TA202A - Manufacturing Processes II

NC Programming

Lecture 4

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How will you program the machine to do this?

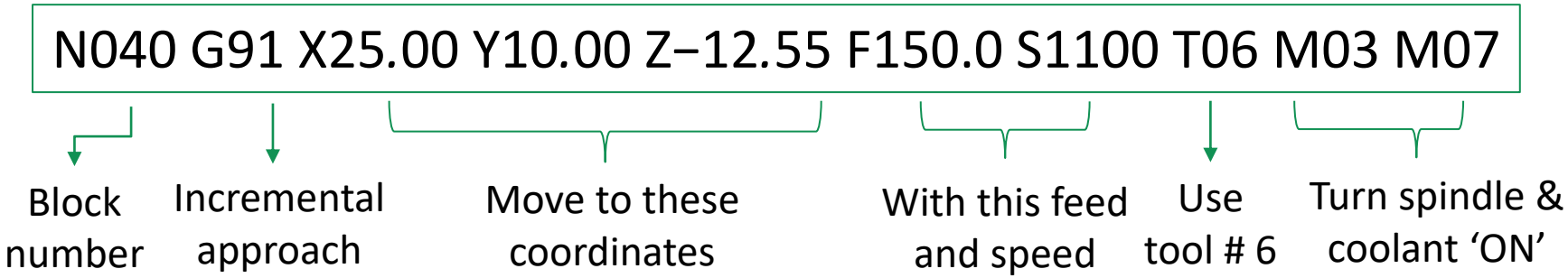
https://www.youtube.com/watch?v=IbV4vIYUg1U

CNC codes and the CNC executive

- NC programs are written in an internationally recognized standard language, called NC codes.
- The CNC executive is the main system software that decodes the NC codes block by block and sends appropriate commands to physical control, computation, and PLC units of the CNC system.
- For example, a 10-mm distance to be traveled at a 200-mm/s feed velocity command can be translated as follows: The real-time clock is set to generate 10,000 pulses at a rate of 200,000 pulses/s (1 pulse = 0.001 mm position). The position pulses (i.e., the discrete velocity commands) are directed to the indicated machine tool axis position control units by converting to their analog voltage equivalent (i.e., typically within ±10 V range). The analog voltage is amplified by the power unit and fed to the axis drive motors to deliver the desired motion.
- Miscellaneous functions, such as spindle ON and tool change commands, are translated as Boolean logic signals (+5 V or −5 V) for PLC units.

Source: Altintas's Mfg. Automation book

NC part program structure



Load tool number 6 on the spindle (T06), rotate the spindle CW at 1,100 rev/min (S1100, M03) and turn the cutting fluid on (M07) before the motion starts. Move the machine tool in 25 mm, 10 mm, and 12.55 mm increments (G91) in the *x*, *y*, and *z* directions with the resultant feeding velocity of 150 mm/min along the tool path. N040 represents the 40th block sequence of the entire part program

Source: Altintas's Mfg. Automation book

Some commonly used NC words

N : Block sequence number.

G : Preparatory function.

X : Primary *X* motion dimension.

Y : Primary *Y* motion dimension.

Z : Primary *Z* motion dimension.

U, V, W : Secondary motion parallel to *X, Y, Z* axis respectively.

A, B, C : Angular dimension about *X, Y, Z* axis respectively.

F : Feed word.

M : Miscellaneous function.

S : Spindle speed word.

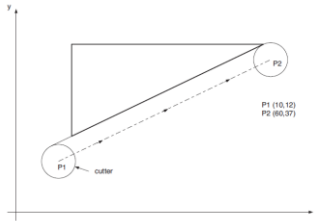
T : Tool number word.

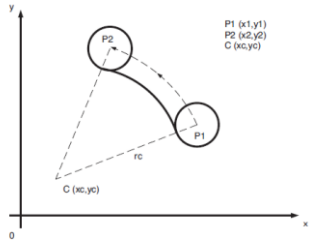
R : Rapid traverse dimension in *Z* axis.

Source: Altintas's Mfg. Automation book

Important preparatory (G) functions

- ***G00****:* Rapid point-to-point positioning
- ***G01****:* Linear interpolation. The tool path velocity is kept constant at the given feed along the indicated straight line.
- ***G02, G03****:* Circular interpolation CW (*G*02) or CCW (*G*03).
- ***G33****:* Constant lead thread cutting.
- ***G70****:* Mode for programming in imperial (inch) units.
- ***G71****:* Mode for programming in metric (mm) units.
- ***G90****:* Coordinate inputs are given in *absolute coordinates* from a fixed Cartesian coordinate center.
- ***G91****:* Coordinate inputs are given *incrementally* from a previous tool location.
- ***G92:*** Showing where the part zero is.

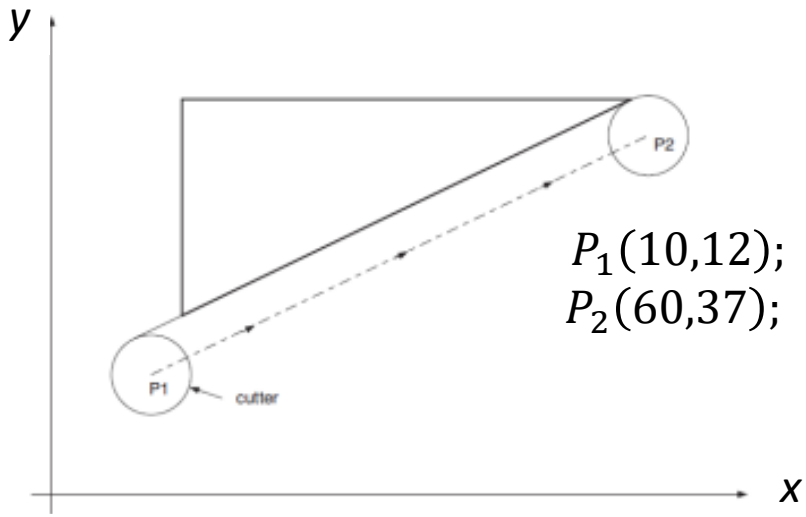




Source: Altintas's Mfg. Automation book

Linear interpolation

The velocities of two axes are controlled to keep the tool on a straight path in a plane of motion. To keep the end mill following the straight line (P_1P_2) at a given vector feed velocity, the linear interpolation command G01 must be used.



$P_1(10,12);$
$P_2(60,37);$

Absolute programming mode

*N*0010 *G*90 *G*01 *X*60.0 *Y*37.0 *F*300.0 or

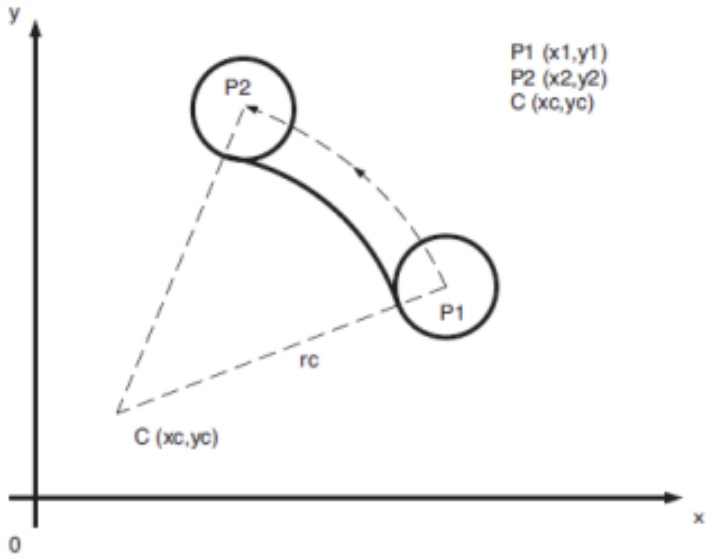
Incremental programming mode

*N*0010 *G*91 *G*01 *X*50.0 *Y*25.0 *F*300.0

Source: Altintas's Mfg. Automation book

Circular interpolation in milling

The velocities of two axes on a plane of motion are varied to keep the tool following the given arc at the specified feed velocity. Some CNC systems require the coordinates of the arc center and arc's end point, whereas others need the radius of the arc and its end point. CNC assumes that the tool is located at the beginning point of the arc.



Using the radius and the end point of the arc

N010 G90 G03 $X\ x_2\ Y\ y_2\ R r_c\ F\ f.$

or

Using center point of the arc and the arc's end point

N010 G90 G03 $X\ x_2\ Y\ y_2\ I\ i_c J\ j_c F\ f,$

wherein: $i_c = x_c - x_1$, $j_c = y_c - y_1$.

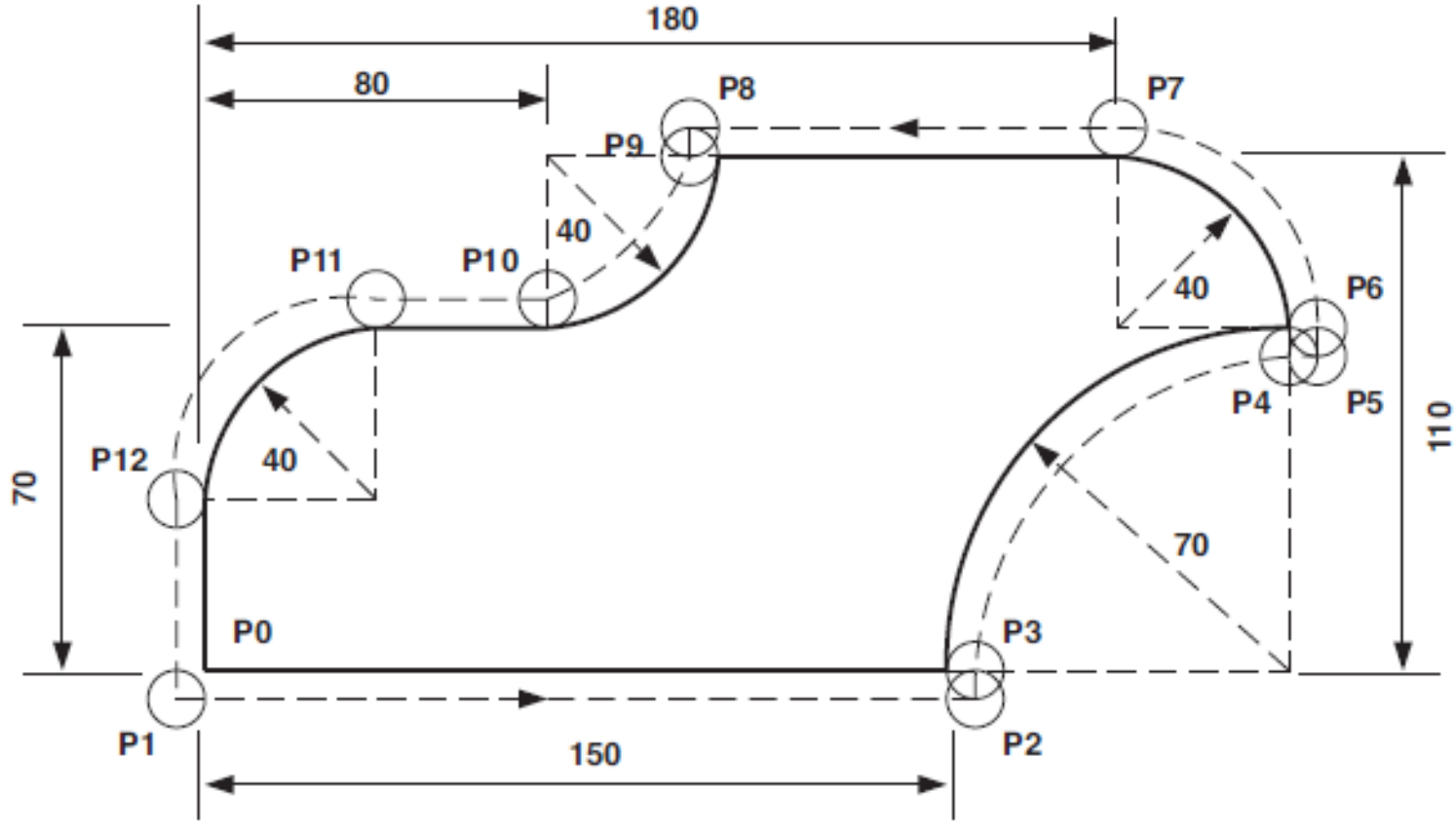
Source: Altintas's Mfg. Automation book

Important miscellaneous (M) functions

- ***M00****:* Program stop. Terminates further program execution after the completion of other commands in the block.
- ***M01****:* Optional stop if it is enabled by the operator. The program continues after the execution of a *continue* command by the operator.
- ***M02****:* End of program indicating completion of machining cycle. Stops spindle, coolant, and feed after the completion of all commands in the last NC block.
- ***M03, M04****:* Start spindle CW (*M*03) or CCW (*M*04).
- ***M05****:* Spindle off.
- ***M06****:* Tool change.
- ***M07, M08****:* Cutting fluid ON (*M*07), OFF (*M*08).
- ***M30****:* End of program. It stops feed, spindle, and cutting fluid and rewinds the NC program to the beginning.
- ***M49****:* Prevents operator from overriding spindle and feed speeds.

Source: Altintas's Mfg. Automation book

Write a CNC program (G code) to make this part



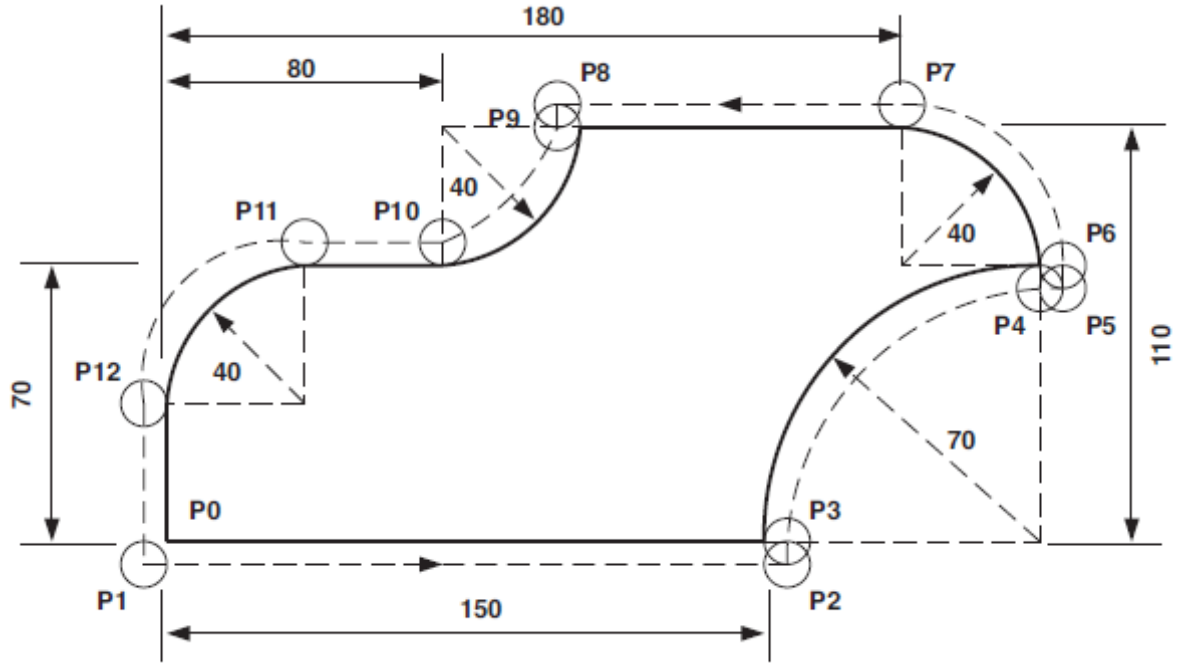
P0 (0,0,0)

Source: Altintas's Mfg. Automation book

First, preparatory functions

N01 G90 - Absolute coordinates

N02 G71 - Metric units (mm)



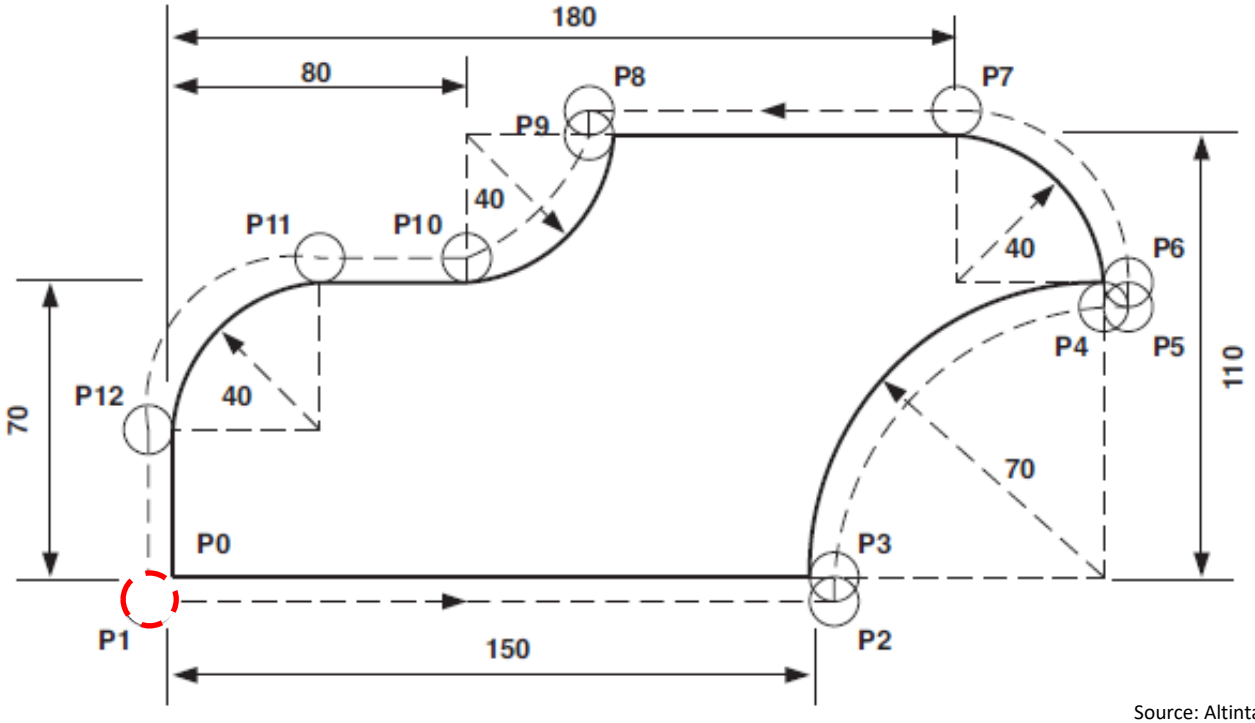
Source: Altintas's Mfg. Automation book

Then, place the cutter with respect to the part

N03 G92 X-12.5 Y-12.5 Z50.0 - Cutter starts from here with respect to the part zero (P1)

N04 G00 Z2.5 M03 S800 - Spindle on CW, move rapidly to 2.5mm above the part (P1)

N05 G01 Z-7.5 F25.0 M08 - Coolant on, plunge with feed in Z (P1)



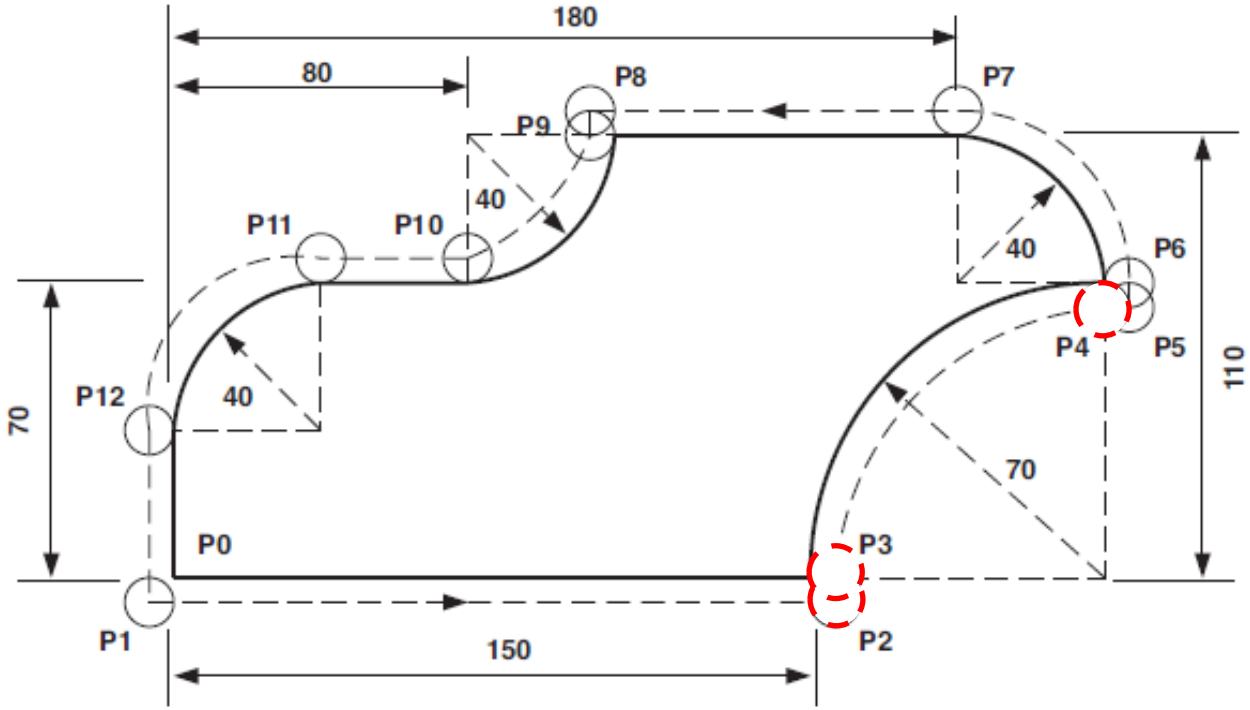
Source: Altintas's Mfg. Automation book

Move to points P2, P3, and P4

N06 X162.5 F125.0 - Move in x with 125 mm/min feed to P2

N07 Y0.0 - Move to P3 at the same feed (125 mm/min)

N08 G02 X220.0 Y57.5 I57.5 J0 - CW circular interpolation (P4)



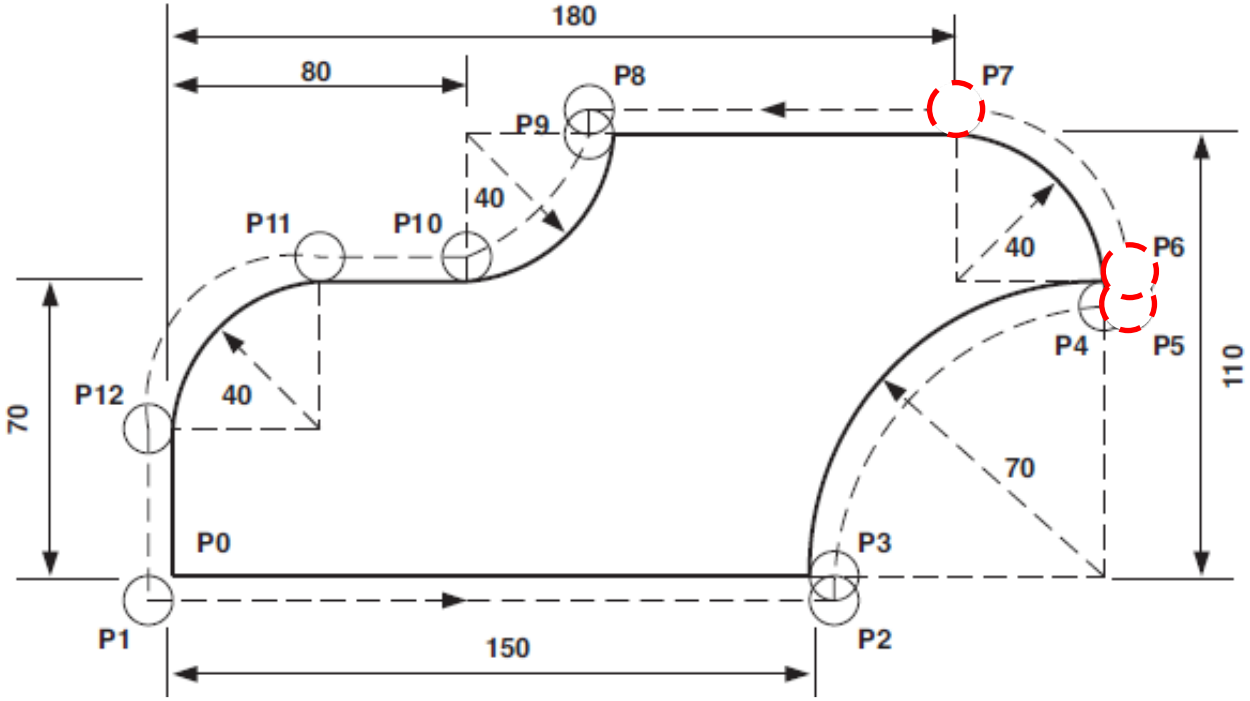
Source: Altintas's Mfg. Automation book

Move to points P5, P6, and P7

N09 G01 X232.5 - Move one cutter radius in the x-direction (P5)

N10 Y70.0 - Move in y (P6)

N11 G03 X180.0 Y122.5 I-52.5 J0 - CCW relative to the tool motion in block N10 (P7)



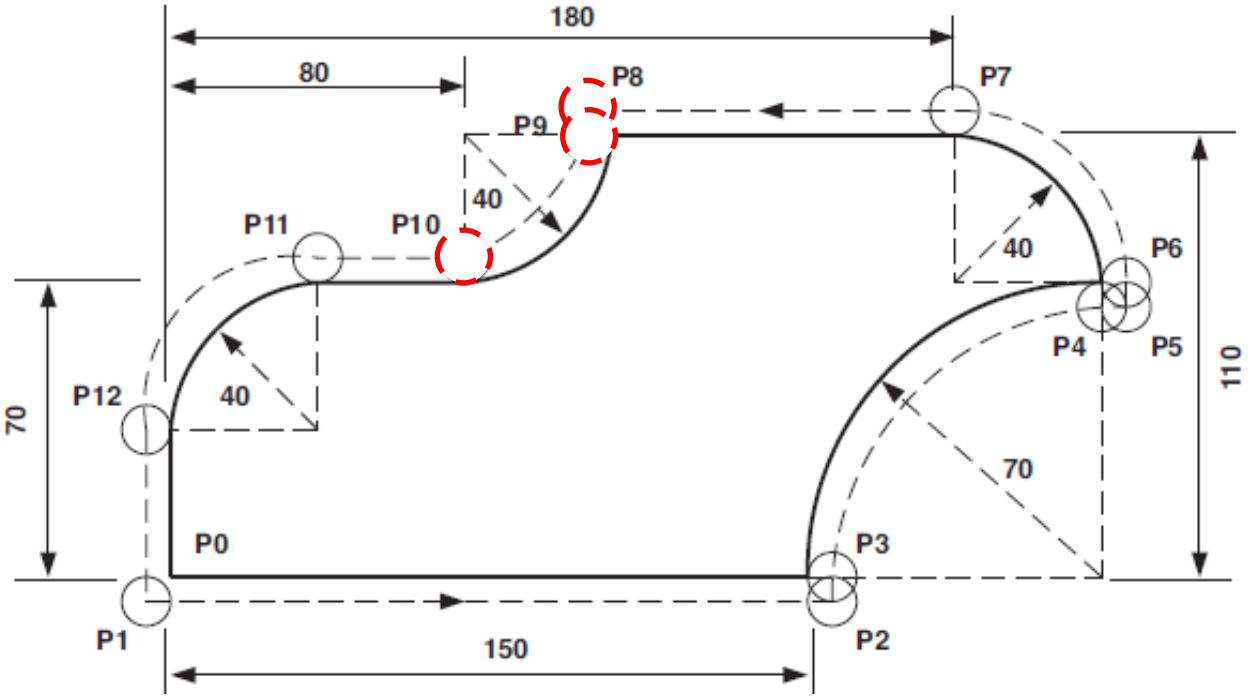
Source: Altintas's Mfg. Automation book

Move to points P8, P9, and P10

N12 G01 X107.5 Move left (P8)

N13 Y110.0 Move to (P9)

N14 G02 X80.0 Y82.5 I-27.5 J0 CW circular interpolation (P10)



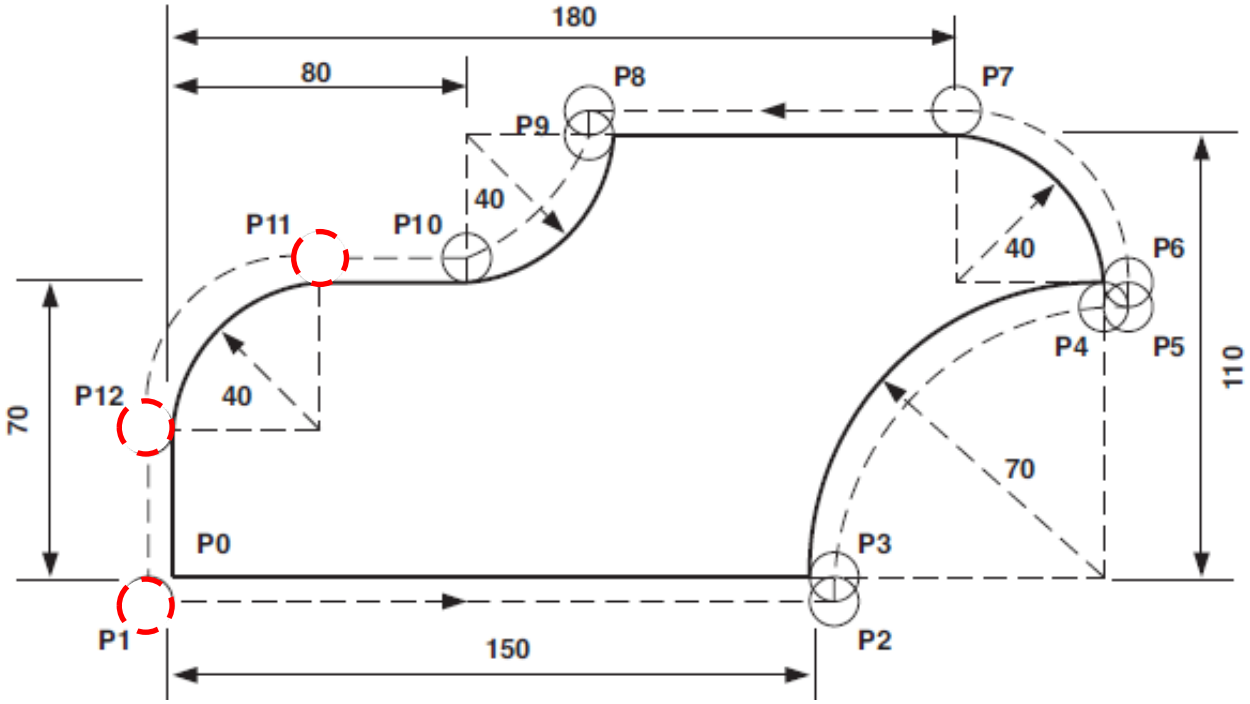
Source: Altintas's Mfg. Automation book

Move to points P11, P12, and back to P1

N15 G01 X40.0 - Move left (P11)

N16 G03 X-12.5 Y30.0 I0 J-52.5 - CCW circular interpolation (P12)

N17 G01 Y-12.5 - Return to starting point (P1)



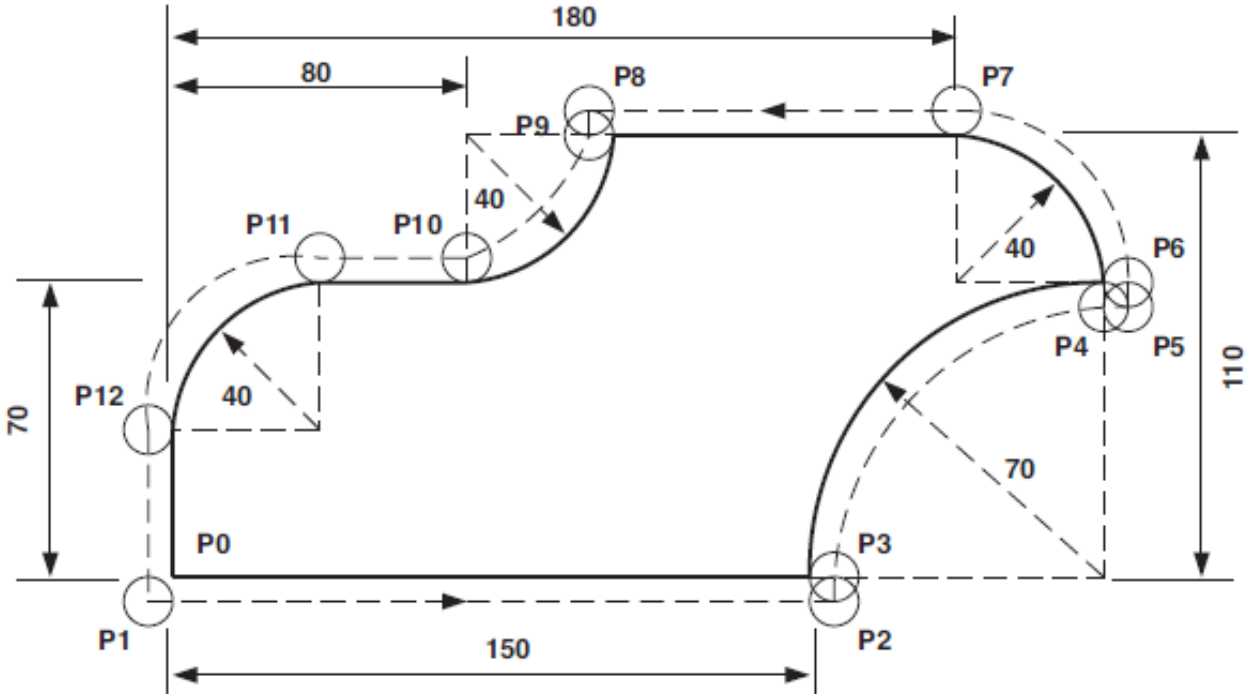
Source: Altintas's Mfg. Automation book

Move the tool back up, and end the program

N18 Z3.8 - Move up to z = 3.8mm position

N19 G00 Z50.0 M09 M05 - Move to Z = 50 rapidly, coolant and spindle are off

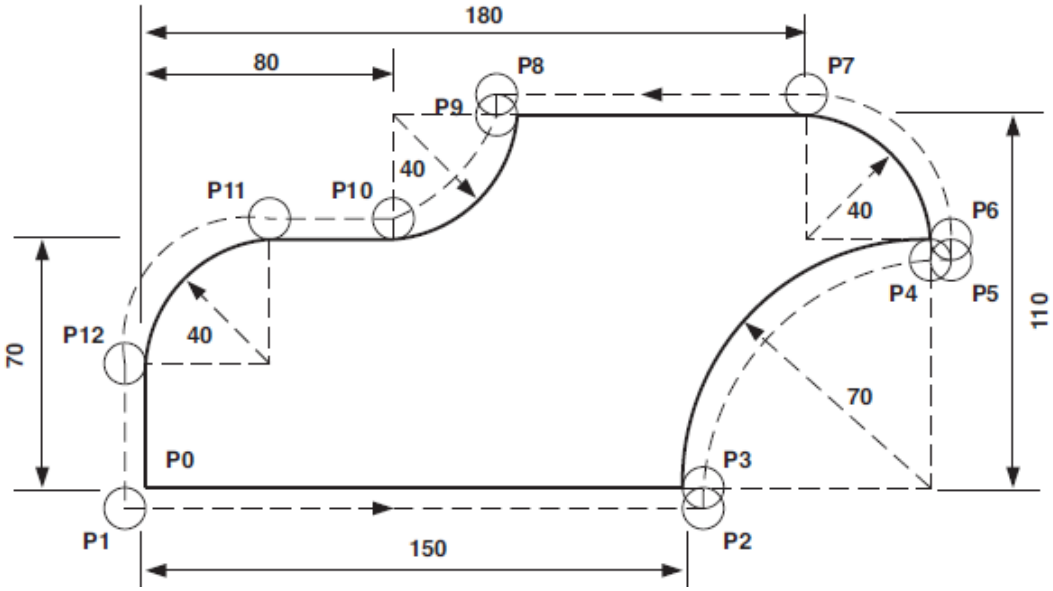
N20 M30 - Program ends.



Source: Altintas's Mfg. Automation book

Recounting the NC program

N01 G90
N02 G71
N03 G92 X-12.5 Y-12.5 Z50.0 (P1)
N04 G00 Z2.5 M03 S800 (P1)
N05 G01 Z-7.5 F25.0 M08 (P1)
N06 X162.5 F125 (P2)
N07 Y0.0 (P3)
N08 G02 X220 Y57.5 I57.5 J0 (P4)
N09 G01 X232.5 (P5)
N10 Y70.0 (P6)
N11 G03 X180 Y122.5 I-52.5 J0 (P7)
N12 G01 X107.5 (P8)
N13 Y110 (P9)
N14 G02 X80.0 Y82.5 I-27.5 J0 (P10)
N15 G01 X40.0 (P11)
N16 G03 X-12.5 Y30.0 I0 J-52.5 (P12)
N17 G01 Y-12.5 (P1)
N18 Z3.8 (P1)
N19 G00 Z50 M09 M05
N20 M30



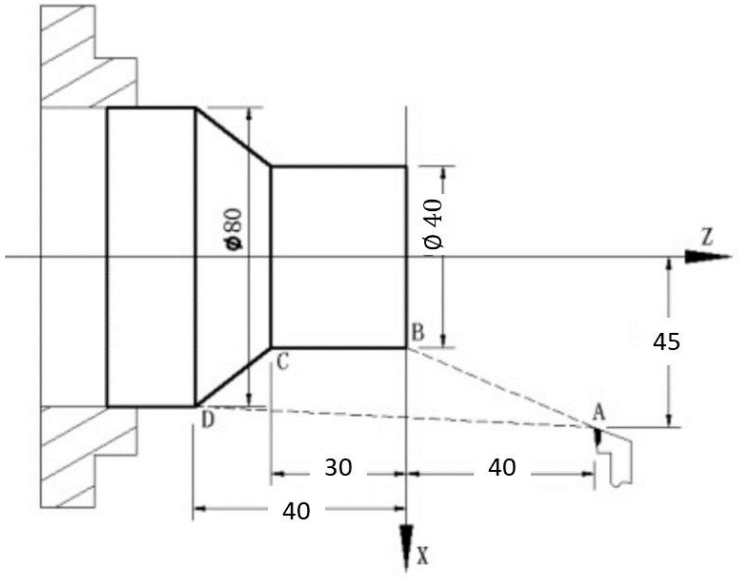
*Note: () are not part of the program

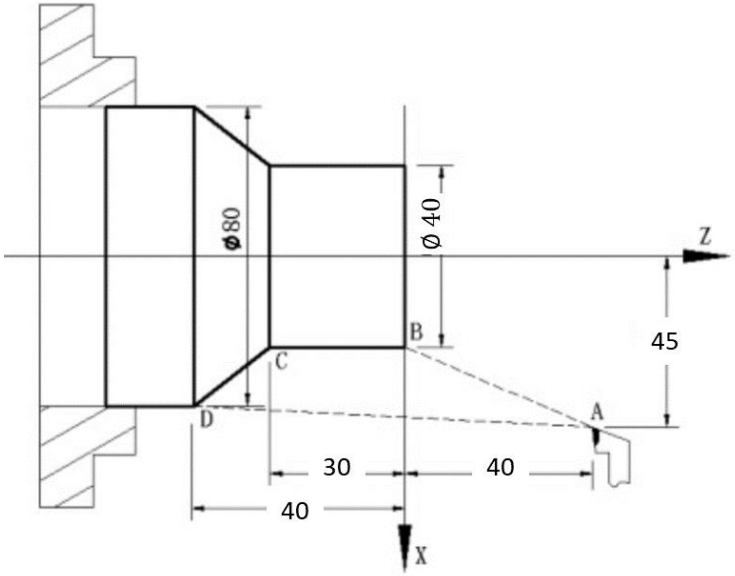
Source: Altintas's Mfg. Automation book

Exam question from 2019

Question 5 [2]

A workpiece with a diameter of 80 mm is provided to you. This has to be machined on a CNC lathe machine to bring it down to the final dimensions shown below. Write a G code to do so. Start and end at point 'A'. Use the incremental mode of programming. Assume you can remove all material in a single pass. The spindle speed must be 500 rpm, and the feed must be 0.2 mm/rev. Note that all dimensions given are in mm. Include all the necessary preparatory and miscelleanous functions you think are important for a full grade. Note that the sketch is not to scale.

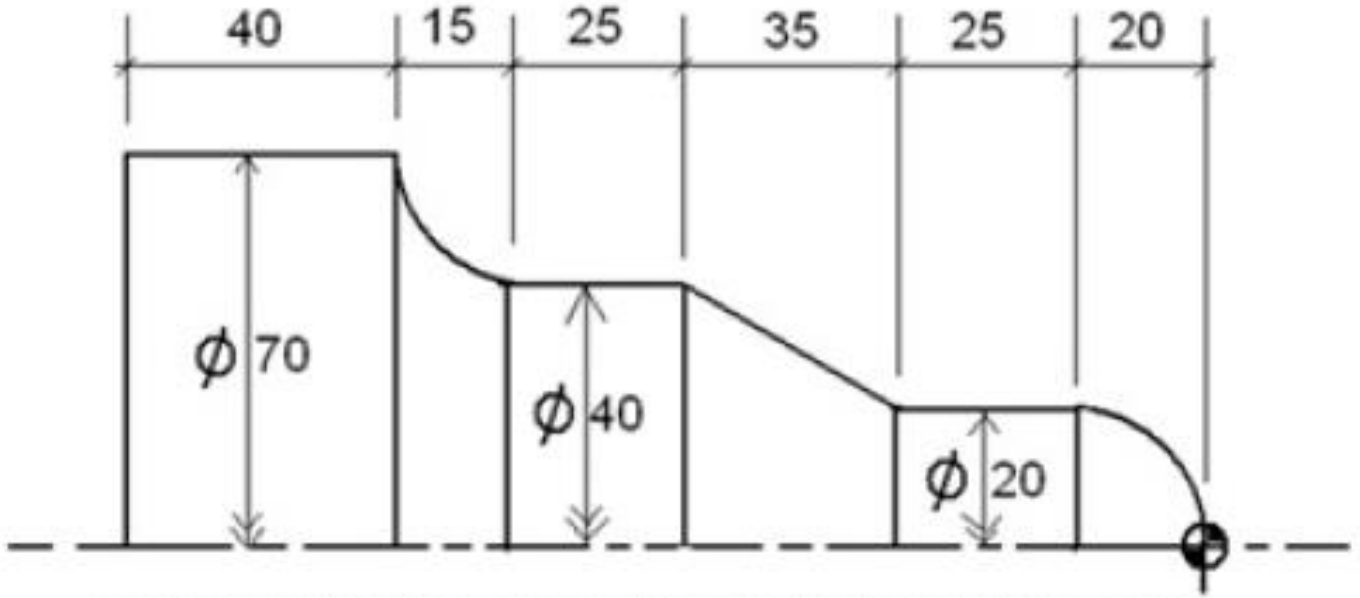




% This program assumes that the tool is already at ‘A’.

Code	Description
N01 G91 G71;	Incremental mode and in SI units
N02 M03 S500 M08;	Turn the spindle on to rotate at 500 RPM, and also turn on the coolant
N03 G01 X-25.0 Z-40.0 F100.0;	Move to point B with a linear feed of 100 mm/min – which is obtained from the given feed in mm/rev multiplied by the speed, i.e., 0.2 mm/rev x 500 RPM = 100 mm/min
N04 G01 Z-30.0;	Tool moves to point C. X position remains unchanged
N05 G01 X20.0 Z-10.0;	Tool moves to point D using linear interpolation
N06 G01 X5.0 Z 80.0;	Back to point A
N07 M30;	End of program

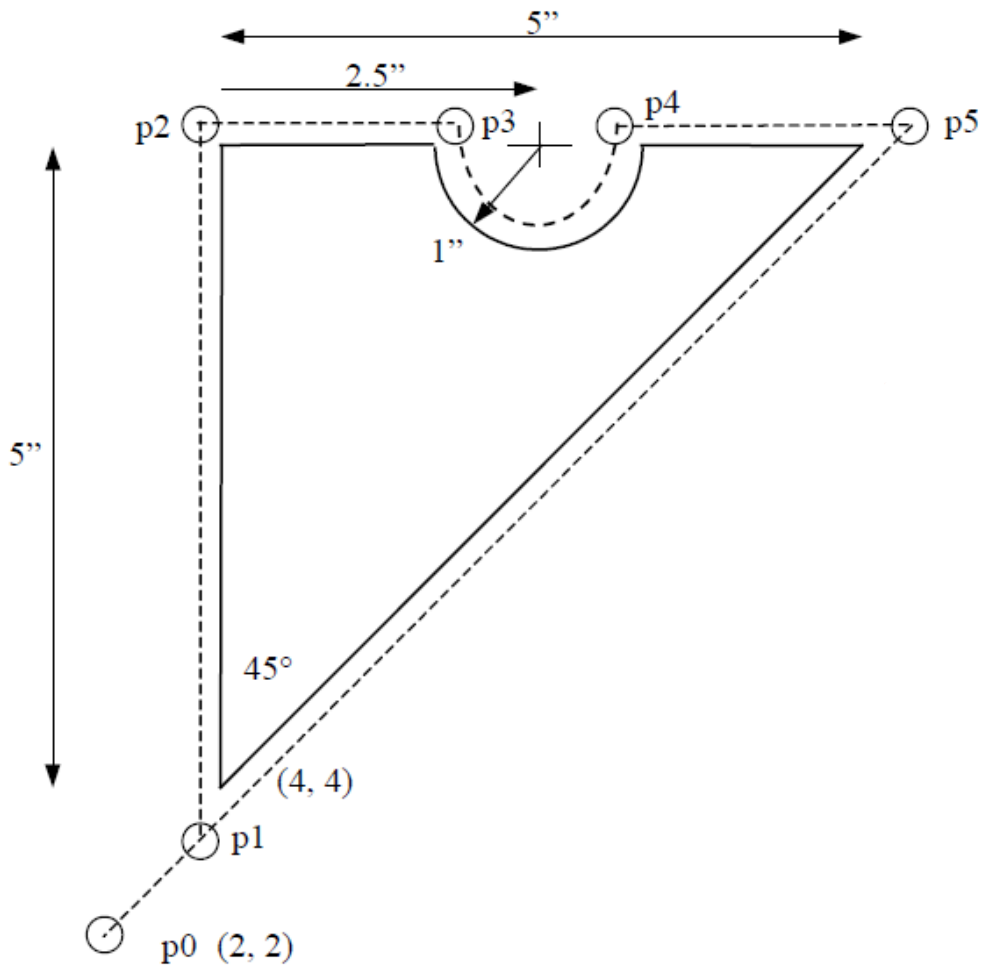
Examples for you to figure G codes on your own



RAW MATERIAL: MS BAR OF DIAMETER 70 MM
AND LENGTH 160 MM
DIAGRAM NOT TO SCALE
ALL DIMENSIONS ARE IN MM

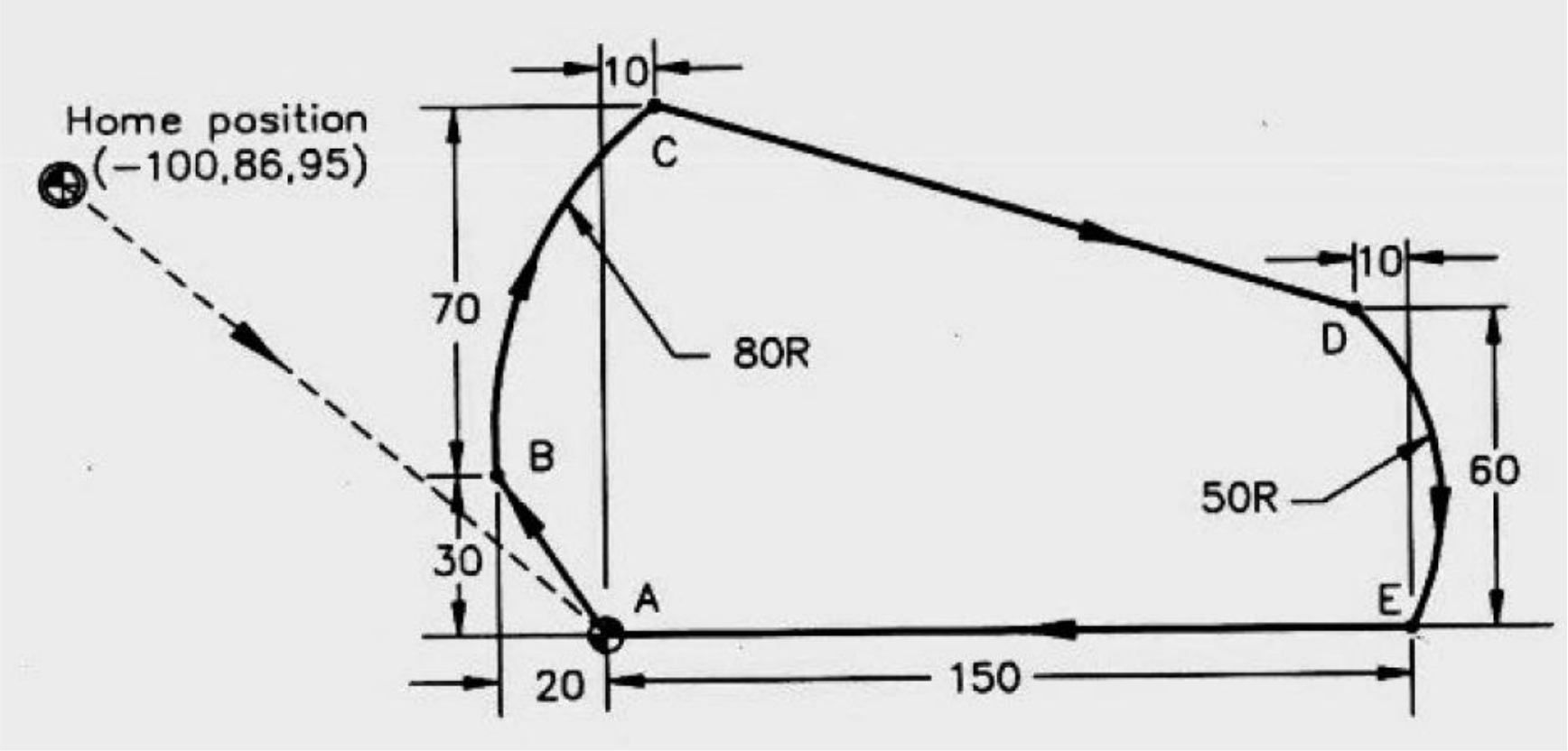
Source: Prof. Choudhury's TA202A notes

Examples for you to figure G codes on your own



Source: Prof. Choudhury’s TA202A notes

Examples for you to figure G codes on your own



Source: Prof. Choudhury's TA202A notes

Alternatively, interpret this CNC code to figure the shape of the part being made.

Example 1:

```
N010 G90 G71 M03 S1200 T01
N020 G00 Z7
N030 G01 Z0 F100 M08
N040 X30
N050 X90 Y10
N060 Y40
N070 G02 G91 X-30 Y30 I0 J30
N080 G01 X-40
N090 G03 G90 X0 Y50 I+10 J-30
N100 G01 Y0
N110 Z7
N120 G00 X30 Y40.0
N140 G01 Z-2.5
N150 Z7
N160 G00 X0 Y0 Z20 M05 M02
```

Source: Altintas's Mfg. Automation book

Alternatively, interpret this CNC code to figure the shape of the part being made.

Example 2:

```
N010 G90 G70 M03 S1200 T05
N020 G00 X0.375 Y0.875
N030 Z0.1
N040 G01 Z-0.1 F10.0 M08
N050 X2.0 F20.0
N060 G02 X2.375 Y0.5 I0.0 J-0.375
N070 G01 Y0.375
N080 X3.625
N090 Y1.25
N100 X3.5
N110 G02 Y1.875 I0.0 J0.375
N120 G01 X3.625
N130 Y2.625
N140 X2.375
N150 Y2.5
N160 G02 X2.0 Y2.125 I-0.375 J0.0
N170 G01 X0.375
N180 Y0.875
N190 Z0.15
N200 G00 Z2.0 M09 M05
N210 M30
```

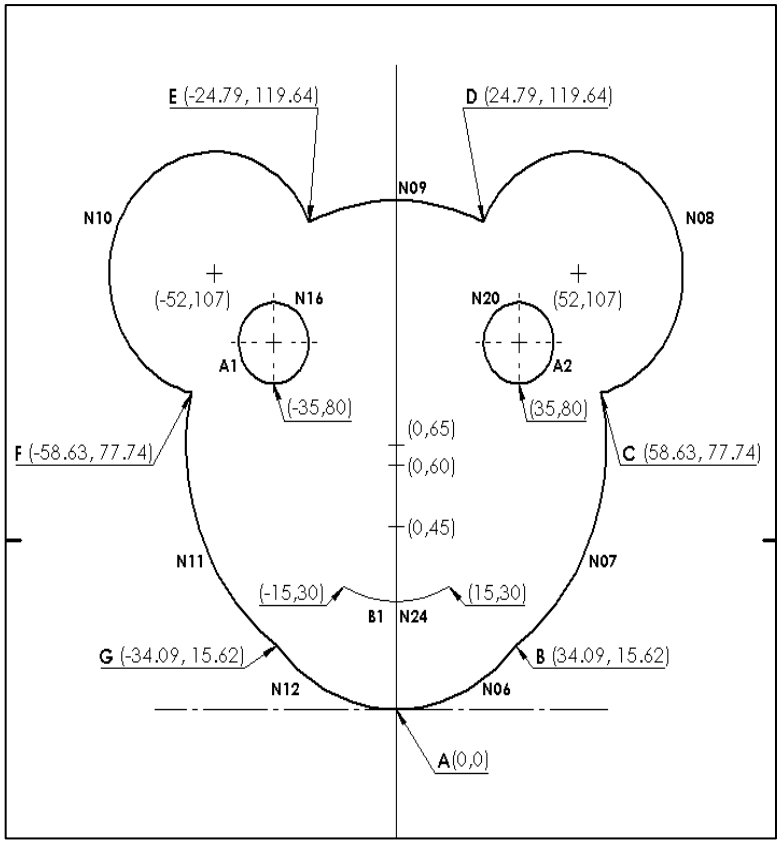
Source: Altintas's Mfg. Automation book

Exam question from 2019, and its solution

Question 4 [4]

Interpret the following NC program block by block. Correctly interpret the G and M functions for each block and plot the complete tool path with the corresponding coordinates. Mark the corresponding NC blocks on the tool path segments. For a complete grade mark each of the A, B, C, D, E, F, and G points on the plot you will make. Also mark the features A1, A2, and B1 on the plot. Note that all dimensions given are in mm. Your plot does not have to be to exact scale.

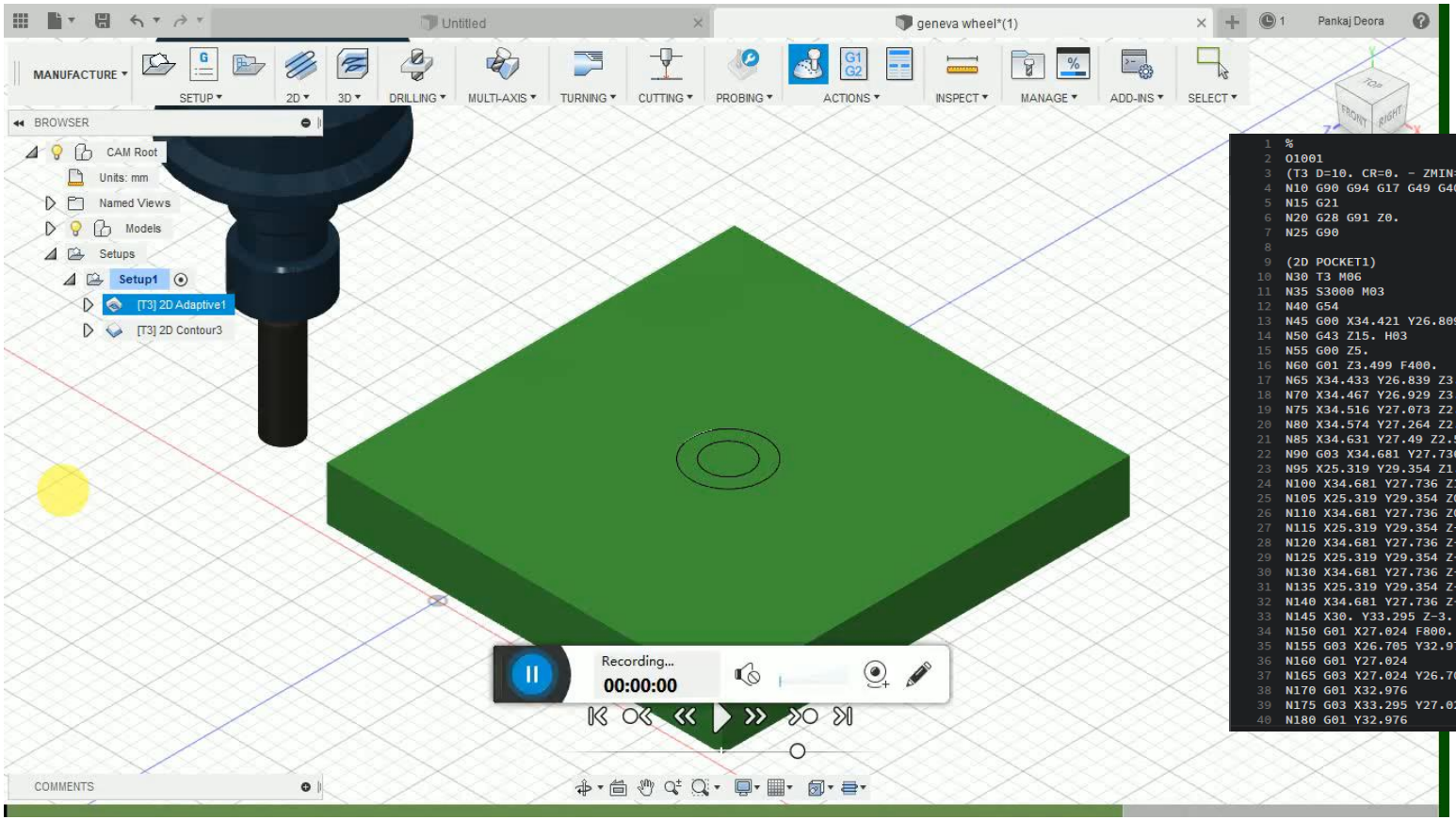
N01 G90;	N15 G01 Z0; (Feature A1)
N02 G71;	N16 G02 X-35 Y80.0 I0. J10.0; (Feature A1)
N03 G00 X0 Y0 Z50.0;	N17 G01 Z50.0;
N04 M03 S900;	N18 G01 X35.0 Y80.0; (Feature A2)
N05 G01 X0 Y0 Z0 F25.0; (Point A)	N19 G01 Z0; (Feature A2)
N06 G03 X34.09 Y15.62 I0 J45.0; (Point B)	N20 G02 X35 Y80.0 I0. J10.0; (Feature A2)
N07 G03 X58.63 Y77.74 I-34.09 J49.38; (Point C)	N21 G01 Z50.0;
N08 G03 X24.79 Y119.64 I-6.63 J29.26; (Point D)	N22 G01 X-15.0 Y30.0; (Feature B1)
N09 G03 X-24.79 Y119.64 I-24.79 J-54.64; (Point E)	N23 G01 Z0; (Feature B1)
N10 G03 X-58.63 Y77.74 I-27.21 J-12.64; (Point F)	N24 G03 X15.0 Y30.0 I15.0 J30.0; (Feature B1)
N11 G03 X-34.09 Y15.62 I58.63 J-12.74; (Point G)	N25 G01 Z50.0;
N12 G03 X0 Y0 I34.09 J29.375;	N26 G01 X0 Y0;
N13 G01 X0 Y0 Z50.0;	N27 M05;
N14 G01 X-35.0 Y80.0; (Feature A1)	



Imagine the G codes for making this!

https://www.youtube.com/watch?v=IbV4vIYUg1U

G code for a part like this?




```
%
O1001
(T3 D=10. CR=0. - ZMIN=-10. - FLAT END MILL)
N10 G90 G94 G17 G49 G40 G80
N15 G21
N20 G28 G91 Z0.
N25 G90

(2D POCKET1)
N30 T3 M06
N35 S3000 M03
N40 G54
N45 G00 X34.421 Y26.809
N50 G43 Z15. H03
N55 G00 Z5.
N60 G01 Z3.499 F400.
N65 X34.433 Y26.839 Z3.246
N70 X34.467 Y26.929 Z3.01
N75 X34.516 Y27.073 Z2.805
N80 X34.574 Y27.264 Z2.645
N85 X34.631 Y27.49 Z2.541
N90 G03 X34.681 Y27.736 Z2.5 I-4.631 J1.055
N95 X25.319 Y29.354 Z1.979 I-4.681 J0.809
N100 X34.681 Y27.736 Z1.458 I4.681 J-0.809
N105 X25.319 Y29.354 Z0.937 I-4.681 J0.809
N110 X34.681 Y27.736 Z0.416 I4.681 J-0.809
N115 X25.319 Y29.354 Z-0.106 I-4.681 J0.809
N120 X34.681 Y27.736 Z-0.627 I4.681 J-0.809
N125 X25.319 Y29.354 Z-1.148 I-4.681 J0.809
N130 X34.681 Y27.736 Z-1.669 I4.681 J-0.809
N135 X25.319 Y29.354 Z-2.19 I-4.681 J0.809
N140 X34.681 Y27.736 Z-2.711 I4.681 J-0.809
N145 X30. Y33.295 Z-3. I-4.681 J0.809
N150 G01 X27.024 F800.
N155 G03 X26.705 Y32.976 J-0.319
N160 G01 Y27.024
N165 G03 X27.024 Y26.705 I0.319
N170 G01 X32.976
N175 G03 X33.295 Y27.024 J0.319
N180 G01 Y32.976
```