We are going to illustrate the use of Excel Solver with the following example:

Chemical, Mechanical and petroleum Engineers often encounter the general problem of designing containers to transport liquids and gases. Suppose that you are asked to determine the dimensions of a small cylindrical tank to transport toxic waste that is mounted on the back of a pickup truck. You overall objective will be to minimize the cost of the tank. However, aside from cost, you must ensure that it holds the required amount of liquid and that it does not exceed the dimensions of the truck's bed. Note that because the tank will be carrying toxic waste, the tank thickness is specified by regulations.

A schematic of the tank and bed are shown in the Figure 1. As can be seen, the tank consists of a cylinder with two plates welded on each end.

The cost of the tank involves two components:

1) Material Expense, which is based on weight
2) Welding expense which is based on length of weld. Note that the latter involves welding both the interior and the exterior seams where the plates connect with the cylinder (see table for extra data)

Parameter	Symbol	Value	Units
Required Volume	V_o	0.8	m^3
Thickness	t	3	cm
Density	ρ	8000	kg/m^3
Bed length	L_{max}	2	m
Bed width	D_{max}	1	m
Material Cost	Cm	4.5	$/kg
Welding Cost	Cw	20	$/m

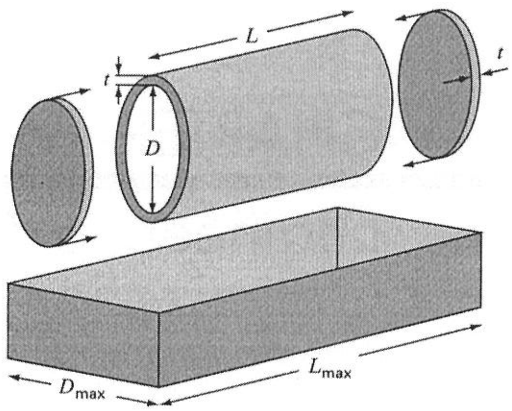
The cost consists of tank Material and welding costs. Therefore the objective function can be formulated as minimizing:

$$C = Cm(M) + Cw(lw)$$

Where:
C= cost ($), *M*= mass (Kg), *lw*= weld length (m), and Cm and Cw are cost factor for mass ($/Kg) and Weld length ($/m), respectively.

The problem can be solved in different ways. However, the simplest approach for a problem of this magnitude is to use a tool like Excel Solver.

Solution: The objective here is to construct a tank for a minimum cost. The cost is related to the design variables (length and diameter) as they affect the mass of the tank and the welding lengths. Further, the problem is constrained because the tank must fit within the truck bed and carry the required volume of material.



The cost consists of tank material and welding costs. Therefore, the objective function can be formulated as minimizing:

$$C = Cm(M) + Cw(lw).$$

Next, we will formulate how the mass and weld lengths are related to the dimensions of the drum. First, the mass can be calculated as the volume of material times its density. The volume of the material used to create the side walls (i.e. the cylinder) can be computed as:

$$V_{cylinder} = L\pi\left[(\frac{D}{2}+t)^2 - (\frac{D}{2})^2\right] = A$$

For each circular end plate, it is

$$V_{plate} = \pi(\frac{D}{2}+t)^2 t = B$$

Thus, the mass is computed by:

$$M = \rho[A + 2B]$$

Where:

ρ=is the density (Kg/m^3)

The weld length for attaching each plate is equal to the cylinder's inside and outside circumference. For the two plates, the total weld length would be:

$$d(\frac{dA}{dt})/dL = 2\left[2\pi(\frac{D}{2}+t)+2\pi\frac{D}{2}\right] = 4\pi(D+t)$$

Constraints:

We must compute how much volume can be held the within the finished tank.(this value must be equal to the desired volume)

$$V = \frac{\pi D^2}{4}L = V_o = 0.8m^3$$

The remaining constraints deal with ensuring that the tank will fit within the dimensions of the truck bed.

$$L \le L_{max}$$
$$D \le D_{max}$$

The problem is now specified. Substituting the values from table1, it can be summarized as:

Minimize:

$$C = 4.5(M) + 20(lw)$$

Subject to:

$$\frac{\pi D^2}{4}L = 0.8m^3$$
$$L \le 2$$
$$D \le 1$$

Where:

$$M = 8000\left[L\pi\{(\frac{D}{2}+0.03)^2 - (\frac{D}{2})^2\} + 2\pi(\frac{D}{2}+0.03)^2 0.03\right]$$

Now create a spreadsheet as follows:

Excel Optimization

	A	B	C	D	E	F	G
1	**Optimum Tank Design**						
2							
3	**Parameters:**			**Design Variables**			
4							
5	**V0**	0.8		D	1		
6	**t**	0.03		L	2		
7	**rho**	8000					
8	**Lmax**	2		**Constraint**			
9	**Dmax**	1					
10	**cm**	4.5		D	1	<=	1
11	**Cw**	20		L	2	<=	2
12				Vol	1.570796	=	0.8
13	**Computed Values**						
14				**Objective Fuction**			
15	M	1976.79063					
16	lw	12.9433617					
17				C	9154.425		
18	Vshell	0.19415043					
19	Vends	0.0529484					

Where:

M= = 8000*(E11*PI()*(((E10/2)+0.03)^2-(E10/2)^2)+2*PI()*((E10/2)+0.03)^2*(0.03))

Lw= = 4*PI()*(E10+0.03)

Vshell= E11*PI()*(((E10/2)+0.03)^2-(E10/2)^2)

Vends= =(PI()*((E10/2)+0.03)^2*0.03)*2

D= =E5

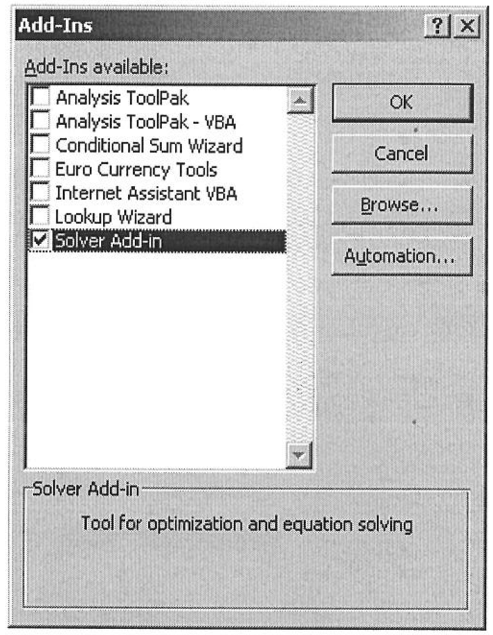
L= =E6

Vol = =PI()*(E10)^2*E11/4

C= = 4.5*B15+20*B16

Now Click on **Tools>Add_Ins**

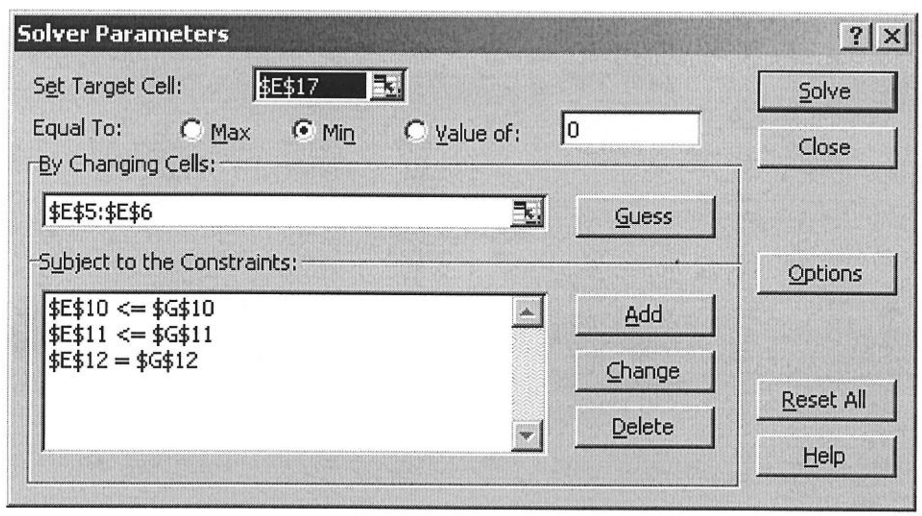
Select Solver and Click **OK**

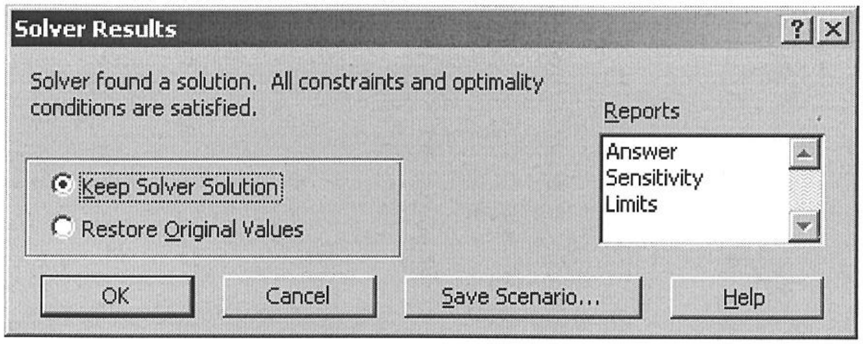


Click on **Tools>Solver**

Select the right cells

Click on solve.





Select Keep solver solution, and click **OK**

Excel Optimization

	A	B	C	D	E	F	G
1	**Optimum Tank Design**						
2							
3	**Parameters:**			**Design Variables**			
4							
5	**V0**	0.8		D	0.98351		
6	**t**	0.03		L	1.053033		
7	**rho**	8000					
8	**Lmax**	2		**Constraint**			
9	**Dmax**	1					
10	**cm**	4.5		D	0.98351	<=	1
11	**Cw**	20		L	1.053033	<=	2
12				Vol	0.799999	=	0.8
13	**Computed Values**						
14				**Objective Fuction**			
15	M	1215.20574					
16	Iw	12.7361437					
17				C	5723.149		
18	Vshell	0.10058688					
19	Vends	0.05131383					
20							

Results of minimization:

The price is reduced from $ 9,154.425 to $5,723.149, because of the smaller volume using dimensions of D =0.98351 m and L =1.053033 m.

Cantielver beam optimization problem using EXCEL
ME345: WELDLINE PROBLEM

Fixed Parameters

max length (m)	max D (m)	density	cost for weld	cost for material	thickness	pi
2	1	8000	20	4.5	0.03	3.14159265

Adjustable Parameters

length, l	Diameter, D (m)
1.053227423	0.983419858

Design Parameters

TOTAL VOLUME
0.8

Calculated values

volume material	weight	cost of material	length of weld	cost of weld	TOTAL COST	Volume capacity
0.151901416	1215.211331	5468.45099	12.7350095	254.7001905	5723.15118	0.8

Constaints
1. Length < max length
2. Diameter < max diameter
3. Volume capacity > TOTAL VOLUME design parameter