

Getting Started with the Turning Center Programming Curriculum

Our course curriculums have been designed to address the needs of instructors working in three similar, but subtly different, learning environments. First, instructors working for colleges, vocational schools, technical schools, and universities will find our ready-made course curriculums especially easy to learn and implement. They make it especially easy to prepare to teach each lesson. It has been our experience that instructors teaching their first CNC courses for technical schools come from one of but two backgrounds. Either they have extensive CNC experience (possibly through working for a manufacturing company), but limited teaching experience --- or they have extensive teaching experience (teaching other courses for the school), but limited CNC experience. It is rare to find a new CNC instructor who has extensive experience in both fields. These course curriculums will help in both cases.

Our proven curriculums, structured lesson plans, audio guidance, instructor notes for each lesson, and concise lesson format will minimize the amount of work an instructor must do in preparation for teaching a new course -- and minimize the work that must be done when getting ready to teach each lesson *during* the course. The proven *key concepts* approach and fly-in text boxes make it easy for even an inexperienced instructor to stay on track during each presentation. And - the high animated slide presentations and comprehensive student manuals will make experienced instructors who may be a little weak with their CNC skills look like CNC experts!

Second, instructors working for companies having their own in-plant training will also find this curriculum easy to implement. Few companies have the resources (or the desire) to completely develop this kind of program from scratch. Additionally, success for an industrial training program is *not* a simple matter of the student getting a good grade. When finished, students *must* know how to safely program and/or operate the machine tools. Training failure will result in scrapped parts, crashed machines, and possibly even injured operators. The real-world exercises in the student workbook will prove the student's knowledge of presented materials each step of the way. When the student successfully completes this course, you can rest assured that they comprehend the subject matter.

Third, training consultants (or instructors working for technical schools) that provide custom training for manufacturing companies will find that this course curriculum makes it easy to teach CNC to their clients. Utilizing standard (and highly portable) computer equipment, the comprehensive slide show can be done on-the-road, meaning instruction can take place anywhere.

Five factors that contribute to learning

While experienced instructors may find this information somewhat basic, we wish to ensure that beginning instructors understand the importance of setting up a good learning environment. Of course, the better the learning environment, the better the training program will be, and the faster, and easier it will be for students to learn. This course curriculum is well suited to facilitating the learning environment in all five ways.

Motivation is the most important factor in any learning environment. First and foremost, students must be highly motivated to learn. Motivation will be the driving force that makes students *stick with it* even when they are having trouble understanding information being presented during training. Indeed, *any* problem with learning can be overcome if the student's motivation is high enough. But just as important, the instructor must also be highly motivated to teach. You must have a burning desire to relate information during training in a way students can understand. When student are having problems, the instructor must be motivated enough to spend the extra time it takes to ensure that the student eventually understands presented material. This can be very challenging since students' aptitude levels vary. This course curriculum inspires motivation on both counts. The colorful and illustrative slide show, the tutorial nature of the manual, the pertinent practice exercises, and the highly structured key concepts

approach will capture and hold your students' attention, and make it easy for them to *stay* motivated. For the same reasons, instructors should find this course almost *fun to teach* - and it is easy to stay motivated with tasks you enjoy.

Aptitude will determine how quickly and easily learning will occur. The aptitude of the instructor for making interesting and attention-holding presentations, giving pertinent analogies, preparing illustrative visuals, designing realistic practice exercises, and in general, keeping the students interested level high will contribute to determining how quickly and easily students catch on to new material. *Instructors with high aptitude make it easy for students to learn.* In similar fashion, the students' aptitude for learning manufacturing related functions and specifically CNC also contribute to how quickly and easily learning takes place. *Students with high aptitude make it easy for the instructor to teach.* This course curriculum pays particular attention to trouble spots. From our own teaching experience, we know where students with minimal aptitude tend to have the most problems and make ample analogies to keep even the most complex topics of CNC as simple as possible to understand.

Presentation is the heart of training. The better the instructor prepares and delivers the presentation, the easier it will be for students to learn. Presentation can consist of many things, including the instructor's lectures, demonstrations, simulations, overhead and projector slides, videos, and anything else that helps to convey an idea. This is the strong point of our curriculums. You will find it very easy to get your ideas across with but a small amount of preparation before delivering each lesson. While you still have to talk, the slide shows, fly-in text boxes, and instructor notes will make sure you know what to say!

Repetition reinforces a student's understanding of learned information. Even students with extremely high aptitude will find it difficult to learn from presentations made only once. *All* training sessions should begin with a review of recent presentations. Depending upon the frequency and duration of each training session, entire sessions should, at times, should be devoted to reviewing what students should already know.

Reviews also help the instructor limit how much complex subject matter is presented during each session. Knowing that certain information will be reviewed, the instructor can avoid getting too deep into complicated topics during the first time the information is presented. Only after students have a firm grasp of basics concepts will the instructor dive deeper and introduce more complicated variations. While you may wish to do more, this curriculum includes a "Review" presentation. For each key concept, we first name the key concept and list the related lessons. We then provide a review slide for each lesson in outline format that lets you reiterate key points about each major topic in the lesson. These are simply bullet points, so you'll have to describe topics being reviewed without the benefit of graphics and animations. If students are having trouble during reviews, it should be taken as a signal that they don't truly understand the subject matter. In this case, you can easily go back to the lesson being reviewed, call up the *presentation links* slide, and click on the link that brings you to the topic in question.

Practice with reinforcement acts as the gauge to judge the success of training. Well designed practice exercises should be realistic, forcing the student to do things in the same way they must when training is completed. Reinforcement must come as the result of the students' practice. If the student demonstrates a firm understanding of the presented information, reinforcement should praise the success. On the other hand, if practice exposes a student's lack of understanding, reinforcement should come in the form of repeated presentations (review) and more practice, ensuring that the student eventually catches on. This course curriculum includes a comprehensive set of practice exercises as well as several quizzes in the student manual, to confirm understanding each step of the way.

The Key Concepts approach

Most training experts agree that students learn best when they have *a light at the end of the tunnel*. The more complex the subject matter, the more important it is to tell (better yet, show) the student early in the training program just what they must master to complete the course. One important benefit of our proven key concepts approach you can do just that. With our curriculum, there are four key concepts to CNC setup and operation. Early on in the course you can truthfully say *“If you can understand just four basic ideas, you are well on your way to becoming proficient as a CNC setup person or operator.”* This gives your students a light at the end of the tunnel and makes learning CNC seem as easy as possible. Also, as you go through the course, students will know where they stand each step along the way.

Another benefit of our key concepts approach is that it lets you work at a very broad level. There are many different CNC machine and control manufacturers making this kind of equipment. Though there are many commonalities in how basic machine utilization is done among current CNC machines, no two machines will be handled exactly the same. For this reason, students will likely have to adapt to their own machines once they complete your course (especially if you teach in a technical school). In each key concept you will be stressing the broad and general reasoning behind how CNC functions, showing students *why* they must do things as importantly as *how* they do them. This reasoning can be applied to any form of CNC machine tool. Once the student understands this reasoning, *then* you will show specific techniques needed to apply the key concept to one very popular CNC control.

By the way, all of the specific examples we give in the student manual and during the slide shows are in the format for a Fanuc control. We chose Fanuc as our sample control since it is the most popular control in the industry, and since several control manufacturers (Mitsubishi Meldas, Mazatrol, Yasnac, HAAS, Fadal, and others) claim to be *Fanuc-compatible*. However, you must be prepared for the possibility that your students will be working with a control made by a manufacturer that is not Fanuc-compatible. Again, rest assured that the ten key concepts apply to every current CNC control on the market. Only the specific techniques needed to apply each key concept must change.

Yet another benefit (from an instructor’s standpoint) of the key concepts approach is that the course can end at any time once students understand the key concepts. One major problem in any training program is the limited time available for training. While manufacturing companies may have the luxury of extending a course if students are slow in picking up the material, technical schools commonly work on a very rigid time frame. If students are slow in picking up the material and getting bogged down with the details of CNC machine utilization (asking many time consuming questions), the course may end before you get through all the material. While this presents a problem even with the key concepts approach, the effects of the problem can be minimized. As long as students understand the reasoning behind each key concept, it will be just a matter of time until they figure out the details. Given our extensive and highly tutorial course manual, any student with motivation will eventually figure out the details (possibly even *after* the course ends).

One last benefit we’ll mention for the key concepts approach is that it makes reviewing the material easy. Since there are only six key concepts, they are easy to remember. You can simply restate each key concept (using the “review” slide presentation) and ask pertinent questions to confirm your students retention of material previously presented.

Lesson structure

These six key concepts are divided further into concise lessons. For the turning center programming curriculum, there are nineteen lessons. Lessons do vary in length (from about 10 minutes of presentation to about an hour), and you can find an approximate time of presentation at the end of the Lesson Plans manual.

Here are the Key Concepts and lessons. Key Concepts are shown in bold. Lessons are indented.

1: Know your machine from a programmer's viewpoint

- 1: Machine configurations
- 2: Understanding turning center speeds and feeds
- 3: Visualizing program execution
- 4: Program zero and the rectangular coordinate system
- 5: Introduction to programming words

2: You must prepare to write programs

- 6: Preparation steps for programming

3: Understand the motion types

- 7: Programming the three most basic motion types

4: Know the compensation types

- 8: Introduction to compensation
- 9: Geometry offsets and wear offsets
- 10: Tool nose radius compensation

5: You must provide structure to your CNC programs

- 11: Introduction to program structure
- 12: Four types of program format

6: Special features that help with programming

- 13: One-pass canned cycles
- 14: G71 and G70 – rough turning and boring multiple repetitive cycles followed by finishing
- 15: G72-G75 – other multiple repetitive cycles
- 16: G76 – threading multiple repetitive cycle
- 17: Working with subprograms
- 18: Other special programming features
- 19: Special machine types and accessories

Student's Course Materials:

All student course materials are copyrighted and must be purchased from CNC Concepts, Inc. Current pricing can be found on our website (www.cncci.com).

Student Manual - These highly tutorial manuals precisely follows the slide show presentations you will be making. They are very detailed and will provide the student with an excellent way to review information you present, during the course and long after the course is finished. There is one student manual for each curriculum. Exercises are included right in the course manual. Of course, you will also want to have this manual to use as a master as you present the course.

Special note about answers to the exercises

Since the student manual is a self-study manual, answers to the exercises are provided at the end of the manual (on page 367). If you do not want your students to have access to these answers as they go through your class (you want to grade them), we suggest that you ask your students to pull these pages from the manual and give them to you during your first session. Ask them to be careful when removing the answer pages (remove one or two pages at a time) so as not to damage the binding of the manual.

Instructor's Course Materials:

CD-rom disk including all instructor materials – The disks include the following instructor materials:

PowerPoint Slide shows:

Each lesson includes a slide show to provide the visuals you need to teach. They are all computer generated graphics and animations that really help you make your points during the class.

Lesson topics links slide – Every lesson begins with this special slide. The lesson topics slide provides links to every main topic for the lesson. Every slide in the lesson will have a “Lesson topics” link at the bottom that returns you to this slide. Again, the lesson topics slide lists the main topic to be covered by the lesson. When you click on a topic, the presentation will skip to the slide that begins that topic. This can help in three ways. First, it provides a very interactive way to get to topics of interest (you will be clicking on topics during your presentation) as you teach. Second, you will be able to easily skip topics that you don’t want to cover. Just remember that once you click on a topic, the presentation will simply continue from the slide that begins the topic. If you get into another topic (that you don’t want to cover), simply click the Lesson topics link in the lower left corner. And third, this special slide should really help when reviewing. It makes an excellent list of bullet points that you can review in a nice logical order. And of course, if students are having problems, you can easily click on the trouble-causing topic and re-present the information related to the topic. The lesson topics slide also makes a great “presentation plan”. You’ll be able to quickly introduce the main topics as you start each lesson and summarize them when your finished with the lesson.

Fly in text boxes – In addition to graphics and animations throughout the slide shows, we also include *fly-in text boxes* on most slides to help you understand where the presentation is going. In some cases, the *fly-in text box* will remind you to make some important point about the topic at hand. In other cases, they are included at a change of pace in the presentation, and provide the next few words of your presentation. In all cases, they will help you stay on track and minimize the amount of preparation you must do to get ready to teach.

Review slide presentation – A link from the startup page, this special presentation is intended to help you review material throughout the course. As stated, at least ten percent of each session should be spent reviewing information that you previously presented. This presentation is made up of at least two slides for each key concept. The first slide for each key concept shows the key concept name and the lesson/s related to the key concept. This is followed by a list of bullet points for each lesson in the key concept. Each list of bullet points is identical to the presentation links slide for the lesson. So if students are having problems during the review, you can easily call up the related lesson, go to the presentation links slide, and click on the topic of interest. Since this collection of slides makes for a very good outline for the entire course, we include a printout of the Review slide show later in this Instructor Manual.

All presentation files are easily started from the startup page, named a_startup.ppt on the CD-rom disc.

PowerPoint Viewer software:

All slideshows are prepared in PowerPoint. In order to view/display/print the slide shows, you must either have the actual PowerPoint software (PowerPoint 95 or above) or the PowerPoint Viewer. We provide the PowerPoint Viewer on disk one. Since the PowerPoint Viewer does not let you modify slides, and since it requires that slide shows always start from the first slide (not very convenient when you’re trying to get to a slide in the middle of a lengthy presentation), we urge you to get the actual PowerPoint software. It can be purchased separately, and it comes with most versions of Microsoft Office.

What you still need:

In order to show the PowerPoint slide presentations to a group of people, you need the following items.

A computer with Windows - Just about any current model computer will work. If using a desktop computer, you can easily watch the monitor of the computer (facing your audience) to see the slide show while slides are displayed behind you by the projection system. Since the left mouse button advances the slides, you even have a remote slide advance button. If portability is an issue, keep in mind that all current notebooks have ample power to run the presentation software. However, be careful in your selection. Many notebooks do not allow you to send data out through the video port *and* see the slide

show on the LCD screen of the notebook at the same time. Without this ability, you may have to turn around to see your slides, which can be distracting to your audience.

A way of displaying the screen show - You have several alternatives in this regard. All involve using a device that takes data from the video port of your personal computer. First, many schools already have a projection system that can display information from a personal computer. Basically, anything that can be shown on the computer screen can be displayed through the projection system. Second, you can use a device that sits on top of an overhead projector to display your screen shows. In essence, this device makes a transparency of what ever is on the display screen of the computer (we don't like this kind of device because of its brightness – it can really hurt your eyes if you try to use it as a normal overhead projector). Third, and especially if price is a concern, you can use a simple scan converter (about \$200.00 - \$300.00) and display your screen show on any television that has a *video in* connector (as most do). If you must use the RF connector of the television (where an antenna plugs in), an RF converter must be purchased. Since there are so many alternatives for displaying your slide shows, we welcome phone calls (847) 639-8847 if you have questions about your alternatives.

Putting It All Together

Getting Ready To Teach

As stated earlier, though these course curriculums dramatically reduce the amount of preparation you must do, they do not eliminate it completely. And as any experienced instructor will agree, the key to successful presentations is in becoming comfortable with the material you present. And the only way to get comfortable is through adequate preparation.

Before your first course:

Skim the entire curriculum - Though you do not have to be perfectly comfortable with every detail of the curriculum to begin teaching, you will at least need to understand where the course is going. You can use the course outline, lesson plans, instructor notes, and student manual to gain an appreciation for the six key concepts and the lesson structure being used.

Before beginning each key concept:

Get comfortable with all lessons in the key concept - While some key concepts have but one lesson, most have more. Be sure you feel comfortable with all major points you need to make before you begin teaching. Again, use the course outline, instructor notes, and student manual to increase your comfort level with the entire concept.

Before you deliver a lesson:

Get ready to teach! - Study the lesson plan and go through the in order to gain an understanding of key points that must be delivered during your presentation.

Practice! - Especially before your first few lessons, get comfortable with your equipment and the material you present by practicing your presentation. In addition to getting you ready to deliver each lesson, this should give you a rough idea of how long it will take to deliver each lesson at your own pace.

During your presentation of each lesson:

Tell them what you're going to tell them - The Lesson topics slide (first slide of every lesson will help you prepare your students for what they will be learning. While you don't have to dwell on this slide too long, it will let them see what is included in the lesson.

Tell them - Go through the lesson, using your slide show as a guide. Be sure to point out the page numbers and sections in the student manual where the information is also included for their own independent study. Be sure everyone is catching on. Encourage participation, questions, and comments. While you should find adequate analogies in the slide show to stress the most complex topics, you must be prepared to handle special questions and concerns. Have a blackboard or overhead available for making special points.

Tell them what you told them - Get back to the Lesson topics page and review the key points of the lesson. Again, encourage questions and participation. The idea is to confirm that students truly understand presented material.

After you finish each lesson:

Assign and check practice exercises - The students' responses to the practice exercises makes an excellent way to gauge your students' understanding of the subject matter. If you find that students are not doing well, it should be taken as a signal that you must review key information. If students are doing well, be sure to praise them.

As you get deeper into the course:

Review often - No student will retain every word of every presentation you make during a course as lengthy as these. On average, you should spend about 10% to 20% of your session time in review, depending upon how well your students are doing. The more problems they are having, the more time you should spend on review. One excellent way to review is to question students from the previous exercises to confirm their retention. The review slide presentation can be activated from the startup page, and will help you review all key topics.

Let students know where they stand - Be sure everyone knows how they are doing as they progress through the course. Assign special exercises and labs for those students having the most problems. Push those students doing well to go further.

Answers to Exercises

If you are attending a class that uses this text, your instructor may ask you not to look at these answers prior to submitting your work. (Each exercise can be removed from this text without removing any content.) On the other hand, if you are reading this text on your own, you can use these answers to check your work.

Exercise 1: Machine Configurations

- | | |
|---|--|
| 1) true | 8) M03 - spindle on forward
M04 - spindle on reverse
M05 - spindle off |
| 2) true | |
| 3) false | 9) c. S word |
| 4) Answers can include chucking style, twin spindle horizontal style, vertical style, twin spindle vertical style, engine lathe style, and gang style. We also mentioned Swiss style turning centers. | 10) b. F word |
| 5) a. The X axis is the motion direction perpendicular to the spindle centerline. It is the diameter-controlling axis.
b. The Z axis is the motion direction to the spindle centerline. It is the length-controlling axis. | |
| 6) a. X plus (for most machines) is the direction opposite the spindle centerline (getting bigger in diameter).
b. Z plus is the direction opposite the chuck face. | |
| 7) The T word has a four digit format. The first two digits specify the tool station number. The second two digits specify the wear offset number. | |

Extension question answers:

- 11) This process breaks an important rule of basic machining practice which states “you should rough everything before you finish anything. The finish face and turn operation should not be done until after the drilling and rough boring is completed.
- 12) We cannot provide answers to this question. Your company or school could have a bar feeder, steady-rest, tool touch-off probe, part catcher, live tooling, automatic tool changer, and many other programmable devices.

Exercise 2: Visualizing Program Execution

- | | |
|--|---|
| 1) a. the operation being performed
b. the material being machined
c. the material of the cutting tool | 7) true |
| 2) in surface feet per minute (meters per minute in metric) | 8) false |
| 3) in per-revolution fashion | 9) true |
| 4) $\text{rpm} = \text{sfm times } 3.82 \text{ divided by cut}$ | 10) G96 S400 M03 |
| 5) a. in surface feet per minute (or meters per minute): G96
b. in rpm: G97 | 11) G97 S550 M04 |
| 6) a. in per-revolution fashion (ipr or mmpr): G99
b. in per-minute fashion (ipm or mppm): | 12) a. easy to program spindle speeds
b. finish is consistent throughout workpiece
c. tool life is improved |

13) Increase in cycle time due to spindle's constantly changing speed in rpm during approach and retract movements

examples of when the per-minute feedrate mode is required.

14) per revolution mode (G99)

16) per-revolution mode (G99)

15) When you want to make a feedrate movement with the spindle stopped. Drawing out the bar during bar feed, light broaching, and live tooling operations are

Extension question answer:

17) The machine will creep along, taking your programmed feedrate (a tiny one) in inches per minute.

Exercise 3: Visualizing The Execution Of A CNC Program

- 1) The person performing the operation manually has every-thing in front of them and available. The person preparing the CNC program must do so with only print, pen, and paper
- 2) true
- 3) true
- 4) true
- 5) false
- 6) true
- 7) false
- 8) a. 0.0007
- 9) A modal word will set a state the remains in effect until changed or canceled.
- 10) An initialized word will be automatically instated when the machine power is turned on.

Extension question answers:

- 11) In order to write CNC programs, a programmer must be able to visualize machining operations as the program is written. Without this ability, it will be impossible to write the program mode at the beginning of the program.
- 12) First the tool will move into the hole center position, just above the hole to tap. With the spindle running cw, the tool is fed into the hole. At the hole bottom, the spindle is reversed and the tool fed out of the hole. Finally the spindle is reversed again to its original direction.
- 13) This set of answers will vary with company. The instructor of this course can compare the students' answers with the operations the company performs

Exercise 4: Program Zero And The Rectangular Coordinate System

- 1) true
- 2) true
- 3) b. 0.0001 in
- 4) c. 0.0010 mm
- 5) The metric mode has a finer resolution than the inch mode. The least input increment in the metric mode is 0.001 mm. The least input increment in the inch mode is 0.0001 inch. 0.001 mm is less than half of 0.0001 inch
- 6) false
- 7) true

- 8) c. It should be placed at the location from which dimensions are taken on the print.
- 9) true
- 10) d. absolute mode
- 11) a. incremental mode
- 12) The absolute mode is better. Mistakes are not compounded, values going into the program make sense, and programs written in the absolute mode are easy to follow.
- 13) a. X word
b. Z word

14) a. U word			4	0.5	-0.625
b. W word					
15) true			5	0.75	-0.625
16) The location of point one is the program zero point.			6	1.0	-1.625
			7	1.0	-2.625
17) Answers:			8	1.25	-2.625
#	X	Z	9	1.5	-2.75
1	0	0	10	1.5	-3.125
2	0.375	0	11	2.0	-3.125
3	0.5	-0.0625			

Exercise 5: Introduction To Programming Words

1) Any of C, E, F, I, J, K, Q, R, U, W, X, and Z	5	0.89	0
2) false	6	1.75	0
3) false	7	2.0	-0.125
4) false	8	2.0	-0.75
5) true	9	2.25	-0.75
6) a. M03	10	2.5	-0.875
7) b. M05	11	2.25	-1.0
8) b. M08	12	2.75	-1.188
9) d. M09			
10) b. G20			
11) a. G21			
12) c. M30			
13) R, Z, P, G, M, I-J-K, S, F, O, U, W, X, A-B- or C			
14) Answers:			

Extension question answers:

- 15) Though we cannot provide answers to this question, you will likely find that your own turning centers have several other programmable functions, like automatic doors and chip conveyer.
- 16) The control will only execute the last three of the G codes in the command. Any prior to them will be ignored.
- 17) Though some controls may generate an alarm in this case, most will simply execute the latter of the two. The first will be ignored.

#	X	Z
1	0	-1.25
2	0.5	-0.5
3	0.75	-0.5
4	0.75	-0.07

Exercise 6: Preparation Steps For Programming

- 1) true
- 2) true
- 3) true
- 4) false

5) true	4	1.685	0.1
6) true	5	1.685	-2.995
7) false	6	2.0	-2.995
8) 1) It allows you to concentrate on processing separate from programming	7	2.0	0.1
2) It minimizes mistakes in your process	8	1.31	0.1
3) You'll be less likely to forget an operation	9	1.31	-1.495
4) You can also determine other things like tooling and cutting conditions.	10	1.685	-1.495
9) 1) Determine each tool's cutting path (in your mind)	11	1.51	0
2) Sketch the path of the tool on the print (or separate page)	12	-0.062	0
3) Draw a dot at each motion end point	13	-0.062	0.1
4) Number each dot	14	1.125	0.1
5) Fill in a coordinate sheet for each calculated value	15	1.125	0
10) 1) That the tool is available	16	1.25	-0.0625
2) That the tool is capable of machining as required	17	1.25	-1.5
11) false	18	1.5196	-1.5
12) 1) The location of program zero	19	1.625	-1.875
2) Any workholding components (jaws, collet, etc.)	20	1.625	-3.0
3) If feasible, the points and their numbers for coordinates	21	2.0	-3.0
4) Highlight the surfaces requiring machining			

13) Answers below:

Coordinate sheet:

#	X	Z
1	2.2	0.005
2	-0.062	0.005
3	-0.062	0.1

Extension question answers:

- 14) Answers cannot be provided
- 15) 1) The math. Most CAM systems do all (or most) coordinate calculations 2) Cutting conditions. Most CAM systems built-in material specifications 3) Possibly processing. Some CAM systems can perform automatic processing, especially for part families having similar processes.

Exercise 7: Types of motion commands

- 16) true
- 17) false
- 18) false
- 19) a. They're all modal
- b. The end point is programmed in the command
- c. Absolute or incremental mode can be used
- d. You can leave out non-moving axes.
- e. You can leave out leading zeros (G1 is the same as G01)
- 20) true
- 21) true

- 22) c. tool nose radius compensation
- 23) a. the extreme left-most tip of the tool in Z
- 24) G00 is rapid motion, G01 is linear motion, G02 is clock-wise motion, and G03 is counter clockwise motion.
- 25) b. to position the tool as quickly as possible to and from its cutting positions.
- 26) d. To machine at a specified feedrate along a perfectly straight line.
- 27) false
- 28) c. to form circular contouring motions on the workpiece.
- 29) true
- 30) false
- 31) true
- 32) b. 0.100"
- 33) c. 0.250"
- 34) false
- 35) c. K
- 36) See programming activity answers.

Extension question answers:

- 37) Answers cannot be provided
- 38) It depends upon the currently instated motion type. If G01 straight line motion is instated, the control will continue to move along straightly, even though a radius may be included in the command.
- 39) The R word is quite forgiving on most controls. It's likely that the control will do something (not generate an alarm), but not what is intended.
- 40) N175 G03 X0.75 Z-0.125 K-0.125 (24)
N185 G02 X0.936 Z-1.0 I0.093
N195 G03 X1.25 Z-1.0625 K-0.0625
N210 G03 X1.5 Z-1.8125 K-0.0625
N225 G03 X1.75 Z-2.3125 K-0.0625

Exercise 8: Introduction To Compensation

- 1) true
- 2) false
- 3) a. geometry offsets
b. wear offsets
c. tool nose radius compensation
- 4) false
- 5) true
- 6) false
- 7) d. four
- 8) b. setting the offset prior to machining in such a way that excess stock is left on a surface by a cutting tool.

- 9) d. T
- 10) c. R
- 11) false
- 12) wear offsets
- 13) geometry offsets
- 14) tool nose radius compensation

Extension question answers:

- 15) We cannot provide an answer to this question.

Exercise 9: Geomety Offsets And Wear Offsets

- 1) false
- 2) b. it is the same as the tool station number
- 3) b. it could cause incorrect movements if geometry offsets are used to assign program zero

- | | |
|---|---|
| 4) b. when the turret index command is activated | 7) b. the last two digits of the T word |
| 5) true | 8) a. T0 |
| 6) a. Deviations in tool placement during setup | 9) true |
| b. Trial machining to ensure a good first-workpiece | 10) true |
| c. Tool wear during the production run | |

Exercise 10: Tool Nose Radius Compensation

- | | |
|---|---|
| 1) false | 10) a: G42 b: G41 |
| 2) true | 11) a. during the tool's approach motion |
| 3) true | 12) b. during the tool's retract motion for tool change |
| 4) true | 13) a. The tool nose radius |
| 5) d. all of the above | b. The tool type. This is specified with a special code number |
| 6) a. Instate tool nose radius comp. | 14) While they could be placed in the wear offset table, we recommend that they be placed in the geometry offset table to minimize entries for tools using more than one offset |
| b. Make motions under influence of tool nose radius comp. | 15) turning tool: type three |
| c. Cancel tool nose radius comp. | boring bar: type two |
| 7) G41 - tool is on left side of surface during machining | 16) G10 |
| G42 - tool is on right side of surface during machining | |
| 8) d. G40 | |
| 9) true | |

Exercise 11: Introduction To Program Structure

- | | |
|--|--|
| 1) true | 10) b. you must include all commands necessary to get the machine running at the beginning of each tool. |
| 2) false | 11) False |
| 3) false | 12) a. G code numbering style (standard or special) |
| 4) true | b. M codes for various machine functions |
| 5) a. to get familiar with programming | c. special machine accessories not addressed |
| b. to be consistent from one program to the next | 13) false |
| c. to be able to rerun tools | |
| 6) to be able to rerun tools | |
| 7) true | |
| 8) false | |
| 9) c. restart the program from the beginning of tool four. | |

Extension question answers:

- 14) No answer can be provided here.
 15) No answer can be provided here.
 16) No answer can be provided here.
 17) No answer can be provided here.

Exercise 12: Four Kinds Of Program Format

- 1) a. program startup format
b. tool ending format
c. tool startup format
d. program ending format
- 2) true
- 3) true
- 4) Yes the G96 is necessary if you expect to be able to run the 3/4 finish boring bar by itself. If the G96 is not in line N120, the control will start the spindle in what ever mode (rpm or css) it happens to be in. If the 7/8 drill had just been run, the spindle would start at 400 rpm in stead of 400 sfm.
- 5) In X, make it just larger than the largest diameter being machined. In Z, determine the "overhang" amount (the distance from the shortest tool in the turret to the longest tool. Add the over hang to about three inches to determine the tool change position.
- 6) b. the zero return position
- 7) One way is to follow the rule-of-thumb: rough in the low range and finish in the high range.
A better way is to use the machine's main spindle power characteristics (the power curve chart) to determine how much power is available at the speeds the tool will be running.
- 8) This is based on the tooling style. Right hand tools usually require forward (M03) direction. Left hand tools usually require reverse (M04) direction.
- 9) c. G50 S2000
- 10) When the tool change position in X is at a large diameter. The spindle will be constantly accelerating and decelerating as each tool approaches and retracts. Since the spindle speed changes take time (usually more than the movement), program execution time will be wasted.
- 11) M01 is called an Optional Stop command. If programmed at the end of each tool, the operator will be able to stop the machine when each tool is finished by turning on the optional stop switch.
- 12) d. M30
- 13) d. all of the above
- 14) N115
- 15) the optional stop switch
- 16) See the programming activity answers.

Extension question answers:

- 17) We cannot provide answers.
- 18) The control would misinterpret ALL values in your program. A value of 1.0 inch would be taken as 1.0 millimeter. You can correct this problem by including a G20 or G21 to select the appropriate measurement system at the beginning of all programs (G20 for inch programs, G21 for metric programs).
- 19) Answers could include:
 - a. include spindle activation within approach movements
 - b. better formatting of constant surface speed
 - c. including all M codes within motion commands
 - d. turning spindle off as the last tool retracts
 - e. confirming the proper spindle range
 - f. minimizing spindle reversals

Exercise 13: One-Pass Canned Cycles

- 1) false
- 2) c. G90
- 3) a. G94
- 4) b. G92
- 5) a. You must send the tool to a convenient starting position
b. The tool will be left at the convenient starting position when finished
c. All cycles can be used for internal and external work

- 6) a. flush with the stock diameter in X and clear of the face in Z
- 7) b. flush with the face in Z and clear of the diameter in X
- 8) d. Clear of the diameter in X and clear of the face in Z
- 9) The one-pass turning and boring cycle provides no help for chamfers, radii, and tapers. It is almost as difficult to use as G00 and G01 in this regard.
- 10) The one-pass threading cycle requires that you determine each pass depth for threading and does nothing to help with the compound in-feed angle commonly needed to keep machining on the front edge of the threading tool.
- 11) See programming activity answers.

Exercise 14: G71 and G70 – Rough turning and boring followed by finishing

- 1) true
- 2) a. repeating identical machining operations
- b. control programs
- c. utilities
- 3) repeating identical machining operations
- 4) Increased ease of program verification. If the first execution is correct, they all will be.
- 5) true
- 6) b. M98
- 7) a. M99
- 8) d. P
- 9) c. L
- 10) false
- 11) d. four
- 12) Incrementally, move over the distance between the operations.
- 13) a. part families
- b. user defined canned cycles
- c. utilities
- d. complex shapes and motions
- e. driving accessory devices (like probes)
- 14) See programming activity answers.

Extension question answers:

- 15) We cannot provide answers to this question.
- 16) The control will generate an alarm.
- 17) a. When running multiple identical workpieces in the same setup.
- b. When machining multiple identical pockets.
- c. When milling multiple identical threaded holes.
- d. When machining multiple dovetails. (many more answers could be correct)

Exercise 15: Other multiple repetitive cycles (G73-G75)

- 1) true
- 2) a. the convenient starting position must be clear of the diameter to be faced in X and flush with the raw material in Z.
- b. The line commanded by the P word must contain only a Z motion and a G00 or G01
- c. the finish pass definition must be done in the facing mode.
- 3) To trace over a series of motions a specified number of times.
- 4) D is the number of passes.
I is the amount of stock to be removed on the side.
K is the amount of stock to be removed in Z.
(The depth of cut will be I and K divided by D.)
- 5) Because the control simply divides the I or (especially) K by the D word to determine the depth of cut. For faces with much material to be removed, this will “bury” the tool as faces are machined.
- 6) The drill will peck in a specified amount and then backup about 0.005 to break the chip. It will continue to peck and backup until the hole bottom is reached.
- 7) b. most programmers want a drilling cycle to clear chips for deep hole drilling

- a. No chamfers or radii will be machined in the corners of the groove.
- 8) b. this cycle won't help if the groove is wider than the grooving tool (it will not make multiple passes)
- 9) See the answers to programming activity number ten.

Exercise 16: G76 – Threading command

- 1) true
- 2) a. Clear of the surface to be threaded in X.
b. 0.2 or four times the thread pitch in Z, whichever is smaller
- 3) b. one divided by the number of threads per inch
- 4) Since most design engineers do not specify this value, you must reference a machining handbook. Some programmers will approximate, making the thread depth 75% of the pitch.
- 5) True
- 6) b. D
- 7) d. I
- 8) a. A
- 9) The low range is better since there will be more torque available to stabilize the threading operation.
- 10) false
- 11) true
- 12) Feed hold and feedrate override will be disabled to ensure that the thread cannot be damaged. Single block will only cause the machine to stop at the end of the pass, not at the end of the motion for the same reason.
- 13) d. G32
- 14) See programming activity answers.

Extension question answers:

- 15) We cannot provide answers to this question.

Exercise 17: Working with subprograms

- 1) true
- 2) a. repeated identical machining operations
b. control programs
c. utilities
- 3) repeated identical machining operations
- 4) a. if the operation comes out right once, it always will.
b. the subprogram can be permanently stored in memory and used among several main programs.
- 5) true
- 6) b. M98
- 7) a. M99
- 8) d. P
- 9) c. L
- 10) false
- 11) a. part families
b. user created canned cycles
c. utilities
d. driving accessory devices
e. complex motions
- 12) See programming activity answers

Extension question answers:

- 13) The control will go into alarm state and alert you that the program is missing.
- 14) Examples could include grooving, threading, hole machining, knurling, among others.

Exercise 18: Other special programming features

- | | |
|--|---|
| 1) c. the slash code (/) | done at every program stop. |
| 2) false | d. to document changes made after a dispute. |
| 3) true | e. to document anything out of the ordinary. |
| 4) false | 8) False |
| 5) a. to give another optional stop (/M00) | 9) c. K |
| b. with trial machining | 10) d. R |
| c. to make the machine make the appropriate number of roughing passes when raw material is varying there are other applications, but these are the three named | 11) true |
| 6) false | 12) d. G04 |
| 7) answers could include: a. at every tool change to name the tool. b. to document general information relative to the program (header). c. to document what should be | 13) false |
| | 14) answers could include: a. G04 X2.0 b. G04 U2.0 c. G04 P2000 |
| | 15) b. G10 |
| | 16) c. G30 |

Answers to programming activities

Again, if you are attending a class that uses this text, your instructor may ask you not to look at these answers prior to submitting your work. (Each activity can be removed from this text without removing any content.) On the other hand, if you are reading this text on your own, you can use these answers to check your work.

Programming activity 1: Test comprehension of motion types

Coordinate sheet:

#	X	Z			
1	2.1	0.005	14	1.06	0.1
2	-0.0625	0.005	15	1.06	-0.995
3	-0.0625	0.1	16	1.31	-0.995
4	1.81	0.1	17	0.81	0.1
5	1.81	-3.045	18	0.81	-0.995
6	2.0	-3.045	19	1.01	0
7	2.0	0.1	20	-0.062	0
8	1.56	0.1	21	-0.062	0.1
9	1.56	-2.245	22	0.5	0.1
10	1.81	-2.245	23	0.5	0
11	1.31	0.1	24	0.75	-0.125
12	1.31	-1.745	25	0.75	-0.907
13	1.56	-1.745	26	0.936	-1.0
			27	1.125	-1.0
			28	1.25	-1.0625

29	1.25	-1.75	N090 X1.06 (14)
30	1.375	-1.75	N095 G01 Z-0.995 (15)
31	1.5	-1.8125	N100 X1.31 (16)
32	1.5	-2.25	N105 G00 Z0.1 (11)
33	1.625	-2.25	N110 X0.81 (17)
34	1.75	-2.3125	N115 G01 Z-0.995 (18)
35	1.75	-3.05	N120 X1.06 (15)
36	2.0	-3.05	N125 G00 Z0.1 (14)
			N130 G00 X6.0 Z5.0
			N135 M01
			(Finish face and turn)
			N140 T0202 M42
			N145 G96 S700 M03
			N150 G00 X1.01 Z0 (19)
			N155 G01 X-0.062 F0.006 (20)
			N160 G00 Z0.1 (21)
			N165 X0.5 (22)
			N170 G01 Z0 (23)
			N175 G03 X0.75 Z-0.125 R0.125 (24)
			N180 G01 Z-0.907 (25)
			N185 G02 X0.936 Z-1.0 R0.093 (26)
			N190 G01 X1.125 (27)
			N195 G03 X1.25 Z-1.0625 R0.0625 (28)
			N200 G01 Z-1.75 (29)
			N205 X1.375 (30)
			N210 G03 X1.5 Z-1.8125 R0.0625 (31)
			N215 G01 Z-2.25 (32)
			N220 X1.625 (33)
			N225 G03 X1.75 Z-2.3125 R0.0625 (34)
			N230 G01 Z-3.05 (35)
			N235 X2.0 (36)
			N240 G00 X6.0 Z5.0
			N245 M30
O0001 (Program number)			
(Rough face and turn tool)			
N005 T0101 M41			
N010 G96 S600 M03			
N015 G00 X2.1 Z0.005 M08 (1)			
N020 G01 X-0.0625 F0.012 (2)			
N025 G00 Z0.1 (3)			
N030 X1.81 (4)			
N035 G01 Z-3.045 (5)			
N040 X2.0 (6)			
N045 G00 Z0.1 (7)			
N050 X1.56 (8)			
N055 G01 Z-2.245 (9)			
N060 X1.81 (10)			
N065 G00 Z0.1 (4)			
N070 X1.31 (11)			
N075 G01 Z-1.745 (12)			
N080 X1.56 (13)			
N085 G00 Z0.1 (8)			

Programming activity 2: Test comprehension of motion types

Coordinate sheet:

#	X	Z	10	1.375	0.1
1	2.2	0.005	11	1.375	0
2	-0.062	0.005	12	1.25	-0.0625
3	-0.062	0.1	13	1.25	-1.375
4	0	0.1	14	1.1	-1.375
5	0	-2.2	15	1.0	1.425
6	1.19	0.1	16	1.0	-2.0
7	1.19	-1.37	17	0.8	-2.0
8	0.875	-1.37	18	0.8	0.1
9	0.875	0.1	19	2.075	0

20	1.05	0	N080 G96 S350 M03
21	1.05	0.1	N085 G00 X1.19 Z0.1 M08 (6)
22	1.75	0.1	N090 G01 Z-1.37 F0.007 (7)
23	1.75	0	N095 X0.875 (8)
24	1.875	-0.0625	N100 G00 Z0.1 (9)
25	1.875	-1.0	N105 X5.0 Z6.0
26	2.2	-1.0	N110 M01
Program:			(3/4 finish boring bar)
O0002 (Program number)			N115 T0404 M42
(Rough facing tool)			N120 G96 S400 M03
N005 T0101 M41			N125 G00 X1.375 Z0.1 M08 (10)
N010 G96 S400 M03			N130 G01 Z0 F0.005 (11)
N015 G00 X2.2 Z0.005 M08 (1)			N135 G02 X1.25 Z-0.0625 R0.0625 (12)
N020 G01 X-0.062 F0.012 (2)			N140 G01 Z-1.375 (13)
N025 G00 Z0.1 (3)			N145 X1.1 (14)
N030 X6.0 Z5.0			N150 X1.0 Z-1.425 (15)
N035 M01			N155 Z-2.0 (16)
(7/8 drill)			N160 G00 X0.8 (17)
N040 T0202 M41			N165 Z0.1 (18)
N045 G97 S354 M03			N170 X6.0 Z5.0
N050 G00 X0 Z0.1 M08 (4)			N175 M01
N055 G01 Z-2.2 F0.008 (5)			(Finish face and turn tool)
N060 G00 Z0.1 (4)			N180 T0505 M42
N065 X6.0 Z5.0			N185 G96 S450 M03
N070 M01			N190 G00 X2.075 Z0 M08 (19)
(3/4 rough boring bar)			N195 G01 X1.05 F0.006 (20)
N075 T0303 M42			N200 G00 Z0.1 (21)
			N205 X1.75 (22)
			N210 G01 Z0 (23)
			N215 G03 X1.875 Z-0.0625 R0.0625 (24)
			N220 G01 Z-1.0 (25)
			N225 X2.2 (26)
			N230 G00 X6.0 Z5.0
			N235 M30

Programming activity 3: Test comprehension of geometry and wear offsets

Coordinate sheet:

#	X	Z	10	0.8	0.1
1	2.2	0.005	11	1.5	0.1
2	0.8	0.005	12	1.5	0
3	0.8	0.1	13	1.375	-0.0625
4	1.8725	0.1	14	1.375	-0.25
5	1.8725	0.005	15	1.1	-0.25
6	2.0	-0.625	16	1.0	-0.3
7	1.315	0.1	17	0.8	-0.3
8	1.315	-0.245	18	0.8	0.1
9	0.8	-0.245	19	2.0125	0
			20	1.175	0

21	1.175	0.1	N075 X0.8 (9)
			N080 G00 Z0.1 (10)
22	1.8125	0.1	N085 X6.0 Z5.0
			N090 M01
23	1.8125	0	(3/4" finish boring bar)
24	1.9375	-0.625	N095 T0404 M42
			N100 G96 S350 M03
25	1.9375	-0.913	N105 G00 X1.5 Z0.1 M08 (11)
			N110 G01 Z0 F0.005 (12)
26	2.1375	-0.913	N115 G02 X1.375 Z-0.0625 R0.0625(13)
			N120 G01 Z-0.25 (14)

Program

O0003 (Program number)

(Rough face and turn tool)

N005 T0101 M41
 N010 G96 S400 M03
 N015 G00 X2.2 Z0.005 M08 (1)
 N020 G01 X0.8 F0.012 (2)
 N025 G00 Z0.1 (3)
 N030 X1.8725 (4)
 N035 G01 Z0.005 (5)
 N040 X2.0 Z-0.625 (6)
 N045 G00 X6.0 Z5.0
 N050 M01

(3/4" rough boring bar)

N055 T0303 M41
 N060 G96 S350 M03
 N065 G00 X1.315 Z0.1 M08 (7)
 N070 G01 Z-0.245 F0.007 (8)

N125 X1.1 (15)
 N130 X1.0 Z-0.3 (16)
 N135 X0.8 (17)
 N140 G00 Z0.1 (18)
 N145 X6.0 Z5.0
 N150 M01

(Finish face and turn tool)

N155 T0505 M42
 N160 G96 S450 M03
 N165 G00 X2.0125 Z0 M08 (19)
 N170 G01 X1.175 F0.005 (20)
 N175 G00 Z0.1 (21)
 N180 X1.8125 (22)
 N185 G01 Z0 (23)
 N190 X1.9375 Z-0.625 (24)
 N195 Z-0.913 (25)
 N200 X2.1375 (26)
 N205 G00 X6.0 Z5.0
 N210 M30

Programming activity 4: Test comprehension of geometry and wear offsets

Coordinate sheet:

#	X	Z	13	1.3115	-0.745
1	1.8095	0.1	14	0.88	0.1
2	1.8095	-3.495	15	0.88	0
3	2.0	-3.495	16	1.0	-0.06
4	2.0	0.1	17	1.0	-0.75
5	1.56	0.1	18	1.1315	-0.75
6	1.56	-2.995	19	1.2515	-0.81
7	1.8095	-2.995	20	1.2515	-1.7515
8	1.3115	0.1	21	1.38	-1.7515
9	1.3115	-1.7465	22	1.5	-1.8115
10	1.56	-1.7465	23	1.5	-3.0
11	1.06	0.1	24	1.6295	-3.0
12	1.06	-0.745	25	1.7495	-3.06

2	-0.062	0.005	O0005 (Program number)
3	-0.062	0.1	(Rough face and turn tool) N005 T0101 M41
4	1.81	0.1	N010 G96 S450 M03 N015 G00 X2.2 Z0.005 M08 (1)
5	1.81	0.005	N020 G01 X-0.062 F0.012 (2) N025 G00 Z0.1 (3)
6	1.935	-0.495	N030 X1.810 (4) N035 G01 Z0.005 (5)
7	1.935	-0.495	N040 X1.935 Z-0.245 (6) N045 Z-0.495 (7)
8	2.06	-0.745	N050 X2.06 Z-0.745 (8) N055 G00 X6.0 Z5.0
9	0	0.1	N060 M01
10	0	-2.1875	(1" drill)
11	1.19	0.1	N065 T0202 M41 N070 G97 S380 M03
12	1.19	-0.4325	N075 G00 X0 Z0.1 M08 (9) N080 G01 Z-2.8175 F0.009 (10)
13	0.94	-1.1825	N085 G00 Z0.1 (11) N090 X6.0 Z5.0
14	0.94	0.1	N095 M01
15	1.5	0.1	(Rough boring bar)
16	1.5	0	N100 T0303 N105 G96 S400 M03
17	1.25	-0.125	N110 G00 X1.19 Z0.1 M08 (11) N115 G01 Z-0.4325 F0.008 (12)
18	1.25	-0.4375	N120 X0.94 Z-1.1825 (13) N125 G00 Z0.1 (14)
19	1.0	-1.1875	N130 X6.0 Z5.0 N135 M01
20	0.8	-1.1875	(Finish boring bar)
21	0.8	0.1	N140 T0404 M41 N145 G96 S450 M03
22	1.95	0	N150 G41 G00 X1.5 Z0.1 (15) N155 G01 Z0 F0.005 M08 (16)
23	1.15	0	N160 G02 X1.25 Z-0.125 R0.125 (17) N165 G01 Z-0.4375 (18)
24	1.15	0.1	N168 X1.0 Z-1.1875 (19) N170 X0.8 (20)
25	1.75	0.1	N175 G00 Z0.1 (21) N180 G40 X6.0 Z5.0 (Cancel tnr comp)
26	1.75	0	N185 M01
27	1.875	-0.25	(Finish turn)
28	1.875	-0.5	N190 T0505 M42 N195 G96 S500 M03
29	2.0	-0.75	N200 G00 X1.95 Z0 M08 (22) N205 G01 X1.15 F0.007 (23)
30	2.2	-0.75	N210 G00 Z0.1 (24) N215 G42 X1.75 (25, instate comp)
Geometry offsets:			N220 G01 Z0 (26)
#4 - R: 0.031 T: 2			N225 X1.875 Z-0.25 (27)
#5 - R: 0.031 T: 3			N230 Z-0.5 (28)
Program:			N235 X2.0 Z-0.75 (29)
			N240 X2.2 (30)

Programming activity 6: Test comprehension of program structure

Coordinate sheet:

#	X	Z
1	1.45	0
2	-0.062	0
3	-0.062	0.1
4	1.025	0.1
5	1.025	0
6	1.125	-0.05
7	1.125	-1.05
8	1.45	-1.05
9	0	0.1
10	0	-1.21
11	0.6625	0.1
12	0.6625	0
13	0.5625	-0.05
14	0.5625	-1.03
15	0.4	-1.03
16	0.4	0.1
17	1.45	-1.125
18	1.025	-1.125
19	1.45	-1.075
20	1.125	-1.075
21	0.44	-1.125

N040 G99 G00 X6.0 Z5.0
N045 M01

(Finish face and turn tool)

N050 T0101 M42
N055 G96 S550 M03
N060 G00 X1.45 Z0 M08 (1)
N065 G01 X-0.062 F0.008 (2)
N070 G00 Z0.1 (3)
N075 G42 X1.025 (4)
N080 G01 Z0 (5)
N085 X1.125 Z-0.05 (6)
N090 Z-1.05 (7)
N095 X1.45 (8)
N100 G40 G00 X6.0 Z5.0
N105 M01

(/12 drill)

N110 T0202 M42
N115 G97 S740 M03
N120 G00 X0 Z0.1 M08 (9)
N125 G01 Z-1.21 F0.007 (10)
N130 G00 Z0.1 (9)
N135 X6.0 Z5.0
N140 M01

(Finish boring bar)

N145 T0303 M42
N150 G96 S300 M03
N155 G41 G00 X0.6625 Z0.1 M08 (11)
N160 G01 Z0 F0.004 (12)
N165 X0.5625 Z-0.05 (13)
N168 Z-1.03 (14)
N170 X0.4 (15)
N175 G00 Z0.1 (16)
N180 G40 X6.0 Z5.0
N185 M01

(1/8 wide cutoff tool)

N190 T0404 M42
N195 G96 S450 M03
N200 G00 X1.45 Z-1.125 M08 (17)
N205 G01 X1.025 F0.005 (18)
N210 G00 X1.45 (17)

N215 Z-1.075 (19)

N220 G01 X1.125 (20)
N225 X1.025 Z-1.125 (18)

N230 M18 (Activate part catcher)

N235 X0.44 (21)

N240 M19 (Retract part catcher)

N245 G00 X1.45 (17)

N250 X6.0 Z5.0

N255 M99 (Return to start and continue)

Program:

O0006 (Program number)

(Bar stop to advance workpiece)

N005 G20 G23 G40

N010 G50 S5000

N015 T1212 M05 (Index, stop spindle)

N020 G00 X0 Z-1.025

N025 M15 (Open collet chuck)

N030 G98 G01 Z0.05 F30.0 (Bar adv.)

N035 M14 (Close collet chuck)

Programming activity 7: Test comprehension of program structure

Coordinate sheet:

#	X	Z			
1	8.2	0.005	21	2.125	0.1
2	-0.062	0.005	22	2.125	0
3	-0.062	0.1	23	2.0	-0.0625
4	8.2	0.1	24	2.0	-0.5
5	8.2	-0.12	25	1.75	-0.5
6	4.06	-0.12	26	1.5	-1.0
7	4.06	0.005	27	1.5	-1.5
8	8.2	-0.245	28	1.45	-1.5
9	7.06	-0.245	29	1.45	0.1
10	6.06	-0.12	30	8.2	-0.455
11	8.2	-0.37	31	8.0	-0.455
12	7.06	-0.37	32	7.84	-0.375
13	0	0.1	33	7.0	-0.375
14	0	-1.8425	34	7.0	-0.25
15	1.69	0.1	35	6.0	-0.125
16	1.69	-0.495	36	4.0	-0.125
17	1.375	-0.995	37	4.0	-0.0625
18	1.375	0.1	38	3.875	0
19	1.94	0.1	39	-0.062	0
20	1.94	-0.495	40	-0.062	0.1

Program:

O0007 (Program number)	N065 Z-0.245 (8)
(Rough facing tool)	N070 G01 X7.06 (9)
N005 G23 G23 G40	N075 X6.06 Z-0.12 (10)
N010 G50 S4000	N080 G00 X8.2 (5)
N015 T0101 M41	N085 Z-0.37 (11)
N020 G96 S450 M03	N090 G01 X7.06 (12)
N025 G00 X8.2 Z0.005 M08 (1)	N095 Z-0.245 (9)
N030 G99 G01 X-0.062 F0.012 (2)	N100 G00 X8.2 (8)
N035 G00 Z0.1 (3)	N105 G00 X10.0 Z5.0
N040 X8.2 (4)	N110 M01
N045 Z-0.12 (5)	
N050 G01 X4.06 (6)	(1.375 drill)
N055 Z-0.005 (7)	N115 T0202 M41
N060 G00 X8.2 (1)	N120 G97 S225 M03

N125 G00 X0 Z0.1 M08 (13)
 N130 G01 Z-1.8425 F0.009 (14)
 N135 G00 Z0.1 (13)
 N140 X10.0 Z5.0
 N145 M01

(Rough boring bar)

N150 T0303 M41
 N155 G96 S400 M03
 N160 G00 X1.69 Z0.1 M08 (15)
 N165 G01 Z-0.495 F0.008 (16)
 N170 X1.375 Z-0.995 (17)
 N175 G00 Z0.1 (18)
 N180 X1.94 (19)
 N185 G01 Z-0.495 (20)
 N190 X1.69 (16)
 N195 G00 Z0.1 (15)
 N200 X10.0 Z5.0
 N205 M01

(Finish boring bar)

N210 T0404 M42
 N215 G96 S450 M03
 N220 G00 G41 X2.125 Z0.1 M08 (21)
 N225 G01 Z0 F0.005 (22)
 N230 G02 X2.0 Z-0.0625 R0.0625 (23)

N235 G01 Z-0.5 (24)
 N240 X1.75 (25)
 N245 X1.5 Z-1.0 (26)
 N250 Z-1.5 (27)
 N255 X1.45 (28)
 N260 G00 Z0.1 (29)
 N265 G40 X10.0 Z5.0
 N270 M01

(Finish facing tool)

N275 T0505 M42
 N280 G96 S500 M03
 N285 G00 G41 X8.2 Z-0.455 M08 (30)
 N290 G01 X8.0 F0.007 (31)
 N295 X7.84 Z-0.425 (32)
 N300 X7.0 (33)
 N305 Z-0.25 (34)
 N310 X6.0 Z-0.125 (35)
 N315 X4.0 (36)
 N320 Z-0.0625 (37)
 N325 G02 X3.875 Z0 R0.0625 (38)
 N330 G01 X1.95 (39)
 N335 G00 Z0.1 (40)
 N340 G40 X10.0 Z5.0
 N345 M30

Programming activity 8: Test comprehension of one-pass canned cycles

Coordinate sheet:

#	X	Z			
			15	1.75	-0.05
			16	1.75	-0.75
			17	2.2	-0.75
1	2.2	0.1			
2	0.8	0.005			
3	2.0	0.1			
4	1.81	-0.745			
5	1.0	0.1			
6	1.19	-0.995			
7	1.35	0.1			
8	1.35	0			
9	1.25	-0.05			
10	1.25	-1.0			
11	0.8	-1.0			
12	1.35	0.1			
13	1.35	0			
14	1.65	0			

Program:

O0008 (Program number)
 (Rough face and turn tool)
 N005 G20 G23 G40
 N010 G50 S4000
 N015 T0101 M42
 N020 G96 S500 M03
 N025 G00 X2.2 Z0.1 M08 (1)
 N030 G99 G94 X0.8 Z-.005 F0.012 (2)
 N035 G00 X2.0 Z0.1 (3)
 N040 G90 X1.81 Z-0.745 (4->3)
 N045 G00 X6.0 Z5.0
 N050 M01

 (Rough boring bar)
 N055 T0202 M42
 N060 G96 S450 M03
 N065 G00 X1.0 Z0.1 M08 (5)
 N070 G90 X1.19 Z-0.995 F0.008 (6)
 N075 G00 X6.0 Z5.0

N080 M01

(Finish boring bar)

N085 T0303 M42

N090 G96 S500 M03

N095 G00 G41 X1.35 Z0.1 M08 (7)

N100 G01 Z0 F0.005 (8)

N105 G02 X1.25 Z-0.05 R0.05 (9)

N110 G01 Z-1.0 (10)

N115 X0.8 (11)

N120 G00 Z0.1 (Must exit hole!)

N125 G40 X6.0 Z5.0

N130 M01

(Finish turning tool)

N135 T0404 M42

N140 G96 S600 M03

N145 G00 G42 X1.35 Z0.1 M08 (12)

N150 G01 Z0 F0.007 (13)

N155 X1.65 (14)

N160 G03 X1.75 Z-0.05 R0.05 (15)

N165 G01 Z-0.75

N170 X2.2

N175 G00 G40 X6.0 Z5.0

N180 M30

Programming activity 9: Test comprehension of G71 and G70 – Roughing and finishing

Coordinate sheet:

#	X	Z
1	4.2	0.005
2	-0.062	0.005
3	-0.062	0.1
4	4.0	0.1
5	3.15	0.1
6	3.15	0
7	3.25	-0.05
8	3.25	-0.125
9	3.5	-1.0
10	3.5	-1.25
11	3.65	-1.25
12	3.75	-1.3
13	3.75	-1.5
14	4.0	-1.5
15	0	0.1
16	0	-2.25
17	1.25	0.1
18	2.85	0.1
19	2.85	0
20	2.75	-0.05
21	2.75	-0.125
22	2.5	-0.25
23	2.25	-0.25
24	2.0	-0.375
25	2.0	-0.5
26	1.5	-1.5
27	1.5	-1.75
28	1.25	-1.75

Program:

O0009 (Program number)

(Rough face and turn tool)

N005 G20 G23 G40

N010 G50 S4000

N015 T0101 M41

N018 G96 S500 M03

N020 G00 X4.2 Z0.005 M08 (1)

N025 G99 G01 X-0.062 F0.012 (2)

N030 G00 Z0.1 (3)

N035 X4.0 (4)

N040 G71 P045 Q090 U.06 W.005 D2000

N045 G00 X3.15 (5)

N050 G01 Z0 (6)

N055 G03 X3.25 Z-0.05 R0.05 (7)

N060 G01 Z-0.125 (8)

N065 X3.5 Z-1.0 (9)

N070 Z-1.25 (10)

N075 X3.65 (11)

N080 G03 X3.75 Z-1.3 R0.05 (12)

N085 G01 Z-1.5 (13)

N090 X4.0 (14)

N095 G00 X6.0 Z5.0

N100 M01	N205 Z-1.75 (27)
(1-1/4 drill)	N210 X1.25 (28)
N105 T0202 M41	N215 G00 X6.0 Z5.0
N110 G97 S270 M03	N220 M01
N115 G00 X0 Z0.1 M08 (15)	(1-1/4 finish boring bar)
N120 G01 Z-2.25 F0.009 (16)	N225 T0404 M42
N125 G00 Z0.1 (17)	N230 G96 S500 M03
N130 X6.0 Z5.0	N235 G00 G41 X1.25 Z0.1 M08 (17)
N135 M01	N240 G70 P160 Q210 F0.005
(1-1/4 rough boring bar)	N245 G00 G40 X6.0 Z5.0
N140 T0303 M41	N250 M01
N145 G96 S450 M03	(Finish face and turn tool)
N150 G00 X1.25 Z0.1 M08 (17)	N255 T0505 M42
N155 G71 P160 Q210 U-.06 W.005 D1250 F0.008	N260 G96 S600 M03
N160 G00 X2.85 (18)	N265 G00 X3.45 Z0 M08 (finish face approach)
N165 G01 Z0 (19)	N270 G01 X2.55 F0.007 (finish face)
N170 X2.75 Z-0.05 (20)	N275 G00 Z0.1
N175 Z-0.125 (21)	N280 G42 X4.0 (4)
N180 G03 X2.5 Z-0.25 R0.125 (22)	N285 G70 P045 Q090
N185 G01 X2.25 (23)	N290 G00 G40 X6.0 Z5.0
N190 G02 X2.0 Z-0.375 R0.125 (24)	N295 M30
N195 G01 Z-0.5 (25)	
N200 X1.5 Z-1.5 (26)	

Programming activity 10: Test comprehension of G72 – Rough facing

Coordinate sheet:

#	X	Z	15	-0.062	0
1	8.2	0.1	16	-0.062	0.1
2	8.2	-1.25	17	0	0.1
3	8.0	-1.25	18	0	-2.33
4	6.5	-1.0	19	1.0	0.1
5	6.5	-0.875	20	3.1	0.1
6	6.25	-0.75	21	3.1	0
7	5.75	-0.75	22	3.0	-0.05
8	5.5	-0.625	23	3.0	-0.245
9	5.5	-0.5	24	2.74	-0.375
10	4.5	-0.25	25	2.6	-0.375
11	4.125	-0.25	26	2.5	-0.425
12	4.0	-0.1875	27	2.5	-0.81
13	4.0	-0.09	28	2.12	-1.0
14	3.82	0	29	1.95	-1.0

30 1.75 -1.1
 31 1.75 -1.44
 32 1.63 -1.5
 33 1.35 -1.5

34 1.25 -1.55
 35 1.25 -2.1
 36 1.0 -2.1

Program:

O0010 (Program number)
 (Rough facing tool)
 N005 G20 G23 G40
 N010 G50 S4000
 N015 T0101 M41
 N020 G99 G96 S500 M03
 N025 G00 X8.2 Z0.1 M08 (1)
 N030 G72 P035 Q105 U.06 W.005 D1750
 F0.012
 N035 G00 Z-1.25 (2)
 N040 G01 X8.0 (3)
 N045 X6.5 Z-1.0 (4)
 N050 Z-0.875 (5)
 N055 G02 X6.25 Z-0.75 R0.125 (6)
 N060 G01 X5.75 (7)
 N065 G03 X5.5 Z-0.625 R0.125 (8)
 N070 G01 Z-0.5 (9)
 N075 X4.5 Z-0.25 (10)
 N080 X4.125 (11)
 N085 G03 X4.0 Z-0.1875 R0.0625 (12)
 N090 G01 Z-0.09 (13)
 N095 X3.82 Z0 (14)
 N100 X-0.062 (15)
 N105 Z0.1 (16)
 N110 G00 X10.0 Z5.0
 N115 M01

 (1.0 drill)
 N120 T0202 M41
 N125 G97 S270 M03
 N130 G00 X0 Z0.1 M08 (17)
 N135 G01 Z-2.33 F0.009 (18)
 N140 G00 Z0.1 (17)
 N145 X10.0 Z5.0
 N150 M01

 (Rough boring bar)
 N155 T0303 M41
 N160 G96 S450 M03

N165 G00 X1.0 Z0.1 M08 (19)
 N170 G71 P175 Q255 U-.06 W.005 D1000
 F0.008
 N175 G00 X3.1 (20)
 N180 G01 Z0 (21)
 N185 X3.0 Z-0.05 (22)
 N190 Z-0.245 (23)
 N195 G03 X2.74 Z-0.375 R0.13 (24)
 N200 G01 X2.6 (25)
 N205 X2.5 Z-0.425 (26)
 N210 Z-0.81 (27)
 N215 G03 X2.12 Z-1.0 R0.19 (28)
 N220 G01 X1.95 (29)
 N225 X1.75 Z-1.1 (30)
 N230 Z-1.44 (31)
 N235 G03 X1.63 Z-1.5 R0.06 (32)
 N240 G01 X1.35 (33)
 N245 X1.25 Z-1.55 (34)
 N250 Z-2.1 (35)
 N255 X1.0 (36)
 N260 G00 X10.0 Z5.0
 N265 M01

 (Finish boring bar)
 N270 T0404 M42
 N275 G96 S500 M03
 N280 G00 G41 X1.0 Z0.1 M08 (19)
 N285 G70 P175 Q255 F0.005
 N290 G00 G40 X10.0 Z5.0
 N295 M01

 (Finish facing tool)
 N300 T0505 M42
 N305 G96 S600 M03
 N310 G00 G41 X8.2 Z0.1 M08 (1)
 N315 G70 P035 Q105 F0.007
 N320 G00 G40 X10.0 Z5.0
 N325 M30

Programming activity 11: Test comprehension of G76 threading cycle

Coordinate sheet:

			1	2.1	0.005
#	X	Z			

2	-0.062	0.005	12	2.0	-1.375
3	-0.062	0.1	13	1.2	0
4	2.0	0.1	14	-0.062	0
5	0.8	0.1	15	-0.062	0.1
6	0.8	0	16	2.0	0.1
7	1.0	-0.1	17	1.7	-1.275
8	1.0	-0.5	18	1.5	-1.375
9	1.35	-0.5	19	1.3	-1.375
10	1.5	-0.575	20	1.7	-0.33
11	1.5	-1.375	21	1.4168	-1.335

Program:

O0011 (Program number)
 (Rough face and turn tool)
 N005 G20 G23 G40
 N010 G50 S5000
 N015 T0101 M41
 N020 G96 S400 M03
 N025 G00 X2.1 Z0.005 M08 (1)
 N030 G99 G01 X-0.062 F0.013 (2)
 N035 G00 Z0.1 (3)
 N040 X2.0 (4)
 N045 G71 P050 Q080 U.06 W.005 D1500
 N050 G00 X0.8 (5)
 N055 G01 Z0 (6)
 N060 X1.0 Z-0.1 (7)
 N065 Z-0.5 (8)
 N070 X1.35 (9)
 N075 X1.5 Z-0.575 (10)
 N078 Z-1.375 (11)
 N080 X2.0 (12)
 N085 G00 X6.0 Z5.0
 N090 M01

(Finish face and turn tool)
 N095 T0202 M42
 N100 G96 S500 M03
 N105 G00 X1.2 Z0 M08 (13)
 N110 G01 X-0.062 F0.007 (14)

N115 G00 Z0.1 (15)
 N120 X2.0 G42 (16)
 N125 G70 P050 Q080
 N130 G00 G40 X6.0 Z5.0
 N135 M01

 (1/8 grooving tool)
 N140 T0303 M42
 N145 G96 S550 M03
 N150 G00 X1.7 Z-1.275 M08 (17)
 N155 G01 X1.5 Z-1.375 F0.005 (18)
 N160 X1.3 (19)
 N163 G04 X0.5 (1/2 second dwell)
 N165 G00 X1.7
 N170 Z-1.275 (17)
 N175 X6.0 Z5.0
 N180 M01

 (Threading tool)
 N185 T0404 M41
 N190 G97 S1146 M03
 N195 G00 X1.7 Z-0.33 M08 (20)
 N200 G76 X1.4168 Z-1.335 D0080 K0.0416
 F0.0555 A60
 N205 G00 X6.0 Z5.0
N210 M30

