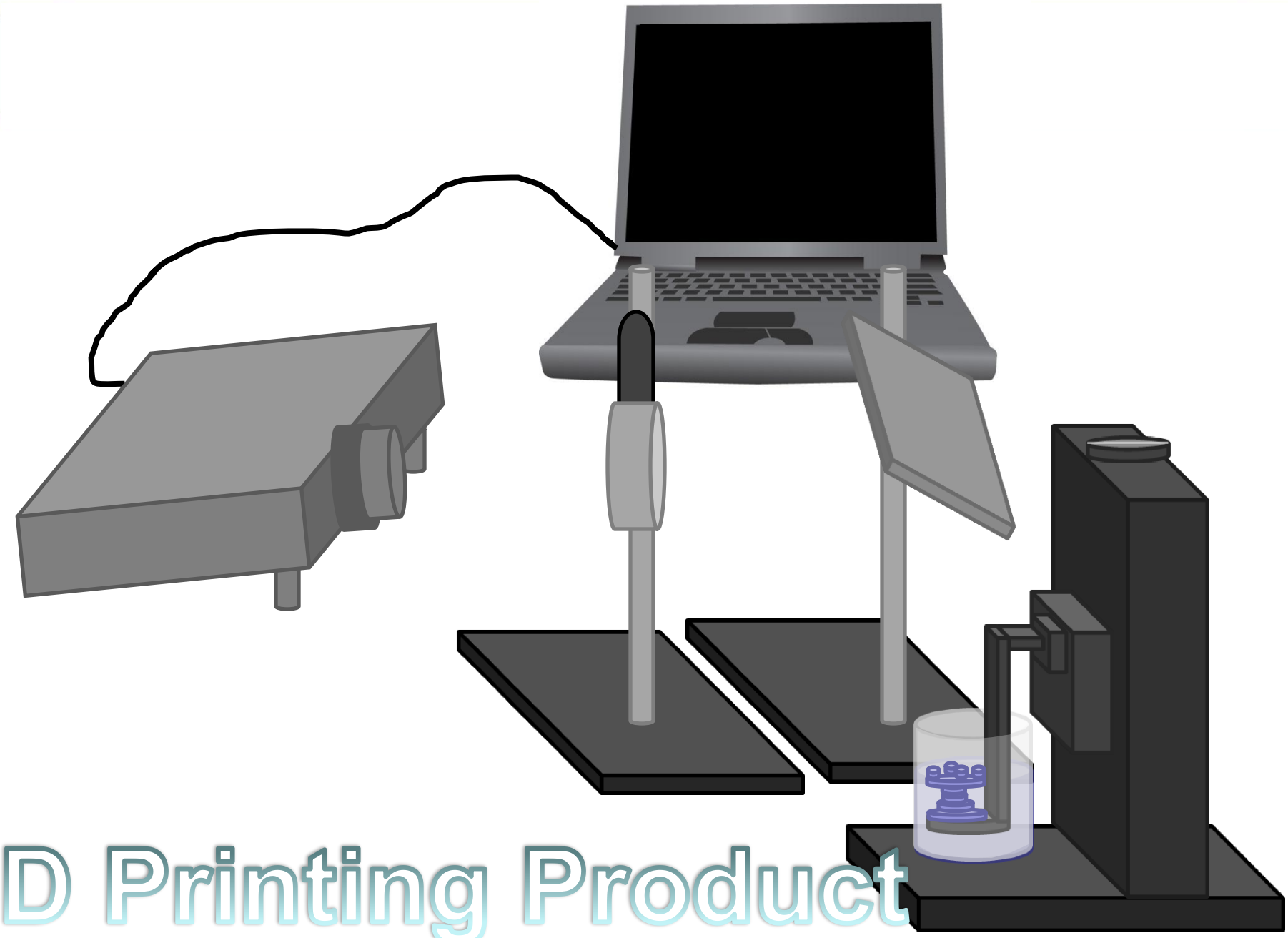
3D Printing Process



3D Printing Process



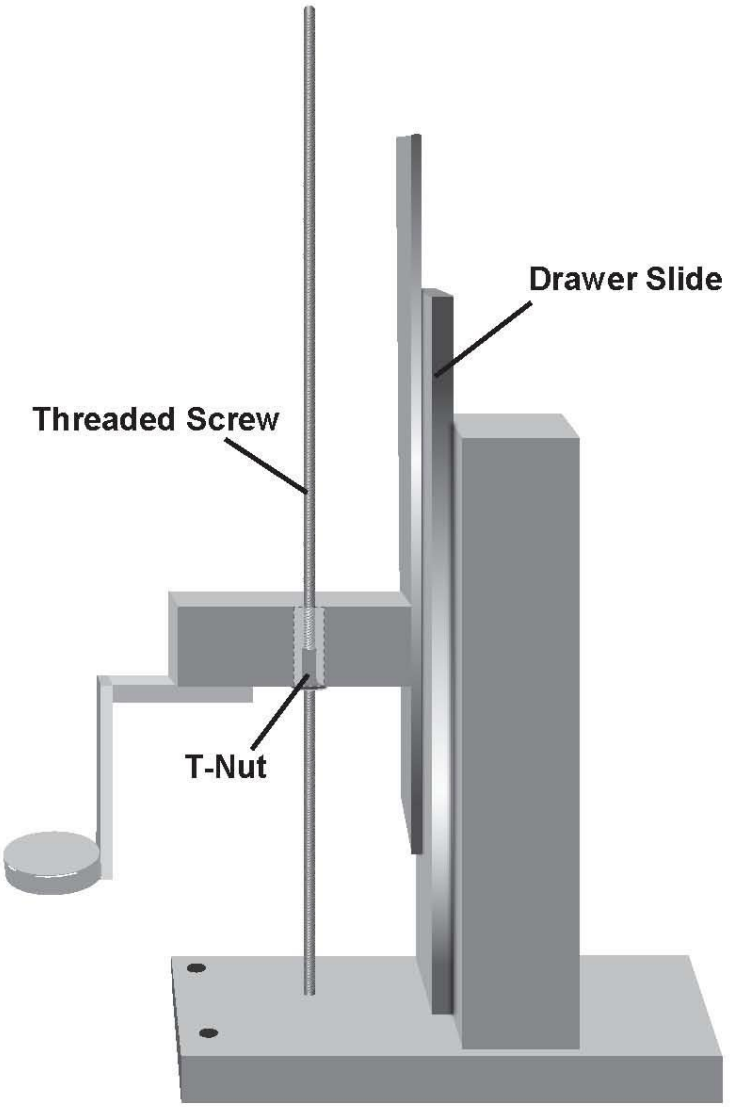
3D Printing Process



3D Printing Product

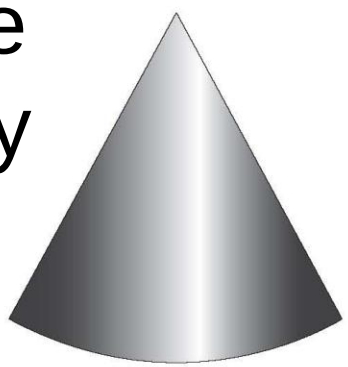
Elevator Design

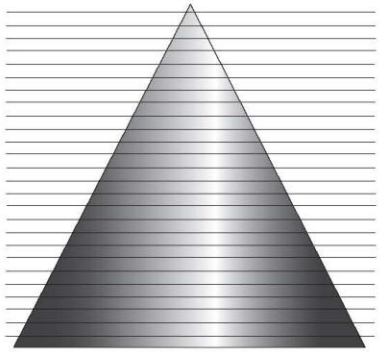
- Drawer slide provides smooth movement.
- T-nut and threaded screw controls motion.

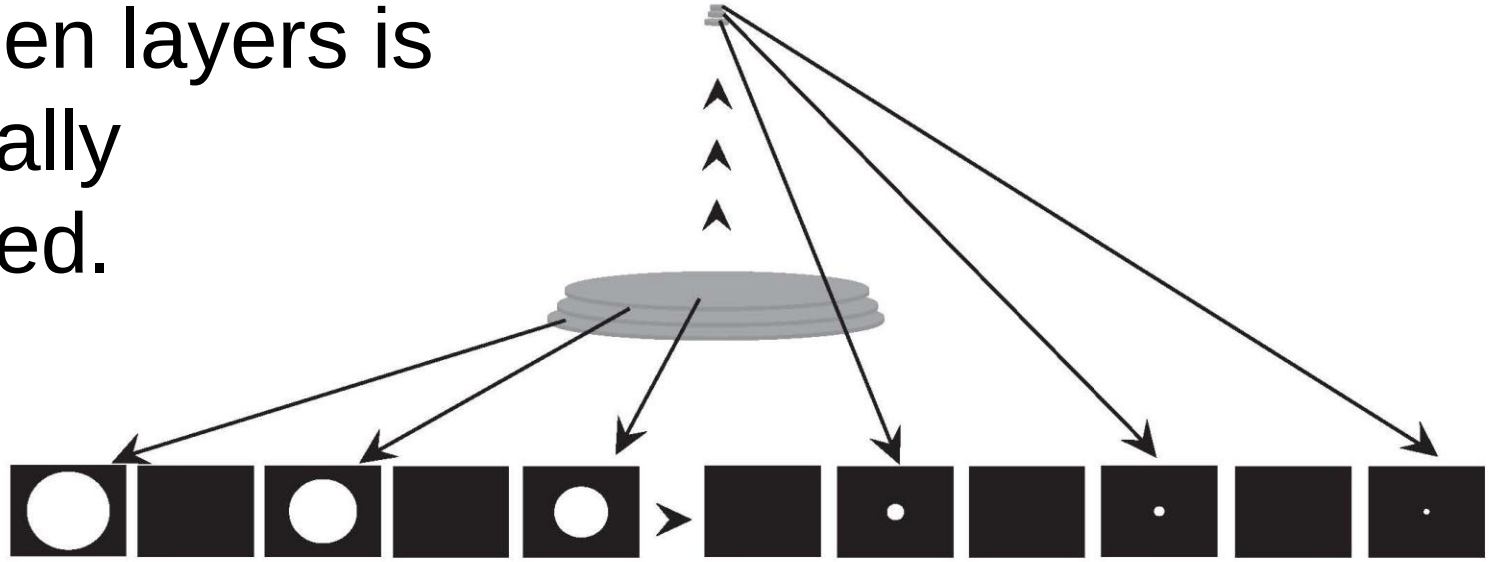


Slicing the 3D Object

- 3D objects are constructed by slices.
- Overlapping between layers is generally required.

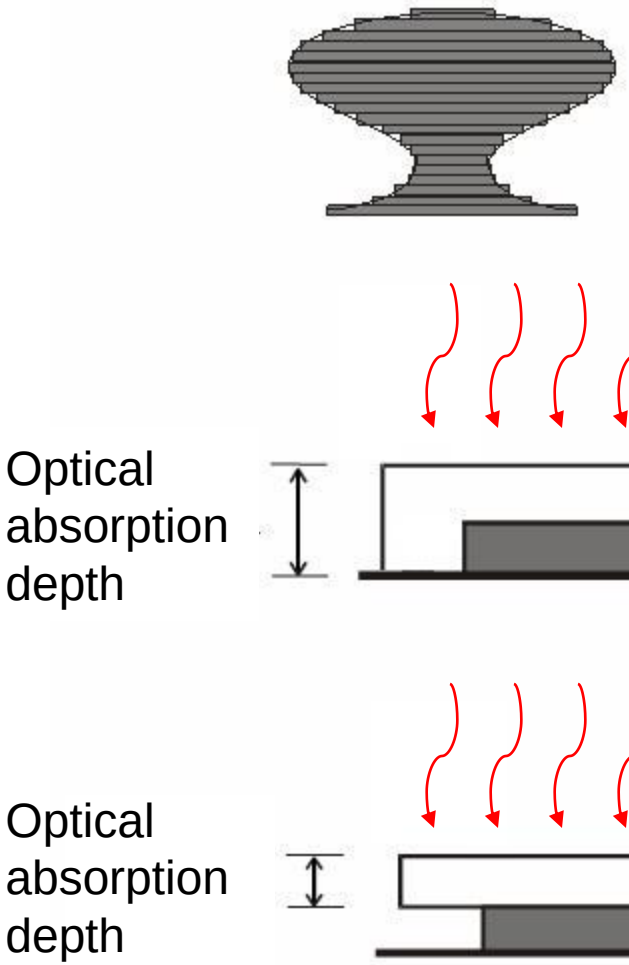






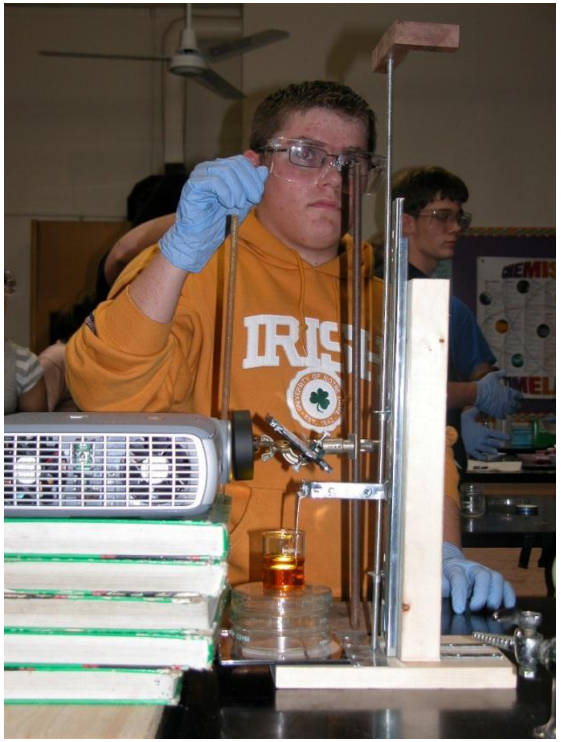
Overhanging Structures?

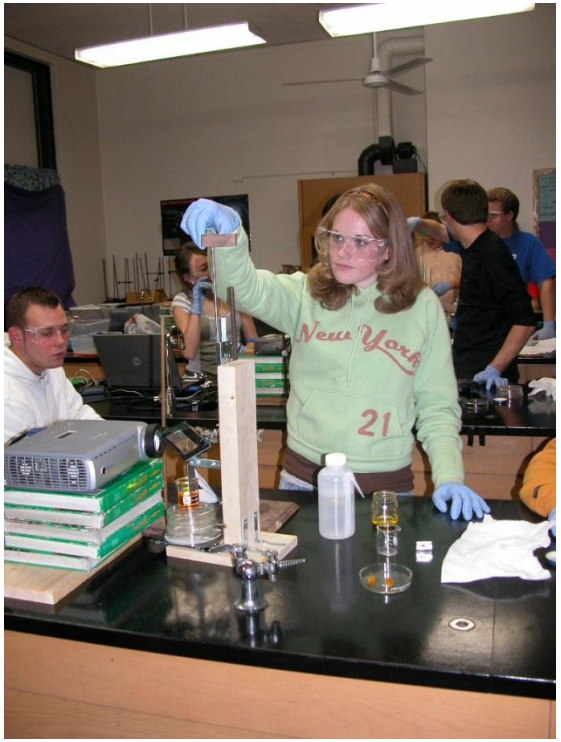
- Amount of Sudan I determines thickness of layer.



What to Do

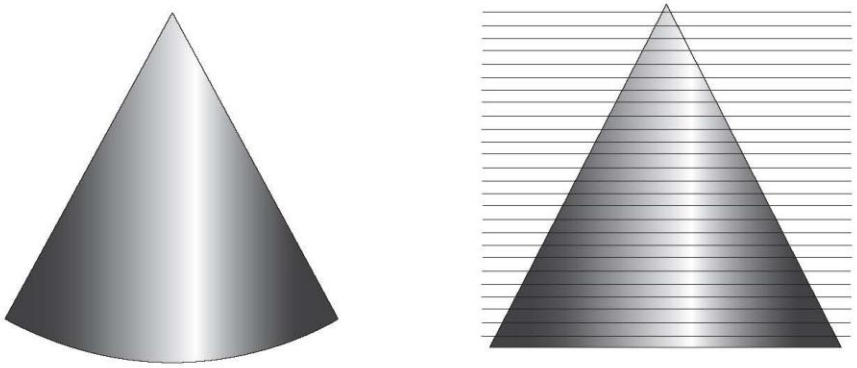
- Make black/white images.
- Set up system.
- Print!



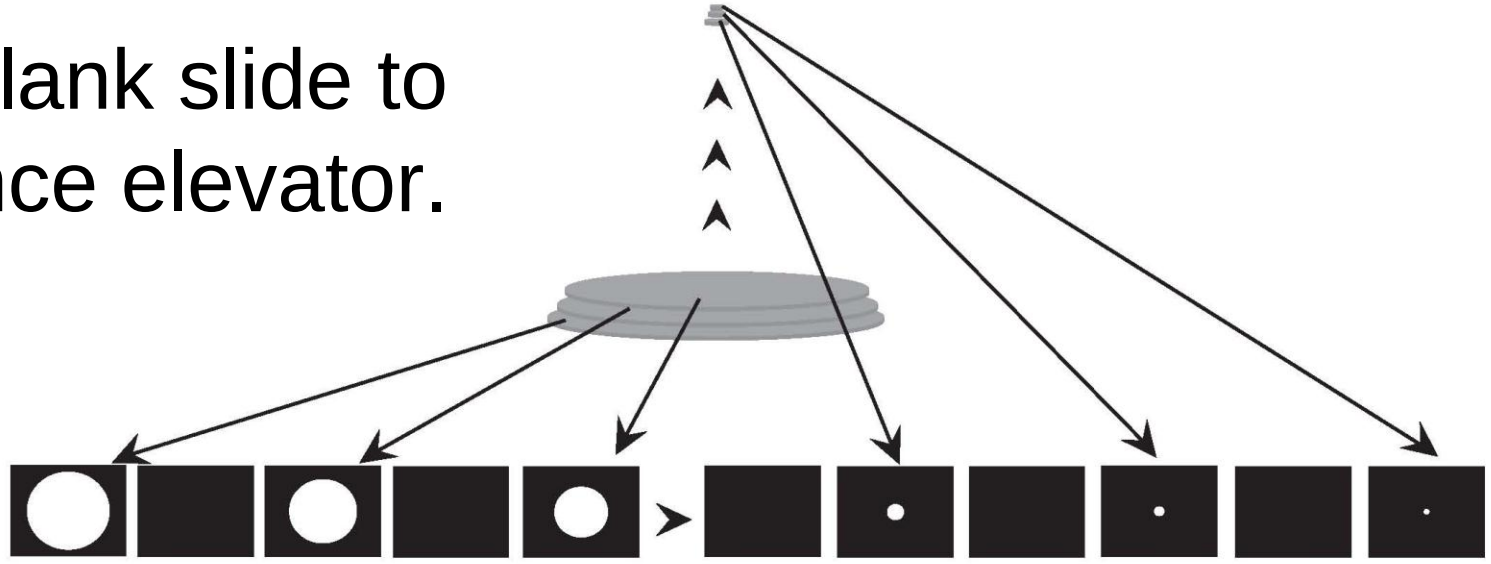


Slicing the 3D Object

- Create each different slice.

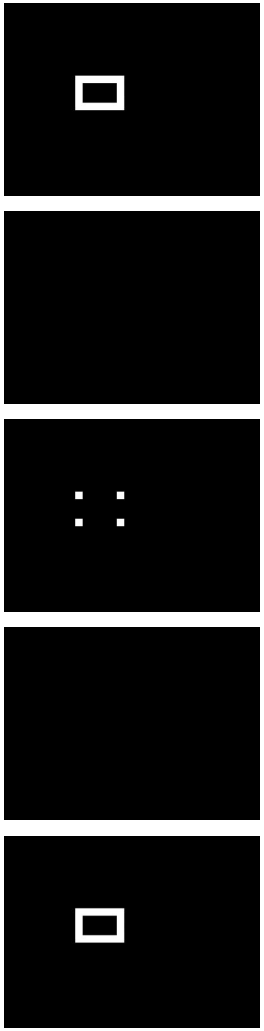


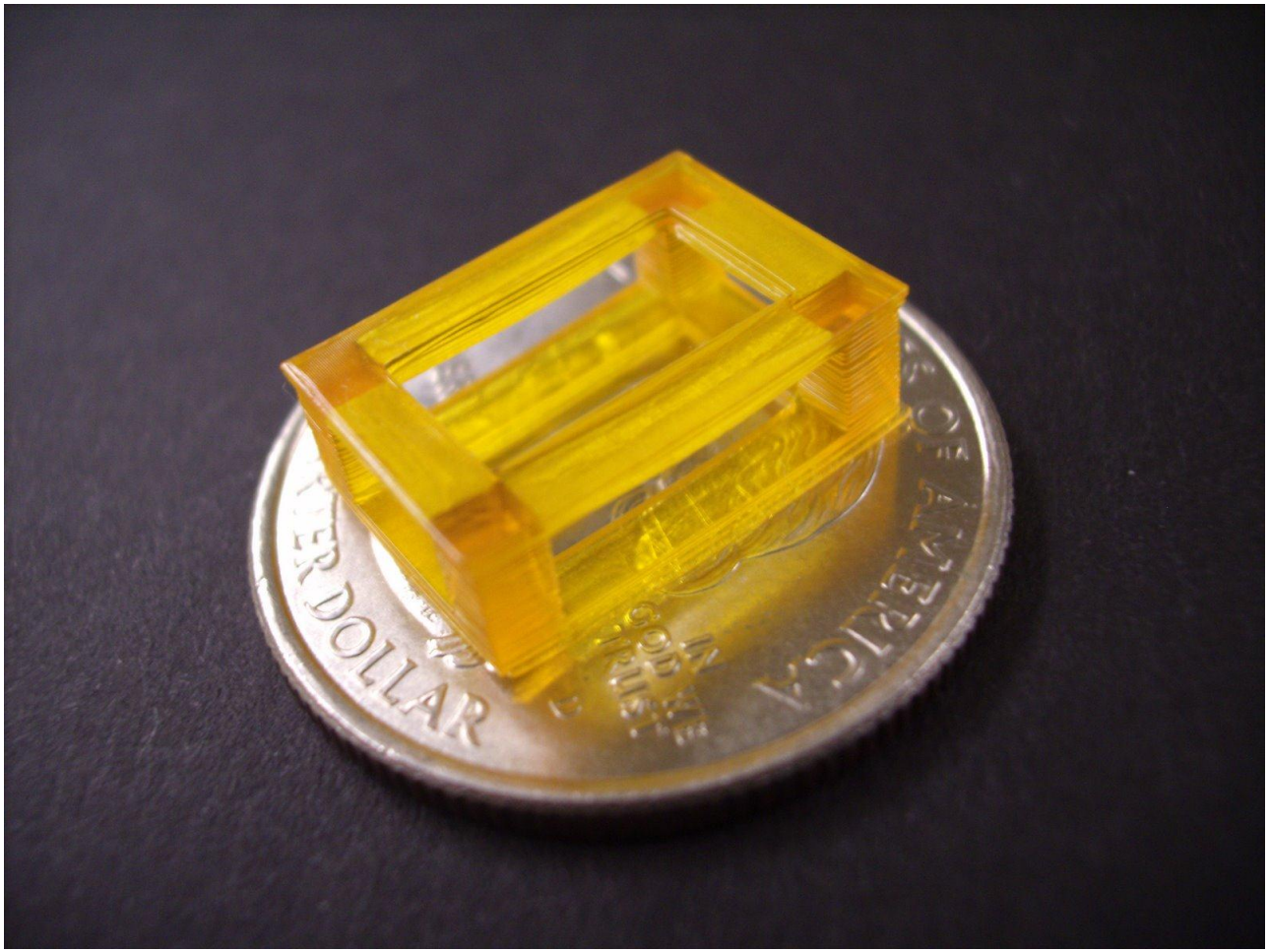
- Add blank slide to advance elevator.



Sample

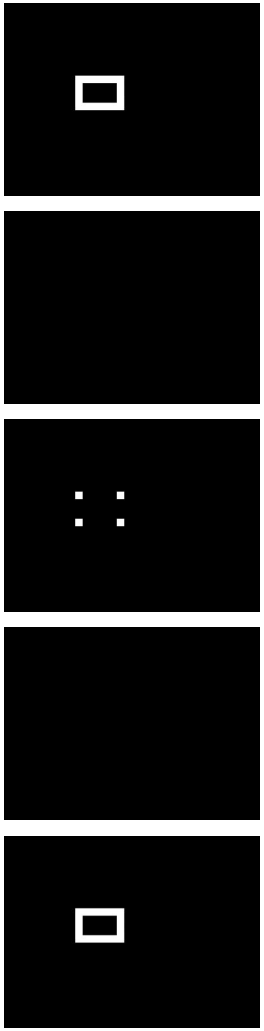
- To make a rectangular box…

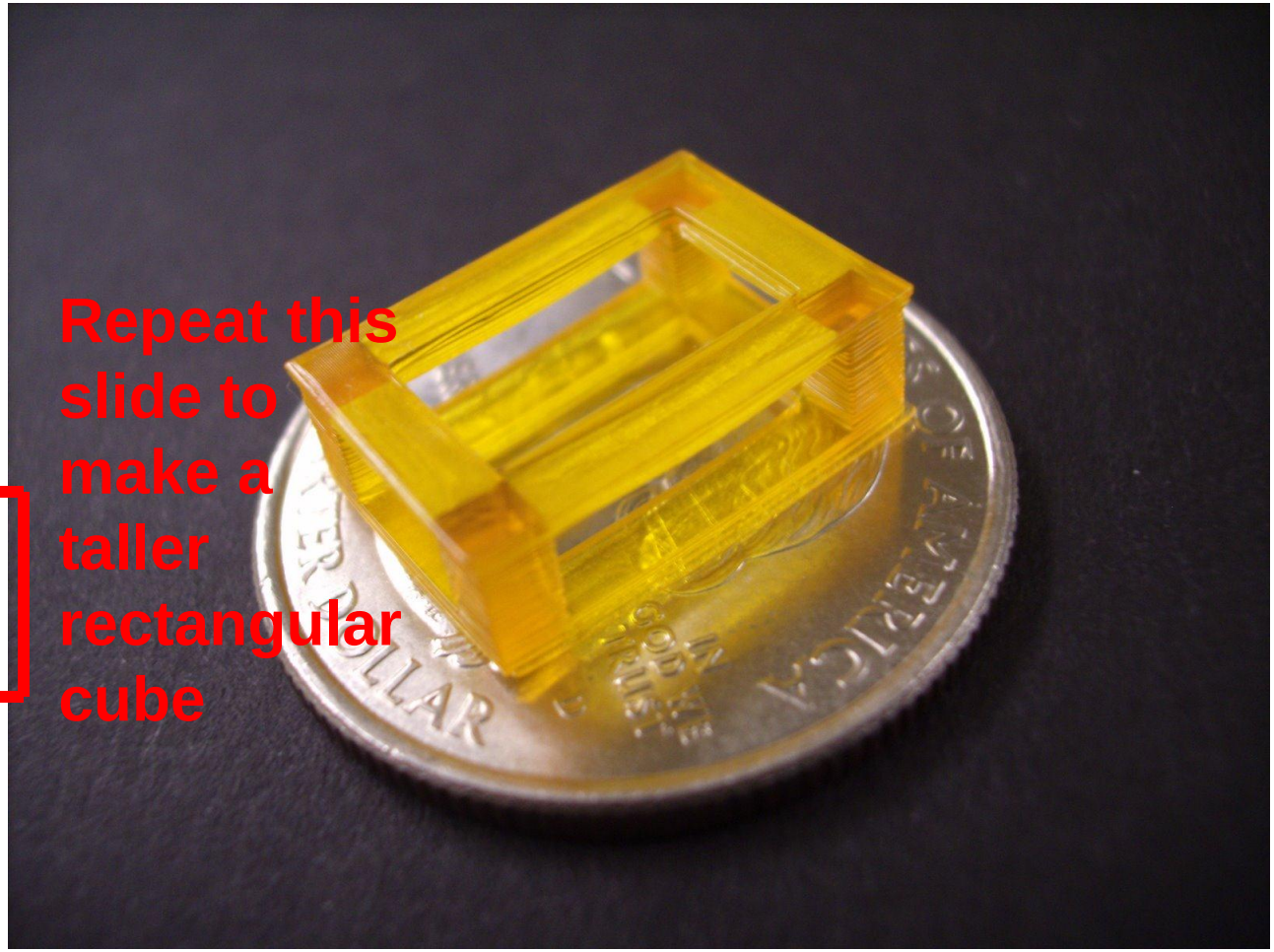




Sample

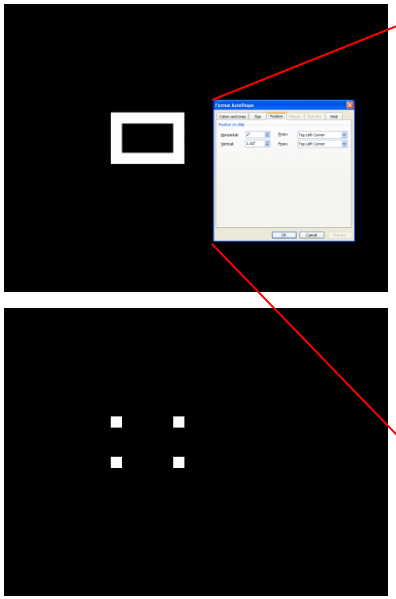
- To make a rectangular box…

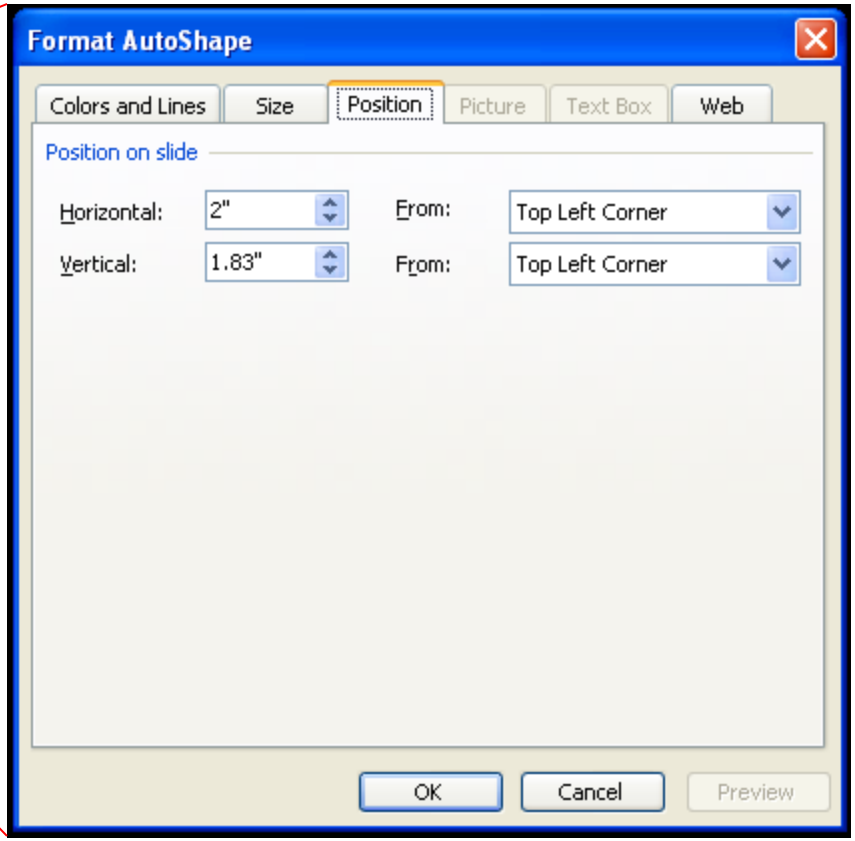




Alignment is Important

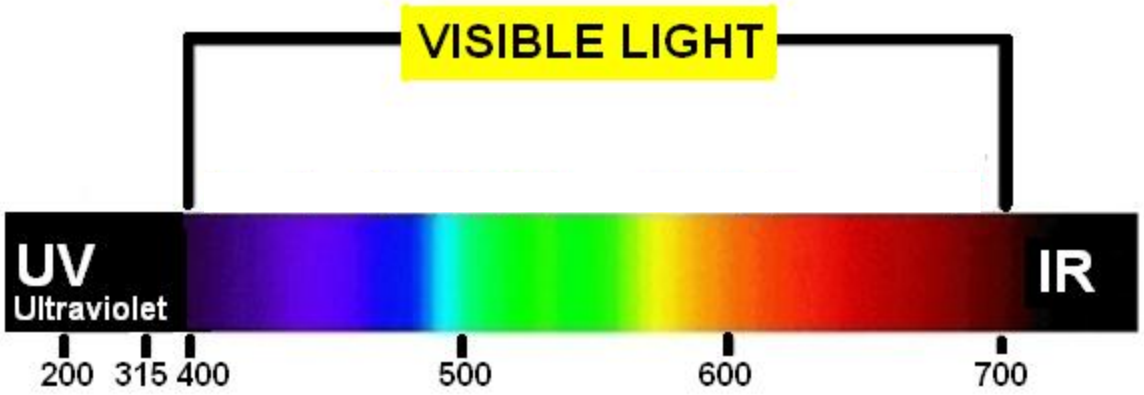
- Be sure each slide aligns.
- To align - copy slide, make modifications.
- Check properties.





Preparation Slides

- Polymer reacts with uv light.
- Polymer does NOT react with red light, but we can see red.



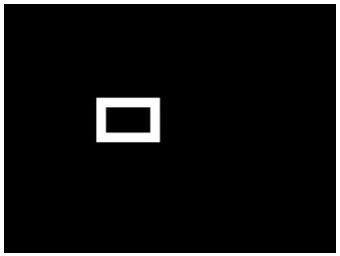
- Red is good color to use for preparing an apparatus.

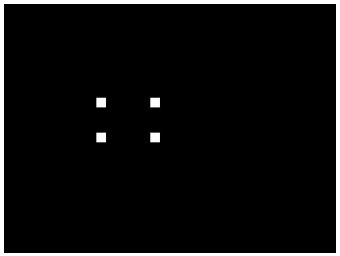
Focus Slide

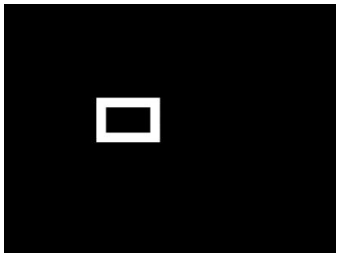
- Use a red complex image to focus.

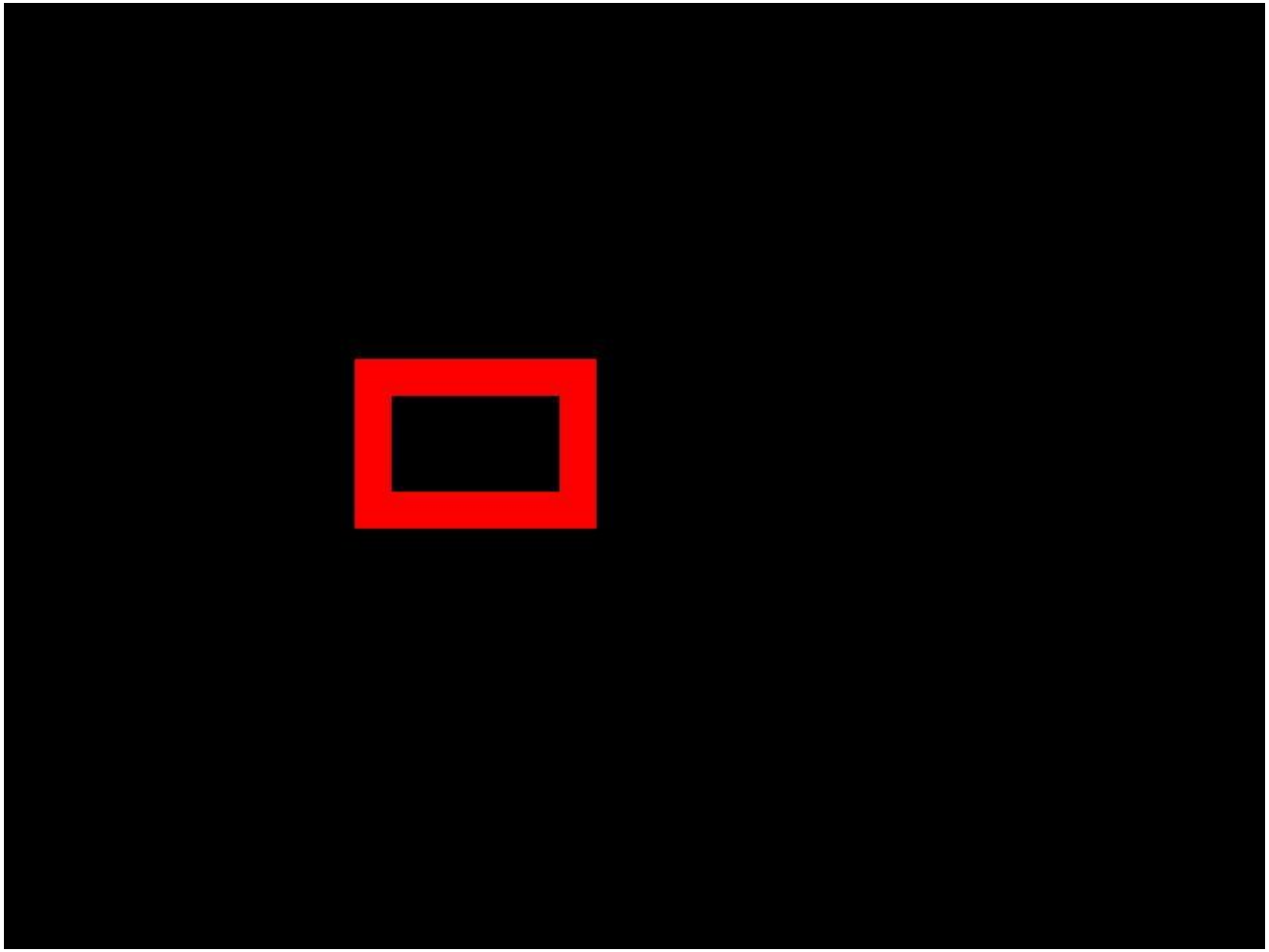
Alignment Slide

- Make a red version of the largest image to align.



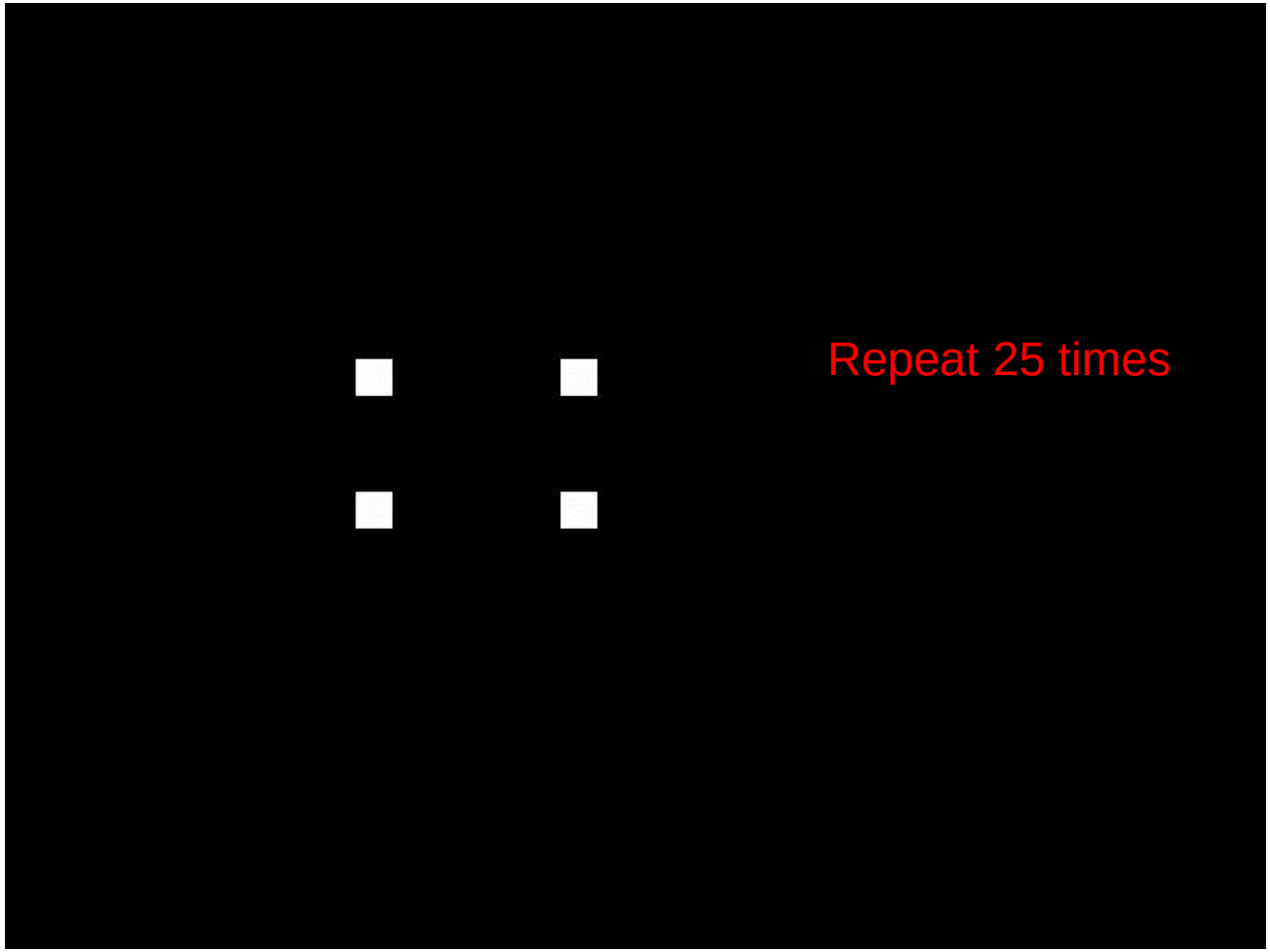






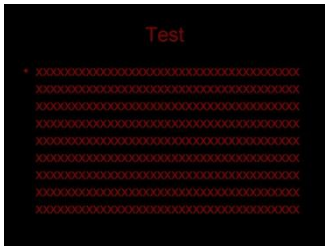
Instructions

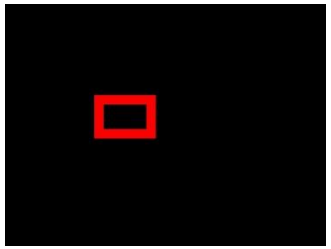
- Use red text for instructions.

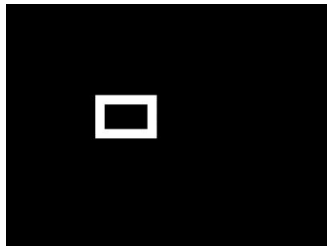


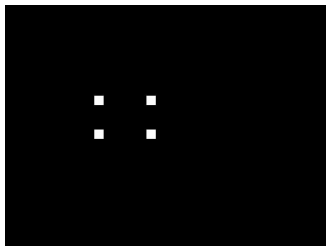
Final

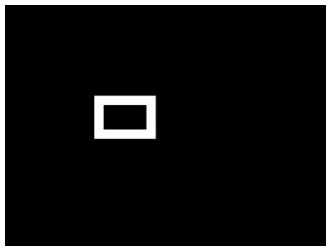
- Put these elements together in one file.







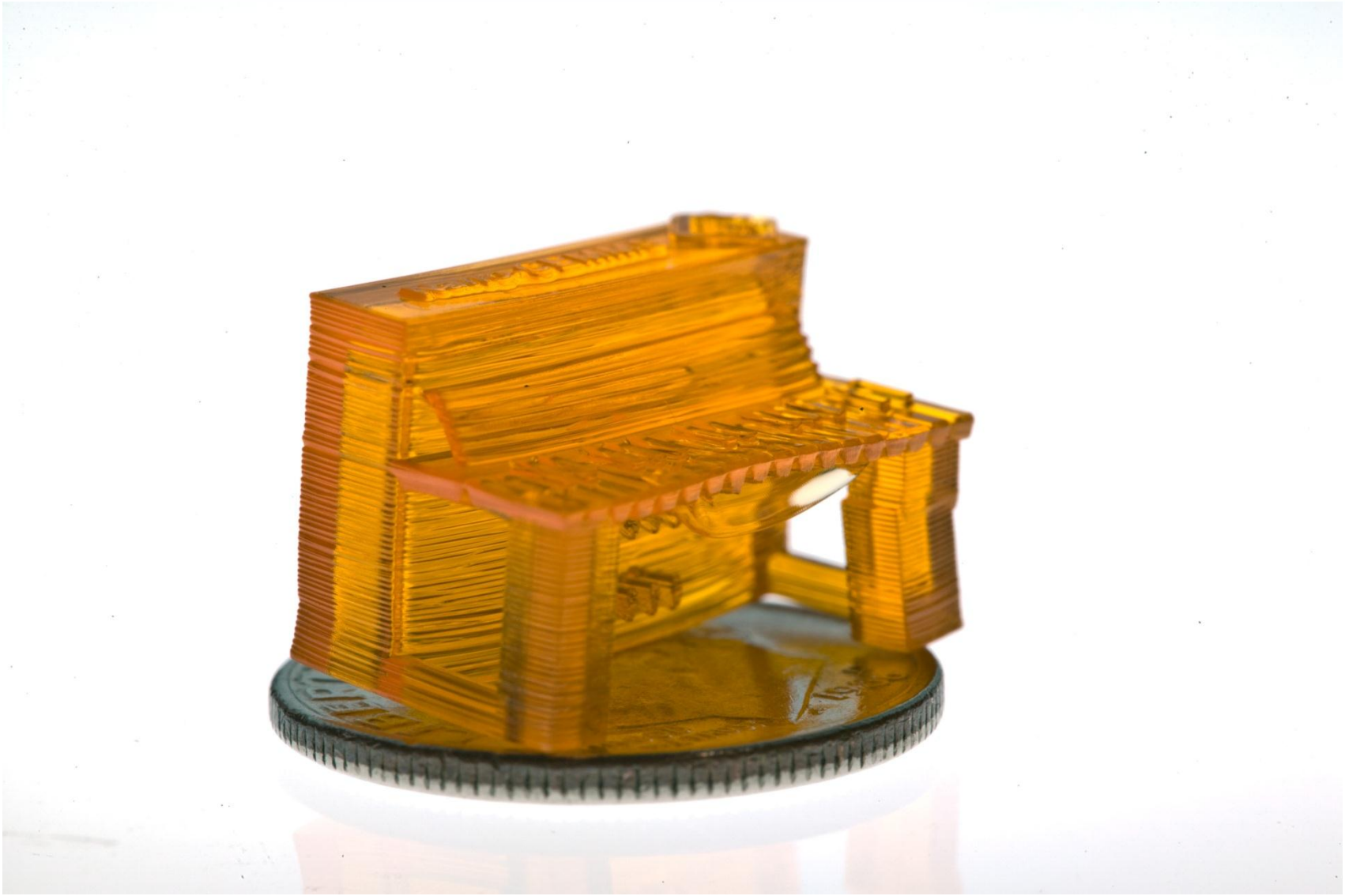




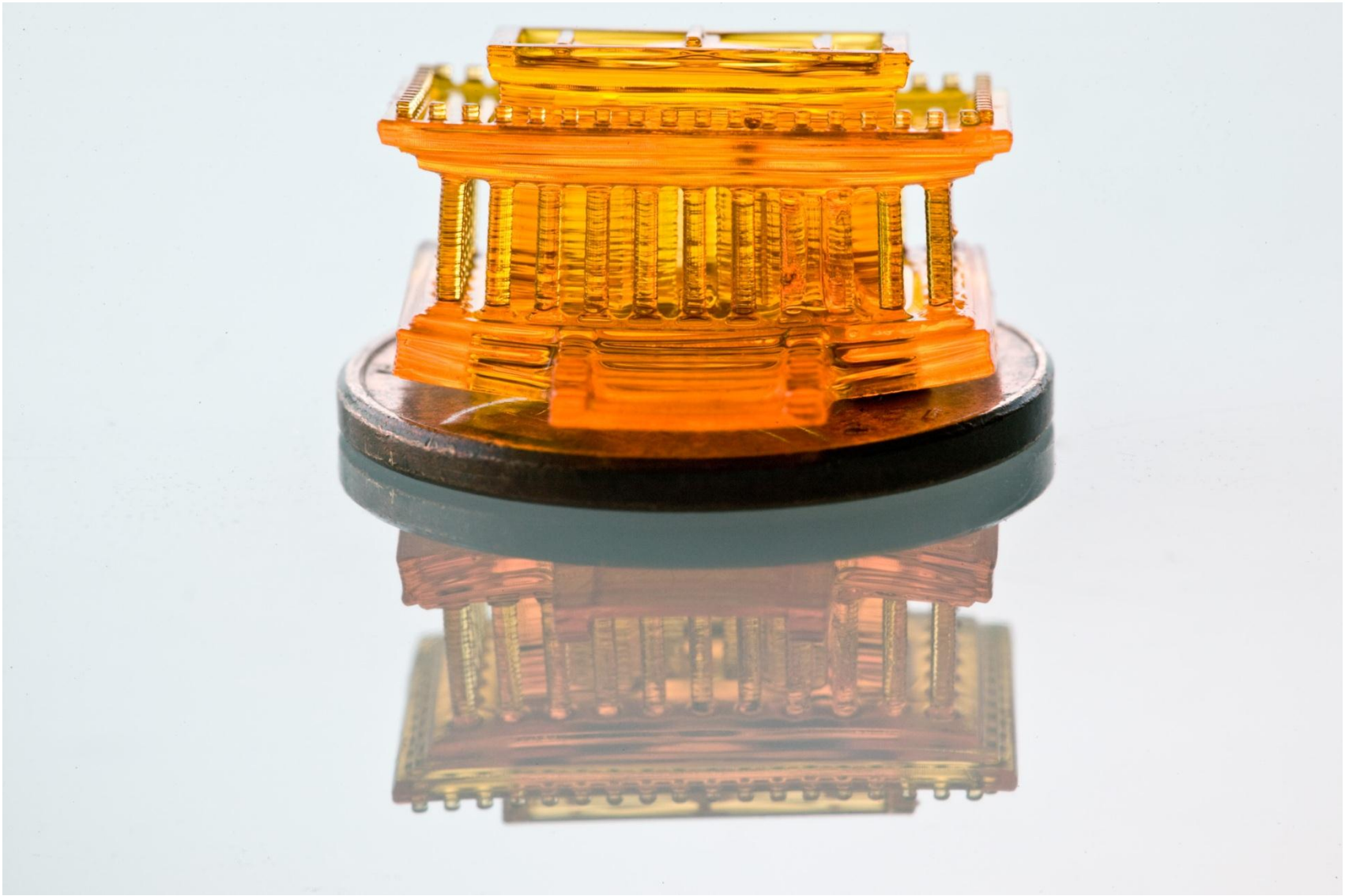

Examples of Objects

Examples of Objects

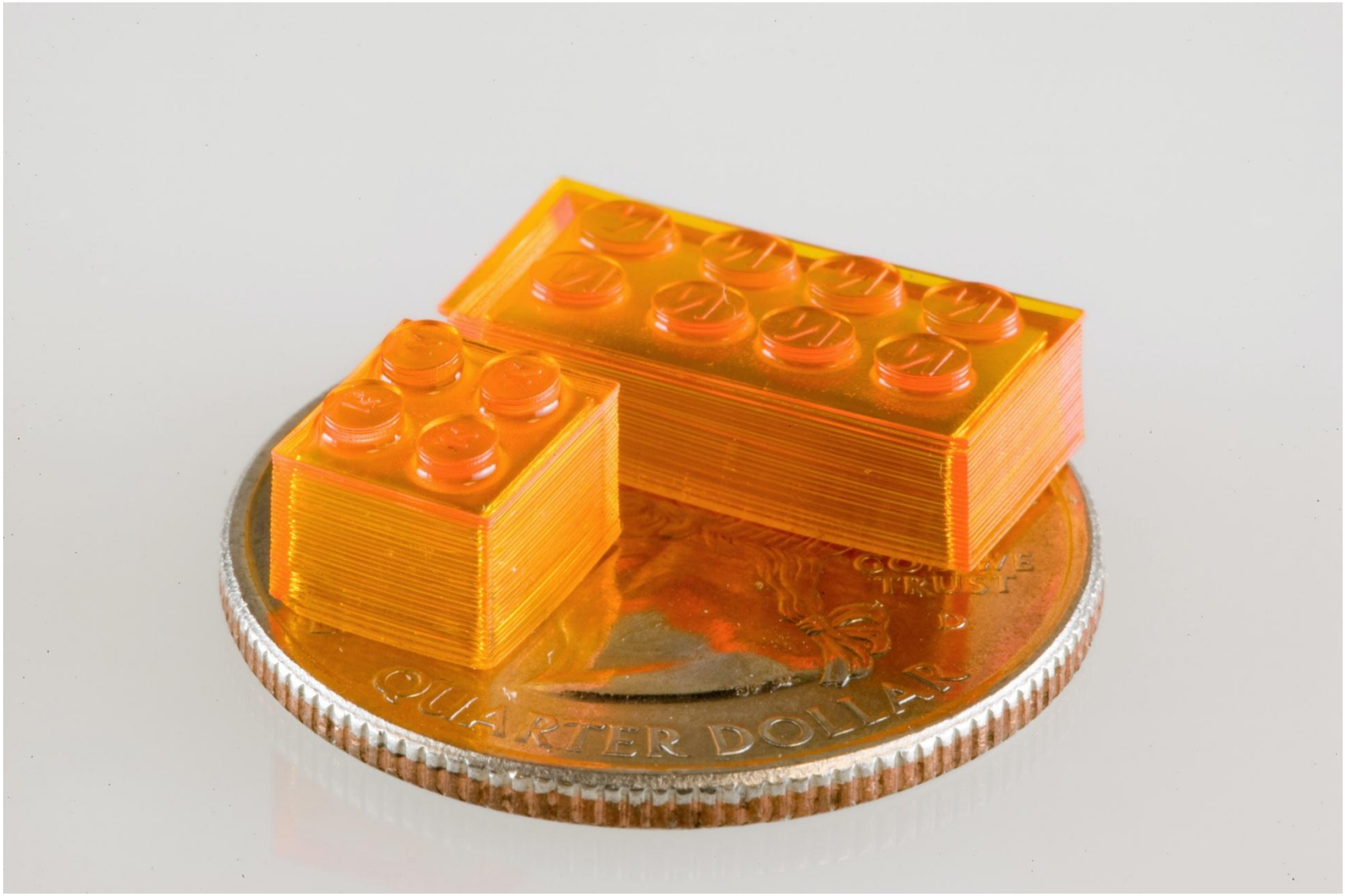
Examples of Objects



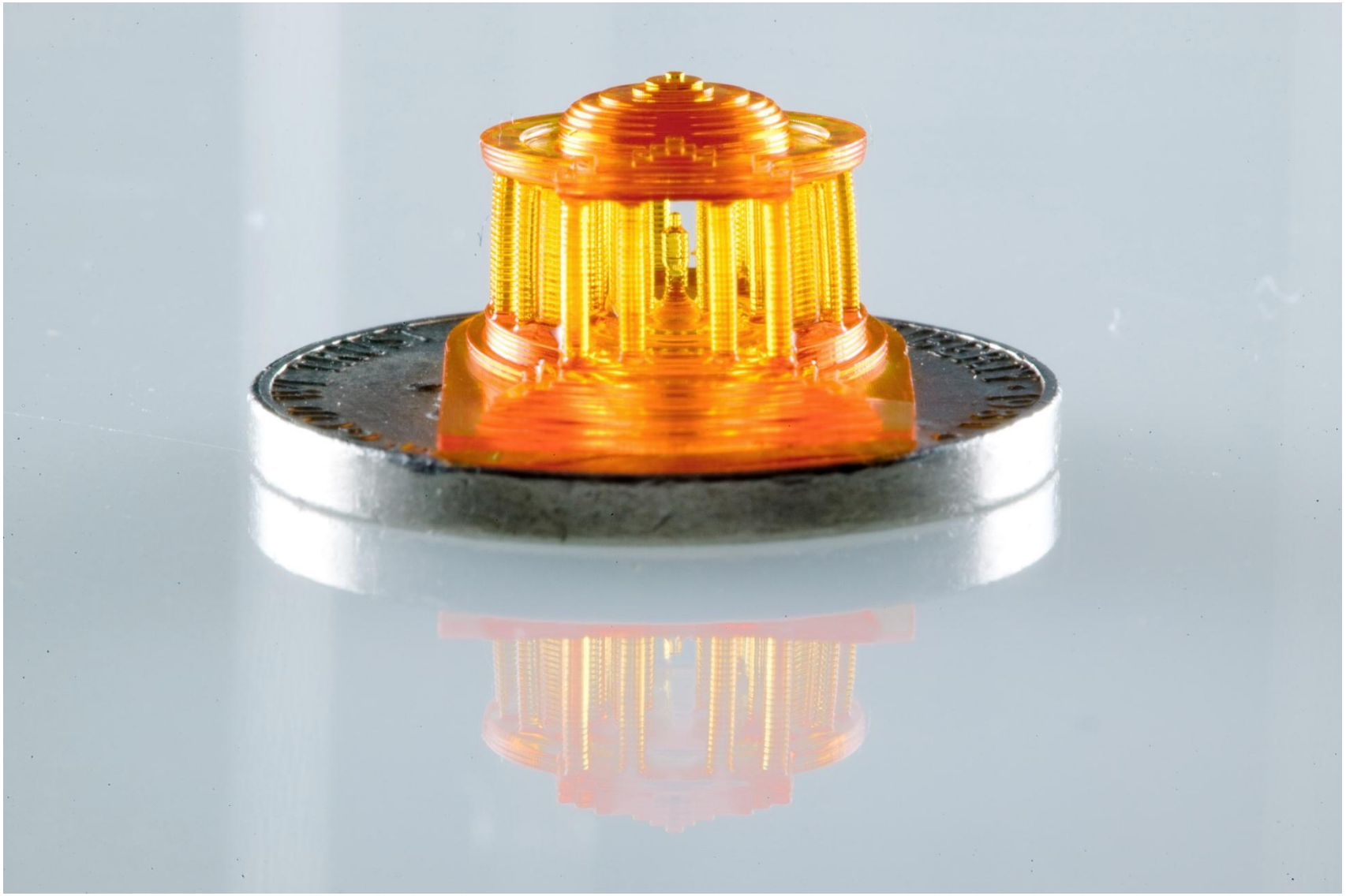
Examples of Objects



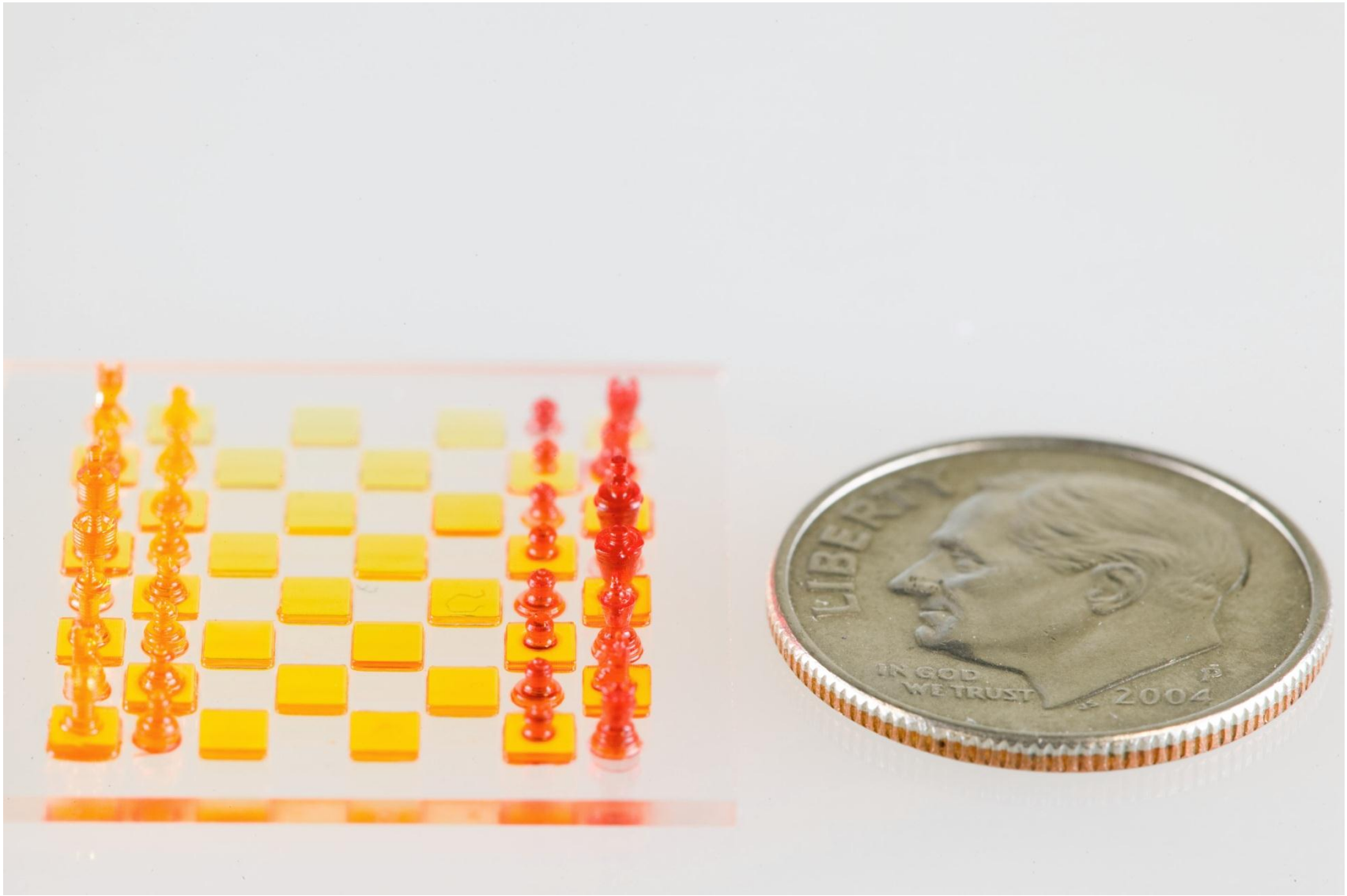
Examples of Objects



Examples of Objects



Examples of Objects



Examples of Objects

Using Math

Welcome to 3-D Printing with *Mathematica*!

If the Program Does Not Load Automatically:

A. Click the long bracket farthest to the right of the screen. Press "Shift", "Enter" (may take a minute)
B. To hide the code, double click the bracket closest to the 3 graphs to the right of the screen

To Create 3-D Objects:

1. Enter in your Upper and Lower Bound Equations and press "Enter"
2. Drag the "Slicer" to view horizontal cross sections of your 3-D object
3. Click "Generate SlideShow!" to obtain the 3-D printing slideshow for your object

Initialization code

Panel interface

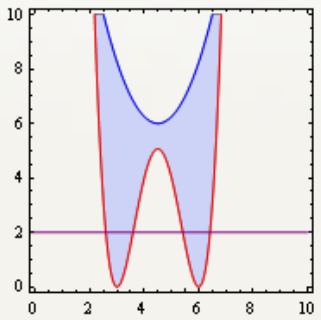
Out[46]=

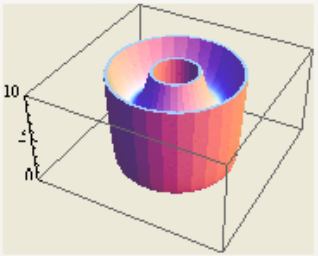
Rotating A Bounded Region Around The Y–Axis

Lower bound Eqn (Red) $(-6+x)^2 (-3+x)^2$

Upper bound Eqn (Blue) $6+(-4.5+x)^2$

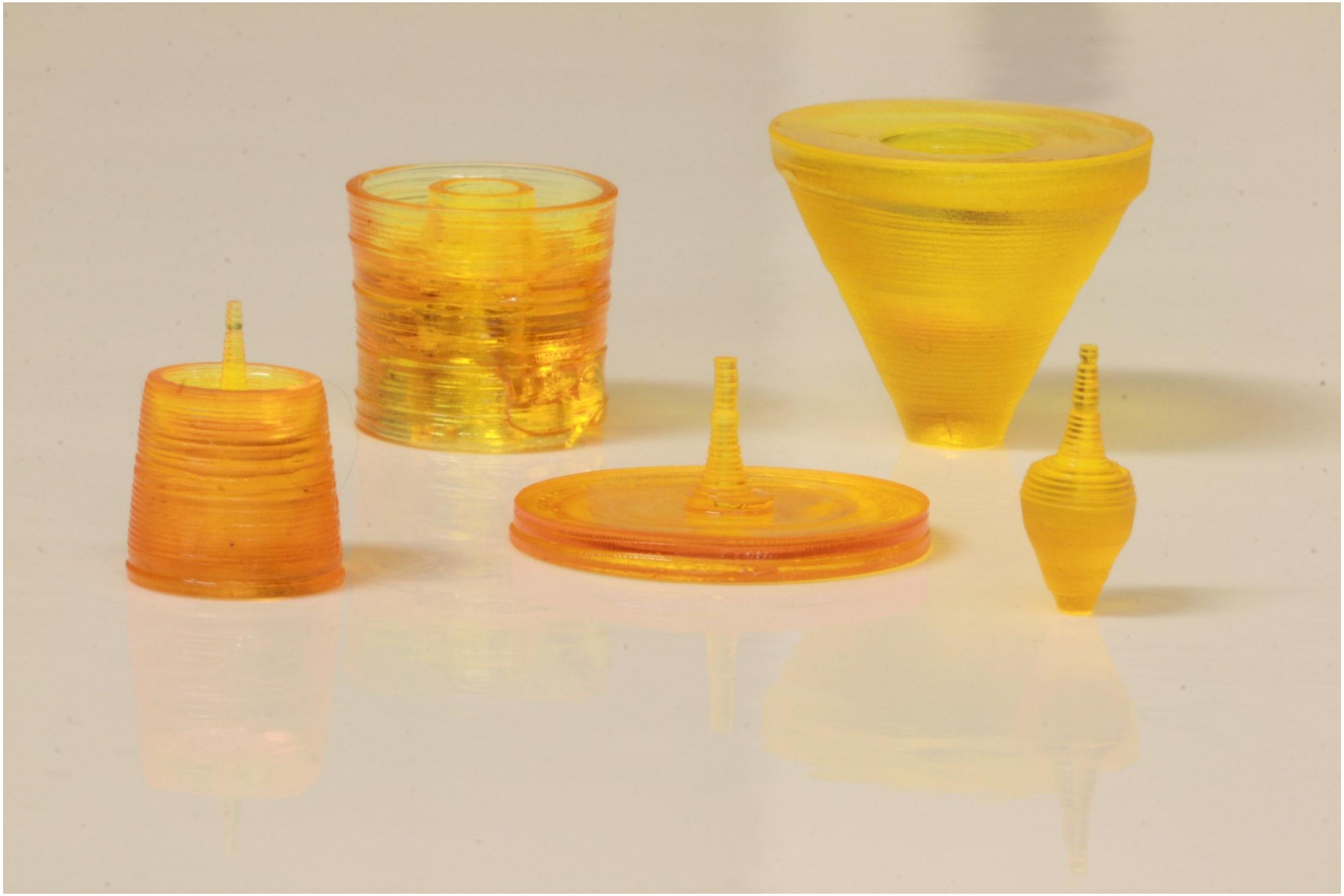
Slicer (Purple) y=2





Generate SlideShow! (This may take up to a minute)

Student Objects



Student Objects

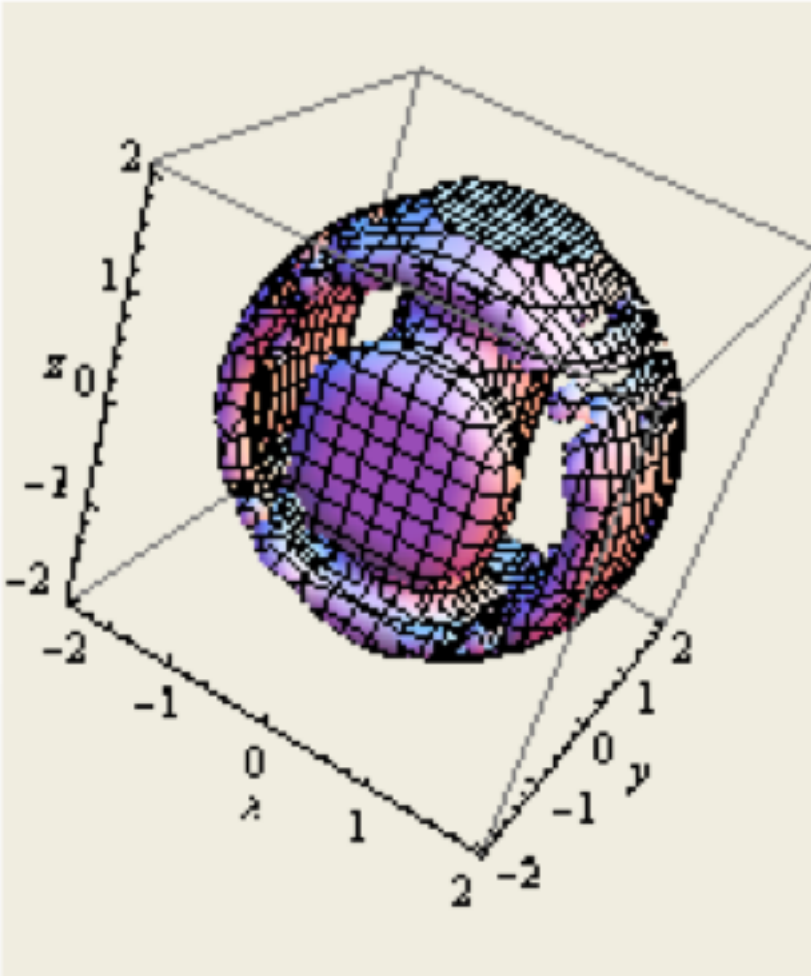
A Different Application!

Printing a 3D Object Using Inequalities

inequalities:

$$\left(x^2+y^2<0.5 \,||\, x^2+(1+y)^2+z^2<1.1 \,||\, 4\geq x^2+y^2+z^2\geq 3\right) \&\& -1.1<y<1.1$$

x_{min}	−2	x_{max}	2
y_{min}	−2	y_{max}	2
z_{min}	−2	z_{max}	2



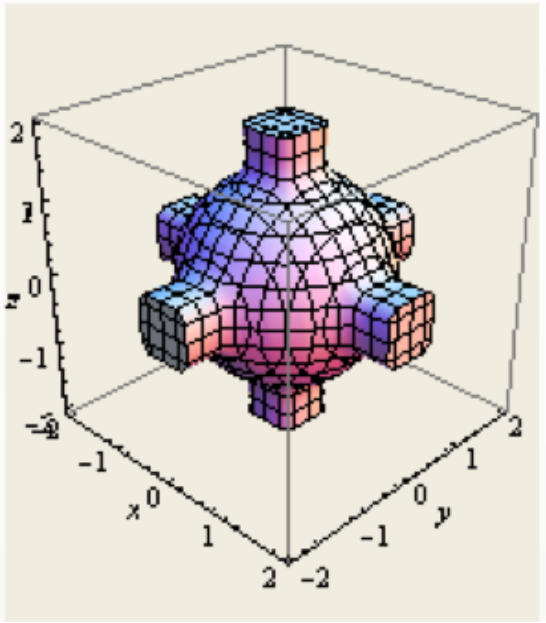
One Layer at a Time

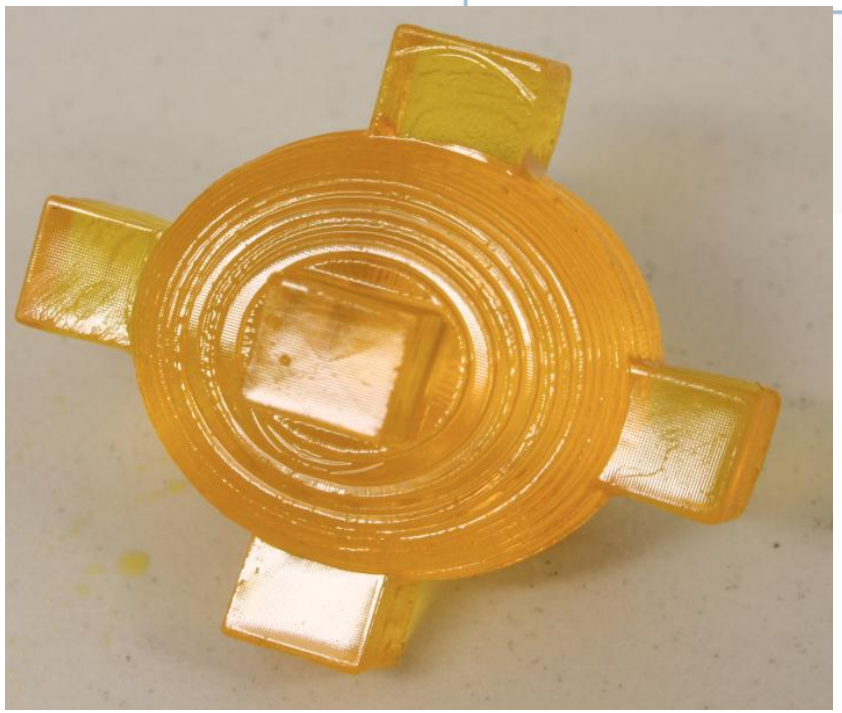
Mathematical Sculpture

Printing a 3D Object Using Inequalities

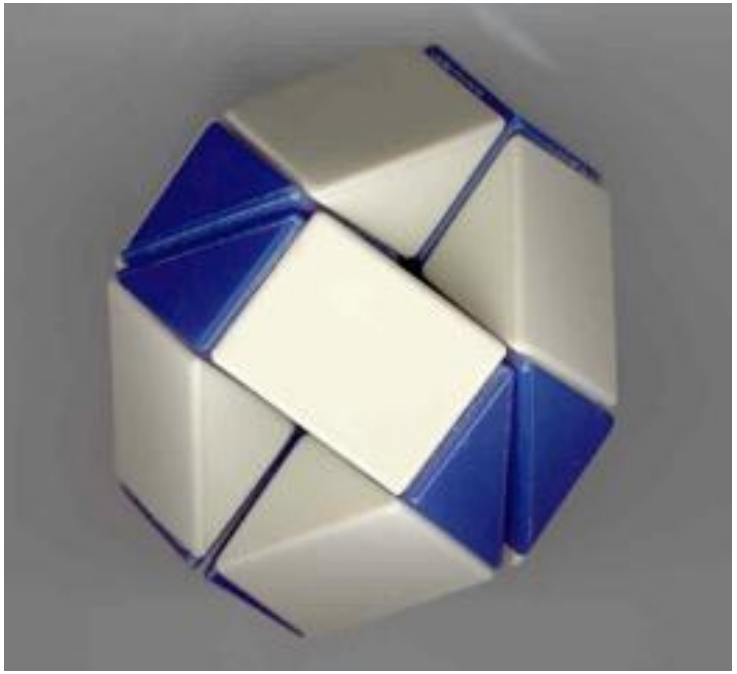
inequalities:

$$x^2+y^2+z^2 < 2 \,||\, (-0.4` \le z \le 0.4` \,\&\&\, -0.4` \le x \le 0.4`) \,||\, (-0.4` \le z \le 0.4` \,\&\&\, -0.4` \le y \le 0.4`) \,||\, (-0.4` \le y \le 0.4` \,\&\&\, -0.4` \le x \le 0.4`)$$





Mathematical Sculptures



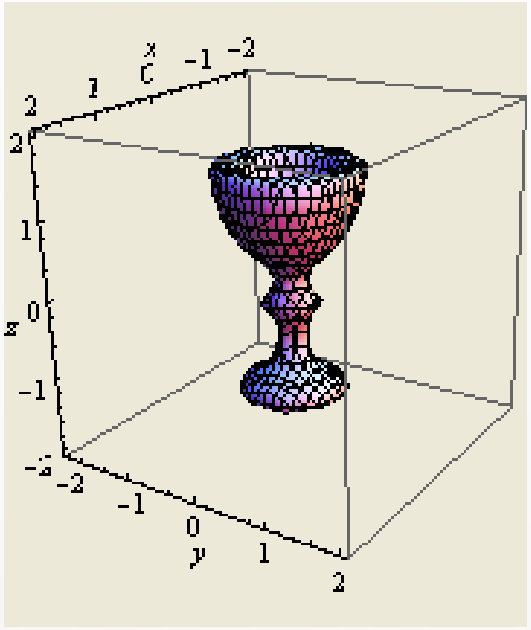
The Holy Grail

Printing a 3D Object Using Inequalities

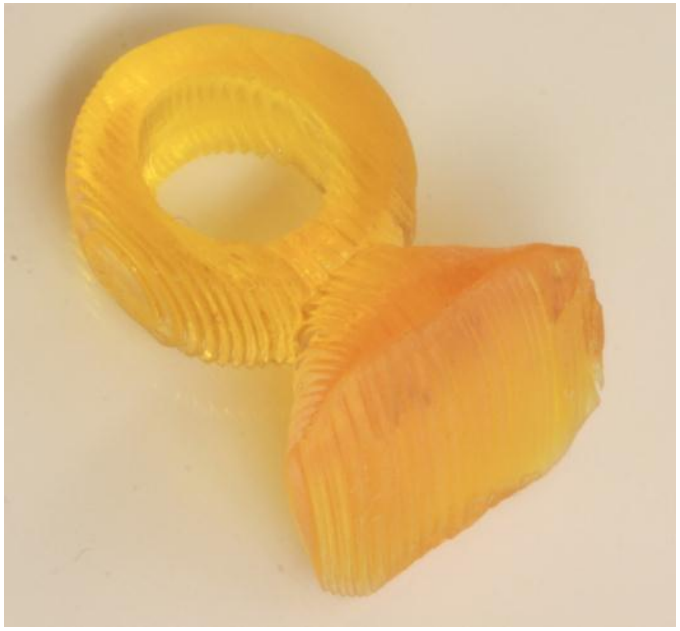
inequalities:

$$\left(2.5x^2+2.5y^2+(-1.75+z)^2>1\ \&\&\ z<1.5\ \&\&\ 2x^2+2y^2+(-1.5+z)^2<1.75\right)\ ||\ \left(5x^2+5y^2<0.25\ \&\&\ z<0.1\ \&\&\ z>-1.6\right)\ ||\ \left(x^2+y^2+3(1.5+z)^2<0.5\ \&\&\ z>-1.5\right)\ ||\ x^2+y^2+5(0.25+z)^2<0.15|$$

x_{min}	−2	x_{max}	2
y_{min}	−2	y_{max}	2
z_{min}	−2	z_{max}	2



Engagement Ring!



Printing a 3D Object Using Inequalities

inequalities:

$$\left(x^2-(-0.3+y)^2+z^2<0\ \&\&\ y>0\ \&\&\ z<1.4\ \&\&\ z>-1.4\ \&\&\ x<1.4\ \&\&\ x>-1.4\right)\ ||$$
$$\left(x^2+(0.45+y)^2+z^2<1.6\ \&\&\ x^2+(0.45+y)^2+z^2>0.8\ \&\&\ -0.5<x<0.5\right)\ ||$$
$$\left(x^2+(0.45+y)^2<0.05\ \&\&\ -1.4<z<-1\right)$$

x_{min}	−2	x_{max}	2
y_{min}	−2	y_{max}	2
z_{min}	−2	z_{max}	2