Brief Contents

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About Mathcad®

All the problems in this text are solved with Mathcad® 7 Professional. Therefore, it was felt that including a short note on use of Mathcad would be useful. However, this short note is not a tutorial on Mathcad; many specialised books are available for that purpose (e.g., *Introduction to Mathcad for Scientists and Engineers* by Sol Wieder, McGraw-Hill, 1993), in addition to the instruction manual supplied along with the software. Mathcad software itself contains a tutorial on its use.

Purpose of this note is to make the reader comfortable with the Mathcad worksheets, using which problems have been solved in this textbook.

What is Mathcad?

Mathcad is a very powerful and popular problem-solving tool for students of science and engineering. It turns your computer screen into a 'live Maths note pad', and has a 'free form interface', i.e. you can add equations, text and graphs in a single document. One great advantage of Mathcad is that equations are entered in 'real Math' notation (i.e., as you would enter in a note pad by hand) and not in a single line, complicated manner as in programming languages such as FORTRAN. This makes it very easy to see if there is any mistake committed while entering the equation. There are built-in functions and formulas and there is facility for user-defined functions, too. Unlimited vectors and matrices, ability to solve problems numerically and symbolically, root finding, quick and very easy 2-D and 3-D graphics, click selecting of Greek and other symbols from palettes are some other highlights. All this is done without any programming, but, just with a few clicks in Windows.

Symbols in Mathcad Worksheet

Mathcad uses usual math notations. +, –, * and / have usual meaning: addition, subtraction, multiplication and division. One advantage in Mathcad is that you can assign a value to a variable and use that variable subsequently throughout your worksheet. Symbol for assignment is := i.e., a colon combined with 'equal' sign.

Consider the following example. Let variables A, B and C be assigned values of 3, 5 and 7, respectively. Then, the product $A \times B \times C$ is obtained by simply typing $A \cdot B \cdot C =$, i.e., result is obtained by typing the desired mathematical operation, followed by = (i.e., equals sign of maths). Some typical calculations using A, B and C are shown below:

$A := 3 \quad B := 5 \quad C := 7$ *(assigning values to variables A, B and C)*

$A \cdot B \cdot C = 105$ *(multiplication)*

$2 \cdot A + 8 \cdot B - 4 \cdot C = 18$ *(multiplication, addition and subtraction)*

$\frac{A \cdot B}{C} = 2.143$ *(division)*

$B^2 - 4 \cdot A \cdot C = -59$ *(exponentiation)*

$\sqrt{A^3 + B^3 + C^3} = 22.249$ *(taking square root)*

$$\exp\left(\frac{A}{B\cdot C}\right) = 1.089$$ *(using 'built-in' exponential function)*

Note that typing the equals sign (' = ') after typing the mathematical operation, gives the final result immediately and accurately.

'What–if' Analysis in Mathcad

If a phenomenon depends on many variables, estimating the effect of varying one variable on the phenomenon, while rest of the variables are held constant, is known as 'what–if' analysis. Such an analysis is carried out very easily in Mathcad.

Consider, for example, the heat flow by conduction through a rod.

Heat flow rate Q, through the rod is given by:

$$Q = k\cdot A\cdot\frac{(T_1 - T_2)}{L}, \text{ W}$$

where,

k = thermal conductivity of the material, (W/(mK)

A = area of cross section of the rod, m^2

$(T_1 - T_2)$ = temperature difference between the two ends of rod, (where $T_1 > T_2$), and

L = Length of rod, m.

Now, suppose that we are interested to find out the value of Q for rods made up of different materials, say, copper, aluminium and stainless steel, i.e. we would like to study the variation of Q with k, rest of the variables being held constant. This is done very easily and quickly in Mathcad, as follows: Let T_1 = 300 K, T_2 = 200 K, L = 05 m, $A = 0.785 \times 10^{-4}$ m^2.

First, define Q as a function of all variables. Then, write the data, assigning values for T_1, T_2, L and A. Next, assign the first value of k (i.e. for copper), and type '$Q(k)$ = ' (i.e. $Q(k)$ followed by an 'equals' sign), and the value of Q appears immediately. Now, to see the change in Q for the next value of k, again, assign the new value for k, followed by '$Q(k)$ = ', and the new value of Q appears immediately. Similarly, repeat for other values of k. Entire worksheet of these calculations is shown below:

$$Q := k\cdot A\cdot\frac{(T_1 - T_2)}{L}\ \text{W}$$ *(heat transfer rate by conduction)*

T_1 := 300 k, T_2 = 200 K, L = 0.5 m, $A = 0.785 \times 10^{-4}$ m^2

$$Q(k, A, T_1, T_2, L) := k\cdot A\cdot\frac{(T_1 - T_2)}{L}$$ *(define Q as a function of variables involved)*

Copper: k := 407 W/(mK) *(mean value of k between* 300 K *and* 200 K)

Then, $Q(k, A, T_1, T_2, L)$:= 6.39 W

Aluminium: k := 237 W/(mK) *(mean value of k between* 300 K *and* 200 K)

Then, $Q(k, A, T_1, T_2, L)$:= 3.721 W

S.S (AISI 304): k := 13.75 W/(mK) *(mean value of k between* 300 K *and* 200 K)

Then, $Q(K, A, T_1, T_2, L)$:= 0.216 W.

In a similar manner, by individually changing other values, namely, area of cross section (A), end temperatures (T_1, T_2) and length (L), effect on the heat transfer rate (Q) can be studied.

Producing the Results in Tabular Form

Many times, we need the results to be presented in a tabular form. This is done very easily in Mathcad. Let us say, we need to produce a table of values for Gaussian error function. Gaussian error function is defined as follows:

$$\text{erf}(y) = \frac{2}{\sqrt{\pi}}\cdot\int_0^y \exp(-V^2)\,dV$$ *(Gaussian error function...defined)*

(Note: In the above definition, integral sign is obtained by clicking on the appropriate button on the calculus palette.)

To present the values of erf(y) for values of y ranging from zero to 1, first define a range variable y, varying from 0 to 1, with an increment of 0.05. Then, typing 'y = ' immediately gives the values of y one below the other; similarly, type 'erf(y) =', and values of erf(y) appear one below the other. Arrange these two sets side by side, and we have the required results in a tabular form. This worksheet procedure is shown below:

$$\mathrm{erf}(y) := \frac{2}{\sqrt{\pi}}\cdot\int_0^y \exp(-V^2)\,dV$$ *(Gaussian error function...defined)*

$y := 0, 0.05, \ldots, 1$ *(define range variable y, varying from 0 to 1 with an increment of 0.02)*

y	erf(y)
0	0
0	0.0564
0.1	0.1125
0.15	0.168
0.2	0.2227
0.25	0.2763
0.3	0.3286
0.35	0.3794
0.4	0.4284
0.45	0.4755
0.5	0.5205
0.55	0.5633
0.6	0.6039
0.65	0.642
0.7	0.6778
0.75	0.7112
0.8	0.7421
0.85	0.7707
0.9	0.7969
0.95	0.8209
1	0.8427

Graphing in Mathcad

Graphing in Mathcad is very easy. Let us say, we would like to produce a graph of the effectiveness (ε) of a parallel flow heat exchanger, which is a function of number of transfer units (N) and the capacity ratio (C). Mathematical expression for the effectiveness of parallel flow heat exchanger is:

$$\varepsilon = \frac{1-\exp(-N\cdot(1+C))}{1+C}$$

Then, first express ε as a function of N and C; this is done in Mathcad by simply typing:

$$\varepsilon(N, C) := \frac{1-\exp(-N\cdot(1+C))}{1+C}$$ *(express ε as a function of N and C)*

Let us draw a graph of variation of ε with N for a value of C = 1, say:

First step is to define a 'range variable' N, varying from say, 0 to 6, in steps of 0.1. In Mathcad, it is written in the form:

$N := 0.\ 0.1, \ldots, 6$ *(define a range variable N, varying from 0 to 6 in increments of 0.1)*

Then, click on the graphing palette, and select the x–y graph. *A* graphing area appears with two 'place holders', one on the x-axis and the other on the y-axis. Fill in the x-axis place holder with N. On the y-axis place holder, fill in $\varepsilon(N, 1)$. Click anywhere outside the graph and immediately the graph appears. If we desire to draw in the same graph, the next curves for C = 0.8, 0.4 and zero, just type a comma after the already typed $\varepsilon(N, 1)$ and type $\varepsilon(N, 0.8)$, ε(N, 0.4), ε(N, 0), and click anywhere outside the graph area, and immediately the graph is redrawn with all the 4 curves. Further, there are simple mouse-click commands for giving titles for the graph, x-axis and y-axis, and also for showing grid lines and legend. Logarithmic scaling also can be applied by simple mouse-click commands. Entire worksheet is shown below:

$$\varepsilon(N, C) := \frac{1-\exp(-N\cdot(1+C))}{1+C}$$ *(express ε as a function of N and C)*

$N := 0, 0.1, \ldots, 6$ *(define a range variable N, varying from 0 to 6 in increments of 0.1)*

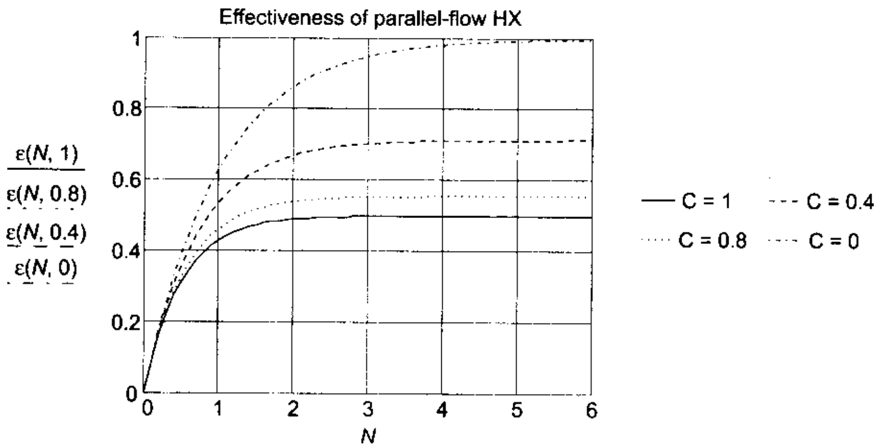


FIGURE 1 Example of graphing in Mathcad

By following the procedure already explained, we can produce a table of NTU vs. ε for, say, C = 1, 0.8, 0.4 and 0; this worksheet is shown below:

$$\varepsilon(N, C) := \frac{1-\exp(-N\cdot(1+C))}{1+C}$$ *(express ε as a function of N and C)*

$N := 0, 0.1, \ldots, 6$ *(define a range variable N, varying from 0 to 6 in increments of 0.2)*

N	*ε(N, 1)*	*ε(N, 0.8)*	*ε(N, 0.4)*	*ε(N, 0)*
0	0	0	0	0
0.2	0.165	0.168	0.174	0.181
0.4	0.275	0.285	0.306	0.33
0.6	0.348	0.367	0.406	0.451
0.8	0.399	0.424	0.481	0.551
1	0.432	0.464	0.538	0.632
1.2	0.455	0.491	0.581	0.699
1.4	0.47	0.511	0.614	0.753
1.6	0.48	0.524	0.638	0.798
1.8	0.486	0.534	0.657	0.835
2	0.491	0.54	0.671	0.865
2.2	0.494	0.545	0.681	0.889
2.4	0.496	0.548	0.689	0.909
2.6	0.497	0.55	0.696	0.926
2.8	0.498	0.552	0.7	0.939
3	0.499	0.553	0.704	0.95
3.2	0.499	0.554	0.706	0.959
3.4	0.499	0.554	0.708	0.967
3.6	0.5	0.555	0.71	0.973
3.8	0.5	0.555	0.711	0.978
4	0.5	0.555	0.712	0.982
4.2	0.5	0.555	0.712	0.985

Contd.

4.4	0.5	0.555	0.713	0.988
4.6	0.5	0.555	0.713	0.99
4.8	0.5	0.555	0.713	0.992
5	0.5	0.555	0.714	0.993
5.2	0.5	0.556	0.714	0.994
5.4	0.5	0.556	0.714	0.995
5.6	0.5	0.556	0.714	0.996
5.8	0.5	0.556	0.714	0.997
6	0.5	0.556	0.714	0.998

Solving Equation with One Variable (Root Finding)

To solve an equation with one variable, we can use the 'root' function:

Let us say, we would like to solve:

$$x + \ln(x) = 0.$$

This is a transcendental equation and solution requires a trial and error procedure. We first define a function: $y(x) = x + \ln(x)$; then, assume a guess value for x, and apply the root function to get the root in a single step. Of course, guess value for x must be assumed carefully, to facilitate a correct solution, since many times, there is a possibility that more than one root may exist. Quickly drawing a graph of $y(x)$ for some values of x will help in choosing a 'good' guess value. In the above case, let us draw the graph of $y(x)$ for $x = 0$ to 5, with an increment of 0.1, see Fig. 2. We can see from the graph, that the curve crosses $y(x) = 0$ at around a x value of 0.5. So, let us assume the guess value of x as 0.5. Then, apply the root function, i.e. simply type: 'root $(y(x), x)$ = ', and the solution appears immediately. We get $x = 0.567$ as the solution. Entire worksheet of this solution is shown below:

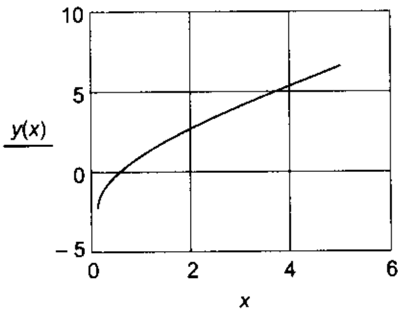


FIGURE 2 $y(x)$ vs. x, to get approximate solution of $y(x) = 0$

$y(x) := x + \ln(x)$ *(define the function $y(x)$)*

$x := 0, 0.1, \ldots, 5$ *(define a range variable x, varying from 0 to 5, in increments of 0.1)*

Draw the graph, to guess the approximate root of $y(x) = 0$:

$x := 0.5$ *(guess value of root, after seeing Fig. 2)*

$\text{root}(y(x), x) := 0.567$ *(correct value of root from the root function)*

Remember that numerical methods are used by Mathcad in the above solution. Calculations are terminated by the computer when a set value of 'tolerance' is achieved. Built-in tolerance is 0.001. You can easily change this value of tolerance by re-assigning its value, say: TOL := 0.0001, for example.

Solving a Set of Simultaneous Equations (Both Linear and Non-linear)

To solve a set of simultaneous equations, we use the "solve block" of Mathcad. Again, the procedure is very simple: start with guess values for the variables involved say x_1, x_2. Then, type 'Given' and immediately below it, type the constraints, i.e. the set of equations to be solved. Here, while typing the constraints, take care to use the ' = ' sign, and not the assignment sign, ' : = '. Then, type 'Find(x_1, x_2) = ', and immediately, the answer appears, in vector form, giving values of x_1, x_2, in that order. Entire worksheet of solving a set of two equations is shown below:

Solve the following set of equations:

$$4 \cdot x_1 - 2 \cdot x_2^2 = 2$$

$$x_1 + x_2 = 3$$

Start with guess values for x_1 and x_2, type 'Given', and below that write the two constraint equations, finally type 'Find (x_1, x_2) = ', and the value of the two variables appear in that order:

$x_1 := 1 \quad x_2 := 1$ *(guess values for x_1, x_2)*

Given

$$4 \cdot x_1 - 2 \cdot x_2^2 = 2$$

$$x_1 + x_2 = 3$$

$$\text{Find}\ (x_1, x_2) = \begin{bmatrix} 1.172 \\ 1.828 \end{bmatrix}$$

i.e. $x_1 = 1.172 \quad x_2 = 1.828$

Take one more example of using the solve block:

Solve the following set of equations

$$3 \cdot x_1 - x_2 + 3 \cdot x_3 = 0$$
$$-x_1 + 2 \cdot x_2 + x_3 = 3$$
$$2 \cdot x_1 - x_2 - x_3 = 2$$

Start with guess values for x_1, x_2, and x_3, type 'Given', and below that write the three constraint equations, finally, type 'Find (x_1, x_2, x_3) = ', and the values of the three variables appear in that order:

$x_1 := 1 \quad x_2 := 1 \quad x_3 := 1$ *(guess values for x_1, and x_2 and x_3)*

Given

$$3 \cdot x_1 - x_2 + 3 \cdot x_3 = 0$$
$$-x_1 + 2 \cdot x_2 + x_3 = 3$$
$$2 \cdot x_1 - x_2 - x_3 = 2$$

$$\text{Find}\ (x_1, x_2, x_3) = \begin{bmatrix} 2 \\ 3 \\ -1 \end{bmatrix}$$

i.e. $x_1 = 2 \quad x_2 = 3 \quad x_3 = -1.$

Note that to solve equation with one variable also we can use the solve block, instead of 'root' function.

Differentiation in Mathcad

Differentiation of a function, $y(x)$, is done easily in Mathcad. On the calculus palette, click on the d/dx button and a format for the first derivative appears, as shown:

$$\frac{d}{d\blacksquare}\blacksquare$$

Now, fill in the place holders with $y(x)$ and x as shown:

$$\frac{d}{dx}y(x)$$

As an example, let us say, we would like to find the value of the first derivative of the following function at $x = 2$:

$$y(x) = 4 \cdot x^3 + 8 \cdot x^2 - 5 \cdot x + 6.$$

First, define the function which has to be differentiated; next, define the first derivative, $y'(x)$ using the calculus palette, as explained above. Then, simply type: $y'(x) =$, and the result appears immediately. See the following worksheet:

$y(x) := 4 \cdot x^3 + 8 \cdot x^2 - 5 \cdot x + 6$ *(define a function)*

Then, let $y'(x) := \dfrac{d}{dx}y(x)$ *(define the first derivative of $y(x)$)*

i.e. $y'(2) := 75$ *(value of first derivative at $x = 2$)*

Finding the Maxima or Minima of a Function

For this purpose, we equate the first derivative to zero, get the value of x and then substitute in the function, i.e. we set $y'(x) = 0$, and get the value of x. To do this, we can easily use the root function. To check if the value of x so obtained gives maximum or minimum, we have to determine if the value of second derivative is positive (for a minimum) or negative (for a maximum). The second derivative is defined simply as the derivative of the first derivative. See the procedure below:

$y(x) := 4 \cdot x^3 + 8 \cdot x^2 - 5 \cdot x + 6$ *(define a function)*

Then, let $y'(x) := \frac{d}{dx} y(x)$ *(define the first derivative of $y(x)$)*

i.e. $x := 1$ *(trial value of x)*

$\text{root}(y'(x), x) = 0.261$ *(use the root function to get the value of x at which $y'(x) = 0$)*

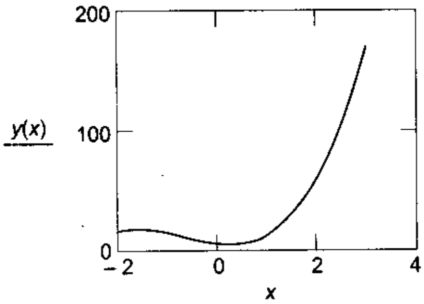
$y''(x) := \frac{d}{dx} y'(x)$ *(define the second derivative)*

Therefore, $y''(0.261) = 22.264$ *(this is > 0; therefore, $y(x)$ is a minimum)*

and, $y(0.261) = 5.311$ *(value of $y(x)$ at $x = 0.261$)*

Confirm it by drawing the graph of $y(x)$ vs. x:

$$x = -2, -1.99, \ldots, 3$$



In general, a minimum may occur not only at $x = 0.261$, but, there may be other values of x also at which the function passes through a minimum. The value of x given by Mathcad is the one nearest to the trial value of x chosen for the 'root' function. Therefore, in such problems, it is always advisable to draw the graph first and examine if there is more than one minimum (or maximum).

Integration

Integration between given limits is an operation required very often while solving heat transfer problems. Again, this is done simply by clicking the appropriate button from the calculus palette, and a format for integration appears as shown:

$$\int_{\blacksquare}^{\blacksquare} \blacksquare \, d\blacksquare$$

Now, just fill in the place holders, type ' = ' (i.e. 'equals' sign) and the result appears immediately.

For example, let us say, we would like to integrate the function $y(x) = 1 + \sin(x)$ between the limits $x = 0$ and $x = \pi/2$. We proceed as shown in the following worksheet:

$y(x) := 1 + \sin(x)$ *(define the function)*

Click the appropriate button on the calculus palette, fill in the place holders, and type '=', and the result appears immediately:

$$\int_0^{\frac{\pi}{2}} y(x)\, dx = 2.571.$$

Take one more example of integration within given limits:

Integrate the following function between the limits $x = 2$ and $x = 5$:

$$y(x) = x^3 + 4 \cdot x^2 - 3 \cdot x + 6$$

We proceed as shown in the following worksheet:

$y(x) = x^3 + 4 \cdot x^2 - 3 \cdot x + 6$ *(define the function)*

Click the appropriate button on the calculus palette, fill in the place holders, and type '=', and the result appears immediately:

$$\int_2^5 y(x)\, dx = 294.75.$$

Programming in Mathcad

Mathcad-7 Professional version has programming capability, too. Just as in the case of other programming languages, there is facility for conditional branching, looping constructs, error handling, using other programs as sub-routines, etc.

A Mathcad program is a special kind of expression, which returns a value—a scalar, vector, array, nested array or string. An 'expression' in Mathcad is only a simple statement, whereas a 'program' can consist of as many statements as required to compute the answer.

Programs are written using the 'programming palette'. Programming palette has only 10 buttons: add line, ← (assignment), if, while, for, break, otherwise, return, on error, continue. However, with its very wide mathematical and graphing functionality, coupled with programming capability and the convenience of Windows platform, Mathcad is a very powerful and versatile tool for engineering and scientific calculations.

It is impossible to illustrate all the programming capabilities of Mathcad in this short introduction.

However, we shall give only two small examples:

Consider the problem of calculating the friction factor for flow of fluid in a smooth tube. Friction factor depends on the Reynolds number (Re_D) based on tube diameter (D). If the Reynolds number is less than 2300, the flow is termed 'laminar' and the friction factor is given by: $f = (64/\,Re_D)$; if $Re_D > 2300$, flow is turbulent, and the expression for friction factor is: $f = 0.184.\ (Re_D)^{-0.2}$.

We would like to write a Mathcad program to return the value of f for any input value of Re_D i.e. $f(Re_D)$. Worksheet for this program is developed as explained below:

We start with the definition of friction factor as a function of Re_D on the LHS; then, click on 'add line' button in the programming palette. Two place holders appear as shown:

$$\text{ffactor}(Re_D) := \left\| \begin{array}{l} \blacksquare \\ \blacksquare \end{array} \right.$$

Now, position the cursor in the top place holder and click on the 'if' button in the programming palette. We see:

$$\text{ffactor}(Re_D) := \left\| \begin{array}{l} \blacksquare \ \text{ if } \blacksquare \\ \blacksquare \end{array} \right.$$

Fill in the place holders on the left and right of 'if' by $64/Re_D$ and $Re_D < 2300$, respectively as shown:

$$\text{ffactor}(Re_D) := \left\| \begin{array}{ll} \dfrac{64}{Re_D} & \text{if } Re_D < 2300 \\ \blacksquare & \end{array} \right.$$

Next, position the cursor on the bottom place holder and click on the 'otherwise' button in programming palette. We see:

$$\text{ffactor}(Re_D) := \left\| \begin{array}{ll} \dfrac{64}{Re_D} & \text{if } Re_D < 2300 \\ \blacksquare & \text{otherwise} \end{array} \right.$$

Now, fill in the remaining place holder by $0.184.Re_D^{-0.2}$. We get, finally:

$$\text{ffactor}(Re_D) := \left\| \begin{array}{ll} \dfrac{64}{Re_D} & \text{if } Re_D < 2300 \\ 0.184 \cdot Re_D^{-0.2} & \text{otherwise} \end{array} \right.$$

Entire worksheet is given below:

Program to compute the friction factor (ffactor) for a smooth tube as a function of Reynolds number (ReD):

$$\text{ffactor}(Re_D) := \left\| \begin{array}{ll} \dfrac{64}{Re_D} & \text{if } Re_D < 2300 \\ 0.184 \cdot Re_D^{-0.2} & \text{otherwise} \end{array} \right.$$

Now, for any value of Re_D, we can get the value of f by simply typing ffactor(Re_D) =.

For example,

$Re_D = 2000$	$\text{ffactor}(Re_D) = 0.032$	*(friction factor when $Re_D = 2000$)*
$Re_D = 4000$	$\text{ffactor}(4000) = 0.035$	*(friction factor when $Re_D = 4000$)*
$Re_D = (2 \times 10^6)$	$\text{ffactor}(2 \times 10^6) = 0.01$	*(friction factor when $Re_D = 2 \times 10^6$)*

Consider one more example of programming in Mathcad:

This program to find the sum of the series, $S = 1 + 2 + 3 + 4 + ...+ N$, illustrates the use of 'for' loop:

We denote the sum of the N terms as Sum (N). Type Sum (N) on the LHS and put the definition sign. We see the following:

$$\text{Sum}(N) := \blacksquare$$

Position the cursor on the place holder and click on 'add line' button in the programming palette. We get:

$$\text{Sum}(N) := \left\| \begin{array}{l} \blacksquare \\ \blacksquare \end{array} \right.$$

In the first place holder, type $S \leftarrow 0$; this initialises the Sum, S. Note that the left arrow ($\leftarrow$) denotes an assignment symbol inside the program, and it must be typed by clicking the left arrow button in the programming palette. Positioning the cursor in the other place holder, click on 'for' button in the programming palette. Then, we see:

$$\text{Sum}(N) := \left\| \begin{array}{l} S \leftarrow 0 \\ \text{for } \blacksquare \in \blacksquare \\ \quad \blacksquare \end{array} \right.$$

After 'for', now, fill in i (the counter which varies through the 'for' loop) and after the ε sign, fill in the range 1, ... , N. We see:

$$\text{Sum}(N) := \left\| \begin{array}{l} S \leftarrow 0 \\ \text{for } i \in 1, \ldots, N \\ \quad \blacksquare \end{array} \right.$$

In the last place holder, type the command $S \leftarrow S + i$; this command updates the value of Sum after each pass through the loop. Loop will stop when the counter 'i' reaches the value of N, passed in the input. We get:

$$\text{Sum}(N) := \left\| \begin{array}{l} S \leftarrow 0 \\ \text{for } i \in 1, \ldots, N \\ \quad S \leftarrow S + i \end{array} \right.$$

Next, select the last line and click on 'add line' button in the programming palette. We see:

$$\text{Sum}(N) := \left\| \begin{array}{l} S \leftarrow 0 \\ \text{for } i \in 1, \ldots, N \\ \quad S \leftarrow S + i \\ \blacksquare \end{array} \right.$$

Now, fill in the place holder by S; it means that when i reaches the value of N, the loop will stop and the last value of S will be returned as Sum (N):

$$\text{Sum}(N) := \left\| \begin{array}{l} S \leftarrow 0 \\ \text{for } i \in 1, \ldots, N \\ \quad S \leftarrow S + i \\ S \end{array} \right.$$

Worksheet containing the entire program described above is shown below:

Problem. Write a Mathcad program to find the sum of the series: $S = 1 + 2 + 3 + \ldots + N$

$$\text{Sum}(N) := \left\| \begin{array}{l} S \leftarrow 0 \\ \text{for } i \in 1, \ldots, N \\ \quad S \leftarrow S + i \\ S \end{array} \right.$$

Examples:

$\text{Sum}(2) = 3$ (*sum of first two terms,* i.e. $S = 1 + 2$)

$\text{Sum}(3) = 6$ *(sum of first three terms, i.e. $S = 1 + 2 + 3$)*

$\text{Sum}(5) = 15$ *(sum of first five terms, i.e. $S = 1 + 2 + 3 + 4 + 5$)*

$\text{Sum}(10) = 55$ *(sum of first ten terms)*

$\text{Sum}(50) = 1.275 \times 10^3$ *(sum of first fifty terms)*

$\text{Sum}(100) = 5.05 \times 10^3$ *(sum of first hundred terms.)*

Note how brief and succinct is the program.

Two programs given above are simple enough; but, they illustrate the way the program is built-up in Mathcad. For longer programs, more lines are added simply by clicking on 'add line' button, as and when required. Few more simple programs are given in the text.

Mathcad has several features, such as sequences, series, sums, products, factorials, derivatives and integrals, vectors and matrices, capability to draw x–y, bar, scatter, polar, surface and contour plots, etc., all by just a few clicks on the mouse. Only the most essential features, used in this text, are described above.

Nomenclature

The following is not a complete list of symbols used. In fact, symbols are explained whenever they appear in the text.

Notation	*Meaning*
A, A_c	Area, Area of cross section
C	Specific heat, mass concentration
C_h, C_c	Capacity rates of hot and cold fluids in a heat exchanger
c_p, c_v	Specific heat at constant pressure and constant volume
D, d	Diameter
D	Diffusion coefficient
E	Energy or emissive power
E_b	Emissive power of black body
$E_{b\lambda}$	Monochromatic emissive power
F	Force
F_{12}	View factor from surface-1 to surface-2
f	Friction coefficient or function
g(or a)	Acceleration due to gravity (or, acceleration)
h	Heat transfer coefficient or head of fluid
h_{fg}	Latent heat
I	Intensity of radiation
J	Joule's constant, or radiosity
k	Thermal conductivity
x, L	Distance, length
m	Mass
N	RPM
n	Number
P, p	Pressure, perimeter
Q	Quantity of heat
q	Heat flux
q_g	Heat generation rate per unit volume
R	Thermal resistance
R_u	Universal gas constant
R, r	Radius
S	Distance, Conduction shape factor
T, t	Temperature (K or deg.C)
t	Time
U, u	Overall heat transfer coefficient or velocity
V	Volume, velocity

Contd.

Contd.

u, v, w	Velocities
w, W	Weight, width
x, y, z	Cartesian coordinates, velocities
α	Thermal diffusivity or absorptivity
β	Coefficient of volumetric expansion
δ	Boundary layer thickness
ε	Effectiveness of heat exchanger, or emissivity of surface
ϕ	Angle
γ	Ratio of specific heats
η	Efficiency
λ	Wavelength or coefficient used in approximate solution of transient conduction problems
μ	Dynamic viscosity
ν	Kinematic viscosity
π	Mathematical constant (= 3.14), or terms in Buckingham -π theorem
θ	Temperature, Angle
ρ	Mass density
σ	Stefan–Boltzann constant, or surface tension
τ	Shear stress, or transmissivity, or time
ω	Angular velocity
AMTD	Arithmetic Mean Temperature Difference
LMTD	Logarithmic Mean Temperature Difference
NTU	Number of Transfer Units

Dimensionless parameters

Name	*Symbol*	*Formula*
Biot number	Bi	$\frac{h \cdot L}{k}$ ...k for solid
Eckert number	Ec	$\frac{u^2}{c_p \cdot \Delta T}$
Euler number	Eu	$\frac{\Delta T}{\frac{1}{2} \cdot \rho \cdot u^2}$
Fourier number	Fo	$\frac{\alpha \cdot \tau}{L^2}$
Grashoff number	Gr	$\frac{g \cdot \beta \cdot \Delta T \cdot L^3}{\nu^2}$
Modified Grashoff number	Gr_m or Gr'	$Gr \cdot Nu$
Graetz number	Gz	$Re.Pr.D/L$
Colburn j factor	j	$St \cdot Pr^{\frac{2}{3}}$
Jakob number	Ja	$\frac{c_p \cdot \Delta T}{h_{fg}}$
Mach number	M	$\frac{u}{\sqrt{\gamma \cdot R \cdot T}}$

Contd.

Contd.

Nusselt number	Nu	$\frac{h \cdot L}{k}$ ...k for fluid
Peclet number	Pe	$\frac{u \cdot L}{\alpha} = Re \cdot Pr$
Prandtl number	Pr	$\frac{c_p \cdot \mu}{k}$
Rayleigh number	Ra	$Gr.Pr$
Reynolds number	Re	$\frac{\rho \cdot u \cdot L}{\mu}$
Stanton number	St	$\frac{h}{\rho \cdot u \cdot c_p} = \frac{Nu}{Re \cdot Pr}$
Weber number	We	$\frac{\rho \cdot u^2 \cdot L}{\sigma}$
Mass transfer parameters:		
Lewis number	Le	$\frac{\alpha}{D}$
Sherwood number	Sh	$\frac{h_m \cdot L}{D}$
Schmidt number	Sc	$\frac{\nu}{D}$