Write a part program to machine the part shown in Figure 1 on the Lodge and Shipley lathe.

Figure 1. Drawing of the Machined Part. All Dimensions Are in Inches.

For the first 4 passes, the cutting process variables are specified. Each pass will have different combinations of feeds and depths-of-cut. In each pass, there are two sections. The first section is denoted by section $a$ and the second is denoted by section $b$. 
Different sections have different cutting speeds, thus spindle speeds. The cutting process variables in the first 4 passes are specified in Table 1.

<table>
<thead>
<tr>
<th>Pass</th>
<th>Cutting speed V (ft/min)</th>
<th>Feed f (in)</th>
<th>Depth of cut d (in)</th>
<th>Spindle speed Ns (rpm)</th>
<th>Workpiece diameter D (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass 1a</td>
<td>180</td>
<td>0.007</td>
<td>0.1</td>
<td>764</td>
<td>1</td>
</tr>
<tr>
<td>Pass 1b</td>
<td>180</td>
<td>0.01</td>
<td>0.1</td>
<td>764</td>
<td>1</td>
</tr>
<tr>
<td>Pass 2a</td>
<td>280</td>
<td>0.007</td>
<td>0.1</td>
<td>1528</td>
<td>0.8</td>
</tr>
<tr>
<td>Pass 2b</td>
<td>280</td>
<td>0.01</td>
<td>0.1</td>
<td>1528</td>
<td>0.8</td>
</tr>
<tr>
<td>Pass 3a</td>
<td>180</td>
<td>0.007</td>
<td>0.05</td>
<td>1250</td>
<td>0.6</td>
</tr>
<tr>
<td>Pass 3b</td>
<td>180</td>
<td>0.01</td>
<td>0.05</td>
<td>1250</td>
<td>0.6</td>
</tr>
<tr>
<td>Pass 4a</td>
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<td>0.007</td>
<td>0.05</td>
<td>2377</td>
<td>0.5</td>
</tr>
<tr>
<td>Pass 4b</td>
<td>280</td>
<td>0.01</td>
<td>0.05</td>
<td>2377</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The spindle speed is determined by $N_s = \frac{24V}{\pi(D_o + D_i)}$, where $D_o$ is the outer diameter (before machining) and $D_i$ is the inner diameter (after machining).

The fifth pass is a roughing pass that leaves 0.01 in for the finish (sixth) pass. Use a feed of 0.012 in for the rough cut and 0.008 in for the finish cut. Use a spindle speed of 2300 rpm for these two passes.

The tool has a 0.031 in radius, and the coordinate system is shown in Figure 2. Use the lathe format (the F word is the feed in inch/revolution) and absolute units.

Detail how you calculate the points in your part program. Use MSG format in the program example to comment on each pass in your part program.

You will measure the longitudinal, radial, and cutting forces. Provide the graphs and comment on the effect of the process variables (i.e., cutting speed, depth-of-cut, and feed). In an assignment later in the term you will model these forces.
Figure 2. Lathe Setup. The Radial, Cutting and Longitudinal Directions Are Positive X, Y and Z Axes, Respectively.

Example of the part program

%  
N10 (ID,PROG,place your ID number here,place your program name here)  
N20 G70  
N30 G90 T0002  
N40 G92 X4.270 Z6.065  
N50 G95  
N52 (MSG, BE SURE WORKPIECE IS ABOUT 1" OUT OF CHUCK)  
N54 (MSG,-----MACHINE IS ABOUT TO **RAPID** TO END OF PART-----)  
N60 M00  
N70 G00 X0.431 Z0.031 M00  
N80 Z0.131  
N90 G97 S764 M04  
N100 Place your code here  
N9970 G00 X4.270 Z6.065  
N9980 T0  
N9990 M30  
N9999 (END,PROG)  
%  
make sure to put a “;” here