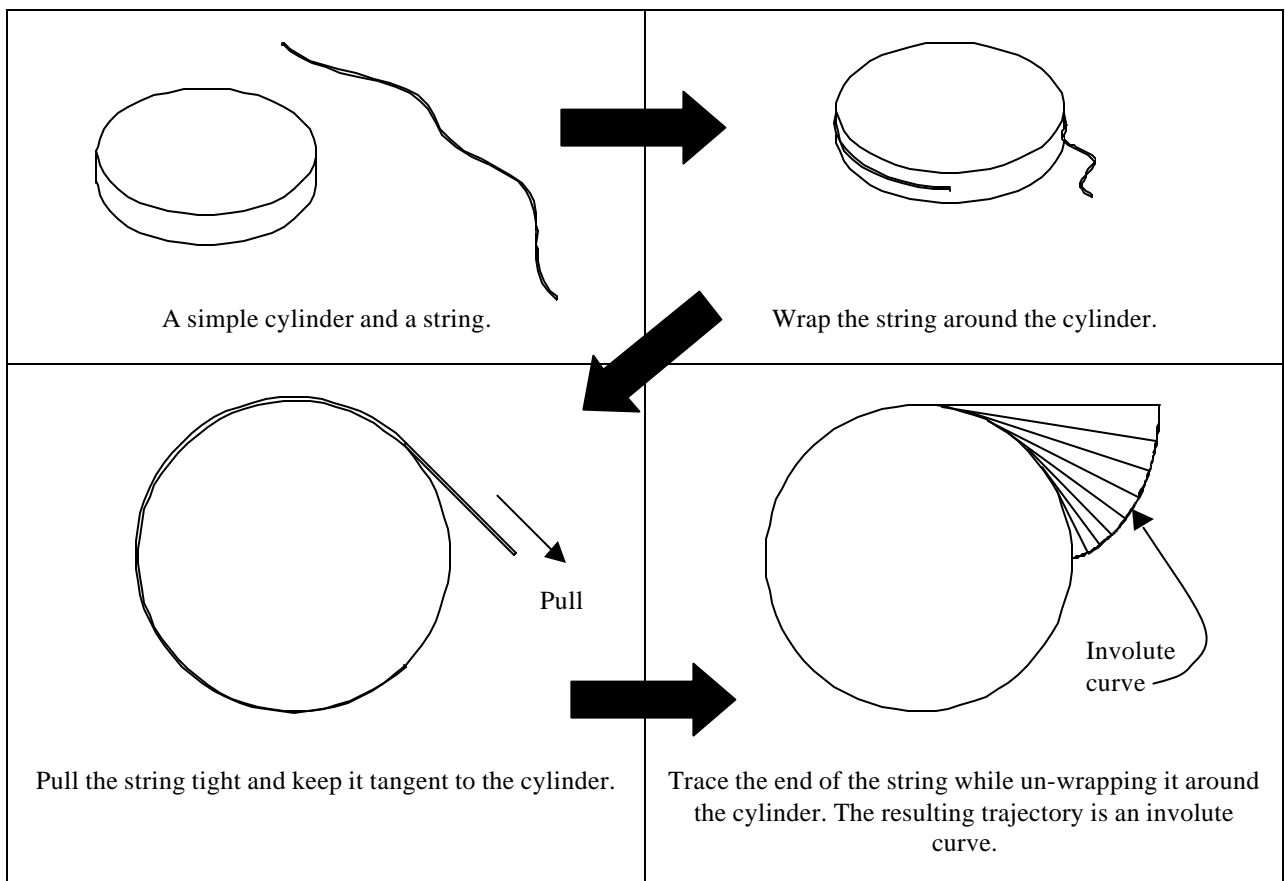


# Involute Gears

## Introduction

This lesson covers the development of ‘involute’ gears. An involute gear is based on an involute curve, which is a mathematical shape. To understand what an involute is, consider a simple cylinder and a string as shown below. Wrap the string around the cylinder. While maintaining tension on the string, trace the path that the end of the string makes while un-wrapping it around the cylinder. This path is an involute curve.



There are two key parameters that control the involute curve: the diameter of the cylinder and the angle that the string is un-wrapped around the cylinder. In the example above, the string is un-wrapped  $90^\circ$  around the cylinder.

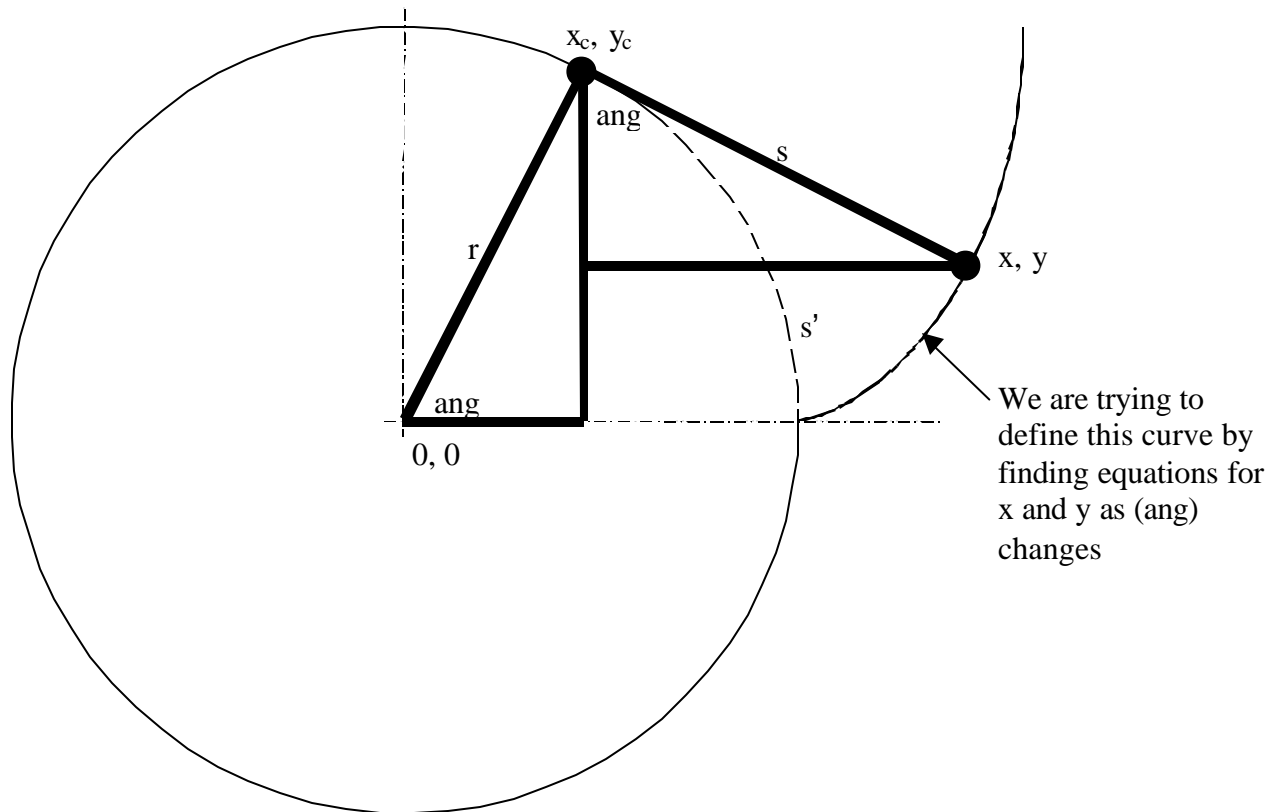
## The Involute Curve

Development of the mathematical equations for the involute curve uses simple trigonometry. We will develop the equations for 90° of one full involute. In other words, we are un-wrapping the string 90° around the cylinder in a counterclockwise direction.

The circumference of a circle is defined by:  $c = 2 * p * r$

One quarter (90°) of the circumference of a circle is then:  $c = p * r / 2$

In the figure below, the line 's' is the same length as the part of the circumference the string has been un-wrapped ( s' ).



Using trigonometry, we find that:

$$x_c = r * \cos(\text{ang})$$

$$y_c = r * \sin(\text{ang})$$

$$x = x_c + (s * \sin(\text{ang}))$$

$$y = y_c - (s * \cos(\text{ang}))$$

## ***Datum Curves From Equation***

In Pro/ENGINEER, datum curves can be defined using mathematical equations. When using this feature, a system variable 't' is used, that varies from 0 to 1 over the length of the curve. For the involute curve, let the angle (ang) be equal to 't' times 90. This means that the variable 'ang' will vary from zero to 90°.

To define 's', we combine the circumference equation and 't' to form:

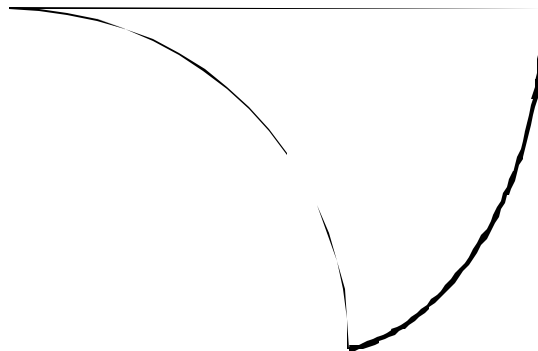
$$s = (p * r / 2) * t$$

In this example, the diameter of the cylinder is 1.500. This is the ***base diameter*** in gear design terminology. The radius of the cylinder is 0.75 inches.

The equations for Pro/ENGINEER are:

$$\begin{aligned} \text{ang} &= t * 90 \\ s &= (\text{PI} * 0.75 * t) / 2 \\ x_c &= 0.75 * \cos(\text{ang}) \\ y_c &= 0.75 * \sin(\text{ang}) \\ x &= x_c + (s * \sin(\text{ang})) \\ y &= y_c - (s * \cos(\text{ang})) \\ z &= 0 \end{aligned}$$

The resulting datum curve is shown in bold below.



## Creating the Gear

In Pro/ENGINEER, the gear is started by modeling a cylinder at the outside diameter of the gear, see Figure 1. Several datum curves are created to define the root diameter, base diameter, and pitch diameter of the gear, see Figure 2. Next, the involute shaped datum curve is created and moved into the correct position to define one side of one gear tooth, see Figure 3. The curve is mirrored and the gear tooth is cut into the cylinder using the edge of the involute datum curves, see Figure 4. The cut is patterned and rounds are added at the base of the gear. The completed gear is shown in Figures 5 and 6.

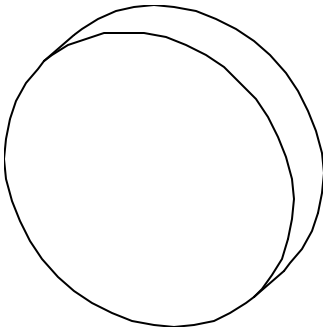


Figure 1

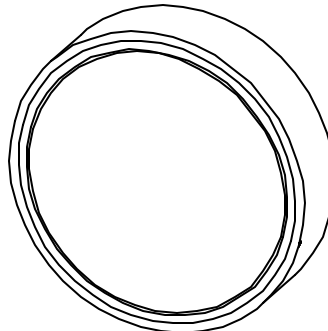


Figure 2

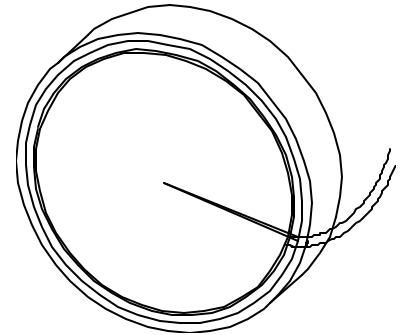


Figure 3

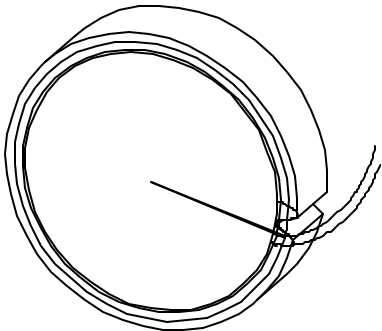


Figure 4

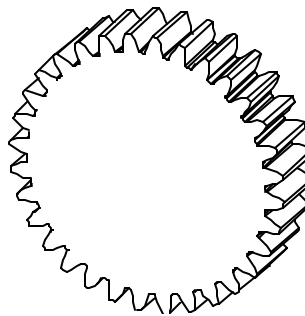


Figure 5

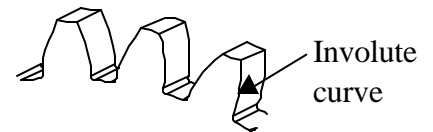


Figure 6

## ***Gear Parameters***

The following are geometric parameters in gear design:

Pitch Diameter

$$\text{Diametral Pitch} = \text{Pitch Diameter} + ( 2 * \text{Addendum} )$$

Root Diameter

$$\text{Circular Pitch} = \pi / \text{Pitch Diameter}$$

Outside Diameter

$$\text{Number of Teeth} = \text{Diametrical Pitch} * \text{Pitch Diameter}$$

Base Diameter

Pressure Angle

Addendum

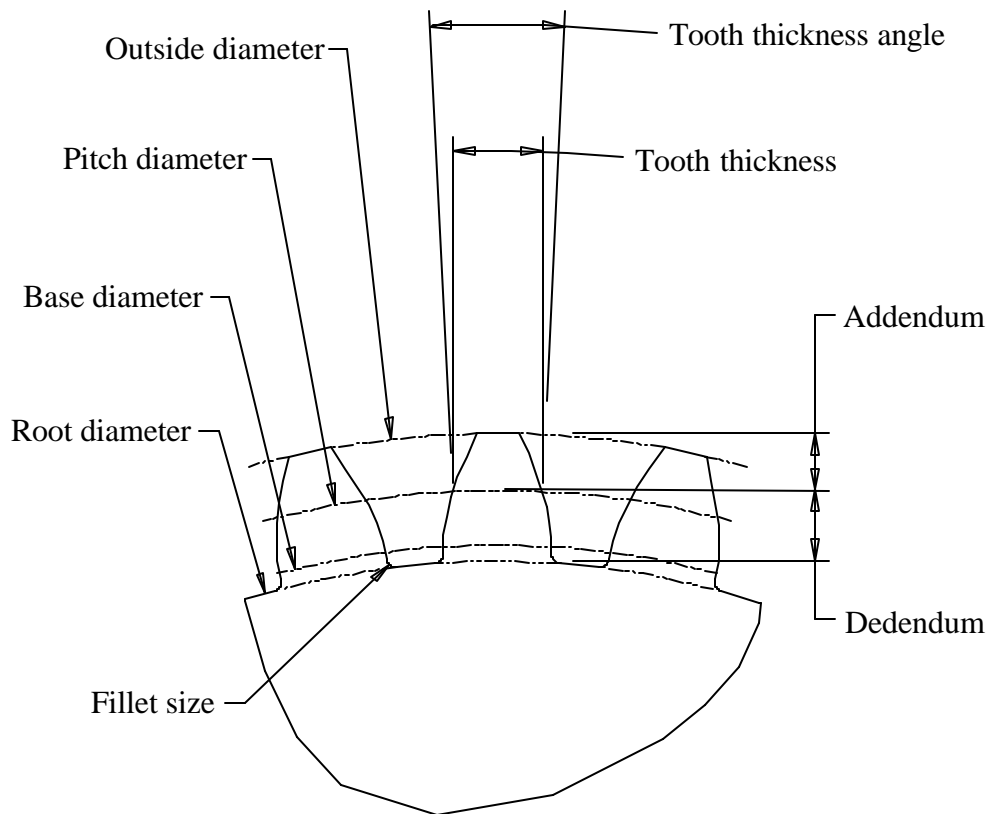
Dedendum

Tooth Thickness

Tooth Thickness Angle

Fillet Size

The figure describes some of the gear parameters.



**Gear Parameters**

## EXERCISE - INVOLUTE GEARS

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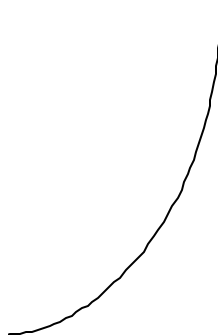
### Task 1: Create a new part with a datum curve driven by an equation.

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- Use **File, New**, pick the **Part** button, enter < involute > for the name, pick **Copy From** and pick the 'inch' start part from the list, then press the middle mouse button
- Create a datum curve using **#Feature; #Create; #Datum; #Curve; #From Equation; #Done**
- For the coordinate system, pick CS0 then pick **#Cartesian**
- In the Notepad window, add the following equations:

```
r = 1.4095
ang = t * 90
s = (PI * r * t) / 2
xc = r * cos(ang)
yc = r * sin(ang)
x = xc + ( s * sin(ang))
y = yc - ( s * cos(ang))
z = 0
```

- **Save** and **Exit** Notepad then pick **OK** in the dialog box or press the middle mouse button
- The result is shown below. This curve will be used to create an involute gear.
- Pick **File, Save** and press the middle mouse button



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**Task 2: Create a cylinder at the outside diameter of the gear.**

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- Create an extruded protrusion sketched on DTM3, flip the direction arrow to point from the red side of DTM3
- Sketch a circle centered on DTM1 and DTM2, with a diameter of 3.250 which is the *outside diameter* of the gear (see the figure on page 5)
- Use a blind depth of 1.000

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**Task 3: Create three datum curves representing the major diameters.**

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- Create a datum curve sketched on DTM3 with a diameter of 2.688 to represent the *root diameter* of the gear
- Create a datum curve sketched on DTM3 with a diameter of 2.819 to represent the *base diameter* of the gear
- Create a datum curve sketched on DTM3 with a diameter of 3.000 to represent the *pitch diameter* of the gear

---

**Task 4: Create two datum points and a datum curve.**

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- Create a datum point at the intersection of the involute curve and the 3.000 diameter circle using the **#Crv X Crv** option
- Create a datum point at the intersection of datums DTM1, DTM2, and DTM3 using the **#Three Srf** option
- Create a datum curve through the two datum points using the **#Thru Points** option

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**Task 5: Create a datum evaluate feature.**

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- Create a datum evaluate feature
- Name the feature 'measure'
- Name the measurement parameter 'angle'
- Measure the angle between the last curve you created and DTM2

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**Task 6: Copy the involute curve.**

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- Copy the involute curve using **#Feature; #Copy; #Move; #Dependent; #Done**
- Pick the involute curve then pick **#Done; #Rotate; #Crv/Edg/Axis**
- Pick the axis in the center of the cylinder then pick **#Okay**
- Enter < 30 > for the angle then pick **#Done Move; OK; #Done**

---

**Task 7: Add a relation using Modify.**

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- **#Modify** the angle dimension of the copied involute curve
- Enter: angle:FID\_MEASURE + ( 7.5 / 2 )
- Answer < Y > to add the relation
- **#Regenerate** the part

---

**Task 8: Mirror the copied involute curve.**

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- Mirror the copied involute datum curve about DTM2 using **#Feature; #Copy; #Mirror; #Dependent; #Done**
- Read the prompts

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**Task 9: Copy the curve again.**

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- Copy the same copied curve (the one created in task 6) again using **#Feature; #Copy; #Move; #Dependent; #Done**
- Pick the curve then pick **#Done; #Rotate; #Crv/Edg/Axis**
- Pick the axis in the center of the cylinder then pick **#Flip; #Okay**
- Enter < 15 > for the angle then pick **#Done Move; #Done; OK; #Done**



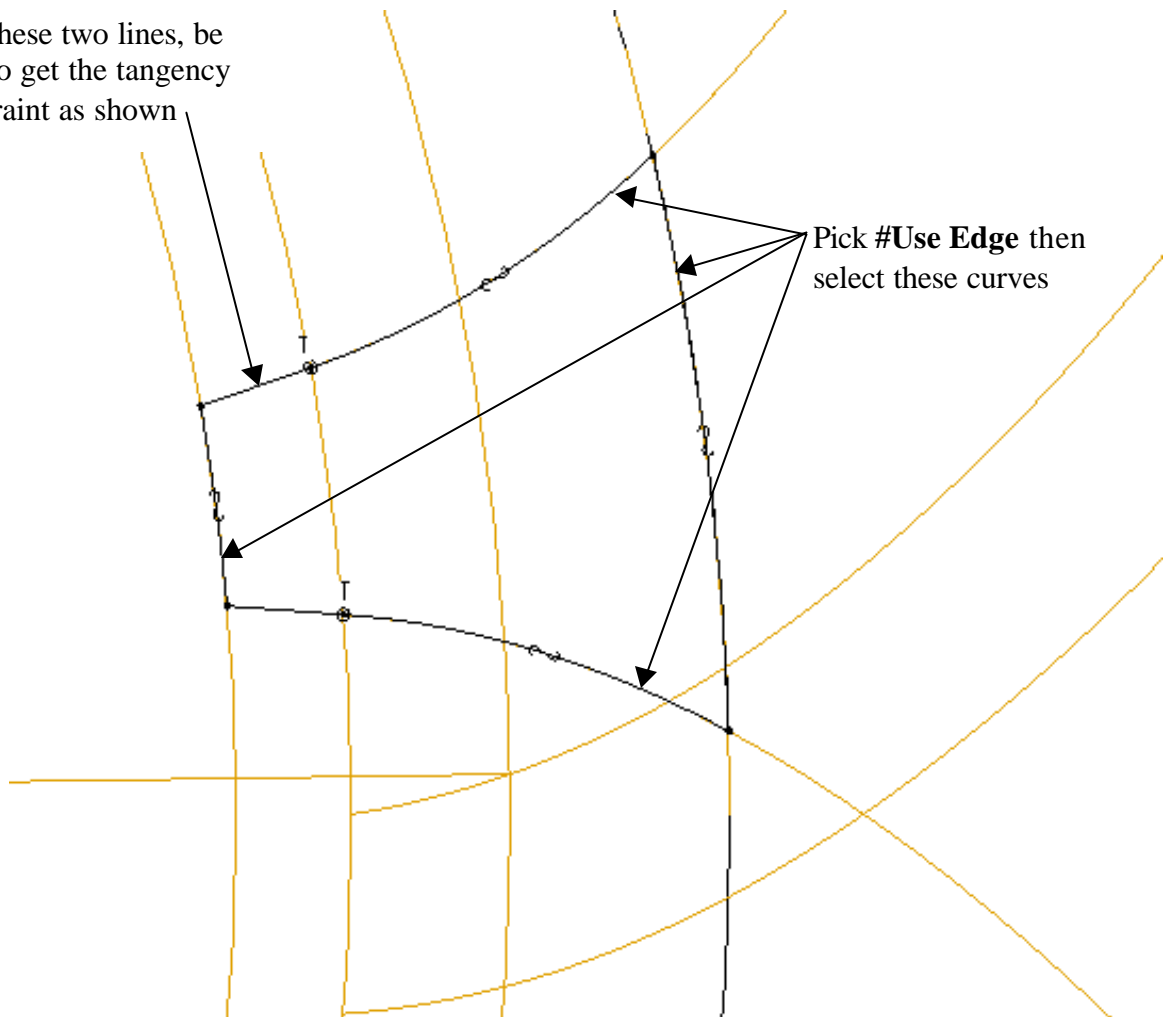
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**Task 10: Create an extruded cut.**

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- Create an extruded (thru all) cut using the edges of the curves as shown below
- Trim the sketch using **#Geom Tools; #Trim**

Add these two lines, be sure to get the tangency constraint as shown



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**Task 11: Copy the cut.**

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- Copy the cut using **#Feature; #Copy; #Move; #Dependent; #Done**
- Pick the cut then pick **#Done; #Rotate; #Crv/Edg/Axis**

- Pick the axis in the center of the cylinder then pick **#Flip; #Okay**
- Enter < 15 > for the angle then pick **#Done Move; #Done; OK; #Done**

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**Task 12: Pattern the copied cut.**

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- Pattern the copied cut, enter < 15 > for the increment, use 23 for the number of instances in the pattern

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**Task 13: Finish the part.**

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- Create a 0.020 round at the base of the gear tooth
- Pattern the round
- Create a coaxial hole with a diameter of 0.750
- The part is shown without the datum curves (Hint: Use layers)
- **Save** the part and **Close** the window

