Aalto University
School of Engineering

EXERCISE – MODELING A PARAMETRIC LEGO BRICK

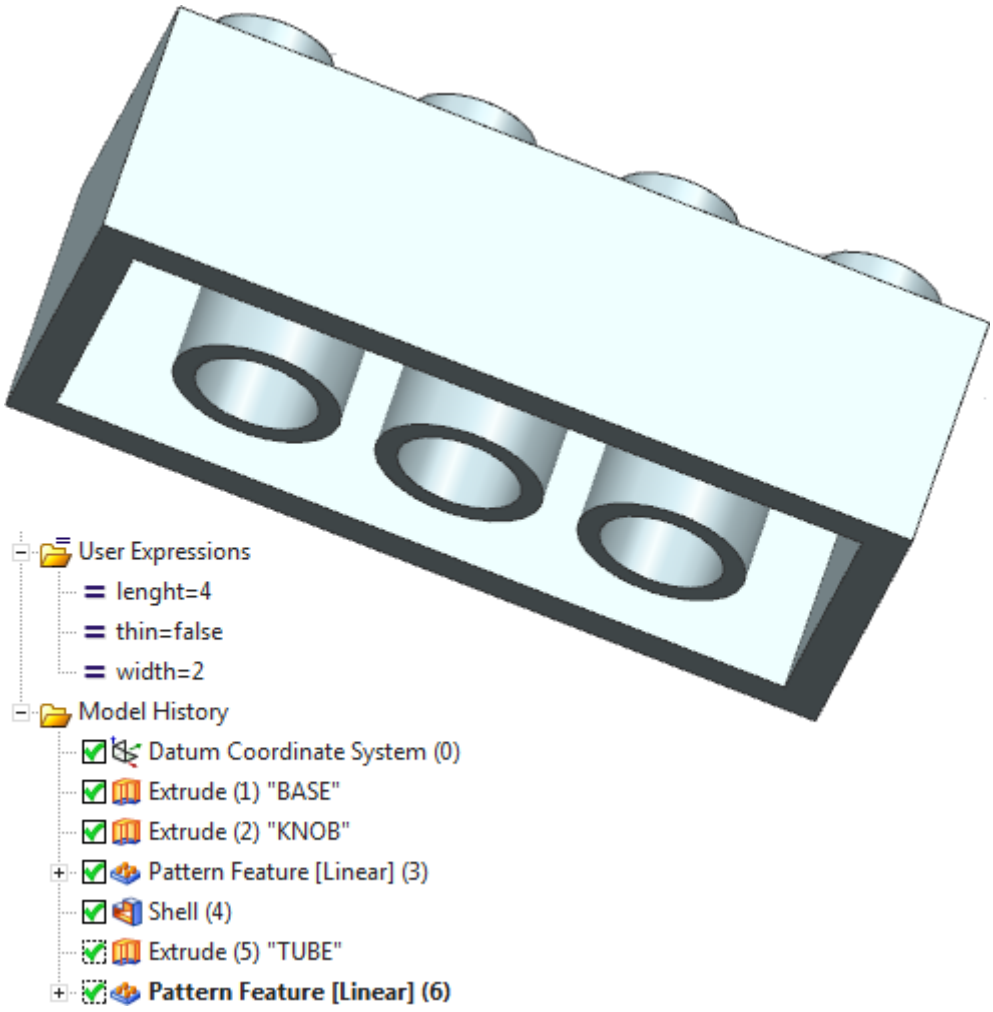

Figure 1: Lego brick and its model history.

Learning Targets

In this exercise you will learn:

- ✓ to use expressions
- ✓ to suppress features

This exercise is an example of what can be achieved by using expressions programming. The result is a highly parametric Lego block part model, which has all the required intelligence built-in in order to create all possible basic block types by just adjusting a few simple user expressions.

Used program version is NX 10.0.2.

About Basic Lego Brick

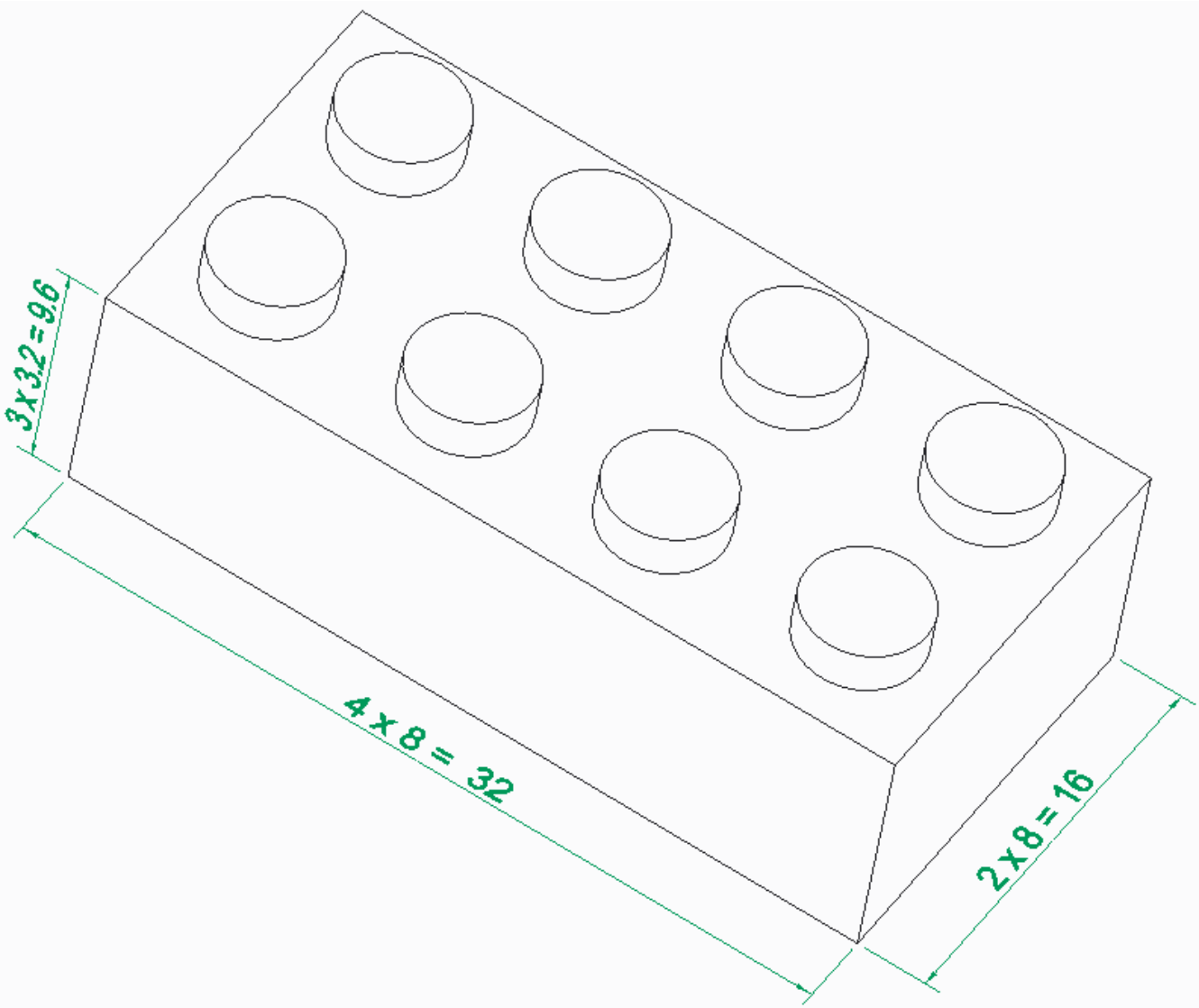

Figure 2: Basic 4 x 2 Lego brick and its dimensions.

The most common and well-known Lego brick is presented in Figure 2. The picture shows a 4 x 2 Lego brick: the 4 is the length of the brick and 2 is the width of the brick. The brick is build using eight same sized modules. One basic module is shown in Figure 3. By multiplying this module, all basic bricks are created. This 8 is a module for length and width.

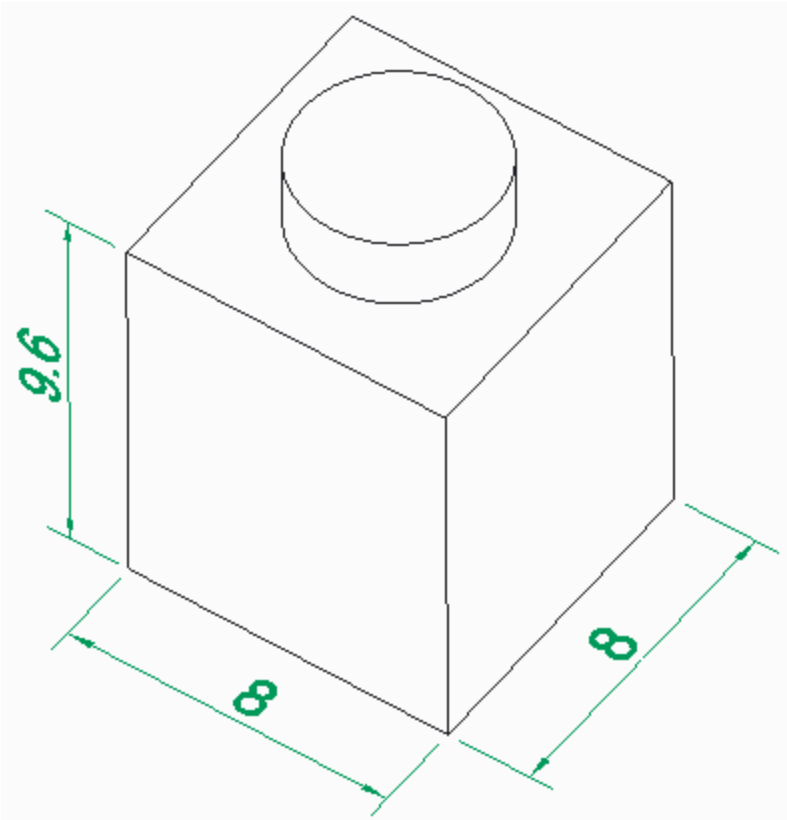

Figure 3: One basic Lego brick module.

The module for the height is 3.2. Basic Lego brick has the height of 9.6, which is 3 times 3.2. However, unlike with length and width, the height is fixed; it can be normal (9.6) or thin (3.2).

Lego brick has knobs on the top to allow attachment to other bricks. The diameter of the knob is 4.8, the height of the knob is 1.8 and it is located in the middle (8 / 2 = 4) of the basic module (Figure 4).

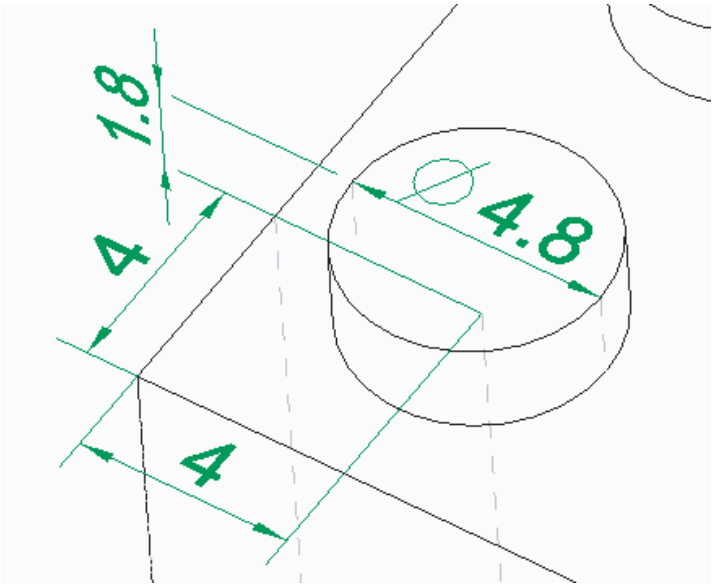

Figure 4: Lego brick knob.

To make Lego bricks connected with each other, the brick has tubes at the bottom of the hollow brick. The outer diameter of the tube is 6.5 and inner 4.8 (the same as the diameter of the taps!). The height of the tube is the height of the brick - 1; for normal brick it is 8.6, for thick brick 2.2. The tube is located in the middle of four basic 8 modules (Figure 5).

Figure 5: The bottom tube of the Lego brick.

There are also taps for the hollow bottom and those are only present when the width of the brick is 1. In this situation, the tubes are removed. The height of the tap depends on the height of the brick. The diameter is 3.2 and it is located in the middle of two basic 8 modules (Figure 6).

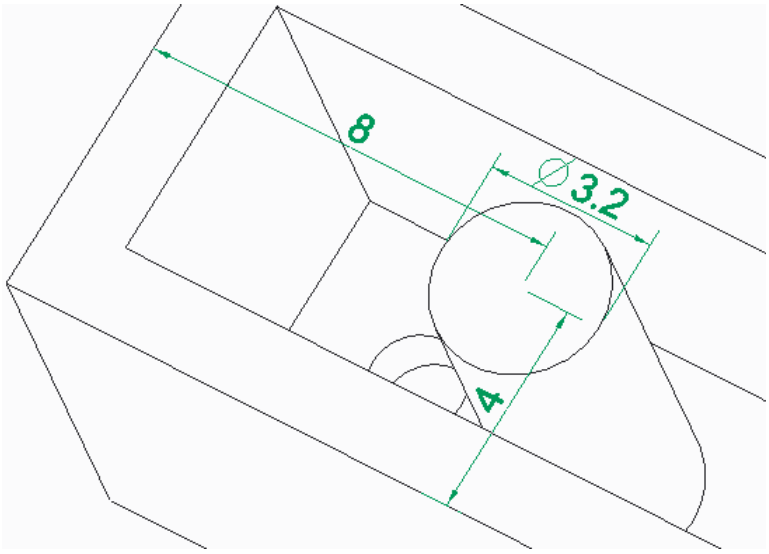

Figure 6: The Lego bricks tap (only when width or length is 1).

As you have noticed from previous pictures, the Lego brick is hollow. The wall thickness on the sides are 1.6 and in the top 1 (Figure 7). There is another configuration of the brick where wall thickness is 1.3 and the needed tightness is created by supporting ribs (thickness of 0.3). In our exercise, we use the version without the ribs.

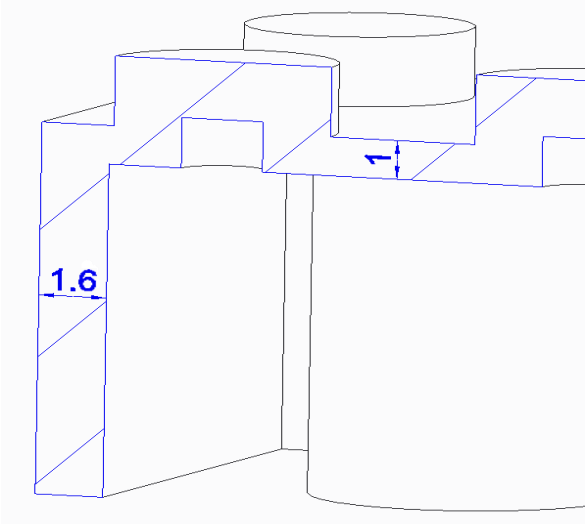

Figure 7: The thicknesses of the Lego brick.

Getting started

Create a **New** ( ) *Model* and name it as Lego (Figure 8).

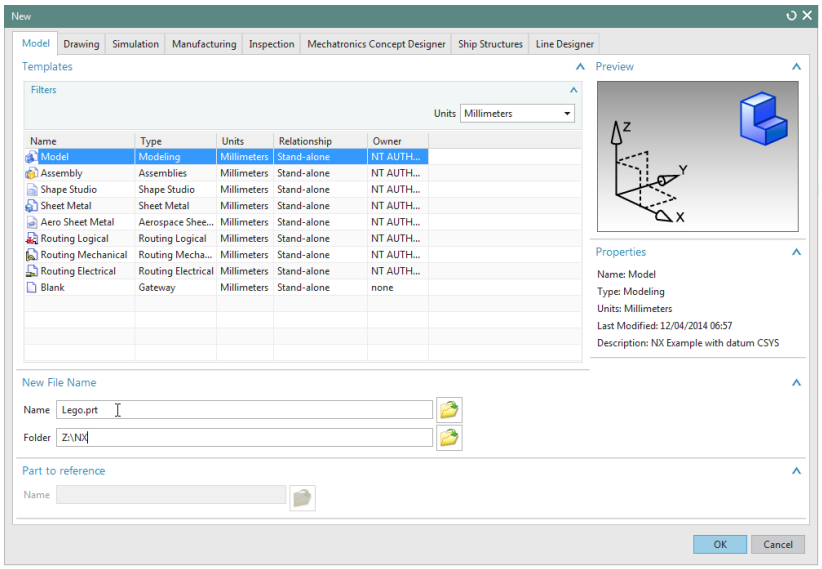

Figure 8: New Lego.prt

First Features

Base geometry

Using **Extrude** ( ), create a Section on the XY Plane as seen in Figure 9.

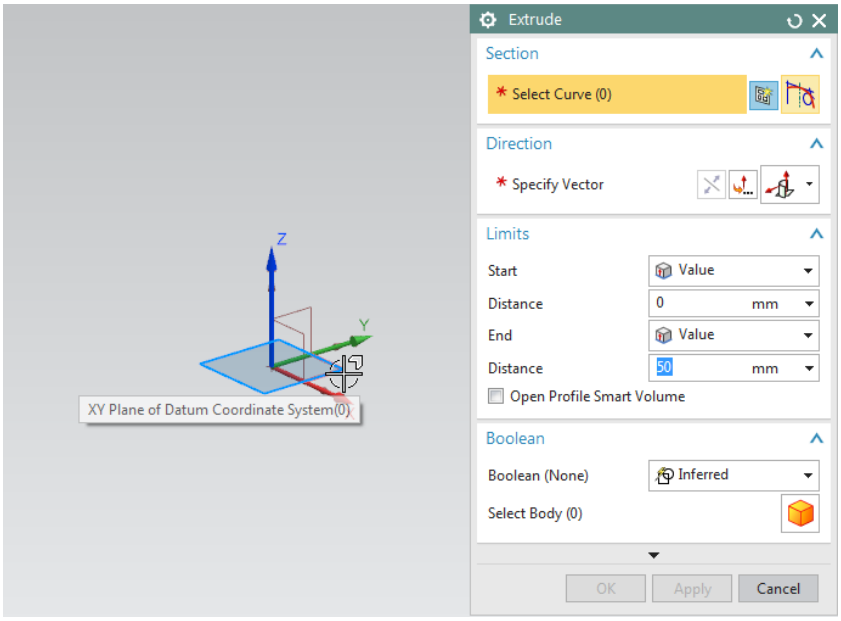

Figure 9: Creating a new section on XY Plane.

Using **Rectangle** (, from *Curve* group), create a shape as seen in Figure 10. Then, change the dimension values by double-clicking them or if needed, use **Rapid Dimensioning** (, *Constraints* group) to create needed dimensions as seen in Figure 11.

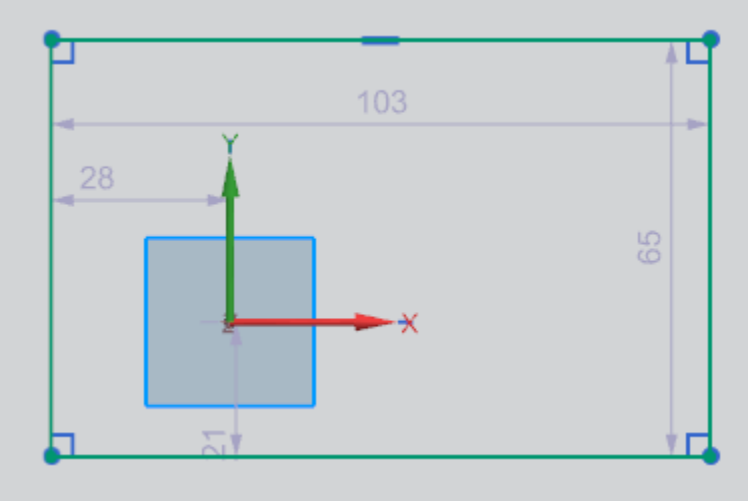

Figure 10: A rectangular shape. Notice the location relative to coordination axis.

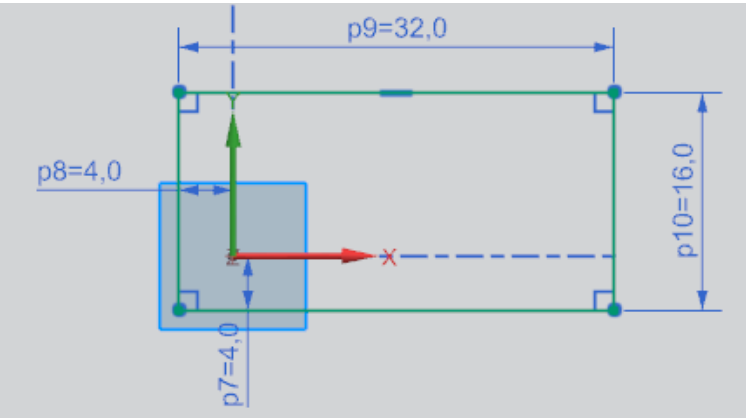

Figure 11: Ready sketch. Dimension names may be different (p#).

The sketch is ready. The reason to use two 4 mm dimensions is to ensure, that 1x1 Lego brick (8mmx8mm) will be symmetric to coordination system. **Finish** (, *Sketch* group) the sketch.

In the Extrude window, change the height of the extrusion to **9.6** mm and press ENTER to update the preview. **OK** or MMB to accept the feature. Select **Extrude (1)** from model tree, press **F2** and name it as BASE. It is a good practice to name features, it helps to find them later.

Knob

Next we create a knob on the top of previously created feature. Select **Extrude** (, *Feature* group) and select the top of BASE feature. In the sketch mode you can notice, that the sketch has different coordination system as the part itself. To use part's coordination system as the base of this sketch (remember the placement of the BASE feature's sketch), select **Reattach** (, *Sketch* group). Click on the **Settings**, check the option **Project Work Part Origin** (Figure 12) and click **OK**. This puts the part's coordination system as the basis of the sketch.

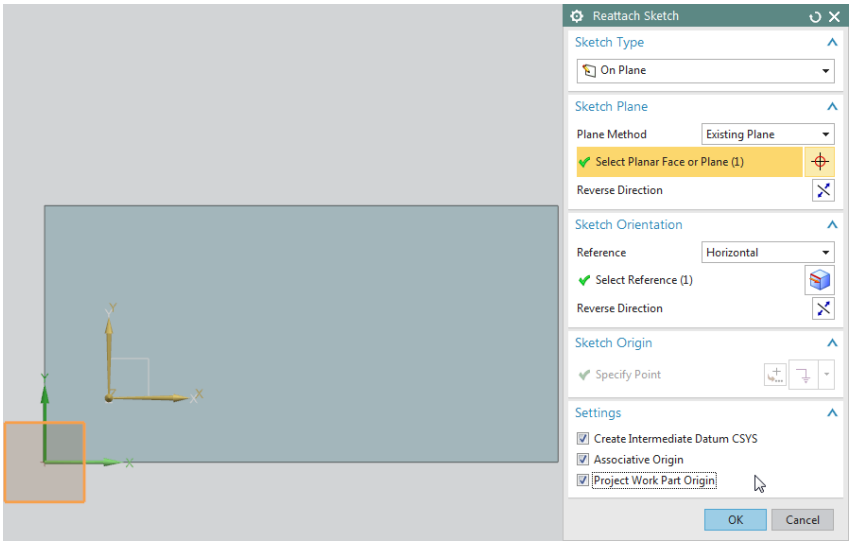

Figure 12: Part's Origin projected (yellow) and old origin still visible (green).

Place a **Circle** (, *Curve* group) width the diameter of **4.8** mm in the middle of coordination system. When ready, Finish (, *Sketch* group) the sketch and extrude the shape by **1.8** mm. Rename the feature as KNOB. Your model should look like in Figure 13.

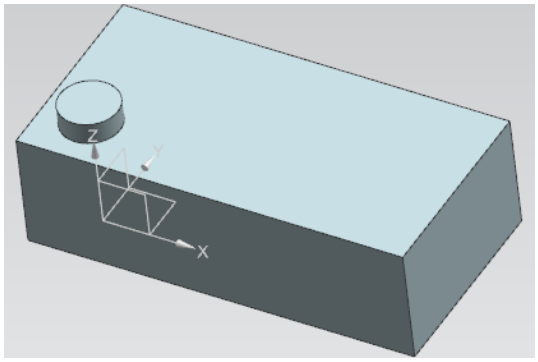

Figure 13: Two first features created.

Pattern of Knobs

Select **Pattern Feature** (, *Feature* group) and select KNOB as a *Feature to Pattern*. Pattern *Layout* should be *Linear*, if not, change it. Notice the * before *Specify Vector*. The program ask the direction to our patterning, click on **Specify Vector** and select **X-axis** as a direction. Set count as 4 and *Pitch Distance* as 8 mm. Check option **Use Direction 2** and select **Y-axis** as a direction. Give values as seen in Figure 14 and accept the feature (**OK**).

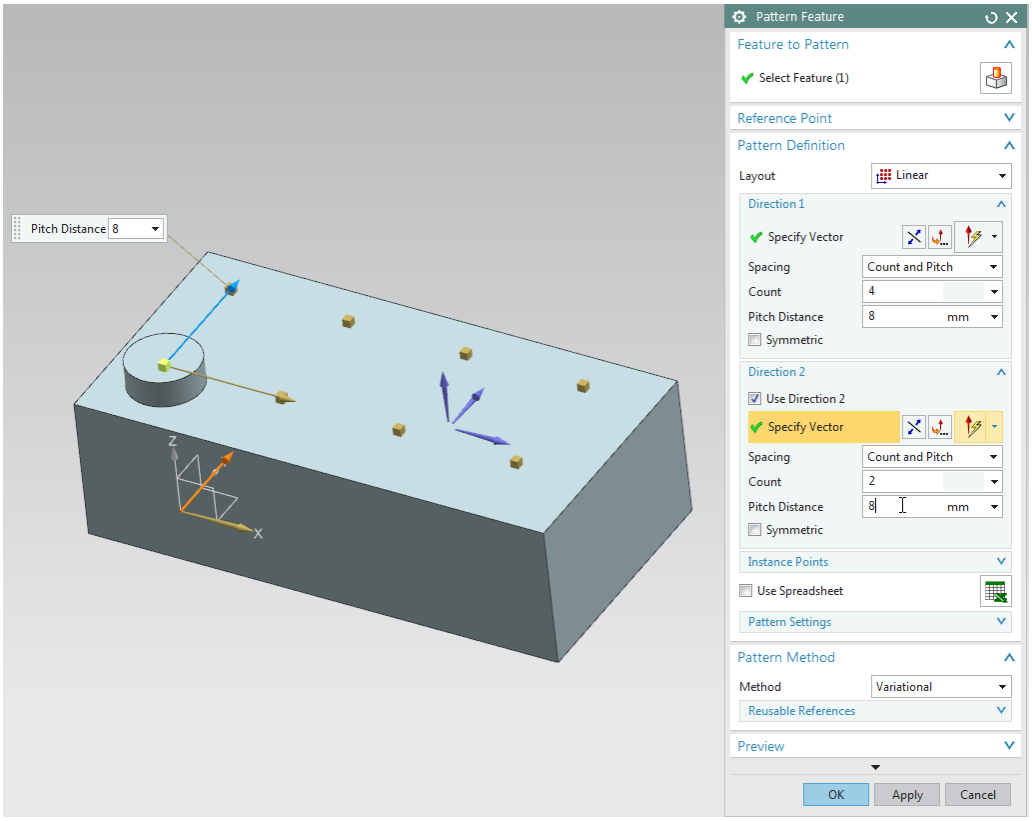

Figure 14: Ready to accept pattern.

Shell

The Lego brick is hollow, but the sides and the top have different thicknesses. Select **Shell** (, *Feature* group) and select the bottom face to be removed. Click on ▾ to see more options. Select **Alternate Thickness**, **Select Face** and select top face of the BASE feature (Figure 15). Give **1** mm as *Thickness 1* and **1.6** mm as *Thickness*. When ready, accept the feature.

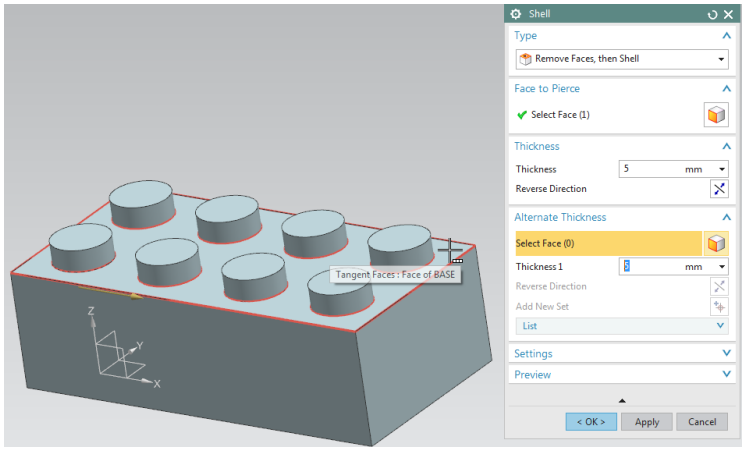

Figure 15: Selecting the face for alternative thickness.

Creating Expressions

Inputs

Now it is the time to create the first expressions to our model. The idea is to use three different user defined expressions to drive the geometry of the model. Select **Tools** tab and **Expressions** (=, *Utilities* group). In *Expressions* window, create a new expression **length** as a *Name*, **Number** and **Constant** as a *Type* and **4** as a *Formula* (Figure 16). Hit **ENTER** or **Accept** (✔) to create this expression.

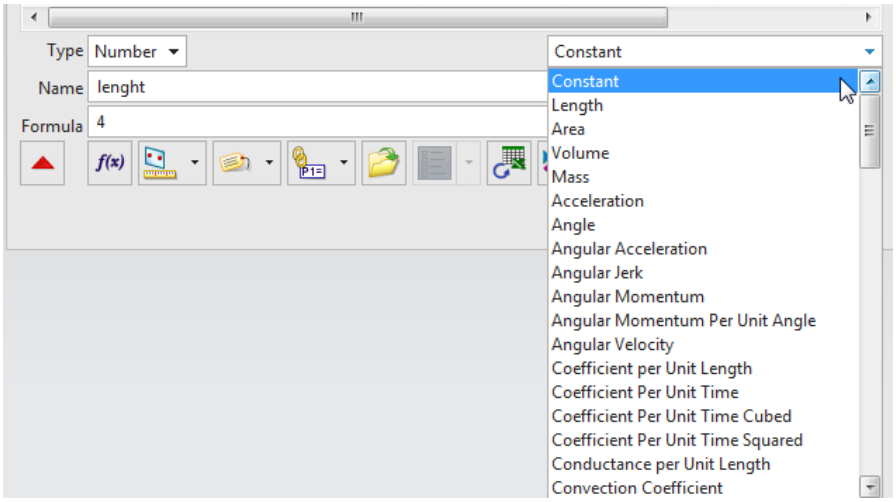

Figure 16: First expressions (length) defined.

Then, using the same method, create two new expressions (**Apply** when ready):

- width Constant 2
- thin Boolean false

Linking expressions to features

We have three input expressions and next we need to link those to the features. Click **Apply** to ensure that nothing is selected. Click on BASE feature from Model History or from screen. Now you can see all expressions affecting BASE feature. Select the one with *Value* **32** from the list, write to the *Formula* field **length * 8** and hit ENTER. Now this dimension is driven by user defined expression. Create another expression to the one with *Value* **16** using *Formula* **width * 8**.

Select the one with *Value* **9.6** from the list. This dimension controls the height of the brick. Select Extended Text Entry (, Figure 17).

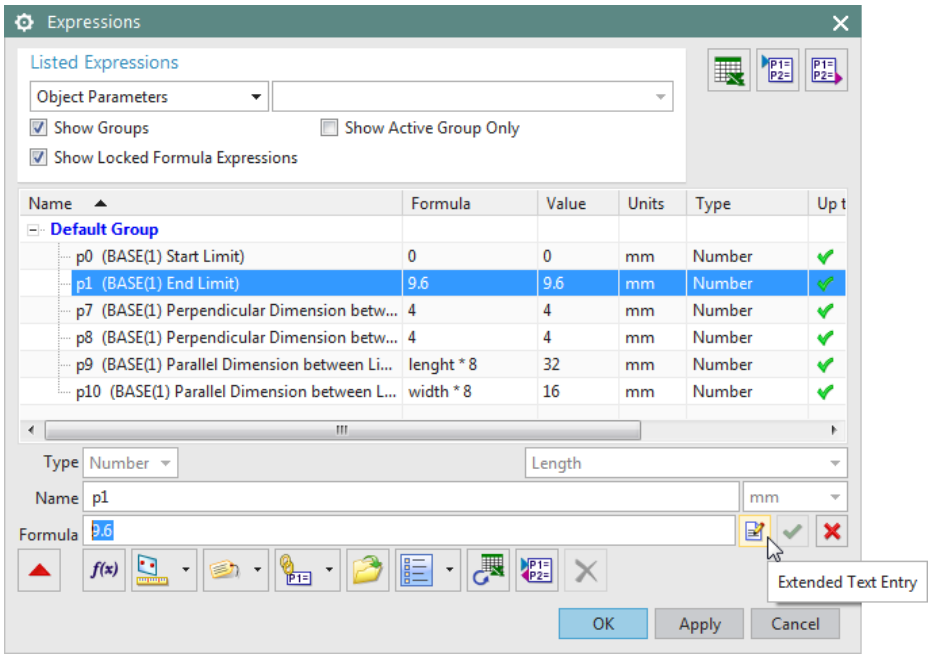

Figure 17: Selecting Extended Text Entry. You may have different names (p#).

This extents the Formula field. Select **Insert Conditional** ( ) and click **OK**. On the text field, write:

```
If ( thin )
Then ( 3.2 )
Else ( 9.6 )
```

Accept field by OK and accept the Formula to the dimension (ENTER).

Created expressions affect only BASE feature. Select the **pattern feature** from the *Model History* to see its dimensions. Select the one with *Value* **2** and write *Formula*: **width**. Create to the one with *Value* **4** *Formula*: **length**. Expressions should now be ready, click **OK** to close *Expressions* tool.

Testing

Check that the model works: In *Part Navigator*, expand **User Expressions** folder to see previously created inputs, there should be tree ones. To change values, just double-click expressions and give new values. Be free to test (thin is true or false). TIP: If you use *Expression* tool (**Ctrl + E**) to change values, you can first give values and then regenerate model.

After some input testing, change *length* to **4**, *width* to **2** and *thin* to **false**.

Remember to save your model!

Creating More Features

Tube

Using **Extrude** (, *Feature* group), create a sketch on **XY Plane**. Create two concentric **Circles** (, *Sketch* group) and using **Rapid Dimensioning** (, *Constraints* group), create dimensions as seen in Figure 18.

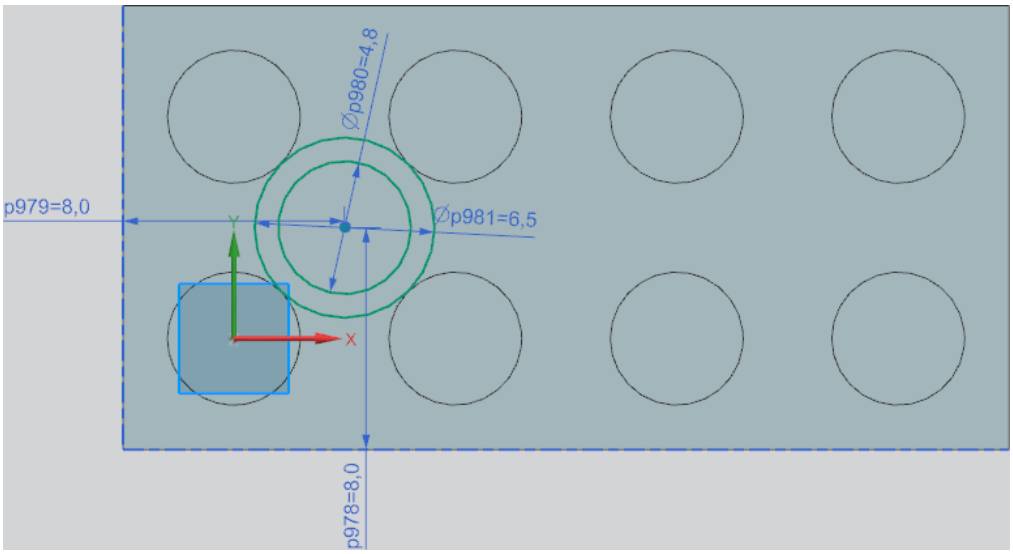

Figure 18: Ready sketch. Notice the dimensioning of the center point of the circle.

Finish (, *Sketch* group) sketch. As *End*, select **Until Next** from the drop-down menu and accept (**OK** or **MMB**) the feature. Rename feature as TUBE.

Patterning the Tube

Using **Pattern Feature** (, *Feature* group), pattern TUBE both X- (**3** times) and Y-direction (**1** times) using **8** mm as *Pitch Distance* (Figure 19).

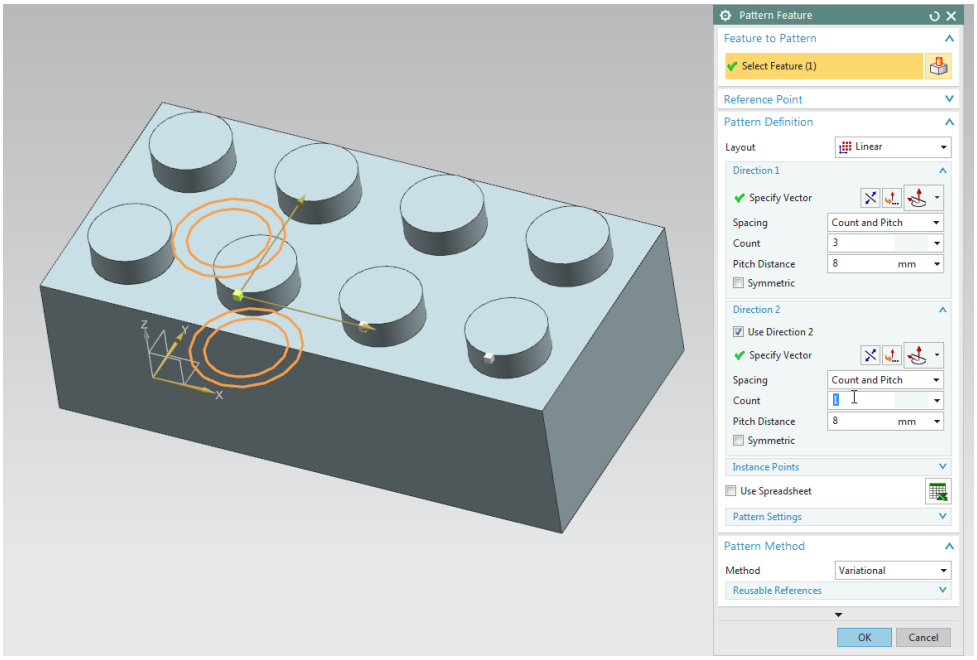

Figure 19: Ready TUBE pattern.

Updating Expressions

Open **Expressions** (**Ctrl + E**) and select previously created pattern feature. The ones with *Value* **1** and **3** is needed to update. Using **Extended Text Entry** (), create *Formulas* with Conditionals as seen below:

TUBE pattern to X-direction	**TUBE pattern to Y-direction**
If (length > 1) Then (length- 1) Else (1)	If (width > 1) Then (width - 1) Else (1)

The conditional statements are there to ensure that values to the patterns can't be 0 (the feature will fail). Be sure to apply the formulas to the right expressions. You can see the definition of an expression by holding mouse over it (**Error! Reference source not found.**).

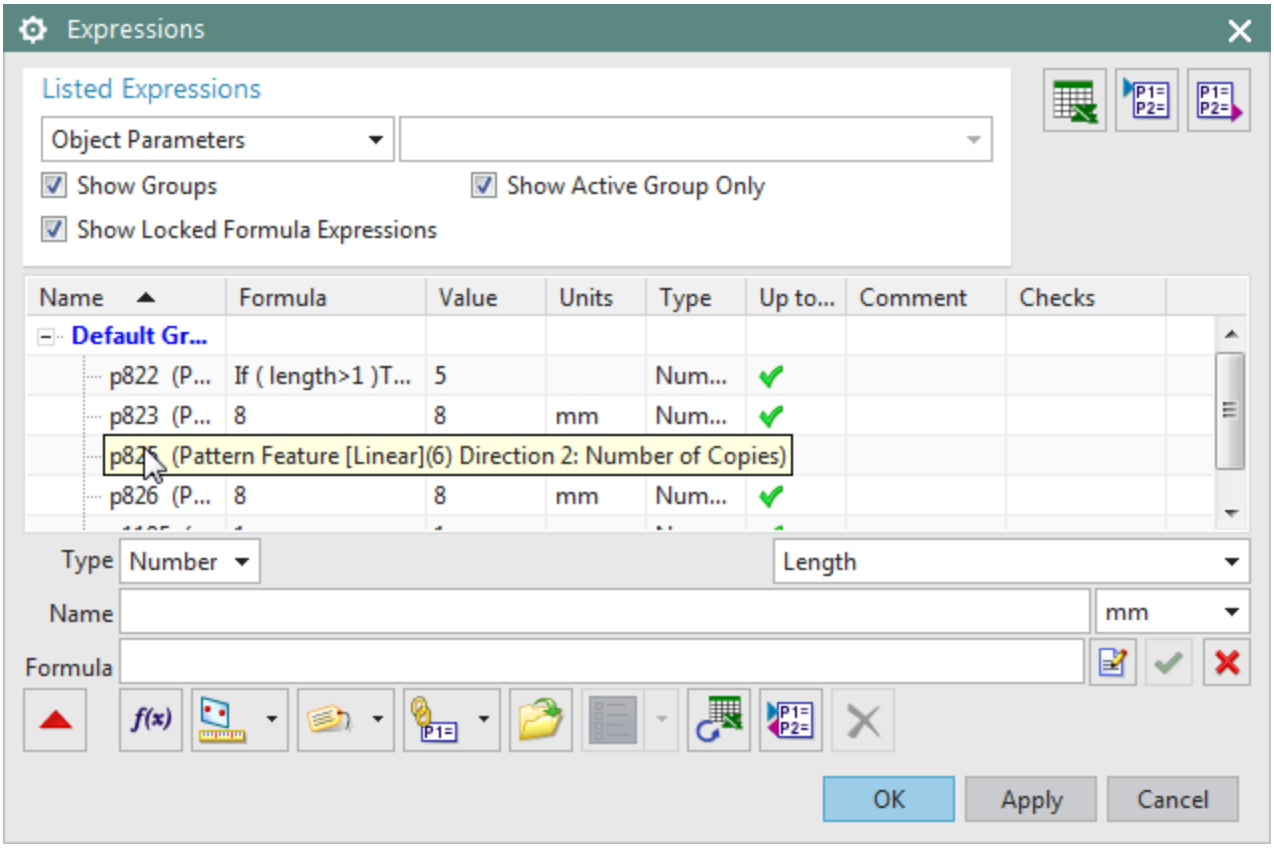

Figure 20: Choosing the right expression.

Suppressing Features

Unfortunately, the number of pattern instances cannot be set to zero. That is, the current model will not work with value 1 of *length* or *width*. Instead of setting the number of pattern instances to zero, the pattern has to be suppressed. Suppressing means temporarily deleting, so that suppressed features can easily be restored. Besides manually, features can be suppressed using expressions.

Suppressing expressions

To suppress a feature, a new expression is needed. Select **Menu→Edit→Feature→ Suppress by Expression** (Figure 21).

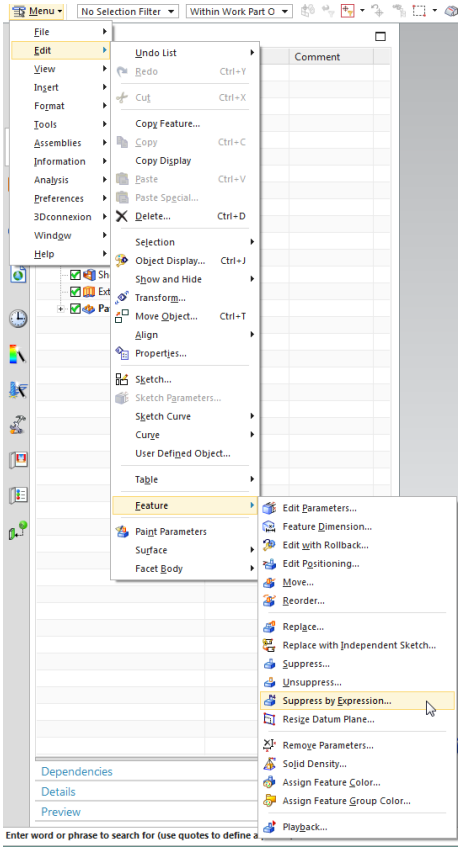

Figure 21: Selecting Suppress by Expression.

Select **Create Shared** from drop-down menu as *Expression Option* because we need to suppress both original feature and its pattern. Holding **Ctrl**, select both TUBE feature and its pattern. OK to accept.

Open Expressions (**Ctrl + E**) and select TUBE feature. As you can notice, new expression with *Value* 1 is created (0 means suppressed). Select that and write expression:

If (length > 1 & width > 1) Then (1) Else (0)

Accept when ready. Be free to test how this expression affect model (set *length* or *width* to 1).

Thing to Do Without Guidance

Create a pattern of taps (Figure 6) which are used instead of tubes if the *width* or *length* of the brick is 1. Then use the techniques you have learned to manage their number and suppress them when necessary (Figure 22). To enable value 1 for both *length* and *width*, individual patterns are needed for both directions (to be honest, not needed, but it is much easier to do this way…).

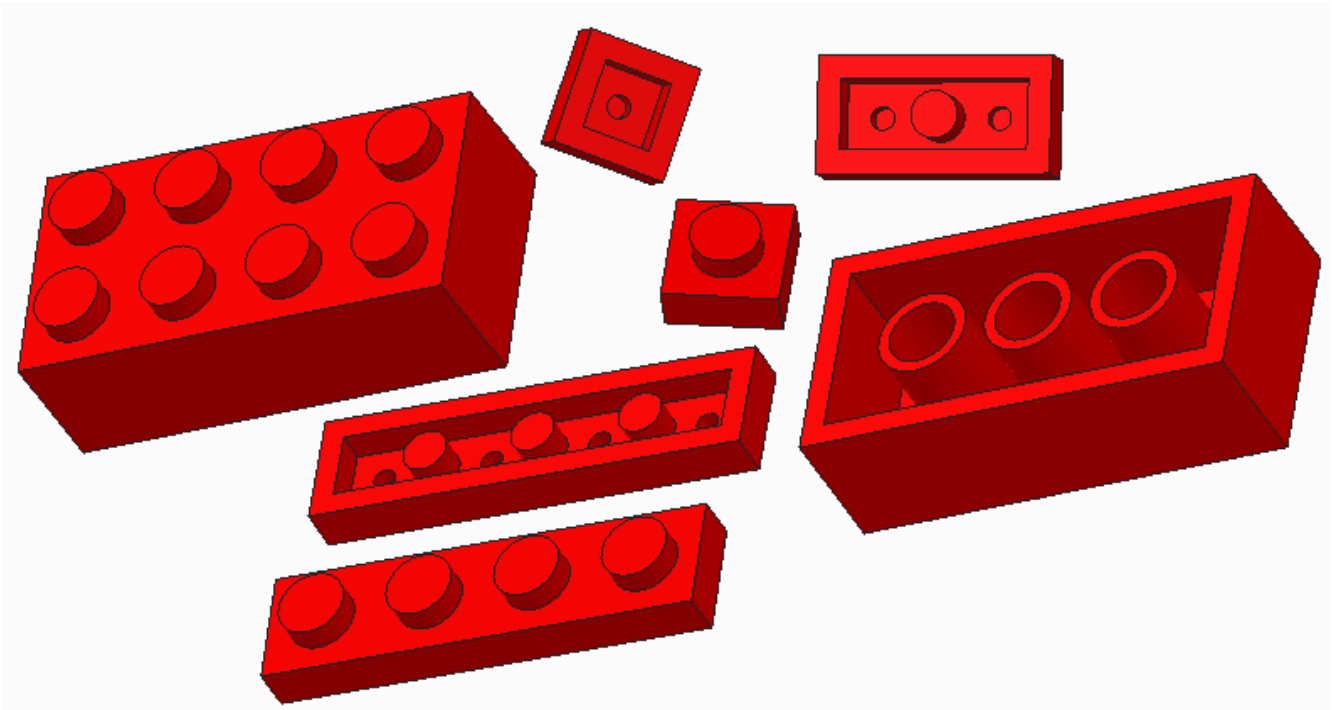

Figure 22: Different kinds of Lego bricks.

Extra Task

If you have time and/or willingness, it would be a good practice to model also ribs. The thickness of the rib is 0.3 and width 0.6, so some redefining to the shell is needed. Also, the ribs are not represented when the width and/or the length of the block is 1 (Figure 23). The ribs should also be robust, so changing the main rib should change the other ones (the dimensions of one rib should be followed by other ribs).

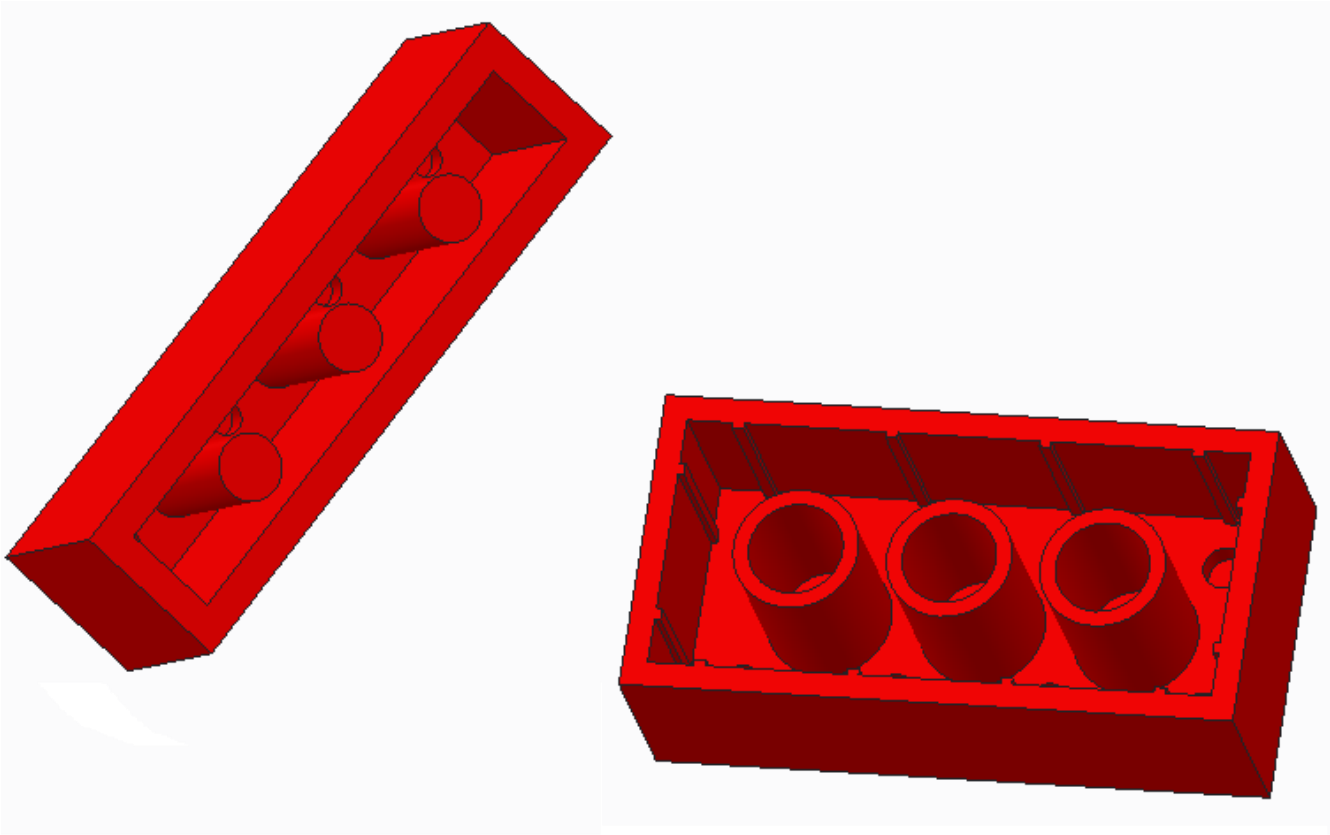

Figure 23: Lego brick without (left) and with ribs (right).