Due Date: End of class the day after the date at the bottom of this file
Peer Assessor's Name: __________________

Mark: _____ / 100 (Thinking)

AutoDesk Inventor for Problem Solving: Wooden Gears

DO THE WORK DESCRIBED AND PUT THIS INPUT FILE IN YOUR ELECTRONIC PORTFOLIO

CONTENTS

1 One Way to Generate Gear Assemblies (Involute): But Not Recommended

NOTE: The following is NOT the way we will create our gears for our tall case clock. Of course, software applications typically include all kinds of "canned" functionality that are intended to make your life easier -- but will you learn anything when you use the "canned" functionality? Maybe or maybe not. And sometimes there are other very good reasons for NOT using the canned functionality such as "Gear Generator" in Inventor2014.

If nothing else, this section is a review of how to start a new Inventor Project.

1. Start a New Project called YourName_GearGenerator
    a. Application icon, Manage, Projects
    b. New, New Single User Project
        i. YourName_GearGenerator (in your usual Inventor projects folder)
        ii. Done
2. Create a new standard.iam file from the default template folder
    a. It should show your recently-created GearGenerator.ipj project file
3. Immediately save your file as YourName_SpurGears.iam – that is, rename the default assembly1.iam file
4. Go to Design Ribbon / Power Transmission tab / Spur Gear (may be below Worm Gear or Bevel Gear in the flyout list)
5. In Spur Gears Component Generator dialog box open the design tab

   a. Under Design Guide, select the Module and Number of Teeth option because you will be working in metric
   b. Use Pressure Angle of 20 as this is the most common industry standard
6. The Design tab of this dialog box is broken down into three major sections. The top is the Common area where you specify the tooth characteristics of the gear. The middle is where you set the requirements for size of the gears that support the teeth, and the bottom (which you may have to expand) is an information area that will offer feedback on the design and calculations.
   a. So, you can proceed to generate a pair of gears to mesh with each other.
7. Unless you intend to become a mechanical engineer, you will ***get very little*** out of this overall "GearGenerator" canned process. Moreover, you won't learn much, if anything, about how to really use parametric CAD applications.
   a. You will simply be following a point-and-click procedure without engaging critical thinking skills.

Note:

Involute gears are important in a high speed power train where a perfectly constant velocity through one rotation of the driven shaft is required. That is, no matter where a pair of meshing teeth are during their brief time of touching each other, the effective contact radii from the centre of each shaft will remain constant. But is this an important factor in gear design for a pendulum clock? Are there other ways of designing gears that will engage both your critical and creative thinking skills and have the added bonus of being easy to layout and fabricate?

2 Gear Design: Practical Considerations for a Pendulum Clock -- Critical Thinking

Before using the "canned" gear design functionality in your CAD application (eg "Gear Generator" or the like) it is best to first do some critical thinking about the realities of your particular design situation -- a wooden works pendulum clock for example.

#	Pendulum Clock Physical Reality / Parameter	Some Analysis / Decision-Making Rationale
1	Friction	In spite of the slowly moving parts in a clock, energy loss due to friction is substantial enough that heavy falling weights provide the energy to keep the clock's moving parts moving, typically for 8 days (in a so-called "8-day" clock). Much of the friction occurs where gear teeth meet each other and at bushings. Oily lubricants should be avoided in clockworks – oil will collect dust and the works will eventually gum-up. Some wood species are naturally self-lubricating such as lignum vitae and to a lesser extent beech and some other hardwoods.
2	All gears move quite slowly	The very slow movement of clock gears suggests that wear on gear bushings may not be severe.
3	Changing humidity in the home environment and grain direction	Wood is hygroscopic – a piece of wood will take in or give up water to the environment. Virtually all wood species will swell, at least somewhat, as its environment gets damper. Shrinkage happens when the environment gets drier. Wood is "anisotropic" meaning that swelling / shrinkage is different in different grain directions. Longitudinal shrinkage (along the length of the log)

#	Pendulum Clock Physical Reality / Parameter	Some Analysis / Decision-Making Rationale
		is usually very minimal. For most wood species, radial shrinkage (outward from the centre of the tree) is roughly half of the tangential shrinkage (tangent to the tree's growth rings.) So a quarter-sawn board (cut radially outward from the tree's centre) would make for a more stable wooden gear than would a flat-sawn board (a generally tangential cut from the log).
4	Mechanical Forces	Although rotational speed on a clock gear is very low, the repetitive loading on teeth could be a consideration. If the turning load is distributed to more than one tooth (such as in involute gear profile design), there will be more friction losses, but less likelihood of tooth breakage. A harder wood species would make sense, perhaps black locust or ironwood as they are locally available and approach the extreme hardness of lignum vitae. A cycloidal gear tooth design will result in less friction between teeth because there is typically only one point of contact as one gear tooth drives another.
5	Rate of rotation	Through the escapement mechanism, the tall case clock gear train gets a small pulse of energy from the falling weights every two seconds. Thus the rotational motion of the gears is intermittent. Hence the constant speed of rotation of an involute gear tooth design is not necessary in a clock. An involute design seems more difficult to fabricate accurately in a wood shop – it has a complex geometry that you would simply have to try to implement using a scroll saw.
6	Clock gears only turn in one direction	Since the clock gears won't be reversed in normal operation, backlash is not a significant concern
7	Fabrication	A traditional cycloidal gear tooth design (common in clocks) modified to minimize the possibility of tooth binding seems a reasonable approach. Note: the design of cycloidal gears seems to be steeped in horological (clock-making) tradition. Clocks actually preceded the industrial revolution – the involute design of gears for engines and other high-speed machines came along later. (Have a look at www.csparks.com/watchmaking/CycloidalGears/index.jxl, if you dare!)

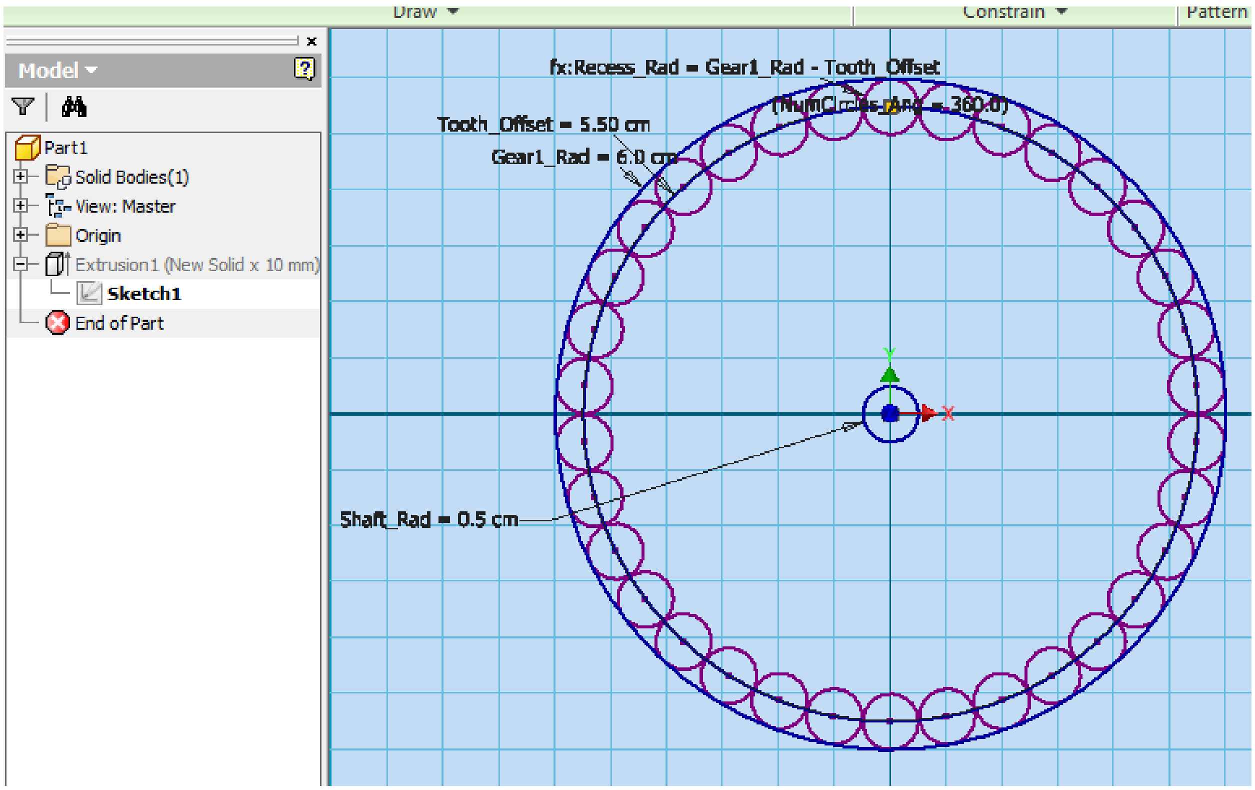
From the above observations – our critical thinking at work -- we will simplify our gear fabrication by designing a very simple gear profile for a tall case clock – our creative thinking.

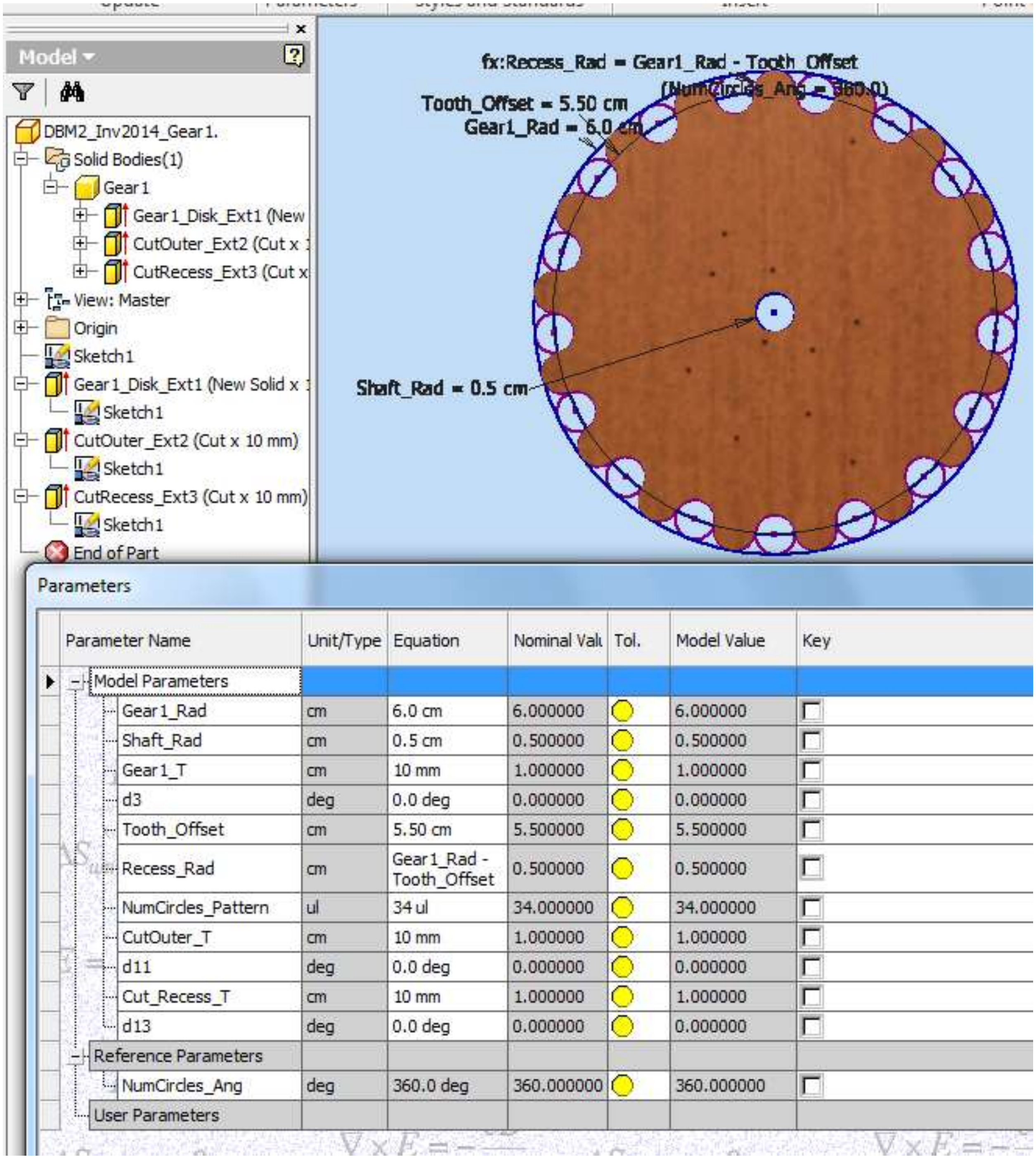
3 A Gear From Scratch (.ipt) – At Least a First Crack at It

You will learn a great deal more if you engage your critical and creative thinking skills and design a gear set yourself using some pretty simple circle geometry and math.

1. Start a New Project called YourName_Gear1
    a. Application icon, Manage, Projects
    b. New, New Single User Project
        i. YourName_Gear1 (in your usual Inventor projects folder)
        ii. Done
2. Start a new .ipt file from the root templates folder using your PromptConstraint_10cmMajor template
    a. The dialog should show your recently-created Gear1.ipj project file

3. Reverse engineer the following design data and screen shots (scroll down) to design a gear (call it Gear1)
    a. Some notes and tips
        i. Centre your circles for the gear and its shaft at the origin of the XY plane
        ii. When dimensioning a circle, right click and choose Radius as the Dimension Type
        iii. You may need to “Share Sketch” in the model browser when extruding a second (or third etc) profile from a given sketch



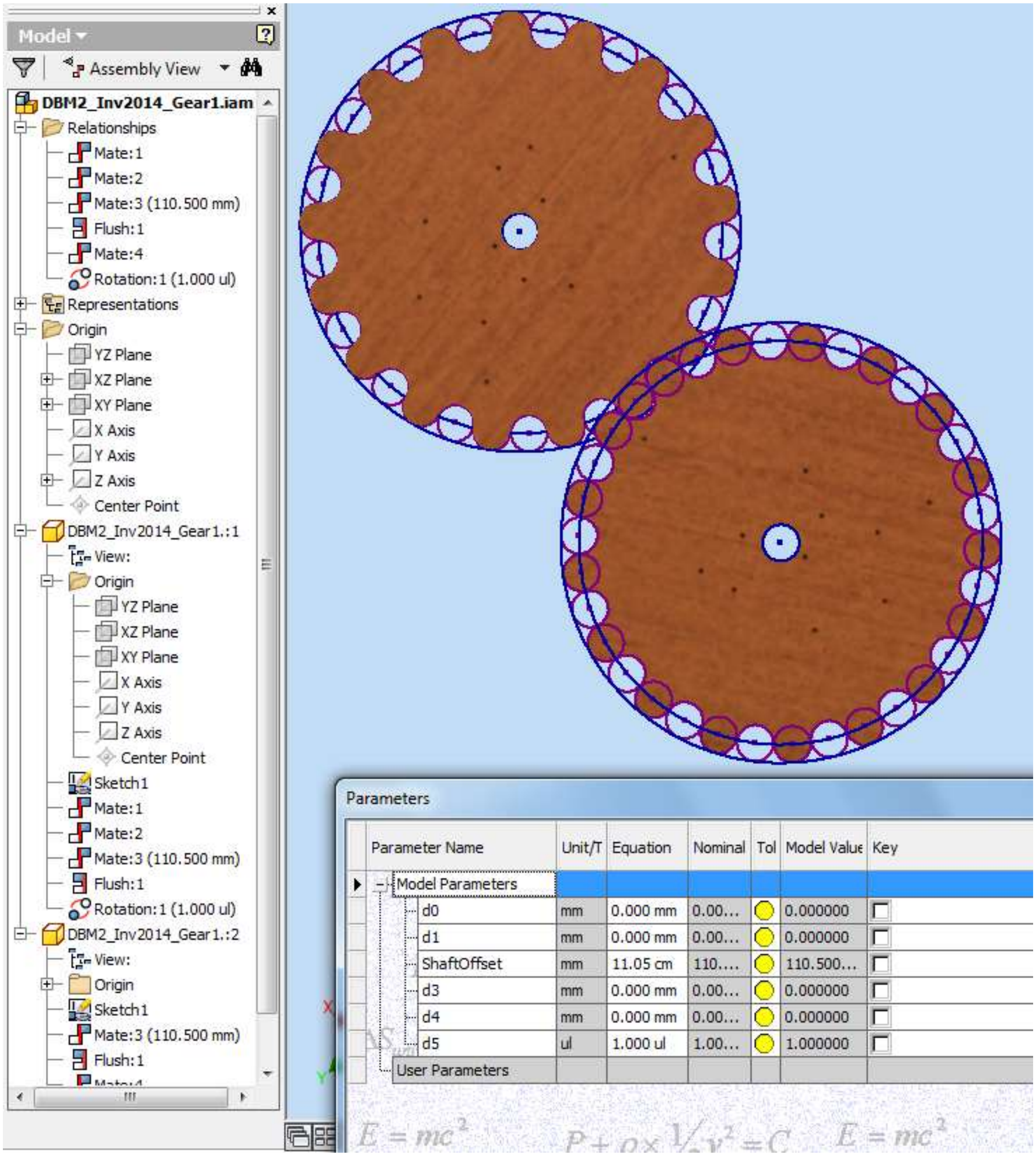


Parameter Name	Unit/Type	Equation	Nominal Valu	Tol.	Model Value	Key
Model Parameters						
Gear1_Rad	cm	6.0 cm	6.000000		6.000000	
Shaft_Rad	cm	0.5 cm	0.500000		0.500000	
Gear1_T	cm	10 mm	1.000000		1.000000	
d3	deg	0.0 deg	0.000000		0.000000	
Tooth_Offset	cm	5.50 cm	5.500000		5.500000	
Recess_Rad	cm	Gear1_Rad - Tooth_Offset	0.500000		0.500000	
NumCircles_Pattern	ul	34 ul	34.000000		34.000000	
CutOuter_T	cm	10 mm	1.000000		1.000000	
d11	deg	0.0 deg	0.000000		0.000000	
Cut_Recess_T	cm	10 mm	1.000000		1.000000	
d13	deg	0.0 deg	0.000000		0.000000	
Reference Parameters						
NumCircles_Ang	deg	360.0 deg	360.000000		360.000000	
User Parameters						

4. Use View / Visual Style to toggle between a wireframe view and a shaded view.
5. One 12 cm diameter gear with 17 teeth on a 1 cm diameter shaft is thus created. The teeth have a simple circular profile.

3.1 Assemble Two Instances of Gear1 Together (.iam)

1) Create a new Assembly file
   a) Application icon / New / New From Template – choose Standard.iam from Default Templates folder
   b) In the Assemble Ribbon / Component panel: Use Place
      i) Place two instances of Gear1 on the assembly screen (click, move pointer, click again, right click, OK)
   c) Both gears (Gear1:1 and Gear1:2) can be dragged around – they are both ungrounded
   d) In Navigation bar, select LookAt
      i) Choose XY plane in the world origin tree in the Model Browser
   e) In Model Browser expand the tree of the two gears as well as their origin tree
   f) Assemble ribbon / Constrain panel
      i) Assembly / Mate constraint
         (1) Choose centre point Gear1:1 shaft hole and constrain to the Z world axis
         (2) Now Gear1:1 can only spin on the Z axis of the coordinate system
   g) But Gear1:1 can still move in and out of the XY world plane
      i) Assemble Ribbon / Constrain / Assembly / Mate constraint
         (1) Constrain front face of Gear1:1 to XY world plane
         (2) Now Gear1:1 can only spin on its central Z axis
   h) Gear1:2 can be dragged anywhere
      i) Assemble Ribbon / Constrain / Assembly / Mate constraint
         (1) Click on Z axis of Gear1:1 and Z axis of Gear1:2 – this is Mate3 in the Gear1:1 tree of the model browser
         (2) Now Gear1:2 spins on the same axis as Gear1:1, but it can be dragged into and away from the XY plane
            (a) They need to be on the same plane
            (b) But first apply the correct distance between their shaft centres which is (2 * (Tooth_Offset-Recess_Rad)) = 11.0 cm
            (c) Right click on Mate3 in model browser
               (i) Enter 10.0 cm as the Offset value
   i) To get the two gears on the same plane
      i) Assemble Ribbon / Constrain / Assembly / Mate / Flush constraint
         (1) click on the faces of both gears
   j) Constrain (Mate) the Z axis of Gear1:2 to the XZ world plane
   k) Now to make the two gears turn together
      i) Assemble Ribbon / Constrain / Motion / Mate constraint
         (1) Choose the inside face of opposing teeth
         (2) If necessary, suppress the Rotation:1 constraint in the Model Browser and slightly drag one gear tooth slightly for a better Mate
         (3) Edit Mate 3: Offset = 11.05 for less chance of binding
   l) Drag one tooth to see how both gear instances rotate relative to one another.



3.2 Some Assembly-Time Tips for Trouble-Shooting

Referring to the assembly browser, in the right-click menu for joints and assembly constraints, note that you may:

- Suppress a joint or constraint. This will temporarily remove the joint or constraint. Uncheck Suppress to bring the joint or constraint back.
- Drive a joint or constraint. Allows you to watch the animation of how the joint or constraint operates within any limits that you had defined.

- Lock a joint. If you need to test only a single particular joint by dragging one of its members, you may lock other joints to prevent them from moving.

4 Critical Thinking Challenge (Due end of Class Next School Day) ___ / 100 Marks

While the above strategy seems to work ok, it may not be very efficient from the design perspective. How so? Keep in mind that we will need a number of gear sets in our tall-case clock and we may want to re-use some of our design intent from one gear set to the next.

1) Identify and discuss at least one "pro" ("good aspects") of the above design strategy for a pair of gears in a gear train.
2) Identify and discuss at least two "cons" ("bad aspects") of the above design strategy for a pair of gears in a gear train. Now consider a larger gear train of several more gears – are there any more "cons"?
3) Design a pair of meshing gears in a ratio of 2:1 using a flexible design methodology – you should be able to very easily generate gear pairs of various diameters. Hint: use a bit of basic circle geometry and Inventor's constraints.
4) **Drop off a short document file, at least one part file and one assembly file using filename:**
    a) **Your name_GearChallenge.*****

5 Inputs / Knowledge / Understanding I Still Need For This Module

Give each issue a number for future reference:

NOTE: In the feedback, the Peer Assessor must "make the student think" – not give the student the answer! Be sure to include comments justifying the mark that you are giving.

Assessor's Name and Additional Notes: