MECE4606 Digital Manufacturing Assignment 5 - Food Printing

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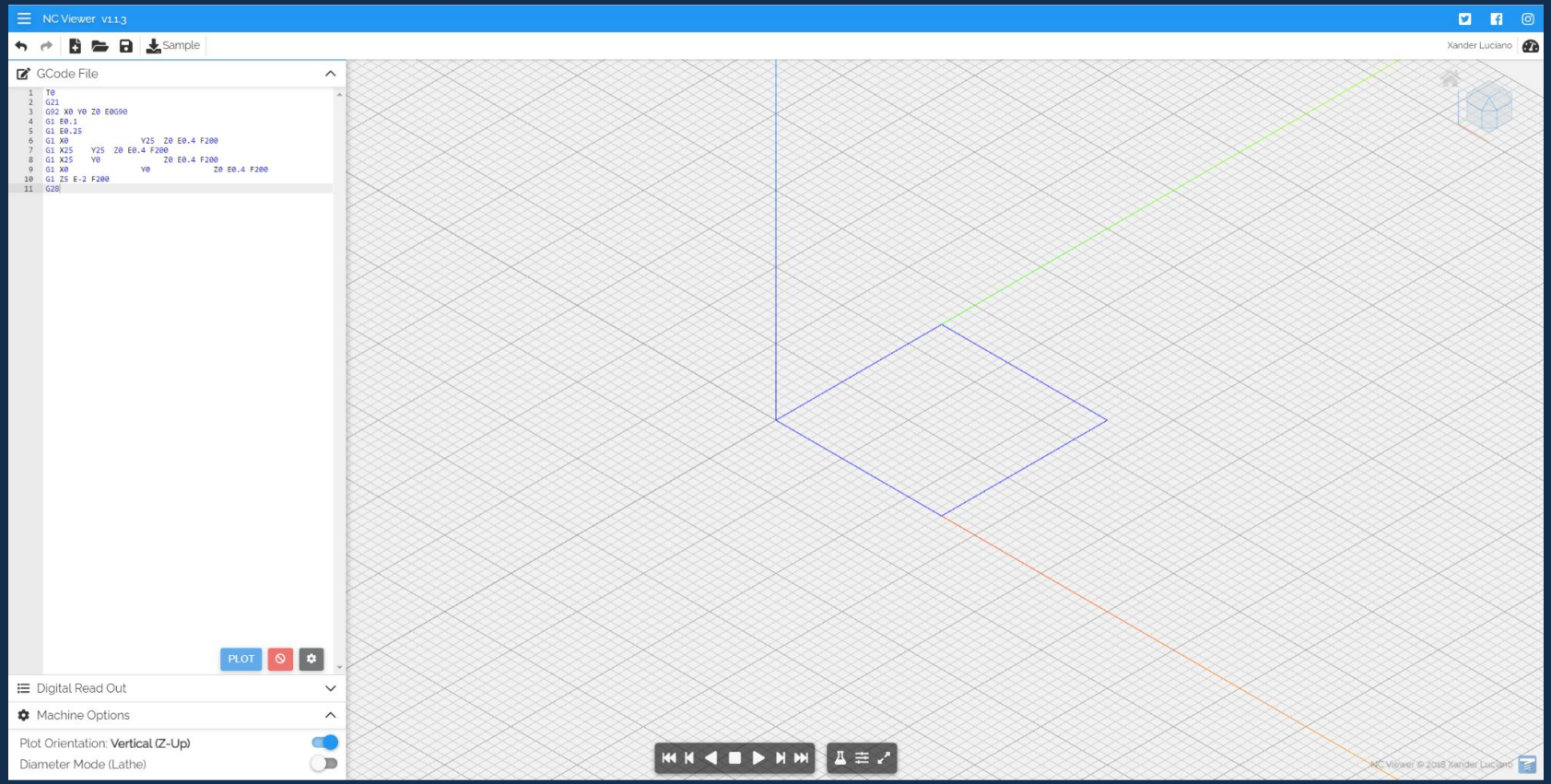
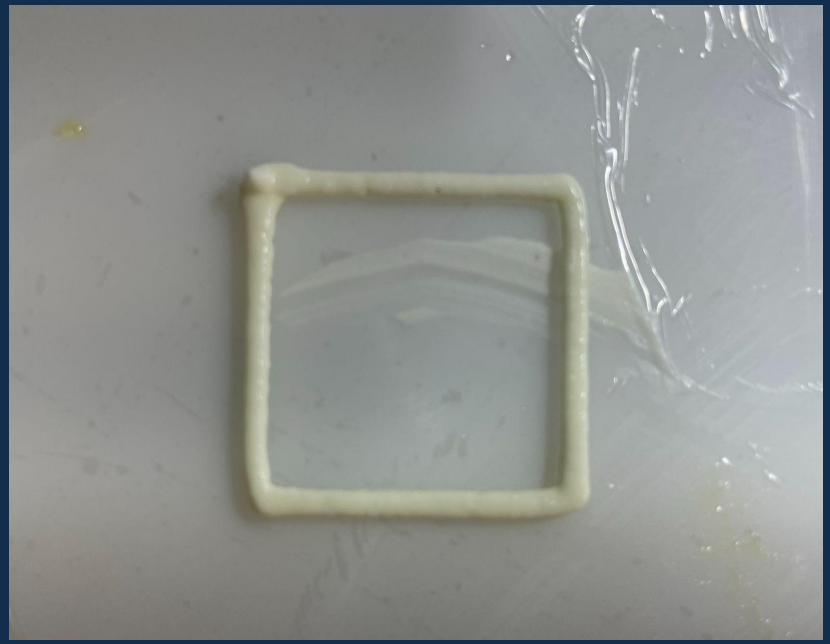
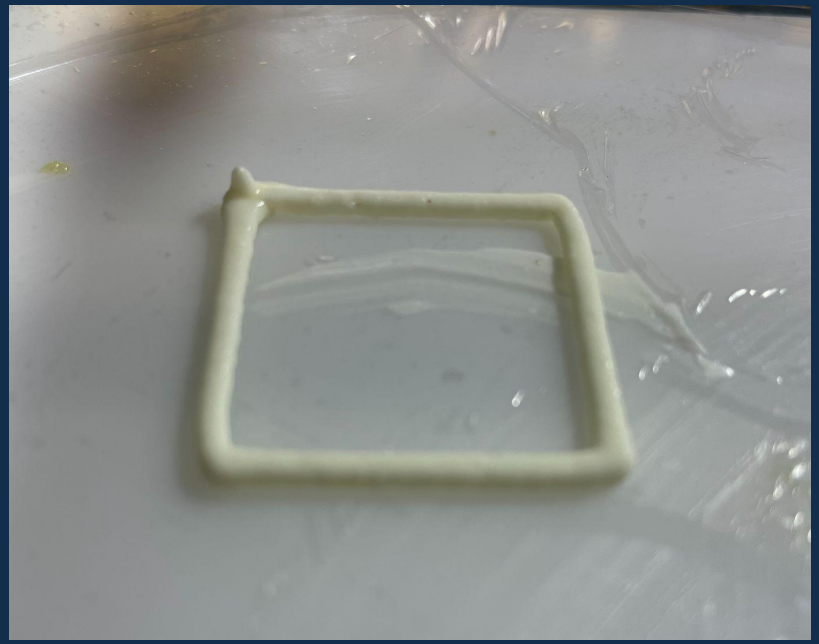
COLUMBIA UNIVERSITY
School of Professional Studies

Square - Simulated Graph



Square - Printed Product



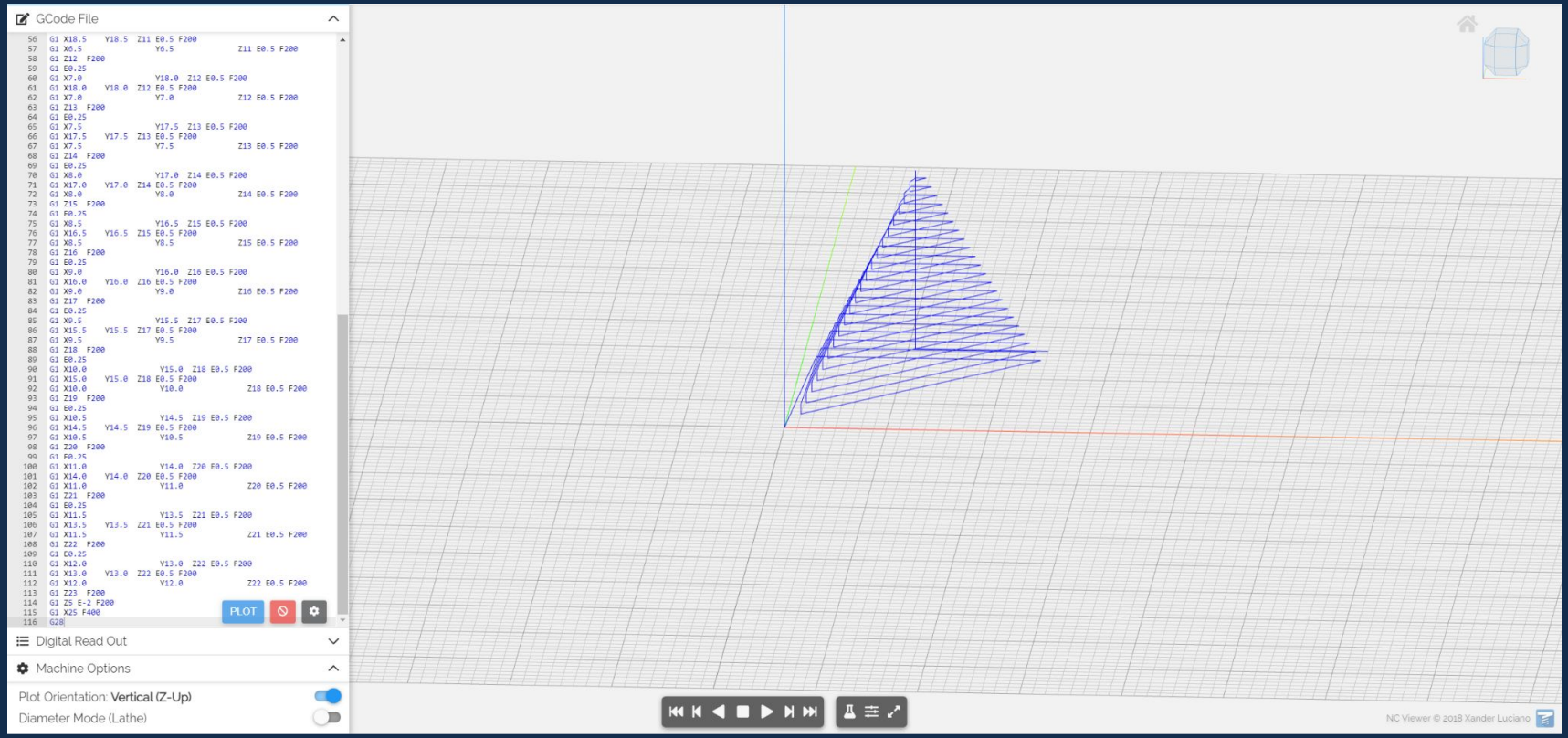


Recipe: Cream Cheese

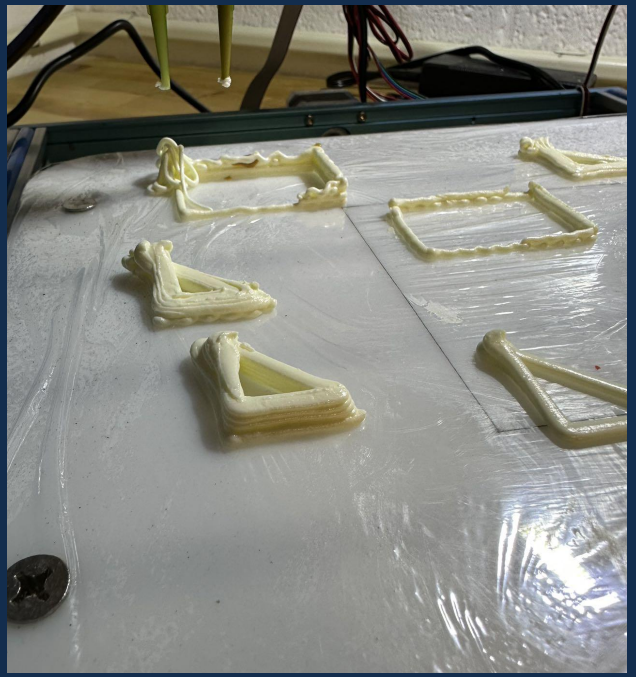
Square - G Code

```
T0
G21
G92 X0 Y0 Z0 E0G90
G1 E0.1
G1 E0.25
G1 X0                Y25  Z0 E0.4 F200
G1 X25    Y25  Z0 E0.4 F200
G1 X25    Y0              Z0 E0.4 F200
G1 X0                Y0              Z0 E0.4
F200
G1 Z5 E-2 F200
G28
```

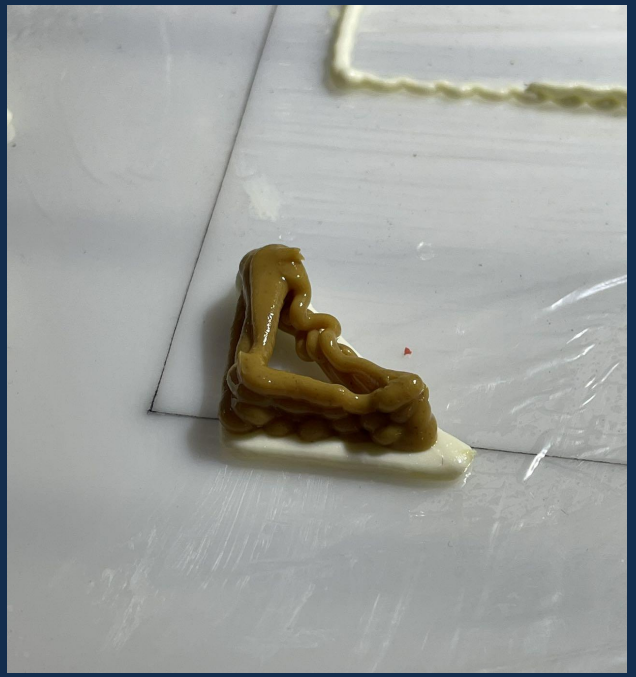
Multi-Material - Simulated Graph



Multi-Material - Printed Product



Failed Trials



Succeeded Trials

Recipe: Cream Cheese + Peanut Butter

Multi-Material - Source Code (Python)

```
FEEDRATE = 200
EXTRUSION = 0.5
import argparse
def main(side_length):
    n = 1
    i = 1
    lines = []
    eol = "\n"
    lines.append("T1" + eol)  # Select extruder 0
    lines.append("G21"+ eol) # Set units to mm
    lines.append("G92 X0 Y0 Z0 E0") # Set current position to be the origin
    lines.append("G90"+ eol) # Send absolute position commands
    # Controlled Movement to X,Y,Z position while Extruding 1-unit at Feedrate (speed) 50[cm/min]
    # NOTE: Z-VALUE can be omitted and instead set Z-height for single layer on printer

    for i in range(1,23):
        n += 0.5
        lines.append(f"G1 E0.25" + eol)  # Extrude a small amount (prime nozzle)
        lines.append(f"G1 X{0 + n}               Y{side_length - n}  Z{i} E{EXTRUSION} F{FEEDRATE}" + eol)
        lines.append(f"G1 X{side_length - n}    Y{side_length - n}  Z{i} E{EXTRUSION} F{FEEDRATE}" + eol)
        lines.append(f"G1 X{0 + n}               Y{0 + n}             Z{i} E{EXTRUSION} F{FEEDRATE}" + eol)
        lines.append(f"G1 Z{i+1}  F200" + eol)  # move up & retract plunger a bit
    lines.append("G1 Z5 E-2 F200" + eol)  # move up & retract plunger a bit
    lines.append("G1 X25 F400 " + eol) # move away from the print
    lines.append("G28") # Home printer
    # write lines to file
    with open('triangle_D.gcode', 'w') as f:
        f.writelines(lines)

if __name__ == '__main__':
    parser = argparse.ArgumentParser(description='Create G-Code for triangle')
    parser.add_argument('side_length', metavar='l', nargs='?', type=int, default = 25,
                        help='Pass an integer for side length in mm')

    args = parser.parse_args()
    main(args.side_length)
```

Multi-Material - G Code

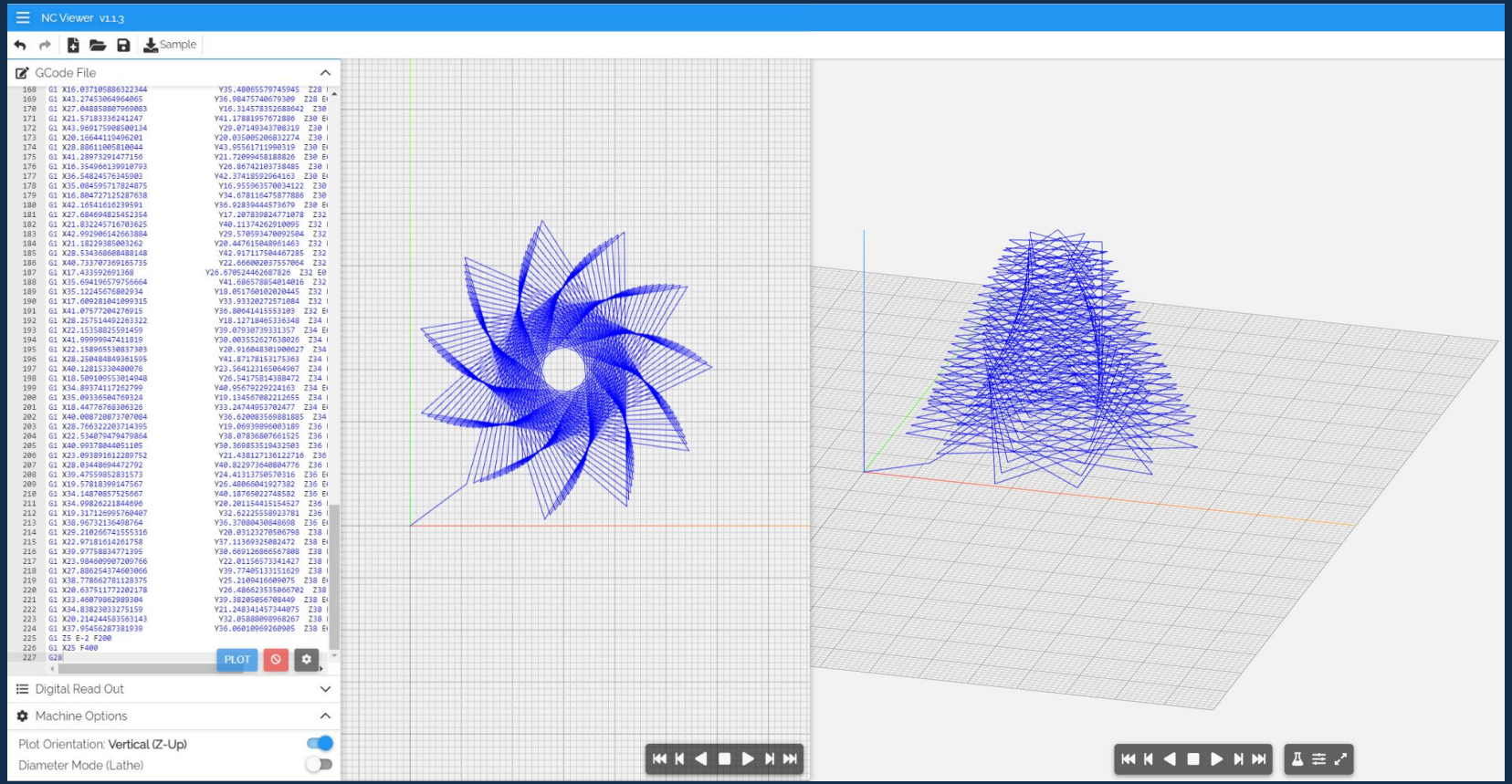
```
T1
G21
G92 X0 Y0 Z0 E0G90
G1 E0.25
G1 X1.5                Y23.5  Z1 E0.5 F200
G1 X23.5    Y23.5  Z1 E0.5 F200
G1 X1.5                Y1.5               Z1
E0.5 F200
G1 Z2  F200
G1 E0.25
G1 X2.0                Y23.0  Z2 E0.5 F200
G1 X23.0    Y23.0  Z2 E0.5 F200
G1 X2.0                Y2.0               Z2
E0.5 F200
G1 Z3  F200
G1 E0.25
G1 X2.5                Y22.5  Z3 E0.5 F200
G1 X22.5    Y22.5  Z3 E0.5 F200
G1 X2.5                Y2.5               Z3
E0.5 F200
G1 Z4  F200
G1 E0.25
G1 X3.0                Y22.0  Z4 E0.5 F200
G1 X22.0    Y22.0  Z4 E0.5 F200
G1 X3.0                Y3.0               Z4
E0.5 F200
G1 Z5  F200
G1 E0.25
G1 X3.5                Y21.5  Z5 E0.5 F200
G1 X21.5    Y21.5  Z5 E0.5 F200
G1 X3.5                Y3.5               Z5
E0.5 F200
G1 Z6  F200
G1 E0.25
G1 X4.0                Y21.0  Z6 E0.5 F200
G1 X21.0    Y21.0  Z6 E0.5 F200
G1 X4.0                Y4.0               Z6
E0.5 F200
G1 Z7  F200
G1 E0.25
G1 X4.5                Y20.5  Z7 E0.5 F200
G1 X20.5    Y20.5  Z7 E0.5 F200
G1 X4.5                Y4.5               Z7 E0.5
F200
G1 Z8  F200
G1 E0.25
G1 X5.0                Y20.0  Z8 E0.5 F200
G1 X20.0    Y20.0  Z8 E0.5 F200
G1 X5.0                Y5.0               Z8 E0.5
F200
G1 Z9  F200
G1 E0.25
G1 X5.5                Y19.5  Z9 E0.5 F200
G1 X19.5    Y19.5  Z9 E0.5 F200
G1 X5.5                Y5.5               Z9 E0.5
F200
G1 Z10  F200
G1 E0.25
G1 X6.0                Y19.0  Z10 E0.5 F200
G1 X19.0    Y19.0  Z10 E0.5 F200
G1 X6.0                Y6.0               Z10 E0.5
F200
G1 Z11  F200
G1 E0.25
G1 X6.5                Y18.5  Z11 E0.5 F200
G1 X18.5    Y18.5  Z11 E0.5 F200
G1 X6.5                Y6.5               Z11 E0.5
F200
G1 Z12  F200
G1 E0.25
G1 X7.0                Y18.0  Z12 E0.5 F200
G1 X18.0    Y18.0  Z12 E0.5 F200
G1 X7.0                Y7.0               Z12 E0.5
F200
G1 Z13  F200
G1 E0.25
G1 X7.5                Y17.5  Z13 E0.5 F200
G1 X17.5    Y17.5  Z13 E0.5 F200
G1 X7.5                Y7.5               Z13 E0.5
F200
G1 Z14  F200
G1 E0.25
G1 X8.0                Y17.0  Z14 E0.5 F200
G1 X17.0    Y17.0  Z14 E0.5 F200
G1 X8.0                Y8.0               Z14 E0.5
F200
G1 Z15  F200
G1 E0.25
G1 X8.5                Y16.5  Z15 E0.5 F200
G1 X16.5    Y16.5  Z15 E0.5 F200
G1 X8.5                Y8.5               Z15 E0.5
F200
G1 Z16  F200
G1 E0.25
G1 X9.0                Y16.0  Z16 E0.5 F200
G1 X16.0    Y16.0  Z16 E0.5 F200
G1 X9.0                Y9.0               Z16 E0.5
F200
G1 Z17  F200
G1 E0.25
G1 X9.5                Y15.5  Z17 E0.5 F200
G1 X15.5    Y15.5  Z17 E0.5 F200
G1 X9.5                Y9.5               Z17 E0.5
F200
G1 Z18  F200
G1 E0.25
G1 X10.0                Y15.0  Z18 E0.5 F200
G1 X15.0    Y15.0  Z18 E0.5 F200
G1 X10.0                Y10.0              Z18
E0.5 F200
G1 Z19  F200
G1 E0.25
G1 X10.5                Y14.5  Z19 E0.5 F200
G1 X14.5    Y14.5  Z19 E0.5 F200
G1 X10.5                Y10.5              Z19
E0.5 F200
G1 Z20  F200
G1 E0.25
G1 X11.0                Y14.0  Z20 E0.5 F200
G1 X14.0    Y14.0  Z20 E0.5 F200
G1 X11.0                Y11.0              Z20
```

Multi-Material - G Code (Cont.)

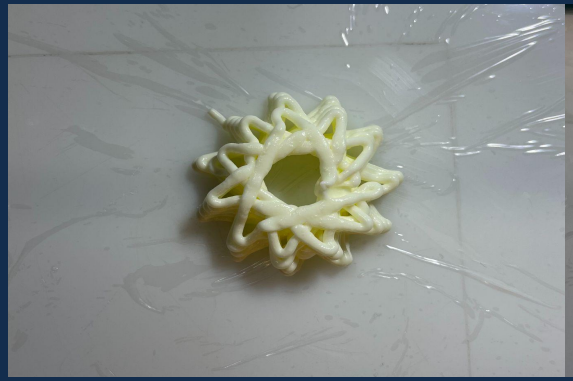
```
E0.5 F200
G1 Z21  F200
G1 E0.25
G1 X11.5                Y13.5  Z21 E0.5 F200
G1 X13.5    Y13.5  Z21 E0.5 F200
G1 X11.5                Y11.5              Z21
E0.5 F200

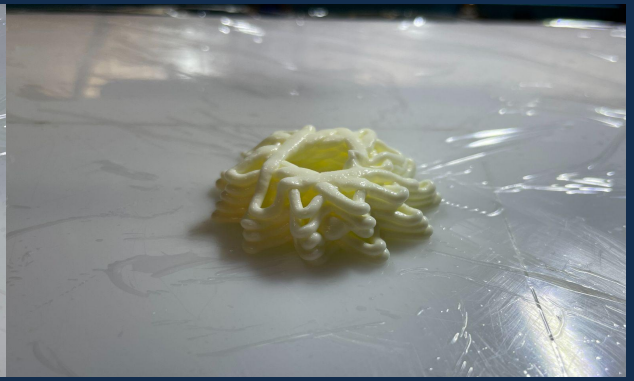
G1 Z22  F200
G1 E0.25
G1 X12.0                Y13.0  Z22 E0.5 F200
G1 X13.0    Y13.0  Z22 E0.5 F200
G1 X12.0                Y12.0              Z22
E0.5 F200
G1 Z23  F200
G1 Z5 E-2 F200
G1 X25 F400
G28
```

Spirograph - Simulated Graph



Spirograph - Printed Product





20 mm radius

30 mm radius

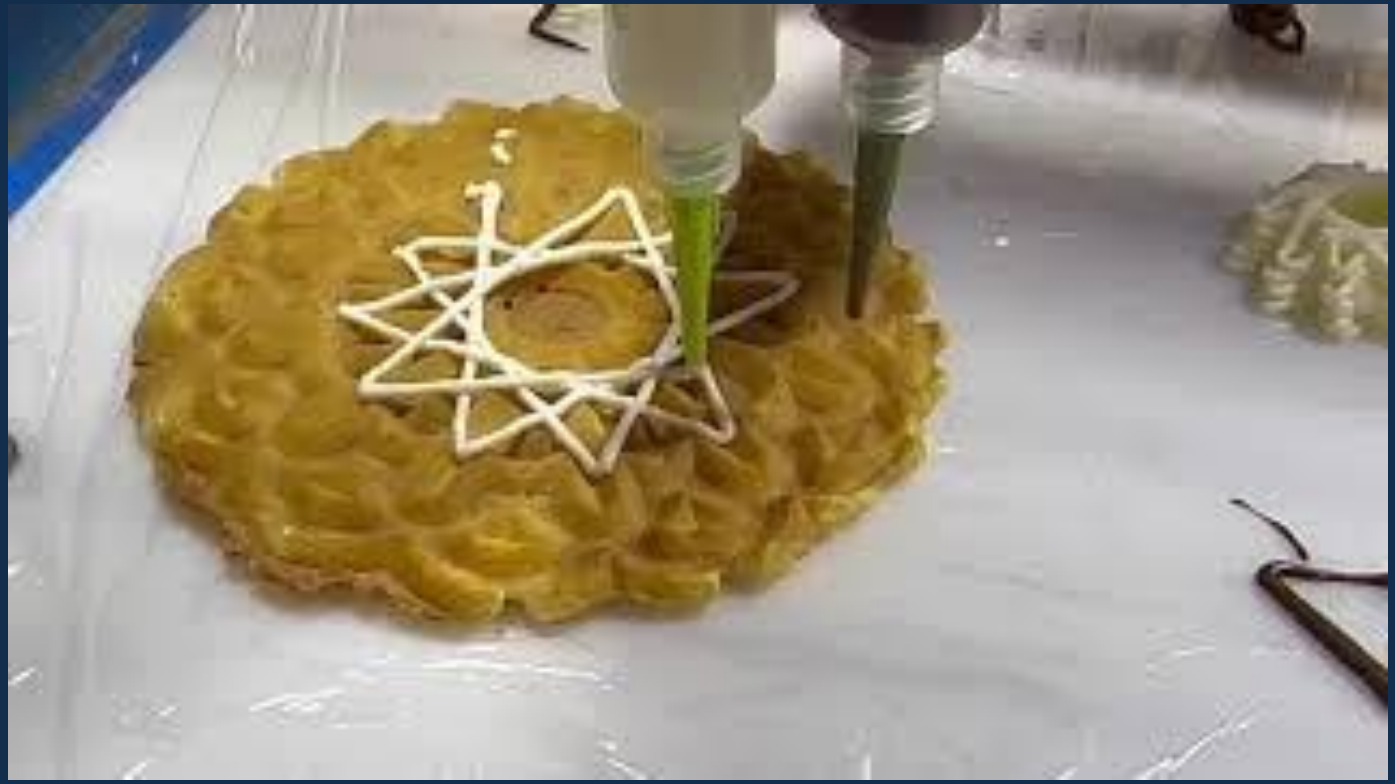
Recipe: Pizzelle + Cream Cheese + Honey

Spirograph - About

Since the G2 and G3 circle commands were not applicable, we used straight lines to create a spirograph. Our idea was to set base using 3 triangles; each triangle rotated 30 degrees from previous one, and to build a spiral pyramid by rotating our base on each layer, with reduction on the side length of 1mm and the rotation angle by 1 degree for each successive layer.

During printing, we set the Z axis distance to 5mm and the extrusion speed to 0.4. However, due to considerations of material strength and consumption, we decided to modify our original plan and print only 5 layers instead of a full spiral pyramid. To stop the printing process, we simply lifted the Z extruder to 10 and used the G28 command to return it to the home position.

Spirograph - Video



Spirograph - Source Code (Python)

```
FEEDRATE = 200
EXTRUSION = 0.4
import argparse
import math
def main(side_length):
    n = 1
    i = 1
    lines = []
    eol = "\n"
    lines.append("T0" + eol)  # Select extruder 0
    lines.append("G21"+ eol) # Set units to mm
    lines.append("G92 X0 Y0 Z0 E0") # Set current position to be the
origin
    lines.append("G90"+ eol) # Send absolute position commands
    # Controlled Movement to X,Y,Z position while Extruding 1-unit at
Feedrate (speed) 50[cm/min]
    # NOTE: Z-VALUE can be omitted and instead set Z-height for
single layer on printer
    lines.append(f"G1 E0.1" + eol) # Extrude a small amount (prime
nozzle)
    r = 30
    theta1 = 2

    for n in range(20):
        z = n
        r -= 1
        #Geometry
        for i in range(1,12):
            dx = r * math.cos(theta1 * (2 * i + n/60))
            dy = r * math.sin(theta1 * (2 * i + n/60))
            lines.append(f"G1 X{30 + dx}                Y{30 + dy}
Z{2 * z} E{EXTRUSION} F{FEEDRATE}" + eol)
    lines.append("G1 Z10 E-2 F200" + eol)  # move up & retract
plunger a bit
    lines.append("G1 X25 F400 " + eol) # move away from the print
    lines.append("G28") # Home printer
    # write lines to file
    with open('triangle_c.gcode', 'w') as f:
        f.writelines(lines)

if __name__ == '__main__':
    parser = argparse.ArgumentParser(description='Create G-Code for
triangle')
    parser.add_argument('side_length', metavar='l', nargs='?',
type=int, default = 25,
                        help='Pass an integer for side length in mm')

    args = parser.parse_args()
    main(args.side_length)
```

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Spirograph - G Code

```
T0
G21
G92 X0 Y0 Z0 E0G90
G1 E0.1
G1 X11.044334994955253 Y8.052727636070081 Z0 E0.4 F200
G1 X25.780499019550206 Y58.691389152078074 Z0 E0.4 F200
G1 X54.47176480324227 Y14.439385377987387 Z0 E0.4 F200
G1 X2.2278750706218453 Y21.650803816713108 Z0 E0.4 F200
G1 X41.834379792588365 Y56.475412271101206 Z0 E0.4 F200
G1 X42.30119121277291 Y3.7382275018079056 Z0 E0.4 F200
G1 X2.084429876906569 Y37.8562678609282 Z0 E0.4 F200
G1 X54.1924774546888 Y45.991373756009025 Z0 E0.4 F200
G1 X26.289053000805264 Y1.238413250149641 Z0 E0.4 F200
G1 X10.658796212084404 Y51.608281653901116 Z0 E0.4 F200
G1 X58.99545595078305 Y30.513355828056994 Z0 E0.4 F200
G1 X12.414363661567553 Y8.211347114325676 Z2 E0.4 F200
G1 X25.005032138167074 Y57.55086742843601 Z2 E0.4 F200
G1 X54.11549409704414 Y15.771755397961806 Z2 E0.4 F200
G1 X3.4690901008189563 Y21.049535211982718 Z2 E0.4 F200
G1 X40.568025925569714 Y55.92907302694191 Z2 E0.4 F200
G1 X42.715464436441216 Y5.053718430082636 Z2 E0.4 F200
G1 X2.8092096440344356 Y36.68288259794604 Z2 E0.4 F200
G1 X52.830708888392266 Y46.20983441166154 Z2 E0.4 F200
G1 X27.344495906582008 Y2.1262076851778176 Z2 E0.4 F200
G1 X10.6407977332875 Y50.22921866005984 Z2 E0.4 F200
G1 X57.963542226708 Y31.428392850415662 Z2 E0.4 F200
G1 X13.75206197644681 Y8.436036774684148 Z4 E0.4 F200
G1 X24.300699863635426 Y56.39162704259884 Z4 E0.4 F200
G1 X53.698560378596824 Y17.062525904103197 Z4 E0.4 F200
G1 X4.718474506122661 Y20.521367783143493 Z4 E0.4 F200
G1 X39.35165535095057 Y55.32876906201794 Z4 E0.4 F200
G1 X43.05622576454953 Y6.3666555734252235 Z4 E0.4 F200
G1 X3.580107281943558 Y35.56680058618845 Z4 E0.4 F200
G1 X51.48216291356759 Y46.35593704301105 Z4 E0.4 F200
G1 X28.33653521644383 Y3.051291590989589 Z4 E0.4 F200
G1 X10.692463375037931 Y48.8737656411154 Z4 E0.4 F200
G1 X56.90396108255018 Y32.2752753830306 Z4 E0.4 F200
G1 X15.054577390135002 Y8.724795112325332 Z6 E0.4 F200
G1 X23.66785200286943 Y55.217135081972245 Z6 E0.4 F200
G1 X53.223358899242385 Y18.309165922100362 Z6 E0.4 F200
G1 X5.972547198098631 Y20.066143153215762 Z6 E0.4 F200
G1 X38.18742359988629 Y54.67723839484526 Z6 E0.4 F200
G1 X43.324138387153646 Y7.673617932141834 Z6 E0.4 F200
G1 X4.394100279579803 Y34.50975603639319 Z6 E0.4 F200
G1 X50.15012763029837 Y46.43083553817901 Z6 E0.4 F200
G1 X29.263894950155922 Y4.010422293627123 Z6 E0.4 F200
G1 X10.812173109933774 Y47.54500781524054 Z6 E0.4 F200
G1 X55.82010633969821 Y33.05321283350449 Z6 E0.4 F200
G1 X16.319155585628355 Y9.075504878020208 Z8 E0.4 F200
G1 X23.106686558108745 Y54.03085994698986 Z8 E0.4 F200
G1 X52.69238513018288 Y19.50925850554619 Z8 E0.4 F200
G1 X7.22784787684261 Y19.683552564967997 Z8 E0.4 F200
G1 X37.07735880709229 Y53.97730160622069 Z8 E0.4 F200
G1 X43.52001124951984 Y8.971226954174025 Z8 E0.4 F200
G1 X5.248102978401889 Y33.51334510576494 Z8 E0.4 F200
G1 X48.837827935361446 Y46.435821813274686 Z8 E0.4 F200
G1 X30.125444899847402 Y5.000314730439062 Z8 E0.4 F200
G1 X10.998179547528292 Y46.24594778681835 Z8 E0.4 F200
G1 X54.71539254726028 Y33.76156499808668 Z8 E0.4 F200
G1 X17.54314499076908 Y9.485937426267842 Z10 E0.4 F200
G1 X22.61725006810326 Y52.836265093992026 Z10 E0.4 F200
G1 X52.108229804062208 Y20.66050456765563 Z10 E0.4 F200
G1 X8.480943171872845 Y19.373138128881415 Z10 E0.4 F200
G1 X36.02335864135164 Y53.231856376055156 Z10 E0.4 F200
G1 X43.64479692394073 Y10.256152429062425 Z10 E0.4 F200
G1 X6.138972424021773 Y32.57902365603857 Z10 E0.4 F200
G1 X47.54842000063713 Y46.37232284928558 Z10 E0.4 F200
G1 X30.920201996674457 Y6.017647565651188 Z10 E0.4 F200
G1 X11.248611669298434 Y44.979500514744444 Z10 E0.4 F200
G1 X53.59324873272445 Y34.399842523977014 Z10 E0.4 F200
G1 X18.72400110916391 Y9.953757234487473 Z12 E0.4 F200
G1 X22.199438197371805 Y51.63680280363478 Z12 E0.4 F200
G1 X51.473573813716655 Y21.760726508552942 Z12 E0.4 F200
G1 X9.728432721668604 Y19.13429431283528 Z12 E0.4 F200
G1 X35.02718745906104 Y52.44387190864044 Z12 E0.4 F200
G1 X43.6995892513298 Y11.525118286039042 Z12 E0.4 F200
G1 X7.063514295772105 Y31.70810524844031 Z12 E0.4 F200
G1 X46.284985879866134 Y46.24189751514769 Z12 E0.4 F200
G1 X31.647331431770 92 Y7.059069348566098 Z12 E0.4 F200
G1 X11.561478756483503 Y43.74848843882086 Z12 E0.4 F200
```

Spirograph - G Code (Cont.)

```
G1 X52.45711214619458 Y34.96770712232915 Z12 E0.4 F200
G1 X19.859290663278717 Y10.476526585975183 Z14 E0.4 F200
G1 X21.852996572167978 Y50.43590798440073 Z14 E0.4 F200
G1 X50.79118297623406 Y22.807871632906235 Z14 E0.4 F200
G1 X10.966955182585 Y18.966269670765374 Z14 E0.4 F200
G1 X34.09047368479501 Y51.616383255160876 Z14 E0.4 F200
G1 X43.685620756661535 Y12.774908287476816 Z14 E0.4 F200
G1 X8.018488904904089 Y30.90175937820202 Z14 E0.4 F200
G1 X45.05052825184276 Y46.046233182291815 Z14 E0.4 F200
G1 X32.30614753020673 Y8.121204704807866 Z14 E0.4 F200
G1 X11.93467450437723 Y42.555636771474475 Z14 E0.4 F200
G1 X51.31042200787046 Y35.46497153208236 Z14 E0.4 F200
G1 X20.946695543644132 Y11.051710409102174 Z16 E0.4 F200
G1 X21.577521861424387 Y49.23699202071924 Z16 E0.4 F200
G1 X50.06390267064221 Y23.80001535300316 Z16 E0.4 F200
G1 X12.193194157988263 Y18.86816880720442 Z16 E0.4 F200
G1 X33.21470742253354 Y50.75248554239968 Z16 E0.4 F200
G1 X43.60425984264783 Y14.002371609087811 Z16 E0.4 F200
G1 X9.000617252030938 Y30.161009950933042 Z16 E0.4 F200
G1 X43.8479653079189 Y45.7871421362663 Z16 E0.4 F200
G1 X32.896114377045485 Y9.200660550991756 Z16 E0.4 F200
G1 X12.365981316386762 Y41.40356896177592 Z16 E0.4 F200
G1 X50.1566132684216 Y35.891599235122015 Z16 E0.4 F200
G1 X21.98401655840049 Y11.676681265010902 Z18 E0.4 F200
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Spirograph - G Code (Cont. 2)

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G28
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