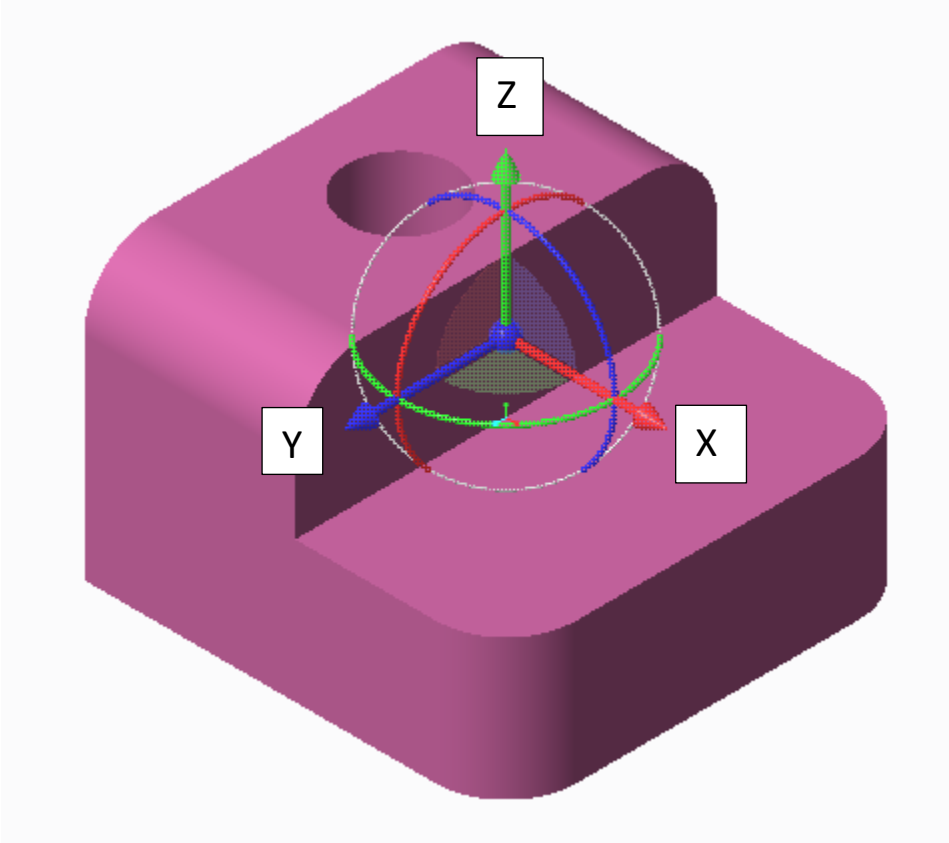
Tutorial: Basic G-Code Programming

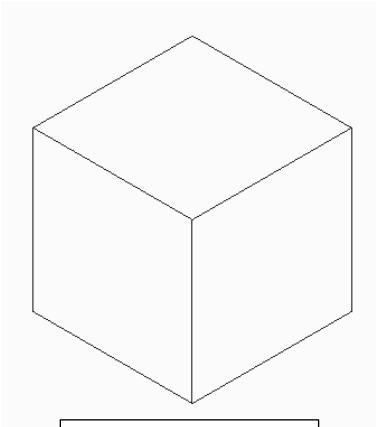
Reference: Coordinate Axis Direction



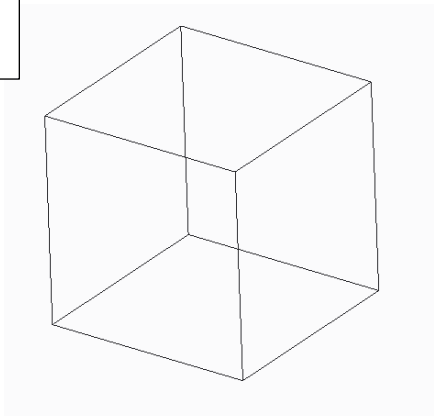
This tutorial is designed to create a wireframe model of a part. This tutorial will not simulate a full G-code program for a 3D print because the program for a whole object is, at minimum, 15,000+ lines long. This is because of the complexity of the layering and infill pattern.

Cube

10 mm x 10 mm x 10 mm



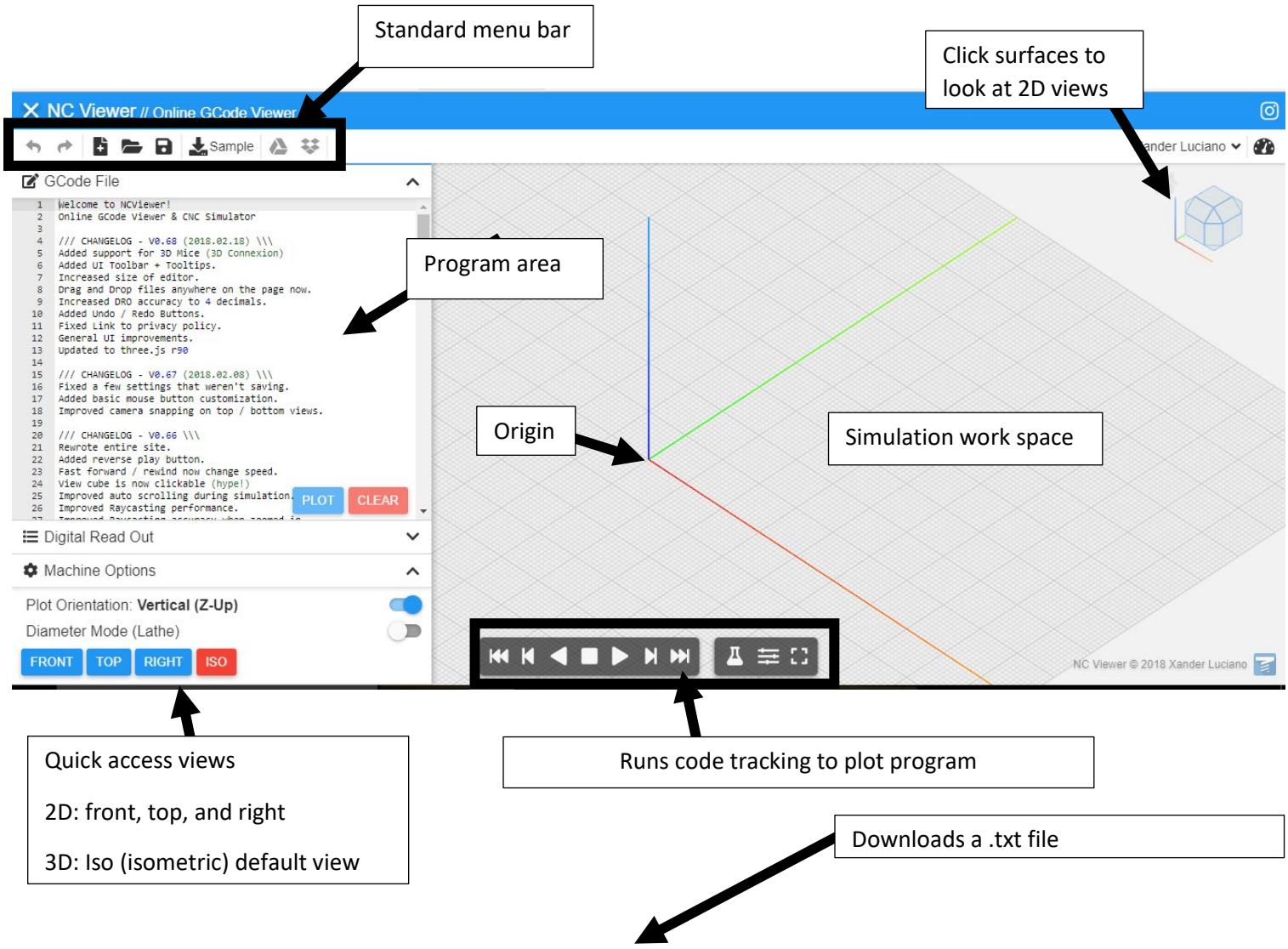
CAD Solid Model



Wireframe Model

NC Viewer Program

1. Open Browser > go to **ncviewer.com**
   This site is a simulator for compiling machining code, whether it is machining, turning, or 3D printing.

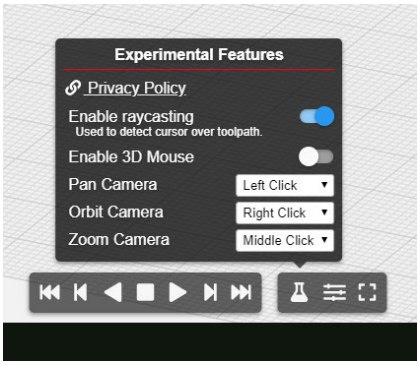


Menu Bar

Work screen movement

Mouse

Left Click - Select
Left Hold - Pan
Right Hold - rotate screen
Center Roll Bar - Pull = Zoom out
Push = Zoom in



Machine Setup Code

Setting Units

G20 = inches
G21 = mm
It is important to set the units so the machine knows how far to incrementally change when programming in the distance from one point to the next

Coordinate Position

G90 = absolute position
G91 = incremental position
G92 = offset coordinate system
User needs to make allotment for the size of the tool they are using. Use absolute position make the change in the *x*, *y*, *z* coordinates when laying out the coordinate points. Use incremental or offset positioning within the program setup phase.

Note: Because we do not know the size of the tool we are using, absolute position will work best.

Homing

A series of *x*, *y*, *z* coordinate movements that moves the tool away from the build plate allows for easy setup and removal of the object. The home position is typically a location up and away from the build plate or off the stock material that is to be machined so nothing gets damaged when the extruder head heats up or the cutting tool begins its motion. For this tutorial we will set a home position that is to the upper-right of the wireframe model. The user will not set this position as the origin of the virtual machine, but keep the origin point as one of the corners of the object.

Code: Cube 10 mm x 10 mm x 10 mm

1. Select New Program Icon 

2. Type in the following Code
   (NOTE: Two forward slashes // allow the user to place a comment. The code after the "//" will not be recognized by the machine and therefore will not interfere with the code.

```
1  //Machine Setup
2  N10 G21 //Set units to mm
3  N20 G90 //Set Absolute Positioning
4  N30 G17 //XY Plane
```

Coded line ID generated by software. Note that not all compilers contain line code ID

Coded line ID generated by user. This is designed to help identify a line of code when each line has a unique marker. Incremental changes (for example: N10, N20) does not have to be by tens, but can be setup as any incremental change. Creating a larger space between ID changes allows the user to add a new line between two existing lines; this way the rest of the program does not need to be renumbered.

3. The next line of codes are used to set up the machine.
   a. 3D Printer: setting up extruder head temperature, build plate temperature, etc.
   b. CNC machine: tool number from the carousel, tool speed, etc.

   We will setup this program as if we were using a 3D printer to create the object.

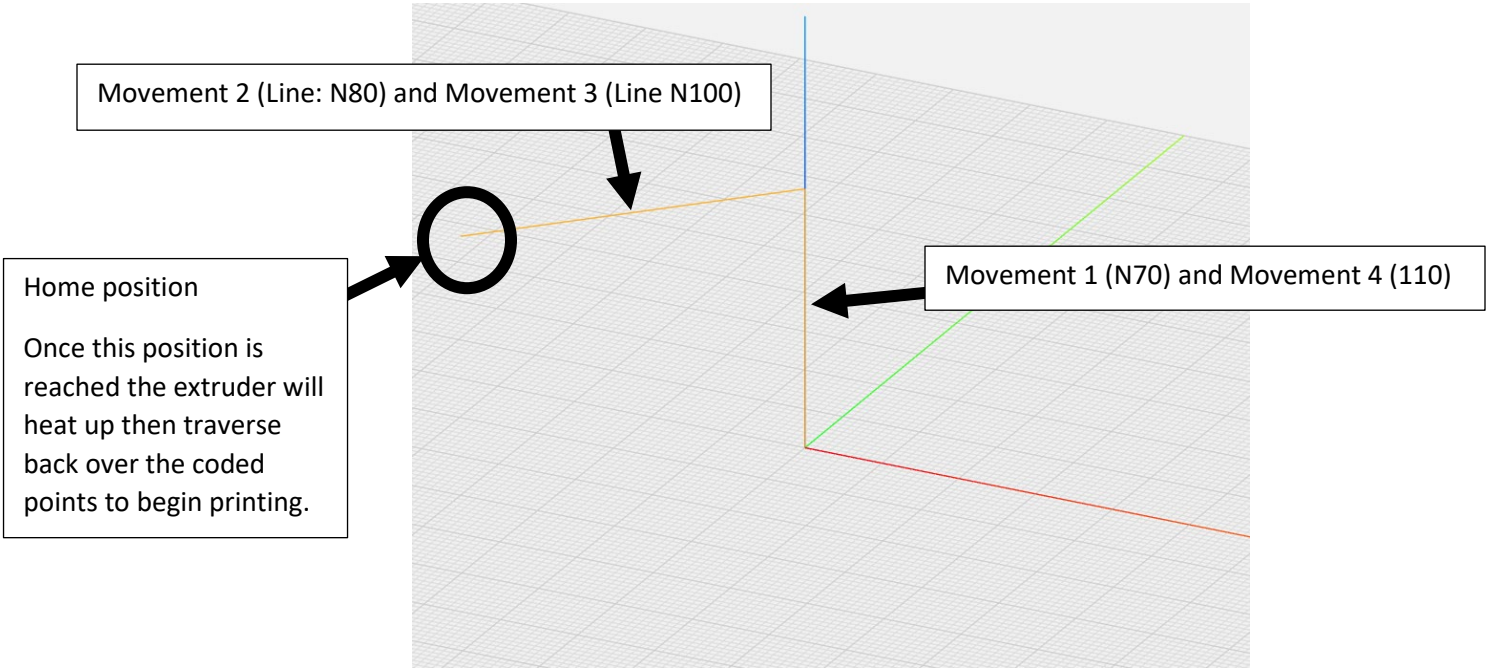
   Practice writing the following code below:

```
1  //Machine Setup
2  N10 G21 //Set units to mm
3  N20 G90 //Set Absolute Positioning
4  N30 G59 //XY Plane
5  N40 M104 S225 //Set the extruder temperature to 225 C
6  N50 M108 R5.0 //Set extruder speed
7  N60 M103 //Extruder is turned OFF
```

4. The homing position should always be set away from where the object is being printed; continue writing the following code.

```
8   //Homing Position
9   N70 G00 x0 y0 z30 //Moves Tooling off the build plate vertically
10  N80 G00 x-30 y-30 z30 //Moves Tooling away from print
11  N90 M105 //Get Extruder Temperature (Heat up to 225C)
12  N100 G00 x0 y0 z30 //
13  N110 G00 x0 y0 z.1 //Z axis is slighlty off the build plate to
14                     //accommodate  for the material that is printed
```

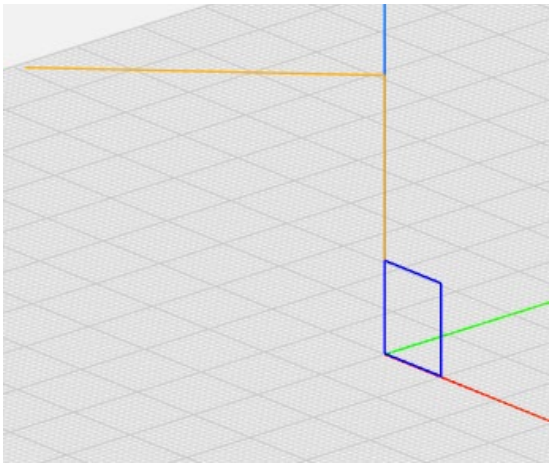
Press play in the work screen or plot from the coding window and you should notice an orange line moving from the center of the build plate up vertically and then on an angle towards the third quadrant on the graph.



5. Code the cube 10 mm x 10 mm x 10 mm
    a. 1st wall (front surface): write down the following lines of code.

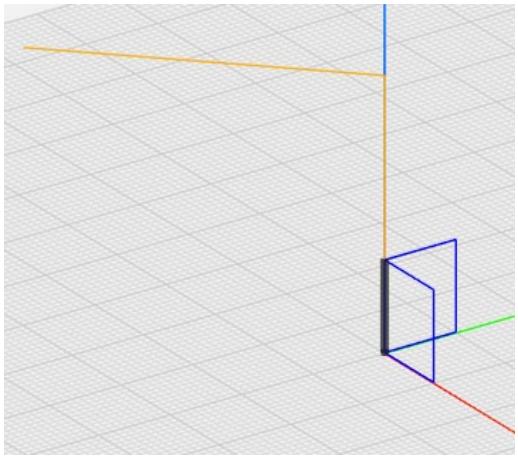
```
15  //10mm x 10mm x 10mm Cube Print
16  //1st Wall
17  N110 G01 x10 y0 z.1
18  N120 G01 x10 y0 z10.1
19  N130 G01 x0 y0  z10.1
20  N140 G01 x0 y0 z.1
```

    b. Press play to plot the code.



c. 2nd wall (left surface): write down the following lines of code. Press play to plot the code. Current tool location = (x0 y0 z.1)

```
21  //2nd Wall Left Face
22  N160 G01 x0 y10 z.1
23  N170 G01 x0 y10 z10.1
24  N180 G01 x0 y0 z10.1
25  N190 G01 x0 y0 z.1
```

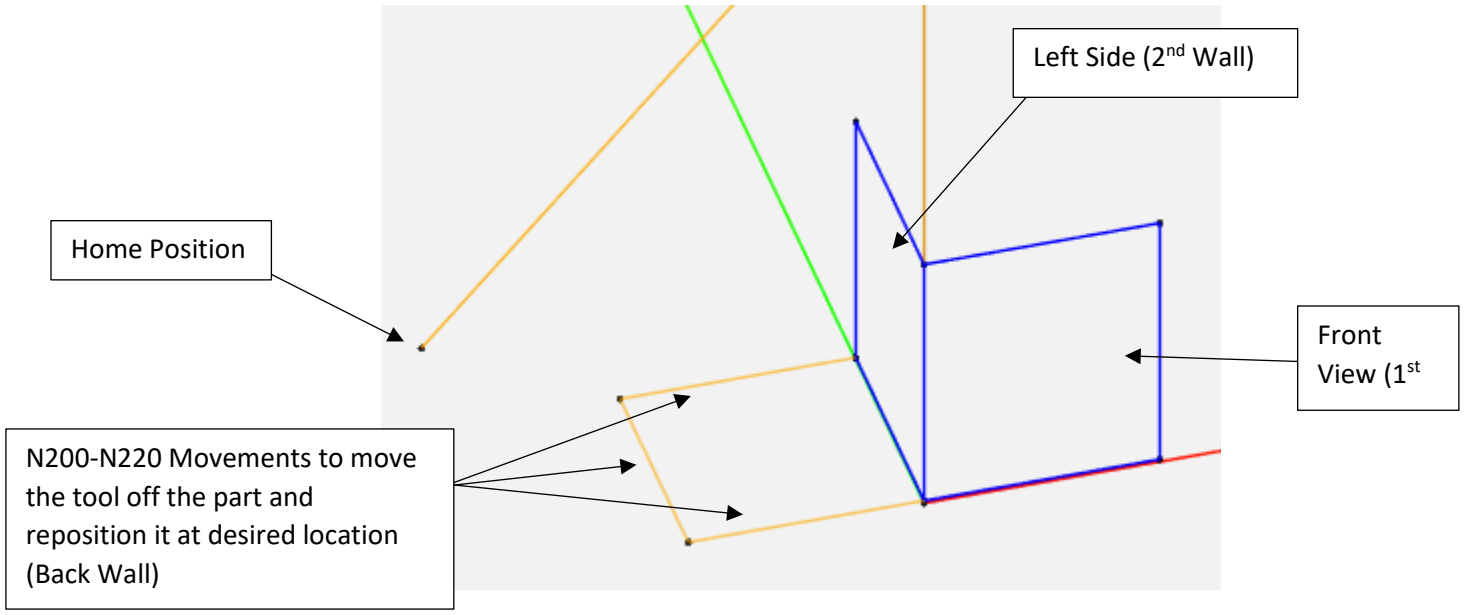


d. Reposition the tool:
Option 1: trace a line to move the tool back to starting location.

```
26  //Trace over bottom left line to reach start of bottom surface
27  N200 G01 x0 y10 z.1
```

Option 2: Move the tool away from the part and reposition it using a combination of G00 and G01. For Example:

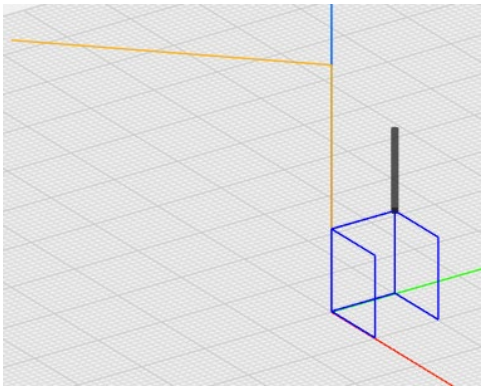
```
//Tool Reposition for Back Surface
N200 G00 x-10 y0 z.1
N210 G00 x-10 y10 z.1
N220 G00 x0 y10 z.1
```



Note: For this tutorial user will follow Option 1

e. 3rd wall (back surface): write down the following lines of code. Press play to plot the code. Current tool location = (x0 y10 z.1)

```
28  //3rd Wall Back Surface
29  N210 G01 x10 y10 z.1
30  N220 G01 x10 y10 z10.1
31  N230 G01 x0 y10 z10.1
```

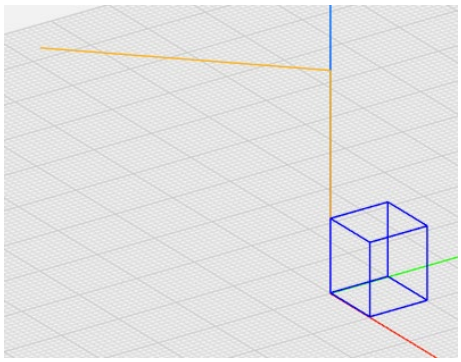


f. Trace a line to move tool back top right corner of back surface

```
32  //Trace over top edge of back surface to begin right surface
33  N240 G01 x10 y10 z10.1
```

g. 4th wall (right surface): write down the following lines of code. Press play to plot the code. Current tool location = (x10 y10 z10.1)

```
34  //4th Wall Right Face
35  N250 G01 x10 y0 z10.1
36  N260 G01 x10 y0 z.1 //Retraces right edge of Front Face
37  N270 G01 x10 y10 z.1
```



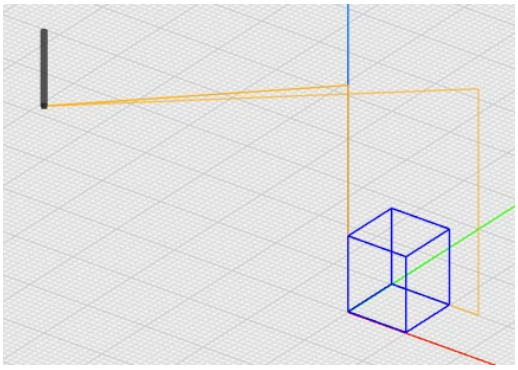
h. The top and bottom surfaces are complete based on the shared edges from the other four surfaces.

6. Return tool to the home position

Once a part is complete it is important to return the tool back to its home position. This makes it easier to remove the part from the machine. The user should make sure not to code movements that run into the part, so we will move the tool away from the part with a series of moves.

Copy the following code > Plot Code

```
38  //Return to Home
39  N280 G00 x15 y10 z.1 //Moves the tool to the right of part
40  N290 G00 x15 y10 z30 //Moves the tool above the part
41  N300 G00 x-30 y-30 z30 //Return to Home Position
```



7. Machine shutdown

```
42  //Program Shutdown
43  N310 G104 P100 //Pause 1000 seconds
44  N320 M103 T0//Extruder Off
45  N330 M18 //Motors Off
46  N340 M104 S0 //Set Extruder Head Temperature to 0 C
47  N350 M02 //End of Program
```

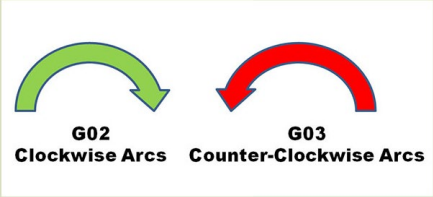
Code: Curves, Arcs, and Circles

To create curves, arcs, or circles, the user needs to choose one of two methods. Method 1: use the radius for its formation; Method 2: use offset values from the start point. For both methods the user needs to program the proper G-code axes (G17=XY, G18=ZX, G19=ZY) - this will place the tool at the correct orientation to create the curve, arc or circle based upon its view plane. Not every machine has the ability to rotate the tool into the different axis positions, so read the instruction manual of a particular machine before trying to run a series of code.

Method 1 Using R (radius)

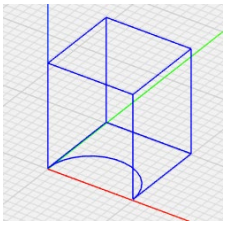
Next we will modify the existing code by adding curves. There are two types of curved edges we can code:

G02: Clockwise interpolation
G03: Counter-clockwise interpolation



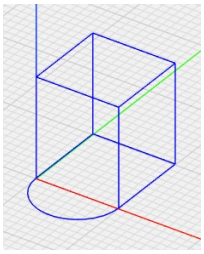
The direction of the curve (concave vs convex) is dependent upon the direction of the tool.
For example: tool moves in a counter clockwise direction (x0 y0 z.1 to x10 y0 z.1)

G02: Clockwise interpolation



```
13  N110 G00 x0 y0 z.1
14  //Cube Print 10mm x 10mm x 10mm
15  //1st Wall Front Face
16  N120 G02 x10 y0 z.1 R5 //Clockwise rotation w/Radius 5mm
```

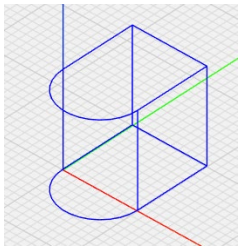
G03: Counter-clockwise interpolation



```
13  N110 G00 x0 y0 z.1
14  //Cube Print 10mm x 10mm x 10mm
15  //1st Wall Front Face
16  N120 G03 x10 y0 z.1 R5 //CounterClockwise rotation w/Radius 5mm
```

a. Change the cube code to the G03 counter-clockwise interpolation.
b. Change the following lines of code to create an arc on the top edge of the front surface; notice how this is a G02 (clockwise). This is because the tool is moving in a clockwise direction from line N130 to line N140.

```
17  N130 G01 x10 y0 z10.1 R5
18  N140 G02 x0 y0 z10.1 //Clockwise rotation w/Radius of 5mm
```



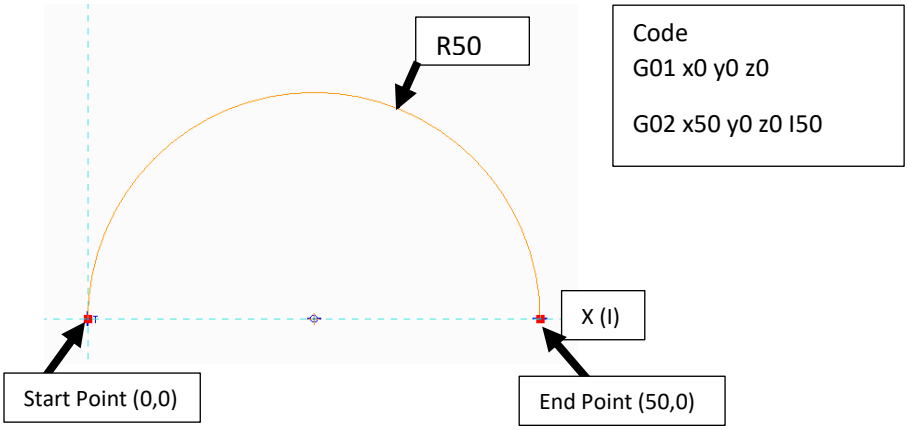
Method 2 Offset Values: I, J, K

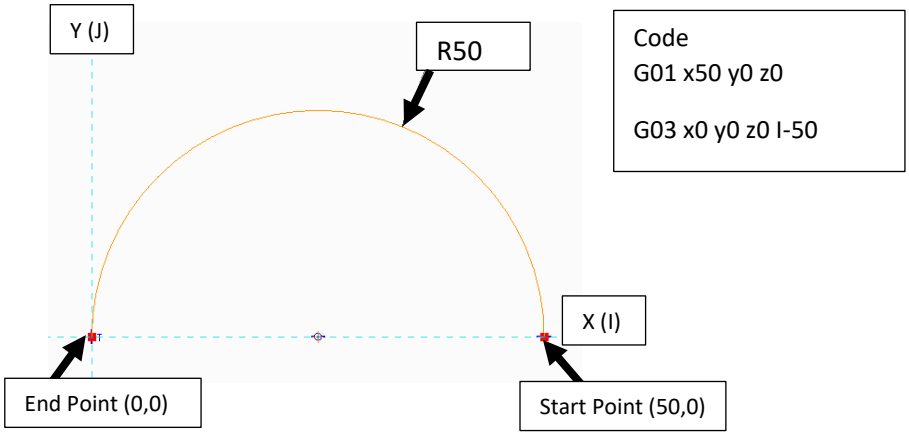
Coding a curve, arc, or circle by radius does not always ensure the proper size in G-Code. Options using code I, K, J allow the user to check the location of curve, arc, or circle by setting values from the start point to locate the center of the object.

The following shows the relationship between axis (*x*, *y*, *z*) and offset value (I,J,K)
I = *x*-axis
J = *y*-axis
K = *z*-axis

Codes I, J, K represent the offset distance from the starting point for the curve, arc, or circle in the direction of motion. The I, J, K value can be either positive or negative based on the starting point and direction of the tool.

Y (J)





a. Change the Code to the following

//Cube Print 10mm x 10mm x 10mm
//1st Wall Front Face
N120 G03 x10 y0 z.1 I5 //I=X-Axis Radius 5 (-5 because of direction of tool; Tool is moving to the right from previous point making the directional motion negative
N130 G01 x10 y0 z10.1
N140 G02 x0 y0 z10.1 I-5 //I=X-Axis Radius 5 (-5 because of direction of tool; Tool is moving to the left from previous point making directional motion negative
N150 G01 x0 y0 z.1

Extra assignment: Add an arc of 5 mm that is 180 degrees on the right face of the cube. Decide the following: 1) choose *y* or *z* direction; 2) concave or convex arc.