MECE 4606 DIGITAL MANUFACTURING

Final Project: Food Printing

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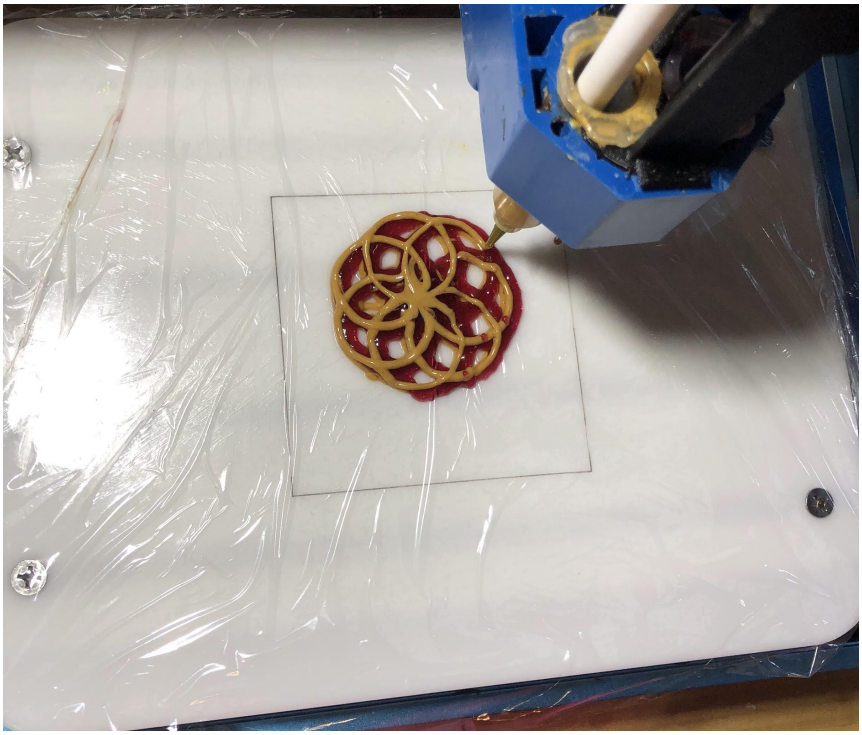
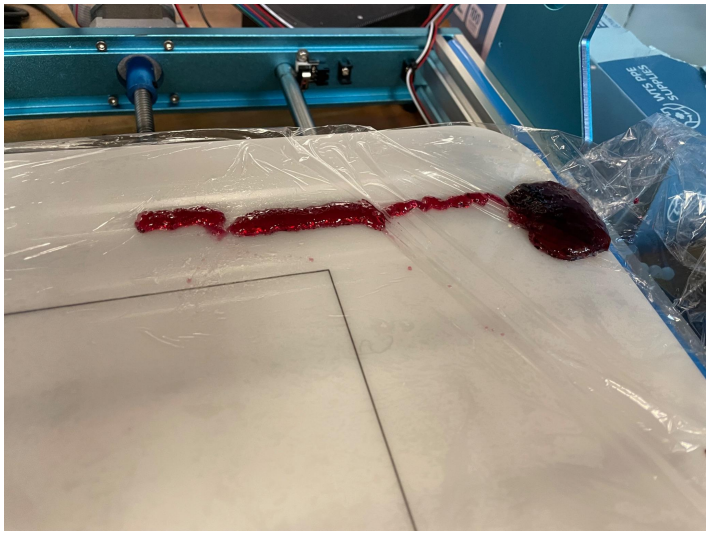
May 5th: 8:30 PM

384 Grace Hours Before Submission, 13 Remaining

Prof. Hod Lipson



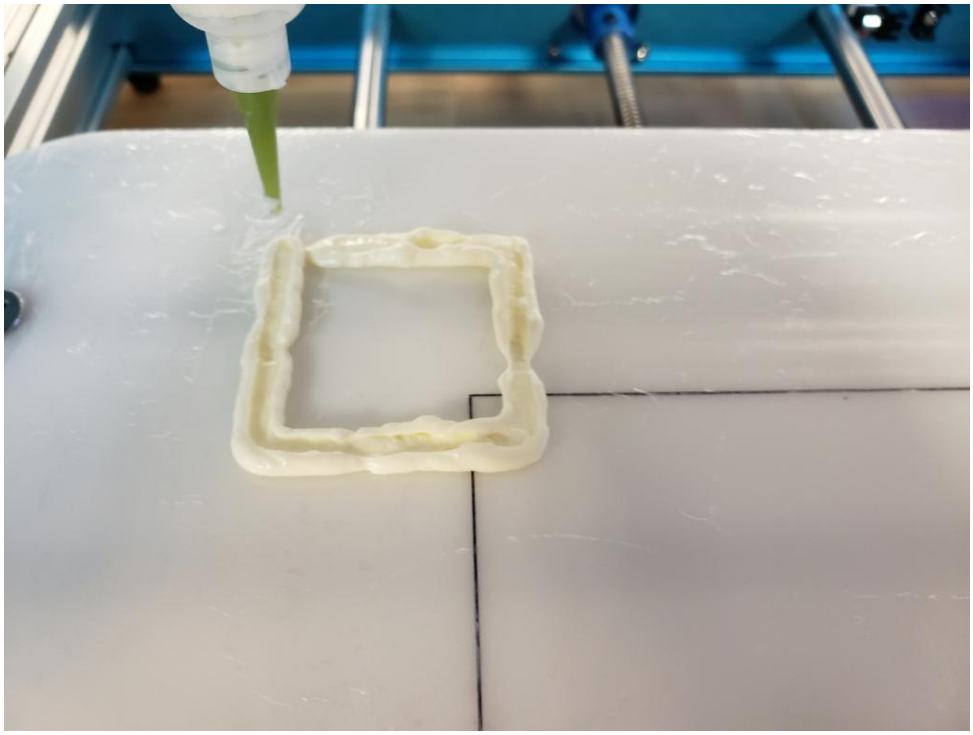
I. Printing Calibration



Four lines of varying feed rates were tested and calibrated for each material. The material shown in the picture, Grape Jelly had an optimal feed rate of 500 mm/min (2nd line). 5 lines are actually in the G-Code test, but the first line did not print due to the low feed rate. This was performed for each material, which gave an indication of the parameters for each case.

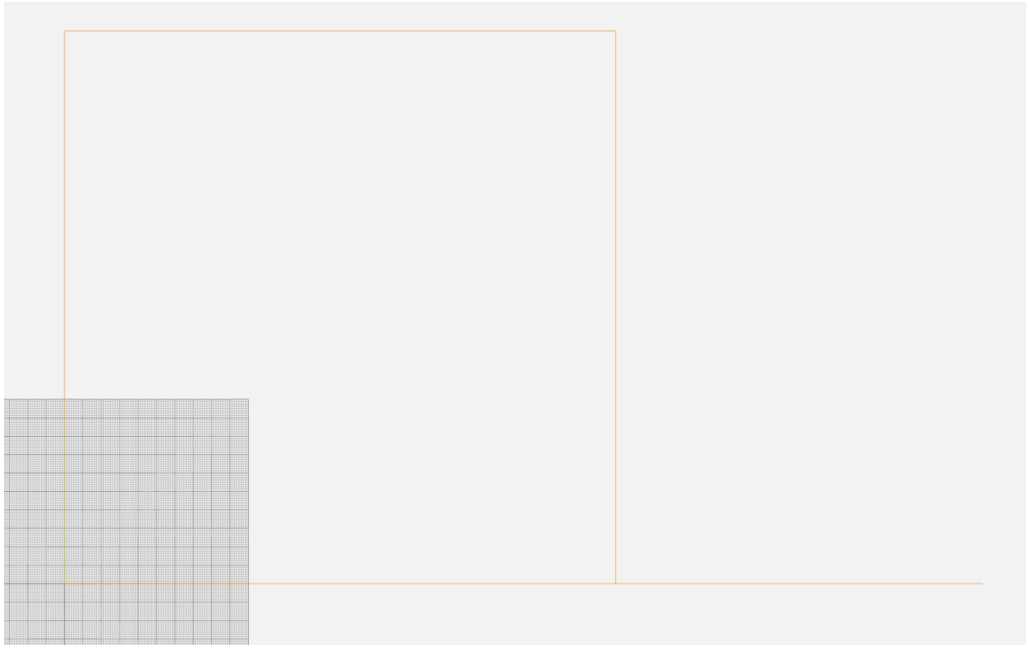
II. Printed Square Photo (Presubmission 1)

A. Print Photo:



B. **Materials:** Cream Cheese

C. Simulated Path:



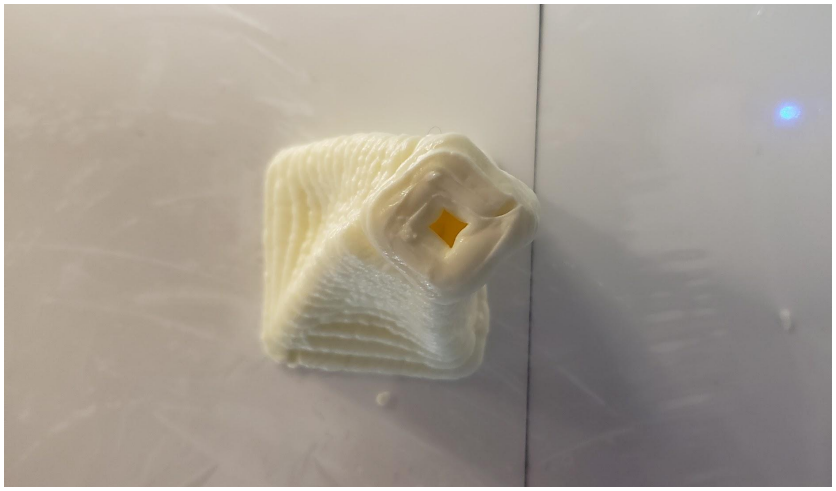
D. As per instructions, python source code omitted for the square.

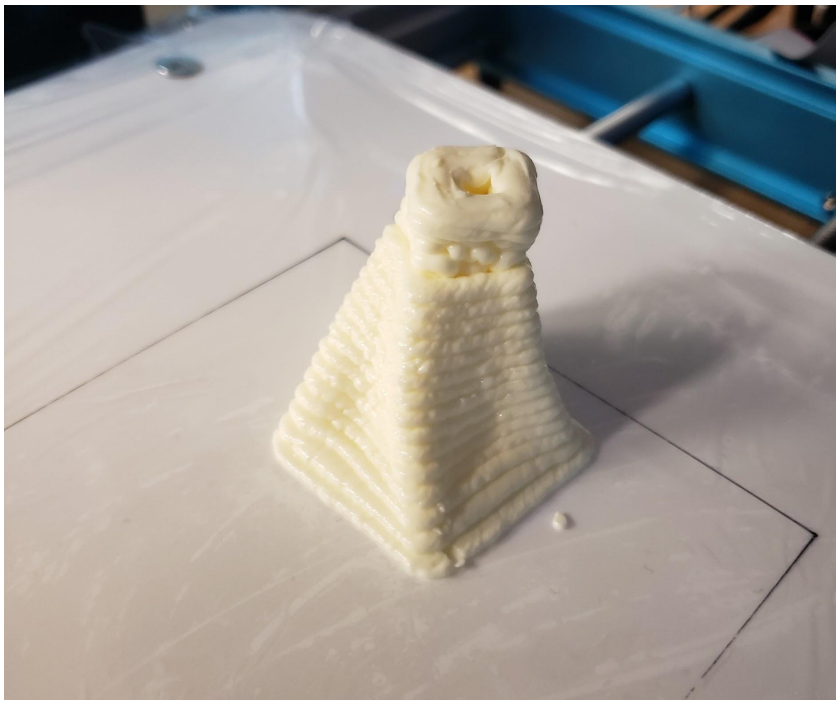
E. G-Code:

```
G91            ;Relative Positioning
M83            ;set extruder to relative mode
G0 F500        ;set feedrate to 500mm/min
T1             ;set tool 0
G1 X30 Y0 E1  ;move x by width
G1 X0 Y30 E1  ;move y by height
G1 X-30 Y0 E1 ;move x by negative width
G1 X0 Y-30 E1 ;move y by negative height
G1 Z10 E-5     ;lift z axis and retract extruder
G0 F1000       ;set feedrate to 1000mm/min
G90            ;set absolute positioning
G1 X50 Y0      ;return to home position
```

III. Twisted Pyramid (Presubmission 2)

A. Print Photos:

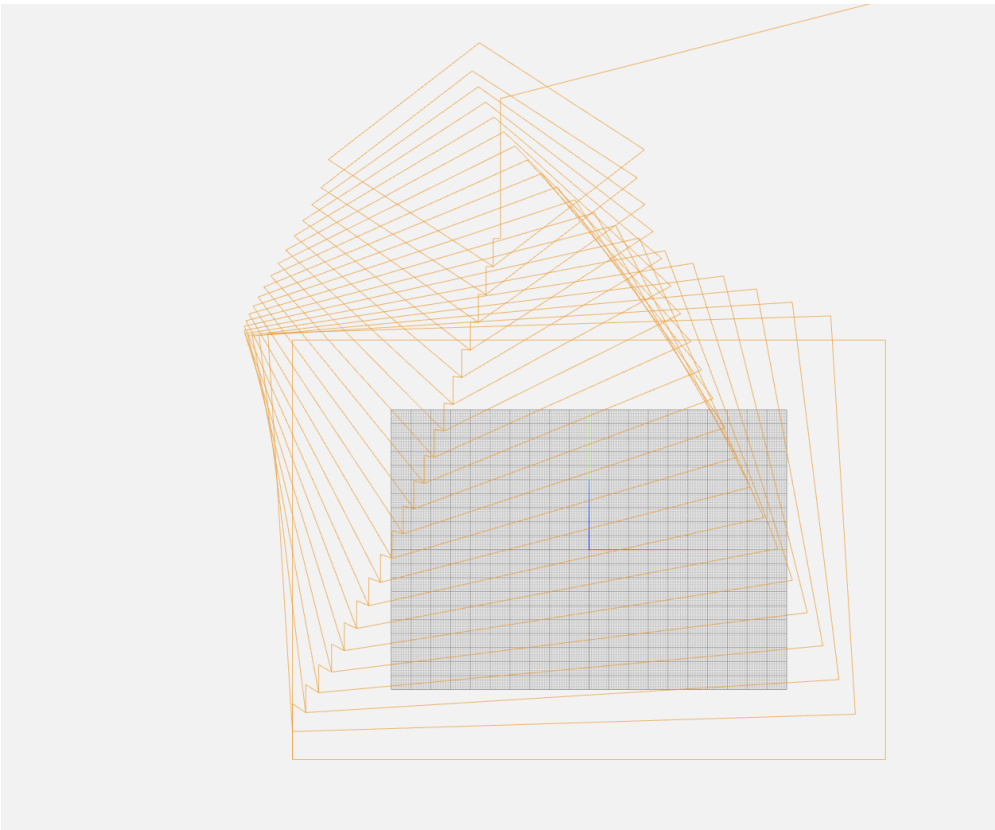




B. **Materials:** Cream Cheese

C. **Video Link:** https://drive.google.com/file/d/1mtESdfJs4_iVOFK1YmxB5id6Qfx2tZ3b/view?usp=sharing

D. Path Simulation:



E. Python Source Code:

```
import math

def escape(f, a, b, c, d, g):
    square(f, a, b, c, d, g, 0) #redo top layer without extruding
    f.write("G1 Z10 E-5     ;lift z axis and retract extruder\n")
    f.write("G0 F1000       ;set feedrate to 1000mm/min\n")
    f.write("G90            ;set absolute positioning\n")
    f.write("G1 X50 Y0      ;return to home position\n")

def square(f, a, b, c, d, g, extrusion_amount):
    f.write(("G1 X{} Y{} E{}  ;move x by width\n").format(a[0], a[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move y by height\n").format(b[0], b[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move x by negative width\n").format(c[0], c[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move y by negative height\n").format(d[0], d[1],
extrusion_amount))
    f.write(("G1 Z2           ;move z up by 2 mm\n"))
    f.write(("G1 X{} Y{}      ;move to new starting position\n").format(g[0], g[1]))


if __name__ == '__main__':
    #prints a spiral pyramid by overlaying squares, rotating by a set angle each layer

    print("Welcome to Pyramid Gcode Generator\n")
    #maximum 40mm x 40mm square, minimum 10mm

    width = int(input("Please input base width: "))
```

```
    while (width < 10 or width > 40):
        width = int(input("You entered an invalid width. Please input between 10 and
40 (mm): "))


    num_layers = int(input("Please input the number of layers: ")) #number of layers
above the base layer
    while (num_layers < 1 or num_layers > 19):
        num_layers = int(input("You entered an invalid number of layers. Please input
between 1 and 19: "))

    angle_deg = 2.5 #2 degree rotation per layer
    angle = (angle_deg / 360) * 2 * math.pi #angle in radians
    scale_factor = 0.95 #reduce size by 5% per layer
    extrusion_rate = 1/20
    extrusion_amount = width * extrusion_rate #extrude 0.5 mm per 10mm of movement
    total_extruded = 0 #total amount extruded so far
    total_material = 55 #55mm of available extrusion materail
    layer_perimeter = 4 * width #base layer

    print(extrusion_amount)
    #setup file
    f = open("spiral_pyramid.g", "w")
    f.write(("G91            ;Relative Positioning\n"))
    f.write(("M83            ;set extruder to relative mode\n"))
    f.write(("G0 F500        ;set feedrate to 500mm/min\n"))
    f.write(("T0             ;set tool 0\n"))
    #define base vectors
    s = [float(-width / 2), float(-width / 2)] #move from center to top left corner
    a = [float(width), 0]
    b = [0, float(width)]
    c = [float(-width), 0]
    d = [0, float(-width)]
    e = [-s[0], -s[0]] #move back to center

    #print base square.

    #extrude on first move to build pressure in syringe
    f.write(("G1 X{} Y{} E{}     ;move to top left corner of square\n").format(s[0],
s[1], extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move x by width\n").format(a[0], a[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move y by height\n").format(b[0], b[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move x by negative width\n").format(c[0], c[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move y by negative height\n").format(d[0], d[1],
extrusion_amount))
    f.write(("G1 Z2           ;move z up by 2 mm\n"))
    # f.write(("G1 X{} Y{}      ;move back to center\n").format(e[0], e[1]))
    total_extruded += layer_perimeter * extrusion_rate
    print(total_extruded)
    #print squares
    has_changed_tool = False
    for i in range(0, num_layers):
        if(total_extruded >= total_material and has_changed_tool == False):
            #switch tools
            f.write(("T1             ;set tool 1\n"))
            f.write(("G1 Z5          ;lift gantry\n"))
            f.write(("G1 X-10.5       ;adjust for tool offset\n"))
            f.write(("G1 Z-5         ;lower gantry\n"))
            has_changed_tool = True
```

```
        #apply rotation matrix
        s = [s[0] * math.cos(angle) - s[1] * math.sin(angle), s[0] * math.sin(angle) +
s[1] * math.cos(angle)]
        a = [a[0] * math.cos(angle) - a[1] * math.sin(angle), a[0] * math.sin(angle) +
a[1] * math.cos(angle)]
        b = [b[0] * math.cos(angle) - b[1] * math.sin(angle), b[0] * math.sin(angle) +
b[1] * math.cos(angle)]
        c = [c[0] * math.cos(angle) - c[1] * math.sin(angle), c[0] * math.sin(angle) +
c[1] * math.cos(angle)]
        d = [d[0] * math.cos(angle) - d[1] * math.sin(angle), d[0] * math.sin(angle) +
d[1] * math.cos(angle)]

        #solve for shift in position from previous end to new start
        g = [s[0] + e[0], s[1] + e[1]]
        print(g)


        e = [e[0] * math.cos(angle) - e[1] * math.sin(angle), e[0] * math.sin(angle) +
e[1] * math.cos(angle)]


        #apply scale factor
        s = [scale_factor * s[0], scale_factor * s[1]]
        a = [scale_factor * a[0], scale_factor * a[1]]
        b = [scale_factor * b[0], scale_factor * b[1]]
        c = [scale_factor * c[0], scale_factor * c[1]]
        d = [scale_factor * d[0], scale_factor * d[1]]
        e = [scale_factor * e[0], scale_factor * e[1]]

        square(f, a, b, c, d, g, extrusion_amount)
        layer_perimeter = layer_perimeter * scale_factor
        total_extruded += layer_perimeter * extrusion_rate
        print(total_extruded)


    escape(f, a, b, c, d, g)
    f.close()
```

F. G-Code:

```
G91            ;Relative Positioning
M83            ;set extruder to relative mode
G0 F500        ;set feedrate to 500mm/min
T0             ;set tool 0
G1 X-15.0 Y-15.0 E0     ;move to top left corner of square
G1 X30.0 Y0 E0  ;move x by width
G1 X0 Y30.0 E0  ;move y by height
G1 X-30.0 Y0 E0  ;move x by negative width
G1 X0 Y-30.0 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X28.4728743151 Y1.24315253991 E0  ;move x by width
G1 X-1.24315253991 Y28.4728743151 E0  ;move y by height
G1 X-28.4728743151 Y-1.24315253991 E0  ;move x by negative width
G1 X1.24315253991 Y-28.4728743151 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.668567486752 Y-0.640014134208      ;move to new starting position
G1 X26.9719714508 Y2.35974173489 E0  ;move x by width
G1 X-2.35974173489 Y26.9719714508 E0  ;move y by height
G1 X-26.9719714508 Y-2.35974173489 E0  ;move x by negative width
G1 X2.35974173489 Y-26.9719714508 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.661055773932 Y-0.579730354464      ;move to new starting position
```

```
G1 X25.5012011406 Y3.35729682164 E0  ;move x by width
G1 X-3.35729682164 Y25.5012011406 E0  ;move y by height
G1 X-25.5012011406 Y-3.35729682164 E0  ;move x by negative width
G1 X3.35729682164 Y-25.5012011406 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.651428374302 Y-0.522826545163      ;move to new starting position
G1 X24.0639620963 Y4.24312578032 E0  ;move x by width
G1 X-4.24312578032 Y24.0639620963 E0  ;move y by height
G1 X-24.0639620963 Y-4.24312578032 E0  ;move x by negative width
G1 X4.24312578032 Y-24.0639620963 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.639933045811 Y-0.469218322365      ;move to new starting position
G1 X22.66317719 Y5.02430542155 E0  ;move x by width
G1 X-5.02430542155 Y22.66317719 E0  ;move y by height
G1 X-22.66317719 Y-5.02430542155 E0  ;move x by negative width
G1 X5.02430542155 Y-22.66317719 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.626801437755 Y-0.418815330925      ;move to new starting position
G1 X21.3013272555 Y5.70767343583 E0  ;move x by width
G1 X-5.70767343583 Y21.3013272555 E0  ;move y by height
G1 X-21.3013272555 Y-5.70767343583 E0  ;move x by negative width
G1 X5.70767343583 Y-21.3013272555 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.612249663337 Y-0.371522215977      ;move to new starting position
G1 X19.9804834987 Y6.29982224837 E0  ;move x by width
G1 X-6.29982224837 Y19.9804834987 E0  ;move y by height
G1 X-19.9804834987 Y-6.29982224837 E0  ;move x by negative width
G1 X6.29982224837 Y-19.9804834987 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.596478883336 Y-0.327239521224      ;move to new starting position
G1 X18.7023385128 Y6.80709452984 E0  ;move x by width
G1 X-6.80709452984 Y18.7023385128 E0  ;move y by height
G1 X-18.7023385128 Y-6.80709452984 E0  ;move x by negative width
G1 X6.80709452984 Y-18.7023385128 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.579675897293 Y-0.285864517331      ;move to new starting position
G1 X17.4682359007 Y7.23558022078 E0  ;move x by width
G1 X-7.23558022078 Y17.4682359007 E0  ;move y by height
G1 X-17.4682359007 Y-7.23558022078 E0  ;move x by negative width
G1 X7.23558022078 Y-17.4682359007 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.56201373893 Y-0.247291963635      ;move to new starting position
G1 X16.2791985125 Y7.59111493503 E0  ;move x by width
G1 X-7.59111493503 Y16.2791985125 E0  ;move y by height
G1 X-16.2791985125 Y-7.59111493503 E0  ;move x by negative width
G1 X7.59111493503 Y-16.2791985125 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.54365227282 Y-0.211414806423      ;move to new starting position
G1 X15.1359553129 Y7.8792796145 E0  ;move x by width
G1 X-7.8792796145 Y15.1359553129 E0  ;move y by height
G1 X-15.1359553129 Y-7.8792796145 E0  ;move x by negative width
G1 X7.8792796145 Y-15.1359553129 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.524738789623 Y-0.178124816928      ;move to new starting position
G1 X14.0389668932 Y8.10540131494 E0  ;move x by width
G1 X-8.10540131494 Y14.0389668932 E0  ;move y by height
G1 X-14.0389668932 Y-8.10540131494 E0  ;move x by negative width
G1 X8.10540131494 Y-14.0389668932 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.505408597459 Y-0.14731317219      ;move to new starting position
```

```
G1 X12.9884496544 Y8.27455500882 E0  ;move x by width
G1 X-8.27455500882 Y12.9884496544 E0  ;move y by height
G1 X-12.9884496544 Y-8.27455500882 E0  ;move x by negative width
G1 X8.27455500882 Y-12.9884496544 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.485785607246 Y-0.118870981836      ;move to new starting position
G1 X11.9843986827 Y8.39156629856 E0  ;move x by width
G1 X-8.39156629856 Y11.9843986827 E0  ;move y by height
G1 X-11.9843986827 Y-8.39156629856 E0  ;move x by negative width
G1 X8.39156629856 Y-11.9843986827 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.465982910073 Y-0.092689763801      ;move to new starting position
G1 X11.0266093492 Y8.46101493958 E0  ;move x by width
G1 X-8.46101493958 Y11.0266093492 E0  ;move y by height
G1 X-11.0266093492 Y-8.46101493958 E0  ;move x by negative width
G1 X8.46101493958 Y-11.0266093492 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.446103344892 Y-0.068661871893      ;move to new starting position
G1 X10.1146976637 Y8.48723907906 E0  ;move x by width
G1 X-8.48723907906 Y10.1146976637 E0  ;move y by height
G1 X-10.1146976637 Y-8.48723907906 E0  ;move x by negative width
G1 X8.48723907906 Y-10.1146976637 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.426240055037 Y-0.0466808780794      ;move to new starting position
G1 X9.2481194165 Y8.47434012237 E0  ;move x by width
G1 X-8.47434012237 Y9.2481194165 E0  ;move y by height
G1 X-9.2481194165 Y-8.47434012237 E0  ;move x by negative width
G1 X8.47434012237 Y-9.2481194165 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.406477032242 Y-0.026641912248      ;move to new starting position
G1 X8.42618814499 Y8.42618814499 E0  ;move x by width
G1 X-8.42618814499 Y8.42618814499 E0  ;move y by height
G1 X-8.42618814499 Y-8.42618814499 E0  ;move x by negative width
G1 X8.42618814499 Y-8.42618814499 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.386889647062 Y-0.00844196213011      ;move to new starting position
G1 X7.64809196044 Y8.34642777339 E0  ;move x by width
G1 X-8.34642777339 Y7.64809196044 E0  ;move y by height
G1 X-7.64809196044 Y-8.34642777339 E0  ;move x by negative width
G1 X8.34642777339 Y-7.64809196044 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.367545164709 Y0.0080198640236      ;move to new starting position
G1 X7.64809196044 Y8.34642777339 E0  ;move x by width
G1 X-8.34642777339 Y7.64809196044 E0  ;move y by height
G1 X-7.64809196044 Y-8.34642777339 E0  ;move x by negative width
G1 X8.34642777339 Y-7.64809196044 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.367545164709 Y0.0080198640236      ;move to new starting position
G1 Z10 E-5     ;lift z axis and retract extruder
G0 F1000       ;set feedrate to 1000mm/min
G90            ;set absolute positioning
G1 X50 Y0      ;return to home position
```

IV. Multi-Material Print (Presubmission 3

A. Print Photo:

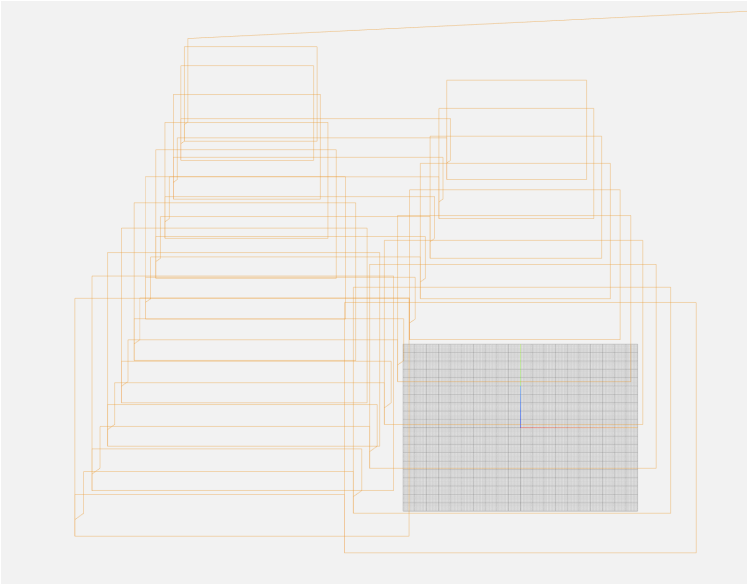
B. Materials:

a. Water and Peanut Butter in 1:4 ratio
b. Yoghurt (150 g) and Protein Powder (36 g)

C. Video Link:

https://drive.google.com/file/d/1V34E8aOTnXwiOtd5lC6xIkC32vHYfARB/view?usp=sharing

D. Path Simulation:



E. Python Source Code

```
import math

def escape(f, a, b, c, d, g):
    square(f, a, b, c, d, g, 0) #redo top layer without extruding
    f.write("G1 Z10 E-5     ;lift z axis and retract extruder\n")
    f.write("G0 F1000       ;set feedrate to 1000mm/min\n")
    f.write("G90            ;set absolute positioning\n")
    f.write("G1 X50 Y0      ;return to home position\n")

def square(f, a, b, c, d, g, extrusion_amount):
    f.write(("G1 X{} Y{} E{}  ;move x by width\n").format(a[0], a[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move y by height\n").format(b[0], b[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move x by negative width\n").format(c[0], c[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move y by negative height\n").format(d[0], d[1],
extrusion_amount))
    f.write(("G1 Z2           ;move z up by 2 mm\n"))
    f.write(("G1 X{} Y{}      ;move to new starting position\n").format(g[0], g[1]))

def tool_change(tool, extruder_offset):
    # switch tools
    # tool = 0 or 1 representing tool to swap to
    x_dif = extruder_offset
    if(tool == 0):
        #swap from tool 0 to tool 1
        new_tool = 1
        x_dif = - x_dif #reverse direction
    else:
        #swap from tool 1 to tool 0
        new_tool = 0

    f.write(("T{}             ;set tool 1\n").format(new_tool))
    f.write(("G1 Z5          ;lift gantry\n"))
    f.write(("G1 X{}       ;adjust for tool offset\n".format(x_dif)))
    f.write(("G1 Z-5         ;lower gantry\n"))
    return new_tool


if __name__ == '__main__':
    #prints a spiral pyramid by overlaying squares, rotating by a set angle each layer

    print("Welcome to Pyramid Gcode Generator\n")
    #maximum 40mm x 40mm square, minimum 10mm

    width = int(input("Please input base width: "))
    while (width < 10 or width > 30):
        width = int(input("You entered an invalid width. Please input between 10 and
30 (mm): "))


    num_layers = int(input("Please input the number of layers: ")) #number of layers
above the base layer
    while (num_layers < 1 or num_layers > 19):
        num_layers = int(input("You entered an invalid number of layers. Please input
between 1 and 25: "))
```

```
    #set constants
    angle_deg = 2 #2 degree rotation per layer
    angle = (angle_deg / 360) * 2 * math.pi #angle in radians
    scale_factor = 0.95 #reduce size by 5% per layer
    extrusion_rate = 1/20
    extrusion_amount = width * extrusion_rate #extrude 0.5 mm per 10mm of movement
    total_extruded = 0 #total amount extruded so far
    total_material = 50 #50mm of available extrusion materail
    layer_perimeter = 4 * width #base layer
    extruder_offset = 23 #distance between extruder nozzles in mm
    current_tool = 0 #start on tool 0

    print(extrusion_amount)
    #setup file
    f = open("spiral_pyramid.g", "w")
    f.write(("G91            ;Relative Positioning\n"))
    f.write(("M83            ;set extruder to relative mode\n"))
    f.write(("G0 F500        ;set feedrate to 500mm/min\n"))
    f.write(("T0             ;set tool 0\n"))
    #define base vectors
    s = [float(-width / 2), float(-width / 2)] #move from center to top left corner
    a = [float(width), 0]
    b = [0, float(width)]
    c = [float(-width), 0]
    d = [0, float(-width)]
    e = [-s[0], -s[0]] #move back to center

    #print base square.

    #extrude on first move to build pressure in syringe
    f.write(("G1 X{} Y{} E{}     ;move to top left corner of square\n").format(s[0],
s[1], extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move x by width\n").format(a[0], a[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move y by height\n").format(b[0], b[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move x by negative width\n").format(c[0], c[1],
extrusion_amount))
    f.write(("G1 X{} Y{} E{}  ;move y by negative height\n").format(d[0], d[1],
extrusion_amount))
    f.write(("G1 Z2           ;move z up by 2 mm\n"))
    # f.write(("G1 X{} Y{}      ;move back to center\n").format(e[0], e[1]))
    total_extruded += layer_perimeter * extrusion_rate
    print(total_extruded)


    #print squares
    for i in range(0, num_layers):
        current_tool = tool_change(current_tool, extruder_offset)

        #apply rotation matrix
        s = [s[0] * math.cos(angle) - s[1] * math.sin(angle), s[0] * math.sin(angle) +
s[1] * math.cos(angle)]
        a = [a[0] * math.cos(angle) - a[1] * math.sin(angle), a[0] * math.sin(angle) +
a[1] * math.cos(angle)]
        b = [b[0] * math.cos(angle) - b[1] * math.sin(angle), b[0] * math.sin(angle) +
b[1] * math.cos(angle)]
```

```
        c = [c[0] * math.cos(angle) - c[1] * math.sin(angle), c[0] * math.sin(angle) +
c[1] * math.cos(angle)]
        d = [d[0] * math.cos(angle) - d[1] * math.sin(angle), d[0] * math.sin(angle) +
d[1] * math.cos(angle)]


        #solve for shift in position from previous end to new start
        s = [scale_factor * s[0], scale_factor * s[1]]
        g = [s[0] + e[0], s[1] + e[1]]
        print(g)
        e = [e[0] * math.cos(angle) - e[1] * math.sin(angle), e[0] * math.sin(angle) +
e[1] * math.cos(angle)]

        #apply scale factor
        a = [scale_factor * a[0], scale_factor * a[1]]
        b = [scale_factor * b[0], scale_factor * b[1]]
        c = [scale_factor * c[0], scale_factor * c[1]]
        d = [scale_factor * d[0], scale_factor * d[1]]
        e = [scale_factor * e[0], scale_factor * e[1]]



        square(f, a, b, c, d, g, extrusion_amount)

        layer_perimeter = layer_perimeter * scale_factor
        total_extruded += layer_perimeter * extrusion_rate

        extrusion_rate *= scale_factor #reduce extrusion rate as tower builds
        extrusion_amount = width * extrusion_rate #set extrusion amount for new rate

        print(total_extruded)


    escape(f, a, b, c, d, g)
    f.close()
```

F. G-Code

```
G91             ;Relative Positioning
M83             ;set extruder to relative mode
G0 F500         ;set feedrate to 500mm/min
T0              ;set tool 0
G1 X-15.0 Y-15.0 E0     ;move to top left corner of square
G1 X30.0 Y0 E0  ;move x by width
G1 X0 Y30.0 E0  ;move y by height
G1 X-30.0 Y0 E0  ;move x by negative width
G1 X0 Y-30.0 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
T1              ;set tool 1
G1 Z5           ;lift gantry
G1 X-23        ;adjust for tool offset
G1 Z-5          ;lower gantry
G1 X28.5 Y0.0 E0  ;move x by width
G1 X0.0 Y28.5 E0  ;move y by height
G1 X-28.5 Y0.0 E0  ;move x by negative width
G1 X0.0 Y-28.5 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.75 Y0.75      ;move to new starting position
T0              ;set tool 1
G1 Z5           ;lift gantry
```

```
G1 X23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X27.075 Y0.0 E0.0  ;move x by width
G1 X0.0 Y27.075 E0.0  ;move y by height
G1 X-27.075 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-27.075 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.7125 Y0.7125      ;move to new starting position
T1             ;set tool 1
G1 Z5          ;lift gantry
G1 X-23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X25.72125 Y0.0 E0.0  ;move x by width
G1 X0.0 Y25.72125 E0.0  ;move y by height
G1 X-25.72125 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-25.72125 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.676875 Y0.676875      ;move to new starting position
T0             ;set tool 1
G1 Z5          ;lift gantry
G1 X23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X24.4351875 Y0.0 E0.0  ;move x by width
G1 X0.0 Y24.4351875 E0.0  ;move y by height
G1 X-24.4351875 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-24.4351875 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.64303125 Y0.64303125      ;move to new starting position
T1             ;set tool 1
G1 Z5          ;lift gantry
G1 X-23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X23.213428125 Y0.0 E0.0  ;move x by width
G1 X0.0 Y23.213428125 E0.0  ;move y by height
G1 X-23.213428125 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-23.213428125 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.6108796875 Y0.6108796875      ;move to new starting position
T0             ;set tool 1
G1 Z5          ;lift gantry
G1 X23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X22.0527567187 Y0.0 E0.0  ;move x by width
G1 X0.0 Y22.0527567187 E0.0  ;move y by height
G1 X-22.0527567187 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-22.0527567187 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.580335703125 Y0.580335703125      ;move to new starting position
T1             ;set tool 1
G1 Z5          ;lift gantry
G1 X-23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X20.9501188828 Y0.0 E0.0  ;move x by width
G1 X0.0 Y20.9501188828 E0.0  ;move y by height
G1 X-20.9501188828 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-20.9501188828 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.551318917969 Y0.551318917969      ;move to new starting position
T0             ;set tool 1
G1 Z5          ;lift gantry
```

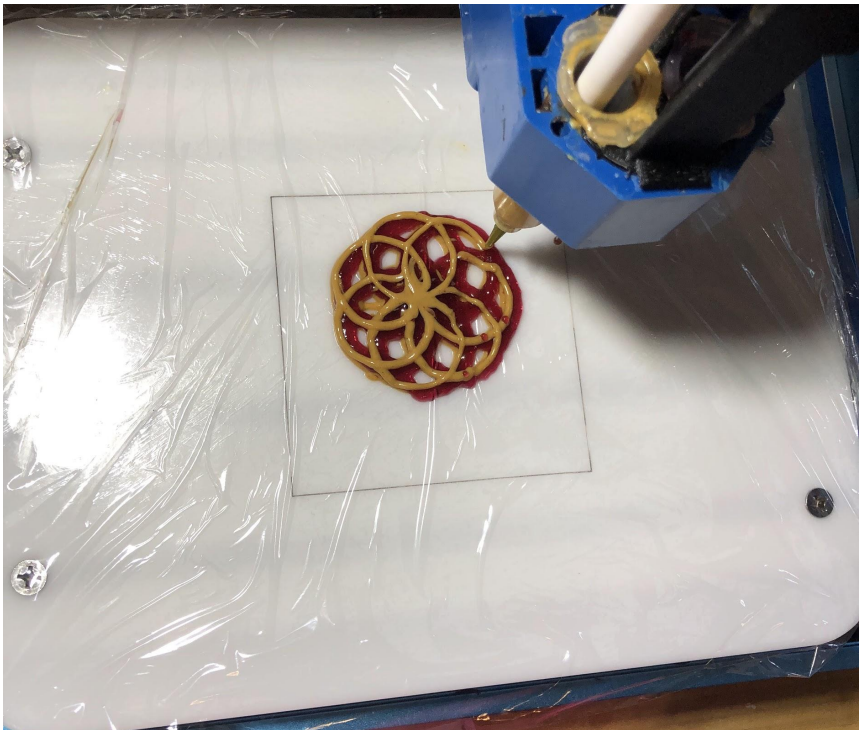
```
G1 X23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X19.9026129387 Y0.0 E0.0  ;move x by width
G1 X0.0 Y19.9026129387 E0.0  ;move y by height
G1 X-19.9026129387 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-19.9026129387 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.52375297207 Y0.52375297207      ;move to new starting position
T1             ;set tool 1
G1 Z5          ;lift gantry
G1 X-23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X18.9074822917 Y0.0 E0.0  ;move x by width
G1 X0.0 Y18.9074822917 E0.0  ;move y by height
G1 X-18.9074822917 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-18.9074822917 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.497565323467 Y0.497565323467      ;move to new starting position
T0             ;set tool 1
G1 Z5          ;lift gantry
G1 X23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X17.9621081772 Y0.0 E0.0  ;move x by width
G1 X0.0 Y17.9621081772 E0.0  ;move y by height
G1 X-17.9621081772 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-17.9621081772 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.472687057293 Y0.472687057293      ;move to new starting position
T1             ;set tool 1
G1 Z5          ;lift gantry
G1 X-23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X17.0640027683 Y0.0 E0.0  ;move x by width
G1 X0.0 Y17.0640027683 E0.0  ;move y by height
G1 X-17.0640027683 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-17.0640027683 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.449052704429 Y0.449052704429      ;move to new starting position
T0             ;set tool 1
G1 Z5          ;lift gantry
G1 X23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X16.2108026299 Y0.0 E0.0  ;move x by width
G1 X0.0 Y16.2108026299 E0.0  ;move y by height
G1 X-16.2108026299 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-16.2108026299 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.426600069207 Y0.426600069207      ;move to new starting position
T1             ;set tool 1
G1 Z5          ;lift gantry
G1 X-23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X15.4002624984 Y0.0 E0.0  ;move x by width
G1 X0.0 Y15.4002624984 E0.0  ;move y by height
G1 X-15.4002624984 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-15.4002624984 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.405270065747 Y0.405270065747      ;move to new starting position
T0             ;set tool 1
G1 Z5          ;lift gantry
```

```
G1 X23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X14.6302493735 Y0.0 E0.0  ;move x by width
G1 X0.0 Y14.6302493735 E0.0  ;move y by height
G1 X-14.6302493735 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-14.6302493735 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.38500656246 Y0.38500656246      ;move to new starting position
T1             ;set tool 1
G1 Z5          ;lift gantry
G1 X-23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X13.8987369048 Y0.0 E0.0  ;move x by width
G1 X0.0 Y13.8987369048 E0.0  ;move y by height
G1 X-13.8987369048 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-13.8987369048 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.365756234337 Y0.365756234337      ;move to new starting position
T0             ;set tool 1
G1 Z5          ;lift gantry
G1 X23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X13.2038000596 Y0.0 E0.0  ;move x by width
G1 X0.0 Y13.2038000596 E0.0  ;move y by height
G1 X-13.2038000596 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-13.2038000596 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.34746842262 Y0.34746842262      ;move to new starting position
T1             ;set tool 1
G1 Z5          ;lift gantry
G1 X-23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X12.5436100566 Y0.0 E0.0  ;move x by width
G1 X0.0 Y12.5436100566 E0.0  ;move y by height
G1 X-12.5436100566 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-12.5436100566 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.330095001489 Y0.330095001489      ;move to new starting position
T0             ;set tool 1
G1 Z5          ;lift gantry
G1 X23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X11.9164295537 Y0.0 E0.0  ;move x by width
G1 X0.0 Y11.9164295537 E0.0  ;move y by height
G1 X-11.9164295537 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-11.9164295537 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.313590251414 Y0.313590251414      ;move to new starting position
T1             ;set tool 1
G1 Z5          ;lift gantry
G1 X-23       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 X11.3206080761 Y0.0 E0.0  ;move x by width
G1 X0.0 Y11.3206080761 E0.0  ;move y by height
G1 X-11.3206080761 Y0.0 E0.0  ;move x by negative width
G1 X0.0 Y-11.3206080761 E0.0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.297910738844 Y0.297910738844      ;move to new starting position
G1 X11.3206080761 Y0.0 E0  ;move x by width
G1 X0.0 Y11.3206080761 E0  ;move y by height
```

```
G1 X-11.3206080761 Y0.0 E0  ;move x by negative width
G1 X0.0 Y-11.3206080761 E0  ;move y by negative height
G1 Z2           ;move z up by 2 mm
G1 X0.297910738844 Y0.297910738844      ;move to new starting position
G1 Z10 E-5     ;lift z axis and retract extruder
G0 F1000       ;set feedrate to 1000mm/min
G90            ;set absolute positioning
G1 X50 Y0      ;return to home position
```

V. Final Print (Spirograph)

A. Print Photos



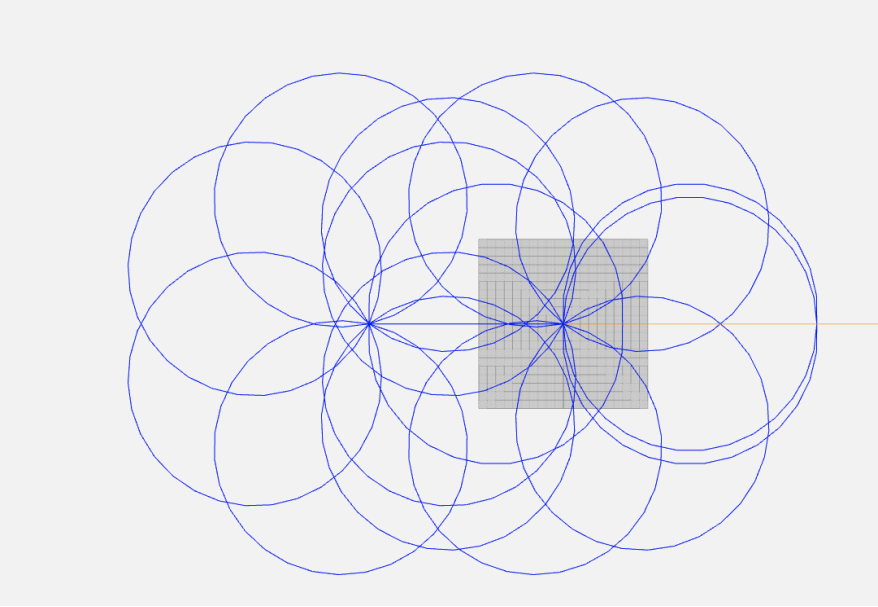
B. Materials

a. Peanut Butter (*Peanut Butter & Co* brand)
b. Jelly (Smuckers Grape)

C. Video Link

https://drive.google.com/file/d/1c9ZCoUd6TvZJCRVHzavnWejs5IhuZD6-/view?usp=sharing

D. Path Simulation



E. Python Source Code

```
import math


def escape(f, D, I, J):
    circle(f, D, I, J, 0)
    f.write("G1 Z10 E-5     ;lift z axis and retract extruder\n")
    f.write("G0 F1000       ;set feedrate to 1000mm/min\n")
    f.write("G90            ;set absolute positioning\n")
    f.write("G1 X50 Y0      ;return to home position\n")

def circle(f, D, I, J, extrusion_amount):
    f.write(("G3 X{} Y{} I{} J{} E{}      ;set feedrate to 500mm/min\n").format(D[0],
D[1], I, J, extrusion_amount))
    f.write(("G3 X{} Y{} I{} J{} E{}      ;set feedrate to 500mm/min\n").format(-D[0],
-D[1], -I, -J, extrusion_amount))


def tool_change(tool, extruder_offset):
    # switch tools
    # tool = 0 or 1 representing tool to swap to
    x_dif = extruder_offset
    if(tool == 0):
        #swap from tool 0 to tool 1
        new_tool = 1
        x_dif = - x_dif #reverse direction
    else:
        #swap from tool 1 to tool 0
        new_tool = 0

    f.write(("T{}             ;set tool\n").format(new_tool))
    f.write(("G1 Z5          ;lift gantry\n"))
    f.write(("G1 X{}       ;adjust for tool offset\n".format(x_dif)))
    f.write(("G1 Z-5         ;lower gantry\n"))
```

```
    return new_tool


if __name__ == '__main__':
    #prints a spirograph which swaps materials each circle

    print("Welcome to Spirograph Gcode Generator\n")
    #maximum 30 mm diameter, minimum 10mm

    dia = float(input("Please input base diameter: "))
    while (dia < 10 or dia > 30):
        dia = float(input("You entered an invalid width. Please input between 10 and
30 (mm): "))


    num_circles = int(input("Please input the number of circles per loop: "))
    while (num_circles < 1 or num_circles > 24):
        num_circles = int(input("You entered an invalid number of circles. Please
input between 1 and 24: "))

    num_layers = int(input("Please input the number of layers: "))
    while (num_layers < 1 or num_layers > 3):
         num_layers = int(input("You entered an invalid number of layers. Please input
between 1 and 3: "))

    #set constants
    radius = dia / 2
    half_circumf = (radius * math.pi)
    angle = (2 * math.pi) / num_circles
    extrusion_rate = 1/20
    extrusion_amount = half_circumf * extrusion_rate #extrude 0.5 mm per 10mm of
movement
    extruder_offset = 24 #distance between extruder nozzles in mm
    current_tool = 0 #start on tool 0
    z_layer_offset = 2 #2 mm per layer

    #setup file
    f = open("spirograph.g", "w")
    f.write(("G91            ;Relative Positioning\n"))
    f.write(("M83            ;set extruder to relative mode\n"))
    f.write(("G0 F300        ;set feedrate to 300mm/min\n"))
    f.write(("T0             ;set tool 0\n"))

    D = [dia, 0] #diameter vector
    I = D[0] / 2
    J = D[1] / 2
    full_arc_extrude = extrusion_rate * dia * math.pi
    f.write(("G1 Z0             ;set tool 0\n"))
    # f.write(("G3 X{} Y{} R{} E{}      ;set feedrate to 500mm/min\n").format(D[0],
D[1], dia / 2, 0))
    # f.write(("G3 X{} Y{} R{} E{}      ;set feedrate to 500mm/min\n").format(-D[0] *
2, -D[1] * 2, dia, full_arc_extrude))
    # f.write(("G3 X{} Y{} R{} E{}      ;set feedrate to 500mm/min\n").format(D[0] *
2, D[1] * 2, dia, full_arc_extrude))
    # f.write(("G3 X{} Y{} R{} E{}      ;set feedrate to 500mm/min\n").format(-D[0],
-D[1], dia / 2, 0))


    for i in range(0, num_layers):
```

```
        for i in range(0, num_circles):

            circle(f, D, I, J, extrusion_amount)
            D = [D[0] * math.cos(angle) - D[1] * math.sin(angle), D[0] *
math.sin(angle) + D[1] * math.cos(angle)]
            I = D[0] / 2
            J = D[1] / 2

        current_tool = tool_change(current_tool, extruder_offset)
        f.write(("G1 Z2             ;set tool 0\n"))
        D = [dia, 0] #diameter vector

        for i in range(0, num_circles):

            circle(f, D, I, J, extrusion_amount)
            D = [D[0] * math.cos(angle) - D[1] * math.sin(angle), D[0] *
math.sin(angle) + D[1] * math.cos(angle)]
            I = D[0] / 2
            J = D[1] / 2
        current_tool = tool_change(current_tool, extruder_offset)
        f.write(("G1 Z2             ;set tool 0\n"))
        D = [dia, 0] #diameter vector

    escape(f, D, I, J)
    f.close()
```

F. G-Code

```
G91            ;Relative Positioning
M83            ;set extruder to relative mode
G0 F300        ;set feedrate to 300mm/min
T0             ;set tool 0
G1 Z0             ;set tool 0
G3 X30.0 Y0 I15.0 J0.0 E2.356194490192345      ;set feedrate to 500mm/min
G3 X-30.0 Y0 I-15.0 J-0.0 E2.356194490192345      ;set feedrate to 500mm/min
G3 X25.98076211353316 Y14.999999999999998 I12.99038105676658 J7.499999999999999
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-25.98076211353316 Y-14.999999999999998 I-12.99038105676658 J-7.499999999999999
E2.356194490192345      ;set feedrate to 500mm/min
G3 X15.000000000000005 Y25.980762113533157 I7.500000000000003 J12.990381056766578
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-15.000000000000005 Y-25.980762113533157 I-7.500000000000003 J-12.990381056766578
E2.356194490192345      ;set feedrate to 500mm/min
G3 X8.881784197001252e-15 Y30.0 I4.440892098500626e-15 J15.0 E2.356194490192345
;set feedrate to 500mm/min
G3 X-8.881784197001252e-15 Y-30.0 I-4.440892098500626e-15 J-15.0 E2.356194490192345
;set feedrate to 500mm/min
G3 X-14.999999999999991 Y25.980762113533164 I-7.499999999999996 J12.990381056766582
E2.356194490192345      ;set feedrate to 500mm/min
G3 X14.999999999999991 Y-25.980762113533164 I7.499999999999996 J-12.990381056766582
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-25.980762113533153 Y15.000000000000009 I-12.990381056766577 J7.500000000000004
E2.356194490192345      ;set feedrate to 500mm/min
G3 X25.980762113533153 Y-15.000000000000009 I12.990381056766577 J-7.500000000000004
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-30.0 Y1.4210854715202004e-14 I-15.0 J7.105427357601002e-15 E2.356194490192345
;set feedrate to 500mm/min
```

```
G3 X30.0 Y-1.4210854715202004e-14 I15.0 J-7.105427357601002e-15 E2.356194490192345
;set feedrate to 500mm/min
G3 X-25.980762113533167 Y-14.999999999999986 I-12.990381056766584 J-7.499999999999993
E2.356194490192345      ;set feedrate to 500mm/min
G3 X25.980762113533167 Y14.999999999999986 I12.990381056766584 J7.499999999999993
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-15.000000000000014 Y-25.98076211353315 I-7.500000000000007 J-12.990381056766575
E2.356194490192345      ;set feedrate to 500mm/min
G3 X15.000000000000014 Y25.98076211353315 I7.500000000000007 J12.990381056766575
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-1.9539925233402755e-14 Y-30.0 I-9.769962616701378e-15 J-15.0 E2.356194490192345
;set feedrate to 500mm/min
G3 X1.9539925233402755e-14 Y30.0 I9.769962616701378e-15 J15.0 E2.356194490192345
;set feedrate to 500mm/min
G3 X14.99999999999998 Y-25.98076211353317 I7.49999999999999 J-12.990381056766585
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-14.99999999999998 Y25.98076211353317 I-7.49999999999999 J12.990381056766585
E2.356194490192345      ;set feedrate to 500mm/min
G3 X25.980762113533146 Y-15.000000000000021 I12.990381056766573 J-7.500000000000011
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-25.980762113533146 Y15.000000000000021 I-12.990381056766573 J7.500000000000011
E2.356194490192345      ;set feedrate to 500mm/min
T1             ;set tool
G1 Z5          ;lift gantry
G1 X-24       ;adjust for tool offset
G1 Z-5         ;lower gantry
G1 Z2             ;set tool 0
G3 X30.0 Y0 I15.0 J-1.4210854715202004e-14 E2.356194490192345      ;set feedrate to
500mm/min
G3 X-30.0 Y0 I-15.0 J1.4210854715202004e-14 E2.356194490192345      ;set feedrate to
500mm/min
G3 X25.98076211353316 Y14.999999999999998 I12.99038105676658 J7.499999999999999
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-25.98076211353316 Y-14.999999999999998 I-12.99038105676658 J-7.499999999999999
E2.356194490192345      ;set feedrate to 500mm/min
G3 X15.000000000000005 Y25.980762113533157 I7.500000000000003 J12.990381056766578
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-15.000000000000005 Y-25.980762113533157 I-7.500000000000003 J-12.990381056766578
E2.356194490192345      ;set feedrate to 500mm/min
G3 X8.881784197001252e-15 Y30.0 I4.440892098500626e-15 J15.0 E2.356194490192345
;set feedrate to 500mm/min
G3 X-8.881784197001252e-15 Y-30.0 I-4.440892098500626e-15 J-15.0 E2.356194490192345
;set feedrate to 500mm/min
G3 X-14.999999999999991 Y25.980762113533164 I-7.499999999999996 J12.990381056766582
E2.356194490192345      ;set feedrate to 500mm/min
G3 X14.999999999999991 Y-25.980762113533164 I7.499999999999996 J-12.990381056766582
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-25.980762113533153 Y15.000000000000009 I-12.990381056766577 J7.500000000000004
E2.356194490192345      ;set feedrate to 500mm/min
G3 X25.980762113533153 Y-15.000000000000009 I12.990381056766577 J-7.500000000000004
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-30.0 Y1.4210854715202004e-14 I-15.0 J7.105427357601002e-15 E2.356194490192345
;set feedrate to 500mm/min
G3 X30.0 Y-1.4210854715202004e-14 I15.0 J-7.105427357601002e-15 E2.356194490192345
;set feedrate to 500mm/min
G3 X-25.980762113533167 Y-14.999999999999986 I-12.990381056766584 J-7.499999999999993
E2.356194490192345      ;set feedrate to 500mm/min
G3 X25.980762113533167 Y14.999999999999986 I12.990381056766584 J7.499999999999993
E2.356194490192345      ;set feedrate to 500mm/min
```

```
G3 X-15.000000000000014 Y-25.98076211353315 I-7.500000000000007 J-12.990381056766575
E2.356194490192345      ;set feedrate to 500mm/min
G3 X15.000000000000014 Y25.98076211353315 I7.500000000000007 J12.990381056766575
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-1.9539925233402755e-14 Y-30.0 I-9.769962616701378e-15 J-15.0 E2.356194490192345
;set feedrate to 500mm/min
G3 X1.9539925233402755e-14 Y30.0 I9.769962616701378e-15 J15.0 E2.356194490192345
;set feedrate to 500mm/min
G3 X14.99999999999998 Y-25.98076211353317 I7.49999999999999 J-12.990381056766585
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-14.99999999999998 Y25.98076211353317 I-7.49999999999999 J12.990381056766585
E2.356194490192345      ;set feedrate to 500mm/min
G3 X25.980762113533146 Y-15.000000000000021 I12.990381056766573 J-7.500000000000011
E2.356194490192345      ;set feedrate to 500mm/min
G3 X-25.980762113533146 Y15.000000000000021 I-12.990381056766573 J7.500000000000011
E2.356194490192345      ;set feedrate to 500mm/min
T0              ;set tool
G1 Z5           ;lift gantry
G1 X24        ;adjust for tool offset
G1 Z-5          ;lower gantry
G1 Z2              ;set tool 0
G3 X30.0 Y0 I15.0 J-1.4210854715202004e-14 E0      ;set feedrate to 500mm/min
G3 X-30.0 Y0 I-15.0 J1.4210854715202004e-14 E0      ;set feedrate to 500mm/min
G1 Z10 E-5      ;lift z axis and retract extruder
G0 F1000        ;set feedrate to 1000mm/min
G90             ;set absolute positioning
G1 X50 Y0       ;return to home position
```

VI. Presentation Slide Deck from Class

II. In-class Presentation Slide Deck Link

https://drive.google.com/file/d/1dKZ8AWM3RULd-ATtZV4PxGw-okKqicAA/view?usp=sharing

VII. Appendix

A. Rubrics attempted

5pts Cover page correct and complete
5pts Report neatly organized and formatted
10pt square test submitted three weeks before the deadline
10pt twisted pyramid submitted two weeks before the deadline
10pt multimaterial structure submitted a week before the deadline
10pt Twisted pyramid: Quality of print, height
10pt Spirograph: Quality of print, complexity of pattern, height
10pt Multi-Material print: Complexity, pattern
10pt Final food print nicely plated
10pt Nice glamor shots provided
10pt Printing calibration tests performed
10pt Presentation delivery and completeness

TOTAL GRADES ATTEMPTED: 110

A. Screenshot of Previous Submission History