3D Printing in the Classroom
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

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.

One micrometer, or micron, is one-millionth of a meter \( (1.0 \times 10^{-6} \text{ m}) \)

One nanometer is one-billionth of a meter \( (1.0 \times 10^{-9} \text{ m}) \)

[Images of Micro Gears, Photonic Crystal, and 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.
• So, can’t take $500,000 machine into classroom – what can students do?
3-Dimensional Printing

- Computer with PowerPoint image
- Magnifying glass
- Data projector
- Product (3-d object)
- Mirror
- Elevator
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.

**Initiation:**

- Photo initiates the process, forming a radical.

**Propagation:**

- Monomer + radical → polymer + heat
- Monomer + polymer → polymer + heat

**Termination:**

- Polymer + radical → polymer + heat
3D Printing Process
• 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…
• To make a rectangular box…

Repeat this slide to make a taller rectangular cube
Alignment is Important

- Be sure each slide aligns.
- To align - copy slide, make modifications.
- Check properties.
• 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.
• Make a red version of the largest image to align.
Instructions

• Use red text for instructions.

Repeat 25 times
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
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

Rotating A Bounded Region Around The Y-Axis

Lower bound Eqn (Red)  Upper bound Eqn (Blue)  Slicer (Purple)

\((-6+x)^2\)  \((-3+x)^2\)  \(6+(-4.5+x)^2\)

Out[45]=

Generate SlideShow! (This may take up to a minute)
Student Objects
Student Objects
A Different Application!

Printing a 3D Object Using Inequalities

inequalities:

\[
\begin{align*}
(x^2 + y^2 &< 0.5 \| x^2 + (1+y)^2 + z^2 < 1.1 \| \\
4 &\geq x^2 + y^2 + z^2 \geq 3) \& \& \\
-1.1 &< y < 1.1
\end{align*}
\]

\[\begin{array}{c}
 x_{\text{min}} & -2 \\
 y_{\text{min}} & -2 \\
 z_{\text{min}} & -2 \\
 x_{\text{max}} & 2 \\
 y_{\text{max}} & 2 \\
 z_{\text{max}} & 2
\end{array}\]
One Layer at a Time
Mathematical Sculpture

Printing a 3D Object Using Inequalities

inequalities:
\[ x^2 + y^2 + z^2 < 2 \]
\[ (-0.4 \leq z \leq 0.4 \& \&
   \quad -0.4 \leq x \leq 0.4) \]
\[ (-0.4 \leq z \leq 0.4 \& \&
   \quad -0.4 \leq y \leq 0.4) \]
\[ (-0.4 \leq y \leq 0.4 \& \& -0.4 \leq x \leq 0.4) \]
Mathematical Sculptures
Printing a 3D Object Using Inequalities

\[
\begin{align*}
(2.5x^2 + 2.5y^2 + (-1.75 + z)^2 > 1 \land \land \\
(2x^2 + 2y^2 + (-1.5 + z)^2 < 1.75) \lor \\
(5x^2 + 5y^2 < 0.25 \land \\
(z < 0.1 \land z > -1.6) \lor \\
(x^2 + y^2 + 3(1.5 + z)^2 < 0.5 \land \\
(z > -1.5)) \lor \\
x^2 + y^2 + 5(0.25 + z)^2 < 0.15)
\end{align*}
\]
Engagement Ring!

Printing a 3D Object Using Inequalities

Inequalities:

\[
\begin{align*}
\left( x^2 - (-0.3+y)^2 + z^2 < 0 \&\& \\
y > 0 \&\& z < 1.4 \&\& z > -1.4 \&\& \\
x < 1.4 \&\& x > -1.4 \right) \\
\left( x^2 + (0.45+y)^2 + z^2 < 1.6 \&\& \\
x^2 + (0.45+y)^2 + z^2 > 0.8 \&\& \\
-0.5 < x < 0.5 \right) \\
\left( x^2 + (0.45+y)^2 < 0.05 \&\& \\
-1.4 < z < -1 \right)
\end{align*}
\]

\[
\begin{align*}
x_{\text{min}} & = -2 & x_{\text{max}} & = 2 \\
y_{\text{min}} & = -2 & y_{\text{max}} & = 2 \\
z_{\text{min}} & = -2 & z_{\text{max}} & = 2
\end{align*}
\]