CAD/CAM/CAE
Computer Aided Design/Computer Aided Manufacturing/Computer Aided Manufacturing

Part-9
CNC Fundamentals

CNC Fundamentals

All CNC machine tools follow the same standard for motion nomenclature and the same coordinate system. This is defined as the EIA 267-C standard. The standard defines a machine coordinate system and machine movements so that a programmer can describe machining operations without worrying about whether a tool approaches a workpiece or a workpiece approaches a tool.


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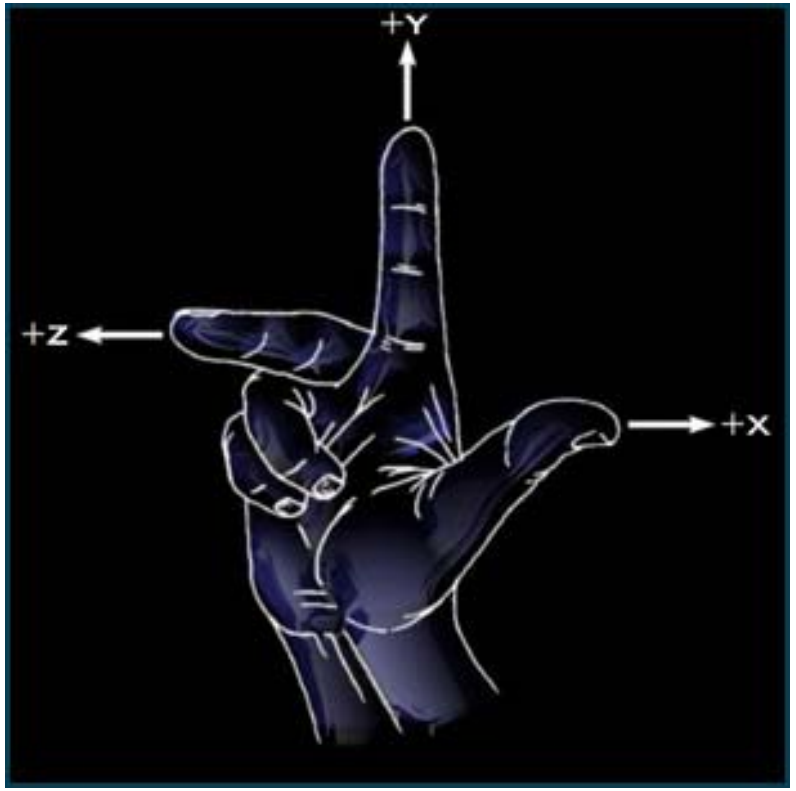
Machine coordinate system

- The direction of each finger represents the positive direction of motion.
- The axis of the main spindle is always Z, and the positive direction is into the spindle.
- On a mill the longest travel slide is designated the X axis and is always perpendicular to the Z axis.
- If you rotate your hand looking into your middle finger, the forefinger represents the Y axis.
- The base of your fingers is the start point or (X0, Y0, Z0).



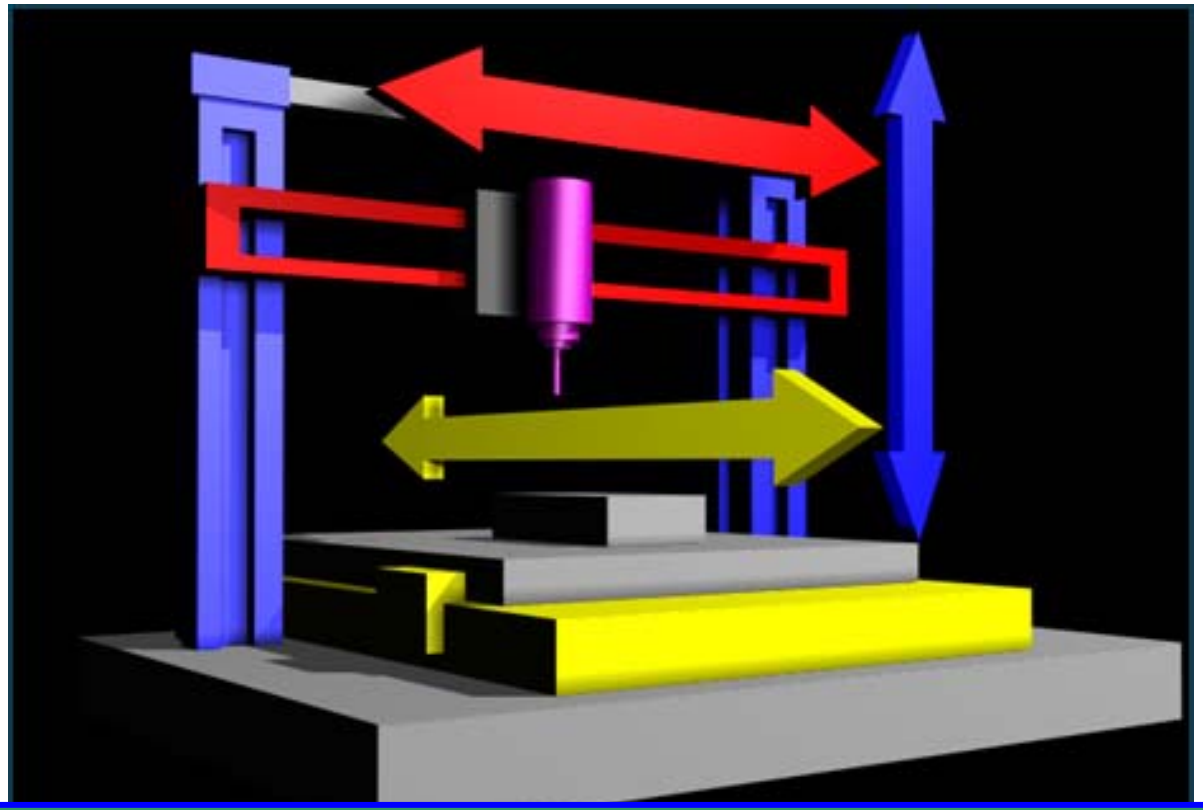
Axis and motion nomenclature – Rotary motion designation

The right-hand rule for determining the correct axis on a CNC machine may also be used to determine the clockwise rotary motion about X, Y, and Z.

- To determine the positive, or clockwise, direction about an axis, close your hand with the thumb pointing out.
  - The thumb may represent the X, Y, or Z direction and **the curl of the fingers may represent the clockwise, or positive, rotation about each axis.**
  - These are known as **A, B, and C and represent the rotary motions about X, Y, and Z, respectively.**

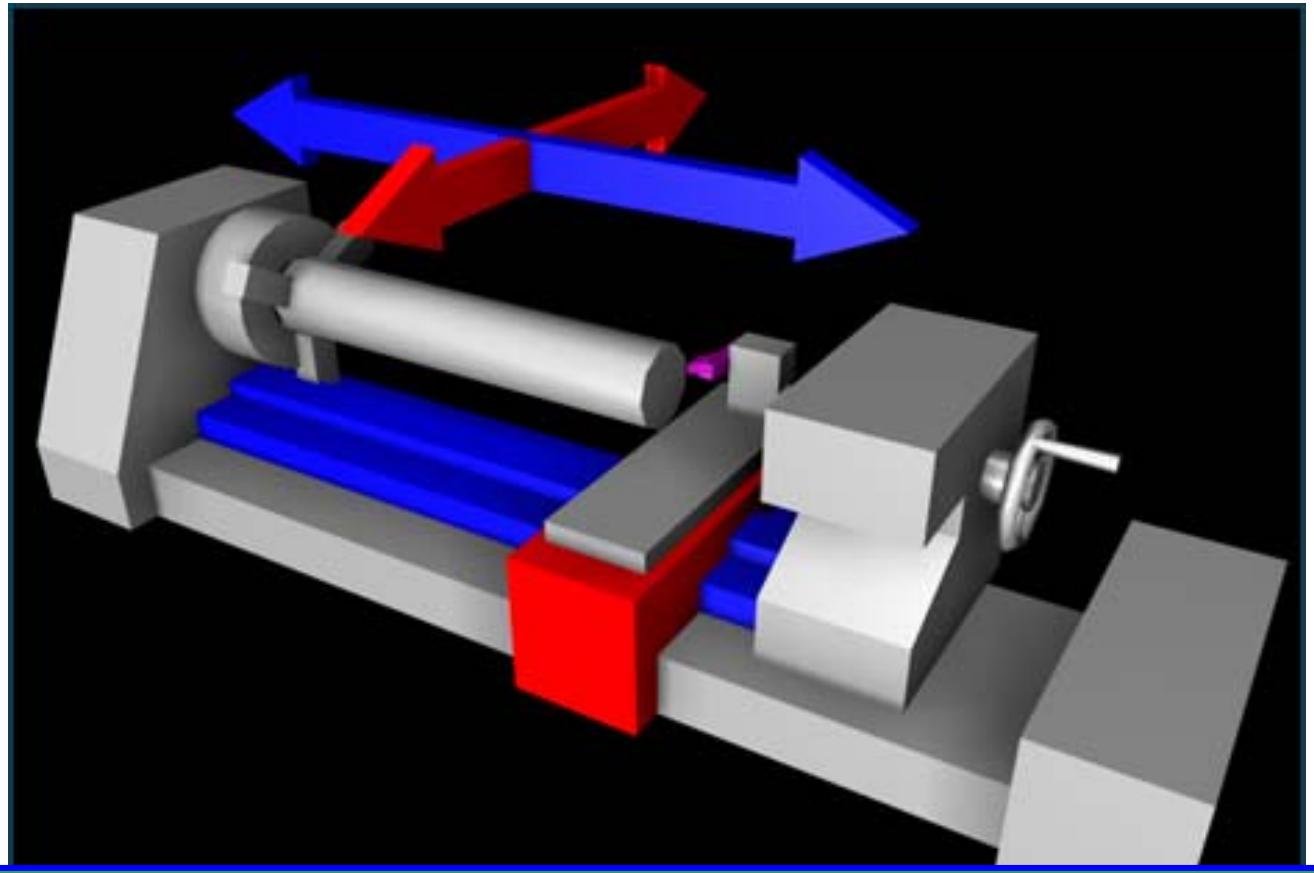

+X, Y, OR Z
+A, B, OR C

Axis and motion nomenclature – CNC mill



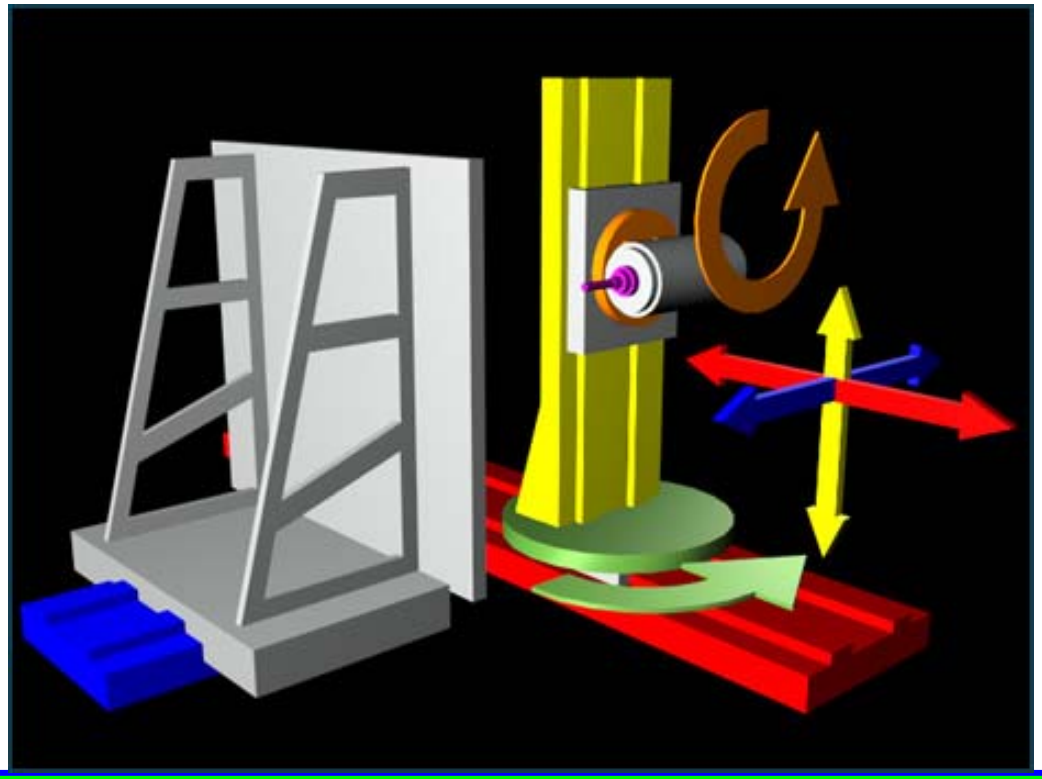
On this gantry mill the spindle travels along the **X Axis**. The travel direction of the table designates the **Y Axis**. The **Z Axis** is designated by the stationary vertical column.

Axis and motion nomenclature – CNC lathe



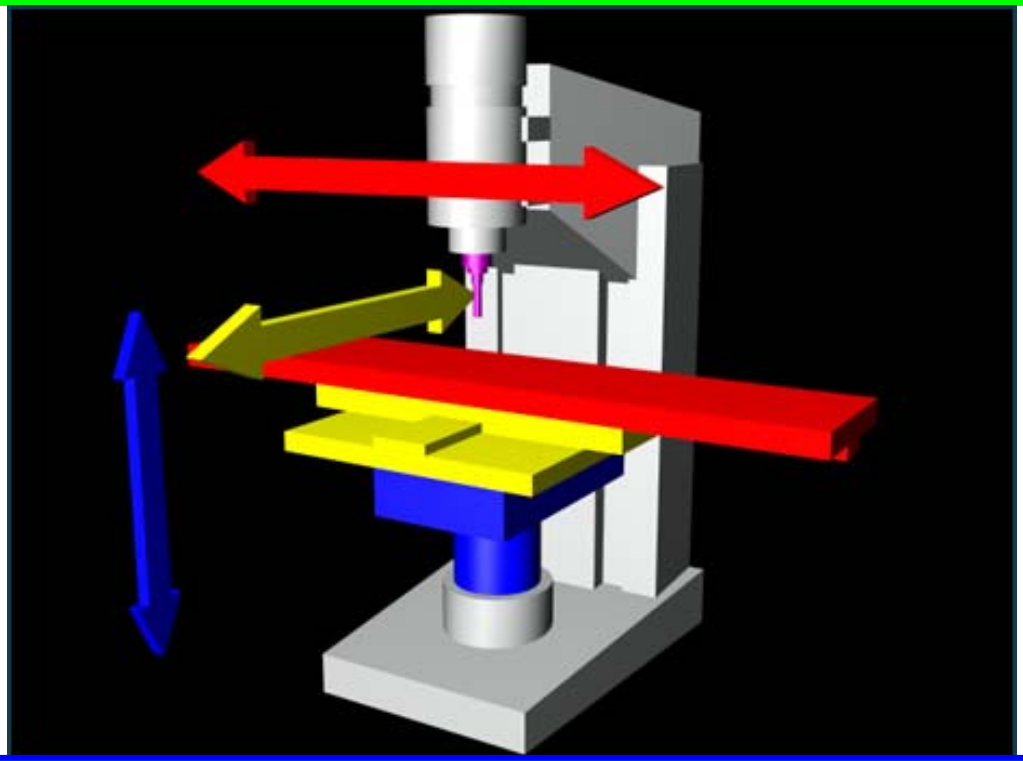
On most CNC lathes the **Z Axis** is parallel to the spindle and longer than the **X Axis**.

Axis and motion nomenclature – 5-axis CNC contour mill



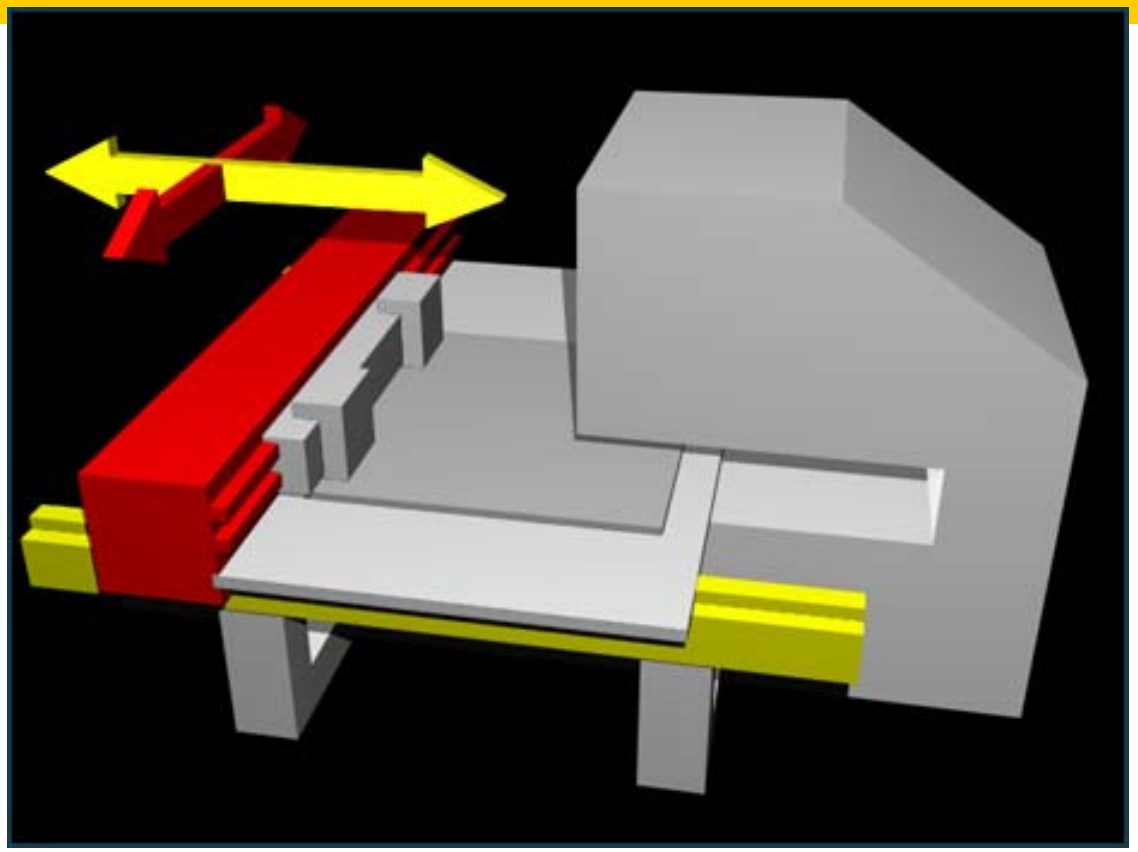
On this five-axis horizontal contour milling machine, note the orientation of the **X** and **Y** axes in relation to the **Z Axis**. The rotary axes for both the **X** and **Y** axes are designated by the **A** and **B** rotary tables.

Axis and motion nomenclature – vertical CNC knee mill



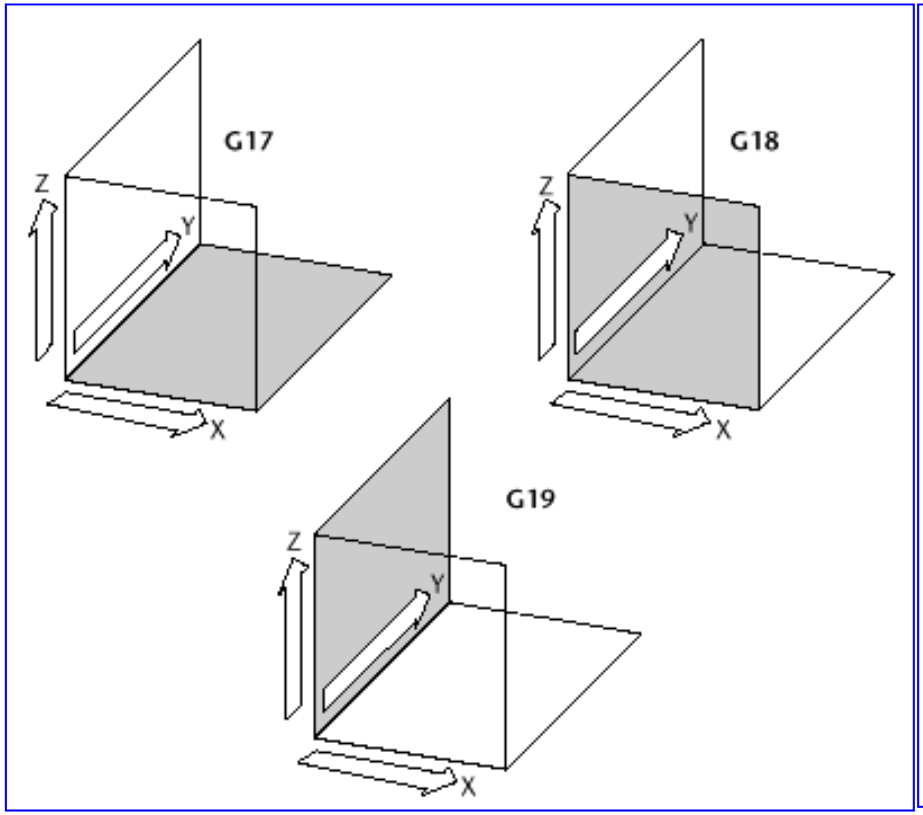
On a common vertical knee CNC mill the spindle is stationary while the rest of the components move according to their axis designations (**X**, **Y**, and **Z**).

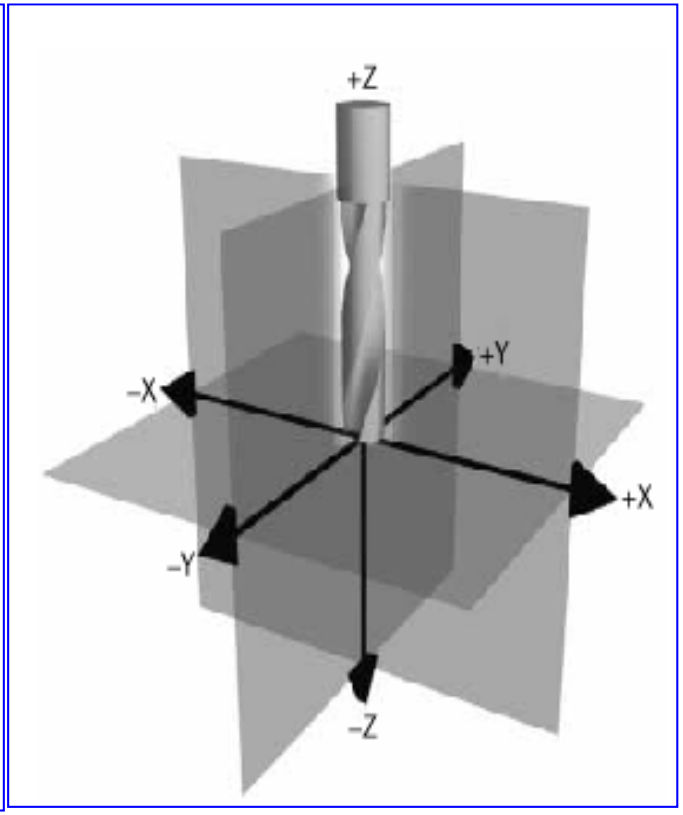
Axis and motion nomenclature – CNC punch machine



On a CNC punch press the part is moved in the **X** and **Y** directions while the punch is stationary.

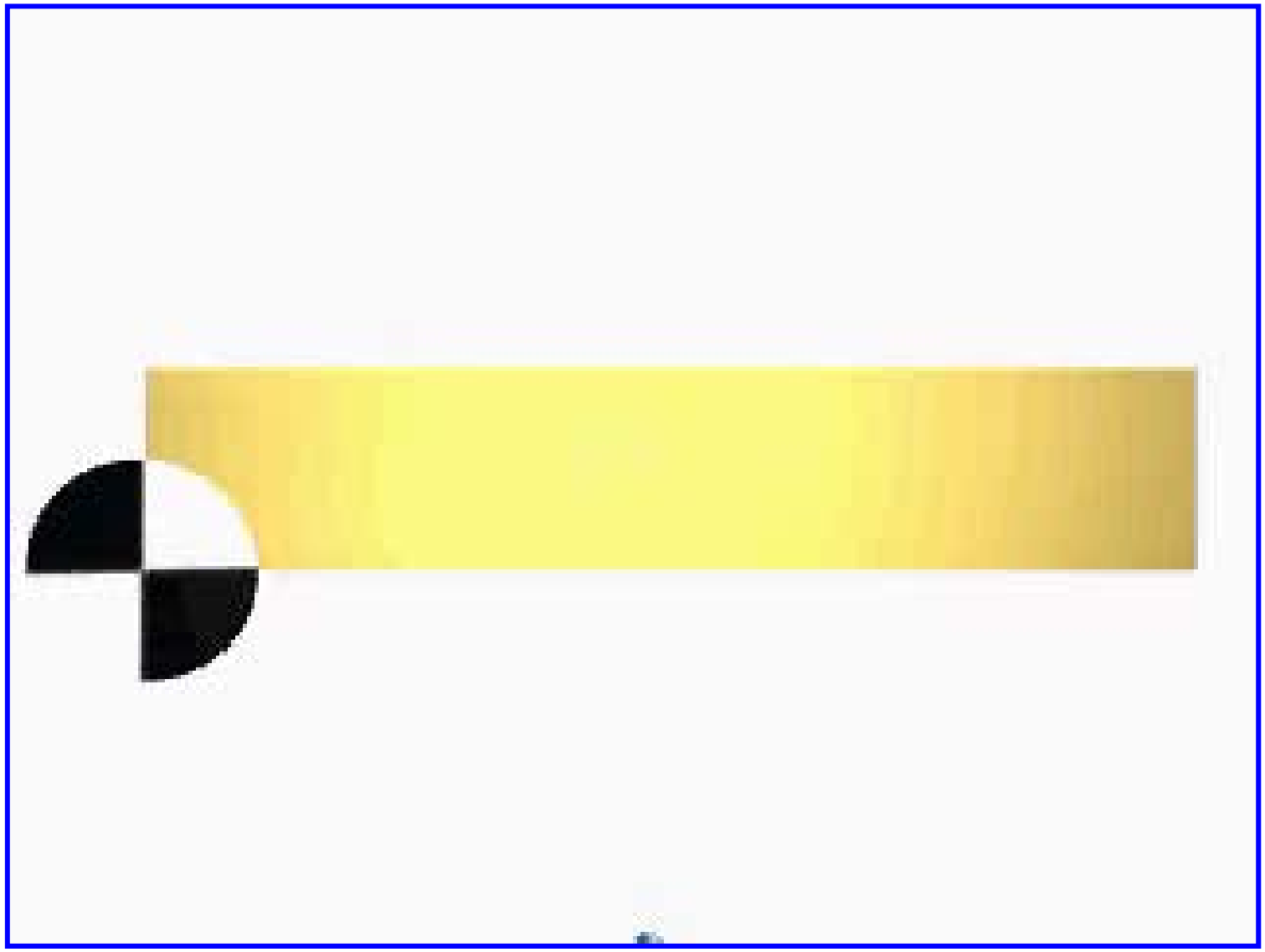
CNC milling fundamentals – The three Cartesian planes





The three planes in the Cartesian coordinate system are **XY**, **XZ**, and **YZ**. These are referred to as **G17**, **G18**, and **G19**, respectively, on the mill.

CNC milling fundamentals – The part reference zero



The video illustrates the two reference points on a CNC Machine: ***Machine Reference Zero*** (MRZ) and the ***Part Reference Zero*** (PRZ). All coordinates are based on these two points.

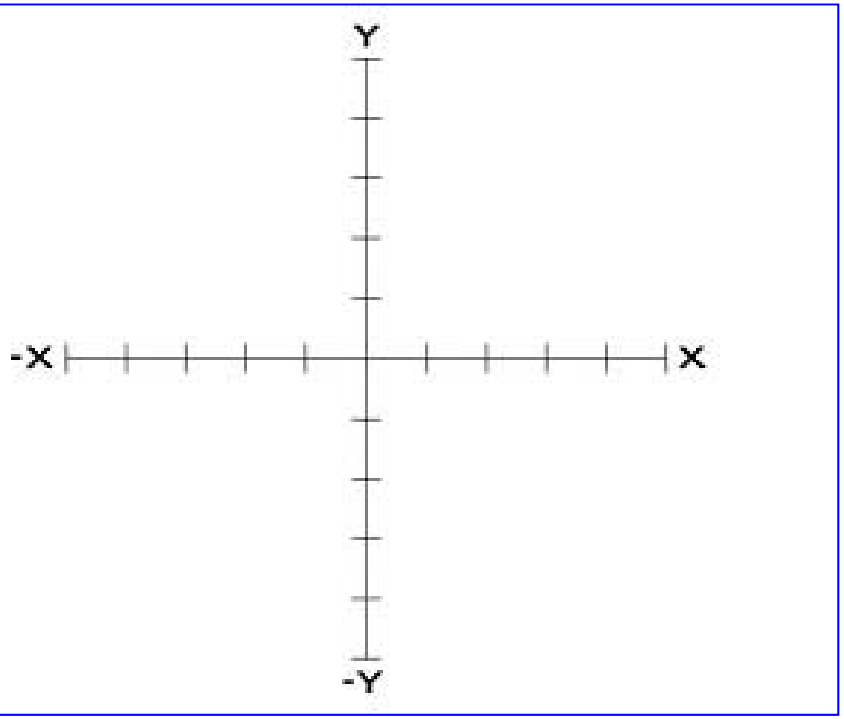
- All CNC machine tools require a reference point from which to base coordinates.
- **It is generally easier to use a point on the workpiece itself for reference, because the coordinates apply to the part anyway – thus the PRZ designation.**
- The PRZ is defined as the lower left-hand corner and the top of the stock of each part.

The advantages of having the PRZ at the lower left top corner are:

1. Geometry creation is in the positive XY plane for CAD/CAM systems.
2. The corner of the workpiece is easy to find.
3. All negative Z depths are below the surface of the workpiece.

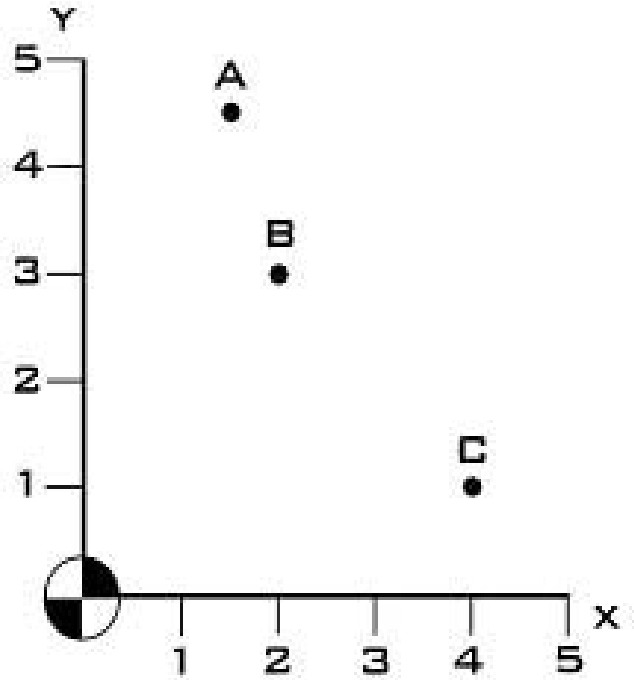
The Cartesian graph

Cartesian coordinates were invented by René Descartes, who is famous for the phrase "I think, therefore I am." Most Cartesian graphs for milling and turning use a three-axis coordinate system, denoted by the X, Y, and Z axes. These coordinates are used to instruct the machine tool where to move on the workpiece.



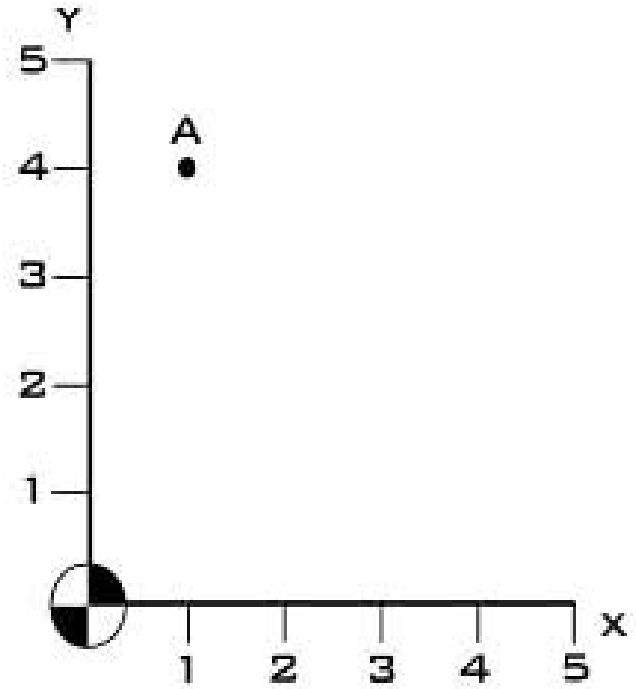
CNC milling fundamentals – Absolute coordinates

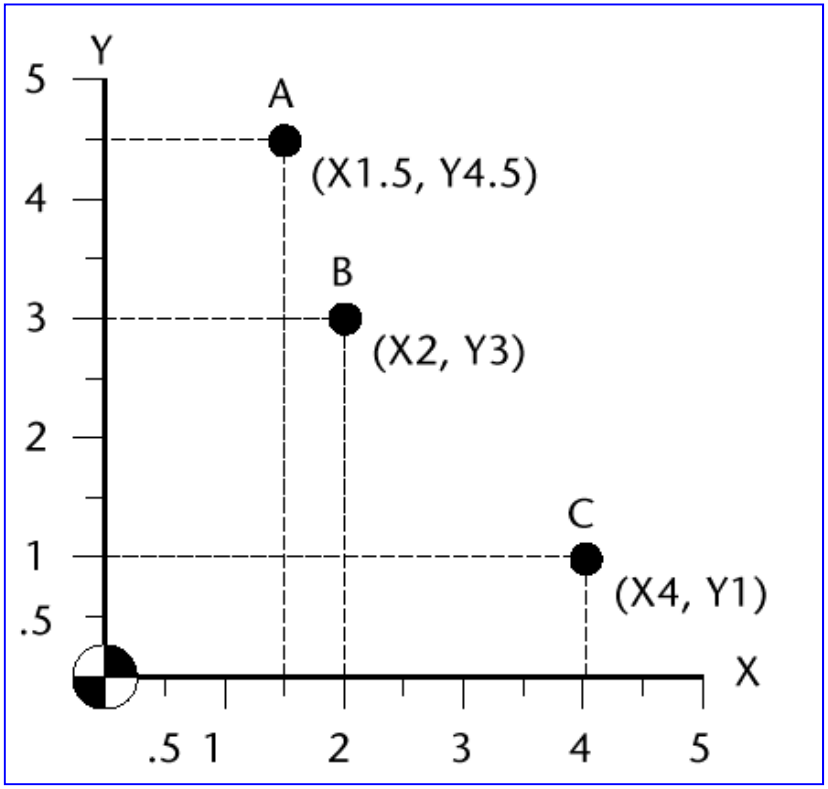
Absolute coordinates use the origin as the reference point. This means that any point on the Cartesian graph can be plotted accurately by measuring the distance from the origin to the point, first in the X direction, then in the Y direction, and then, if applicable, in the Z direction.

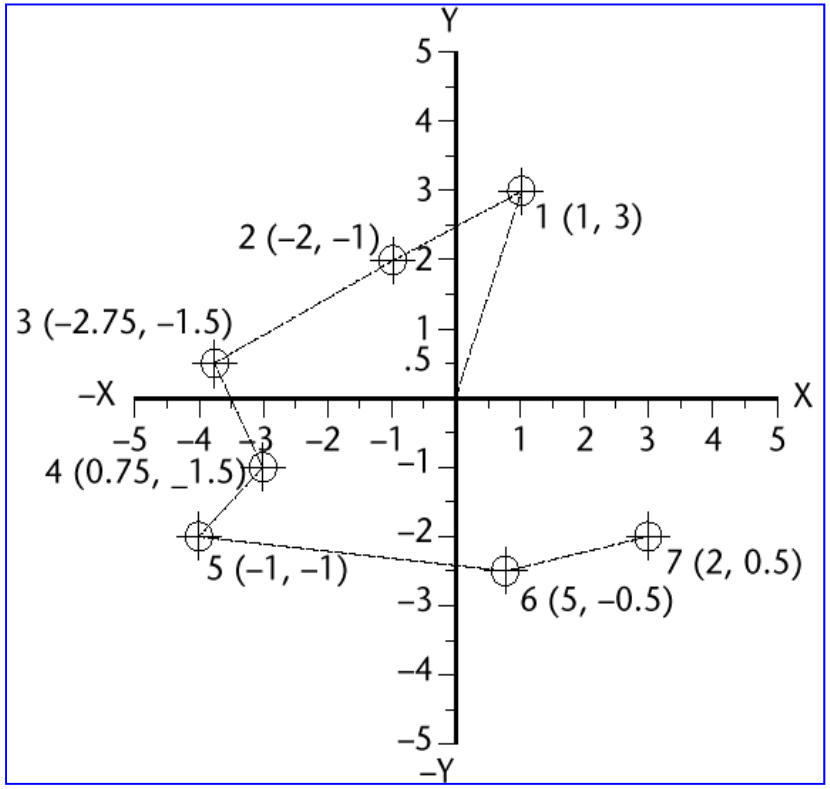


CNC milling fundamentals – Incremental coordinates

Incremental coordinates use the present position as the reference point for the next movement. This means that any point in the Cartesian graph can be plotted accurately by measuring the distance between points, generally starting at the origin.




Y
5
4
3
2
1
.5
A
(X1.5, Y4.5)
B
(X2, Y3)
C
(X4, Y1)
X
.5 1 2 3 4 5


Y
5
4
3
2
1
.5
–X
X
–5 –4 –3 –2 –1 1 2 3 4 5
–1
–2
–3
–4
–5
–Y
1 (1, 3)
2 (–2, –1)
3 (–2.75, –1.5)
4 (0.75, _1.5)
5 (–1, –1)
6 (5, –0.5)
7 (2, 0.5)

EXERCISE 1: Absolute Coordinates

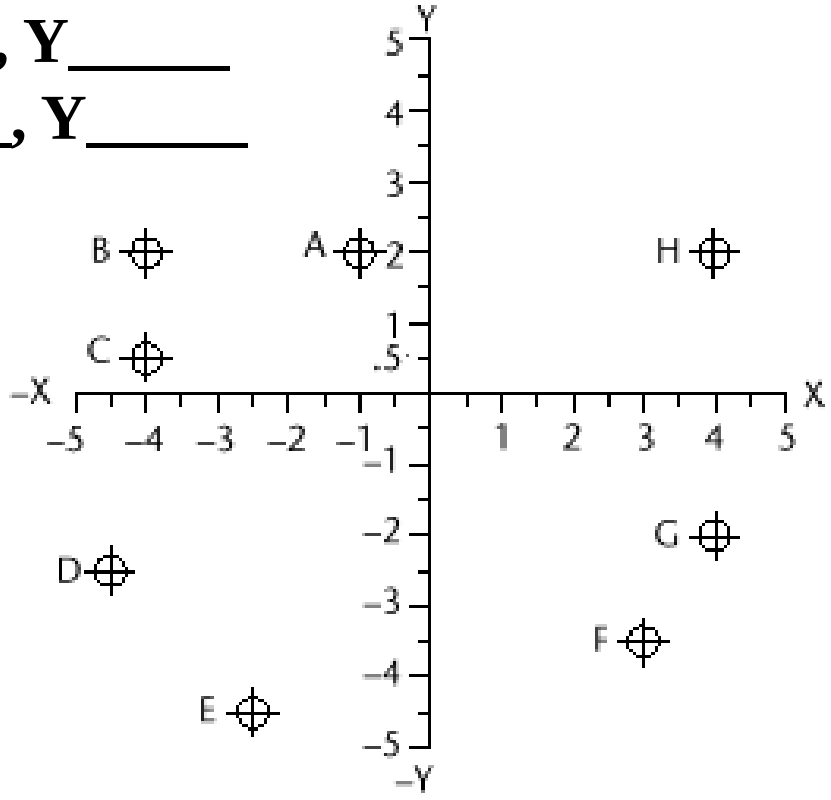
Fill in the X and Y blanks with the appropriate absolute coordinates for points A through H.

A: X_____, Y_____ B: X_____, Y_____

C: X_____, Y_____ D: X_____, Y_____

E: X_____, Y_____ F: X_____, Y_____

G: X_____, Y_____ H: X_____, Y_____



EXERCISE 2: Incremental Coordinates

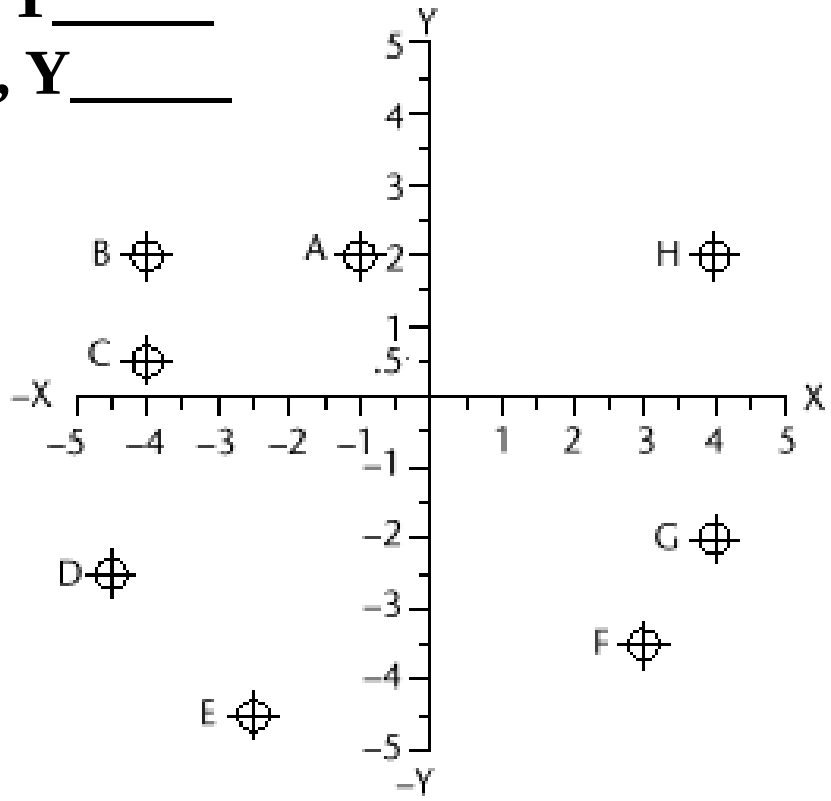
Fill in the X and Y blanks with the appropriate incremental coordinates for points A through H.

A: X_____, Y_____ **B: X_____, Y_____**

C: X_____, Y_____ **D: X_____, Y_____**

E: X_____, Y_____ **F: X_____, Y_____**

G: X_____, Y_____ **H: X_____, Y_____**

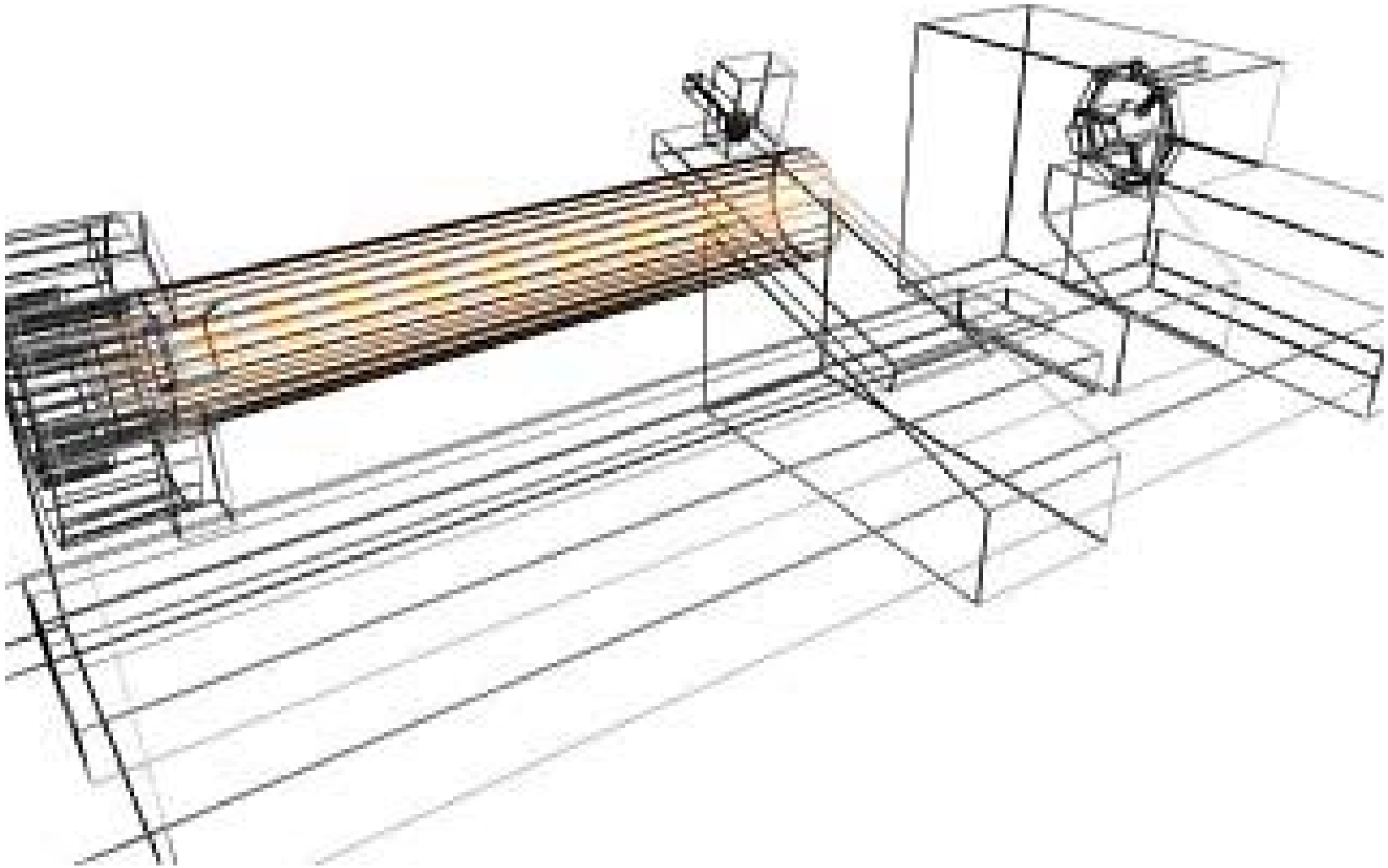


CNC turning fundamentals

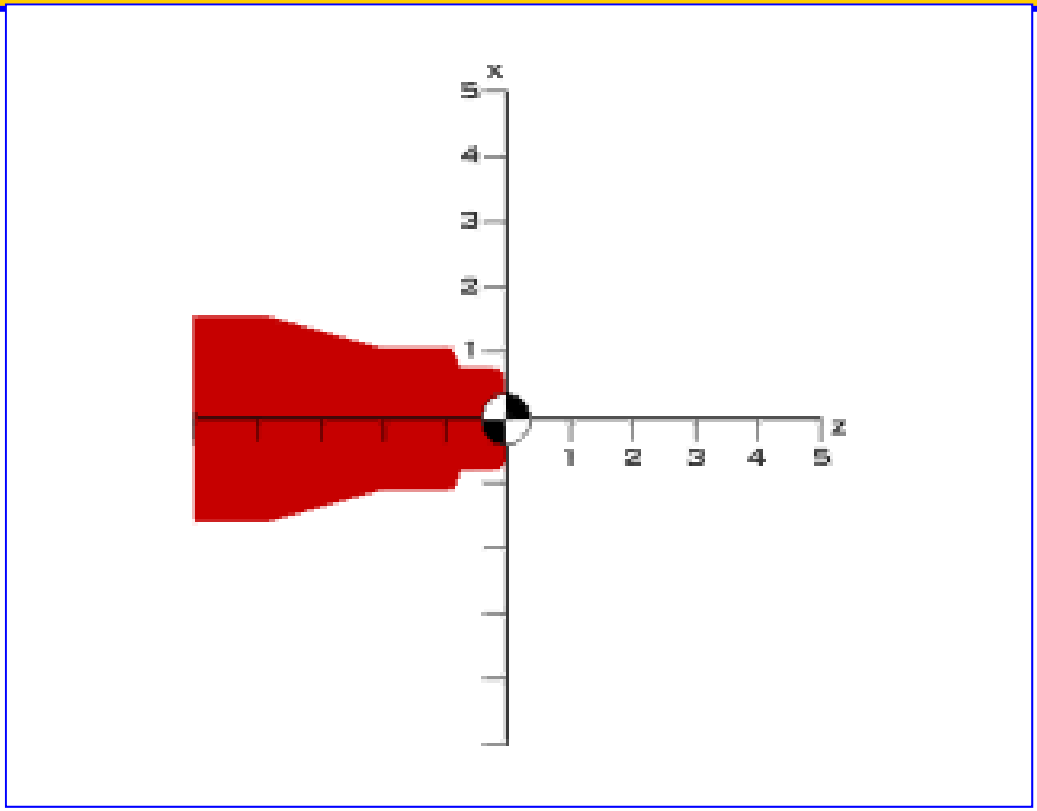
CNC lathes share the same two-axis coordinate system. This allows for the transfer of CNC programs among different machines, as all measurements are derived from the same reference points.

In CNC turning there is a primary, or horizontal, axis and a secondary, or vertical, axis. Because the major axis always runs through the spindle(horizontally), the Z axis is usually the longer one. The X axis is perpendicular to the Z axis (or vertical).

It is important to remember that on most CNC lathes the tool post is on the top, or backside, of the machine, unlike on a conventional lathe. This is why the tool is shown above the part in the simulation examples.



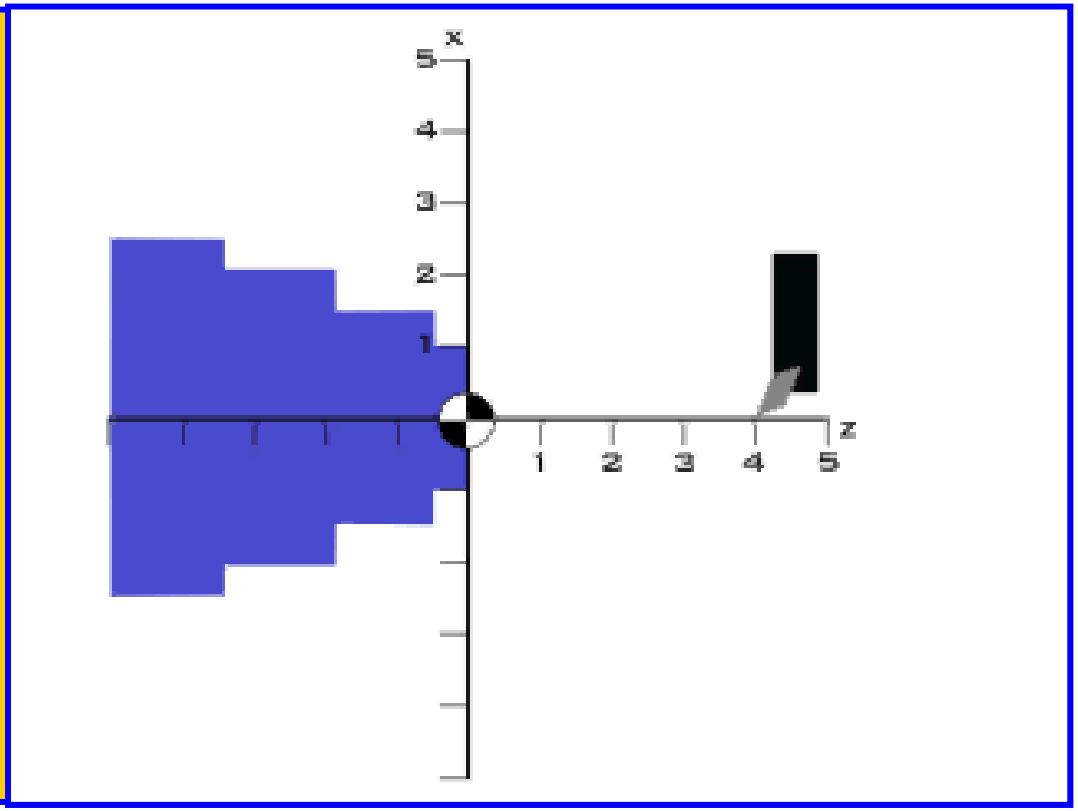
CNC turning fundamentals – Cartesian graph for turning



When measuring X and Z coordinates, use a central reference point. Start all measurements at this reference point, the origin point (X0, Z0). For all our examples **the origin is located at the center right-hand endpoint of the workpiece**. Keep in mind that at times the center left-hand endpoint of the workpiece may be used

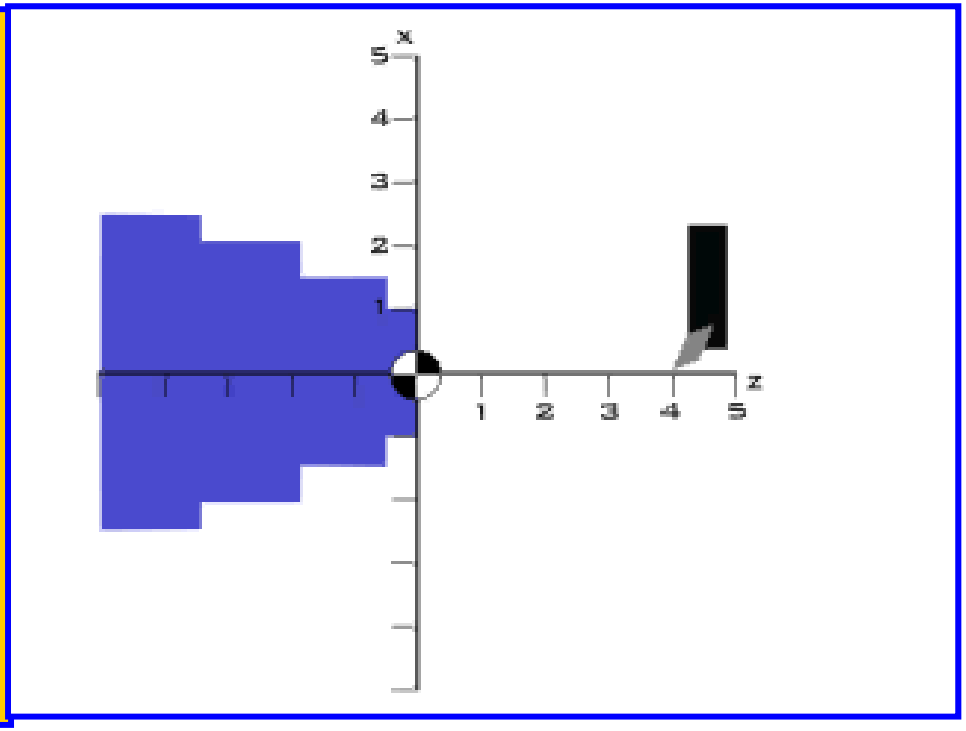
CNC turning fundamentals – Diameter programming

Diameter (or diametrical) programming relates the X axis to the diameter of the workpiece. For example, if the workpiece has a 5-in. outside diameter and you want to command an absolute move to the outside, you would program X5.0.



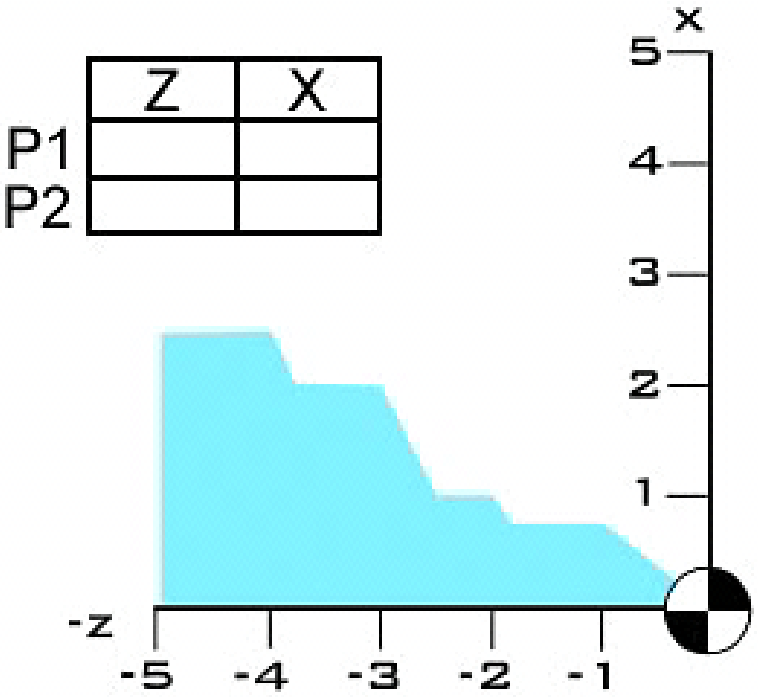
CNC turning fundamentals – Radial programming

Radius (or radial) programming relates the X axis to the radius of the workpiece. For example, for the same 5-in. outside diameter workpiece, you would program X2.5 to move the tool to the outside.



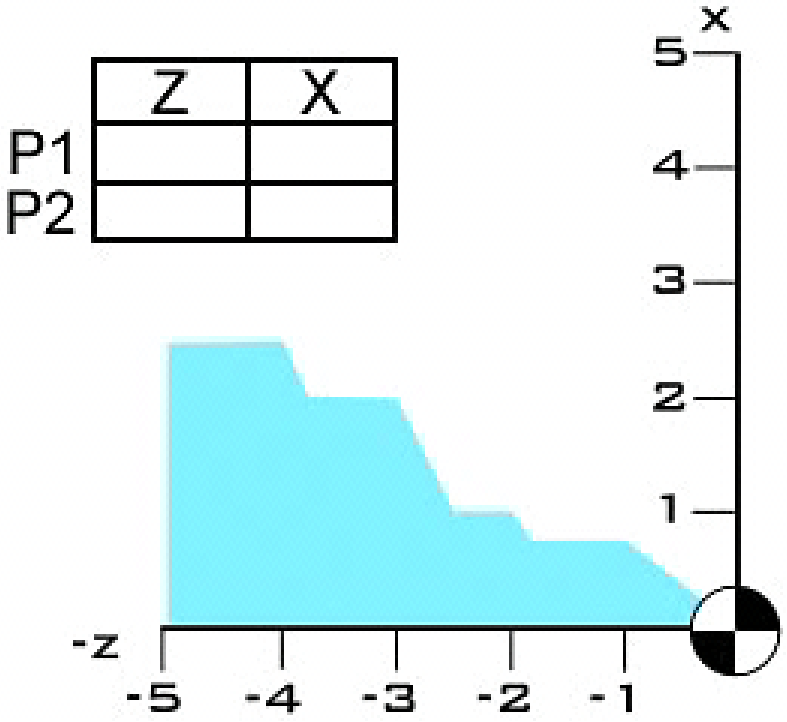
CNC turning fundamentals – Absolute coordinates

When plotting points using absolute coordinates, always start at the origin (X0, Z0). Then travel along the Z axis until you reach a point directly below the point that you are trying to plot. Write down the Z value and then go up until you reach your point. Write down the X value. You now have the XZ (or ZX) coordinate for that point.



CNC turning fundamentals – Incremental coordinates

The second method for finding points in a Cartesian coordinate system is by using incremental coordinates. Incremental, or relative, coordinates use each successive point to measure the next coordinate. Instead of constantly referring back to the origin, the incremental method refers to the previous point



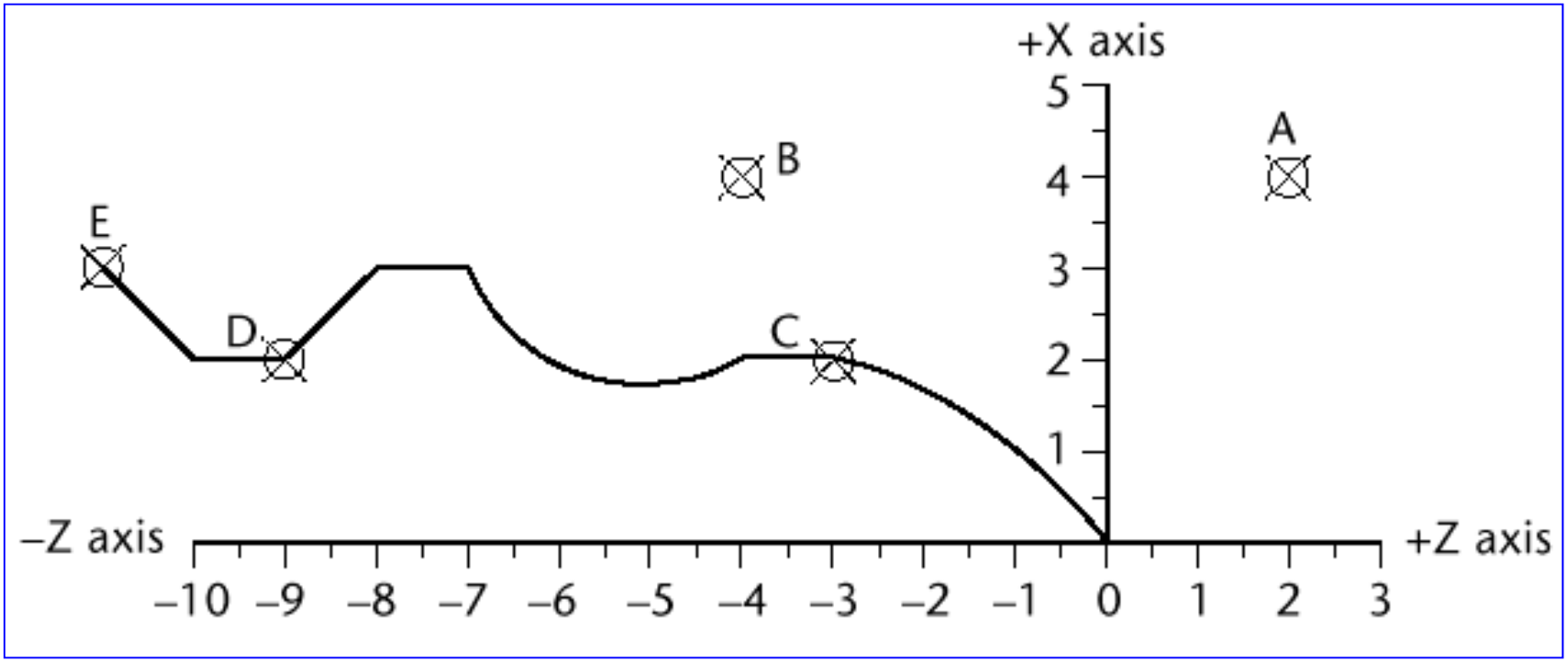
EXERCISE 1: Using Incremental Coordinates.

Find the diametrical X and Z coordinates for points A through E.

A: X_____, Z_____ B: X_____, Z_____

C: X_____, Z_____ D: X_____, Z_____

E: X_____, Z_____



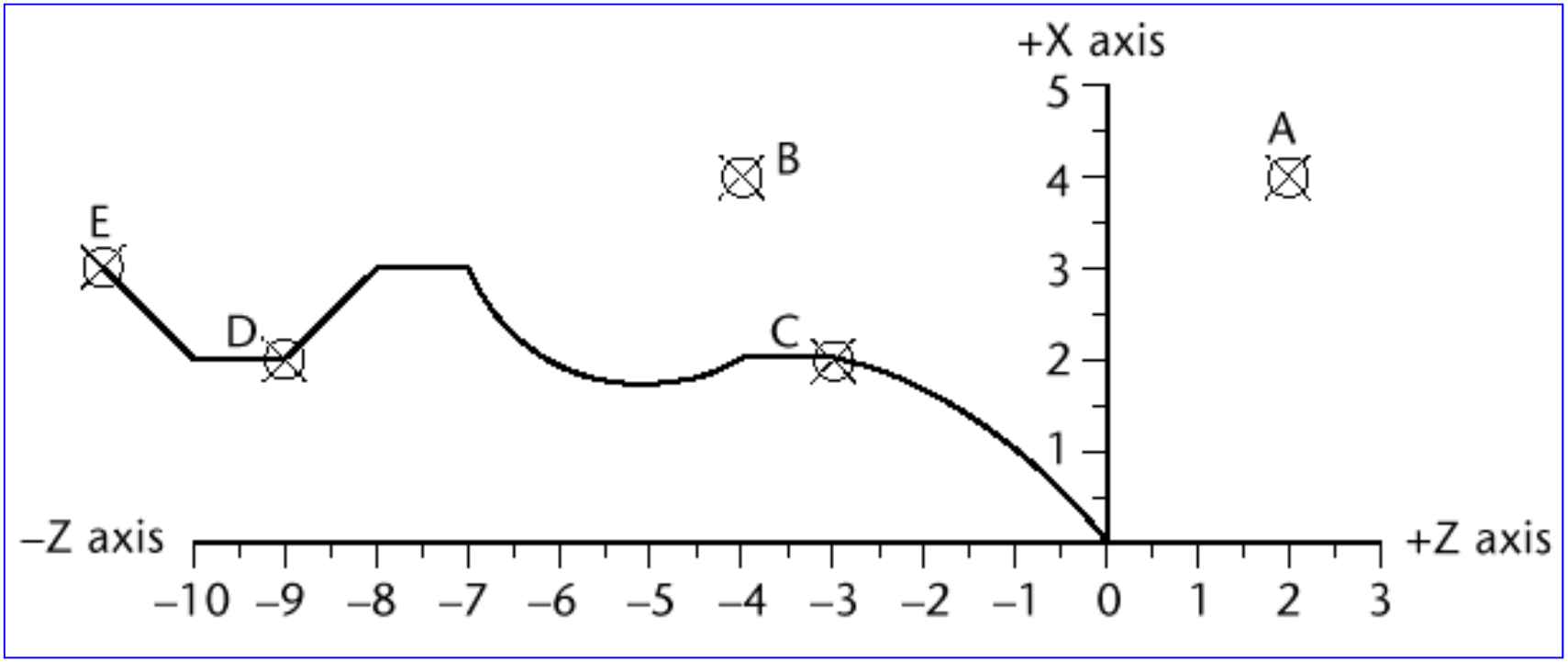
EXERCISE 2: Using Absolute Coordinates

Find the X and Z coordinates for points A through E.

A: X_____, Z_____ **B: X_____, Z_____**

C: X_____, Z_____ **D: X_____, Z_____**

E: X_____, Z_____



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