Conclusion of VBA Review

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Mechanical Engineering 309

Numerical Analysis of Engineering Systems

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California State University Northridge

Outline

- Assessment quiz results
- Review
  - User-defined functions (UDF)
  - Choice (If) statements
  - Conditional and count-controlled looping
- Arrays
- Strings
- Debugging and Help
- First programming exercise

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Assessment Quiz Results

- 23 Responses (Non-responses not shown)
- General computer skills: **0** None **0** Minimal **10** OK **9** Good **4** Excellent
- Word processing skills: **0** None **0** Minimal **8** OK **14** Good **1** Excellent
- Spreadsheet skills: **0** None **0** Minimal **11** OK **12** Good **3** Excellent
- Programming language(s): VBA(**11**), C/C++(**5**), Java(**3**), HTML(**1**), MATLAB(**2**), Python(**1**), EES(**1**) No Response(**7**)

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Assessment Quiz Results II

- Programming skills: **1** None **6** Minimal **8** OK **5** Good **0** Excellent
- Highest math course: Math 150B(**4**) Math 250(**7**) Math 280(**12**)
- Code output?

```
j = 0 :  For i = 0 To 5   'missing j = 0
  If i = j Then Print #1 2 * i else j=j+2
Next i
```

- Answer: 0, 4, 8
- None correct with j = 0 missing

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Assessment Quiz Results III

- Solution of equations: $4x_1 + 2x_2 = 2$, $3x_2 = 3$
- $x_2 = 3/3 = 1$; $x_1 = [2 - 2(1)]/4 = 0$
- **19** Correct, **2** Partially correct, **2** incorrect
- Describe what the following code does

```
sum = 0.0  : For i = 1 to n
    sum = sum + x(i)  :  Next i
result = sum / n
```

- Computes average of the first n elements of the x array: **5** Correct, **11** Partially Correct, **7** incorrect

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User-Defined Functions (UDF)

- The function has the following form

```
Function <name> ( <arguments> ) As <type>
   <code to do computations>
   <name> = <value from computations>
End Function
```

- Example

```
Function vCyl ( R as Double, H as Double ) As Double
   vCyl = 4 * atn(1) * R^2 * H
End Function
```

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Using Your UDF

- Use with cell references or range names in worksheet
  - =vCyl(B1, B2)
  - =vCyl(1, 20)
  - =vCyl(radiusName, heightName)

Correspondence between arguments here and arguments in function definition based on **order**

- Call from other VBA procedures

```
V = vCyl( radius, height)
cylVol = vCyl( 1, 20)
v10cyls = 10 * vCyl( rad, hgt)
```

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If – Else If Explained

- If any condition is true, the statements following the If or Else If are executed
- Once those statements are executed controls to the first statement after the End If
- Statements for only the first true condition are executed
- The Else block is optional
  - If no conditions are true those statements are executed

```
If <condition1> The
    <Statements don
Else If <condition2>
    <Statements don
Else If <condition3>
    <Statements don
<May be other cond
Else
    <Statements don
End If
<Execute here after
```

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Count Controlled Loop

```
For <counter> = <start> to <end>
    <statements>
Next <counter>
```

If Step not specified, <increment> = 1

```
For <counter> = <start> to <end> _
                Step <increment>
    <statements>
Next <counter>
```

Statements in loop repeated nTimes = (<end> – <start>) /<increment> + 1 (converted to integer)

Loop not executed if nTimes <= 0

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Conditional Loop

<cond> is a condition (can be true or false)

<stmts> are statements executed in the loop (which can change the condition)

Do
  <stmts>
  if <cond> _
  Then Exit Do
  <stmts>
Loop
	Do While <cond>
	  <stmts>
	Loop
		Do Until <cond>
		  <stmts>
		Loop

	Do <stmts> Loop While <cond>	Do <stmts> Loop Until <cond>

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Solutions to Looping Exercises

- Looping exercise given at end of class for ungraded homework
  - Two functions use Taylor sine series
    - mySine uses fixed number of terms
    - mySine2 uses fixed allowable relative error
- Modify functions to allow user inputs for
  - Total number of terms in mySine
  - Relative error and maximum iterations in mySine2
  - Download solution from web site home page

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Looping Solutions

Original Worksheet

	A	B
1		
2		
3	Enter x value here:	2
4	Value of sin(x) from Excel function:	=SIN(B3)
5	Value of sin(x) from mySine function:	=mysine(B3)
6	Error in mysine function:	=ABS(B5-B4)
7	Value of sin(x) from mySine2 function:	=mysine2(B3)
8	Error in mysine2 function:	=ABS(B7-B4)

Revised Worksheet

	A	B
2	**Input Data and Exact Value**	
3	Enter x value here:	2
4	Value of sin(x) from Excel function:	=SIN(B3)
5	**Input Data and Result from Fixed Term Series**	
6	Number of terms in mySine function:	7
7	Value of sin(x) from mySine function:	=mysine(B3,B6)
8	Error in mysine function:	=ABS(B7-B4)
9	**Input Data and Result from Fixed Error Series**	
10	Allowed error in mySine2 function:	0.001
11	Maximum terms in mSine2 function:	50
12	Value of sin(x) from mySine2 function:	=mysine2(B3,B10,B11)
13	Error in mysine2 function:	=ABS(B12-B4)

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mySine Code Revisions

```
Function mySine(x As Double) _
                          As Double
For k = 1 To 4
```

- Two original statements above modified as shown below

```
Function mySine(x As Double,
  nTerms As Long) As Double
For k = 1 To nTerms - 1
```


mySine2 Code Revisions

```
Function mySine2(x As Double) As Variant
Converged = Abs(term) <= _
                        0.0001 * Abs(mySine2)
Loop Until Converged Or k > 100
```

- Three original statements above modified as shown below

```
Function mySine2(x As Double, allowedError _
 As Double, maximumTerms As Long) As Variant
Converged = Abs(term) <= _
                  allowedError * Abs(mySine2)
Loop Until Converged Or k > maximumTerms
```


Arrays

- Arrays can be visualized as data on an experimental variable
  - Could describe pressure data points mathematically as P_1, P_2, *etc*.
  - In VBA we can represent these data points as P(1), P(2), *etc*.
  - We call the numbers (1, 2, *etc*.) indices or subscripts
    - We can use constants or variables for the subscripts: P(4), P(k), where k has a value

Two-dimensional Arrays

Consider an experiment where you vary the current over six levels, the voltage over four levels and measure the efficiency, e, of an electromechanical device. The data for each combination of current and voltage can be represented as shown below

	I(1)	**I(2)**	**I(3)**	**I(4)**	**I(5)**	**I(6)**
V(1)	e(1,1)	e(1,2)	e(1,3)	e(1,4)	e(1,5)	e(1,6)
V(2)	e(2,1)	e(2,2)	e(2,3)	e(2,4)	e(2,5)	e(2,6)
V(3)	e(3,1)	e(3,2)	e(3,3)	e(3,4)	e(3,5)	e(3,6)
V(4)	e(4,1)	e(4,2)	e(4,3)	e(4,4)	e(4,5)	e(4,6)

Declaring Arrays

- Arrays must be declared as arrays by specifying the size of the array
  - The maximum size of the array must be specified in the Dim statement
- In VBA the lowest array subscript is zero by default
  - Can use `Option Base 1` in declarations section to change default lowest subscript to one
    - Can also set lowest subscript on each array

Dimensioning Arrays

- Declare **maximum array subscript**

```
Dim I(1 to 6) as double
Dim V(1 to 4) as double
Dim e(1 to 4, 1 to 6) as double
```

- Size below depends on Option Base 0/1

```
Dim I(6) as double
Dim V(4) as double
Dim e(4, 6) as double
```

How many elements are in these arrays?

Option base 0: 7, 5, 35
Option base 1: 6, 4, 24

Using Arrays

- Arrays components are referenced by their subscripts
- This is often done in a For loop

```
PI = 4 * atn(1)
For k = 0 to 100
      x(k) = sin(k * PI / 100)
Next k
```

- x is an array with 101 components giving sin(x) for $0 \le x \le \pi$, with $\Delta x = \pi/100$

Two-Dimensional Arrays

- Use nested for loops
  - Use example of current and voltages

```
For k = 1 to 4
   For j = 1 to 6
      Power(k,j) = I(j) * V(k)
   Next j
Next k
```

Recall table:
V was in rows
I was in columns
Power(k,j) is Power(row, column)
Are k and j indices correct?

Dynamic Arrays

- What if you do not know array size until program is actually running?
- Use Dim a() to tell compiler that a is an array then use ReDim with actual dimensions

```
Sub getArray( N as long) as Variant
Dim x() as Double : ReDim x(1 to N)
```

- Can go from Dim a() as Double to any size ReDim: ReDim a(1 to 10, 6 to 12)

Passing Arrays to Procedures

- Declare array in argument list with parentheses to indicate array

```
Sub mine( A() as double)
 'No dim statement for A
A(2,3) =
```

Use this for any size array. Variant arrays do not need ()

- Calling program sets actual dimensions on array and uses only the following

```
Dim B(1 to 10, 1 to 6) as double
Call mine(B)
```


Determining Array Bounds

- The UBound and Lbound functions determine the upper and lower bounds of unknown array dimensions
- For a two-dimensional array, A(m,k)
  - LBound(A,1) is the lower bound of m
  - UBound(A,1) is the upper bound of m
  - LBound(A,2) is the lower bound of k
  - UBound(A,2) is the upper bound of k

Worksheet Arrays to VBA

- Passed as a range of cells
- First step is to set a type variant variable equal to the input range variable
  - The variant variable is now a two-dimensional array
  - May have single row or single column, but is still a two-dimensional array
  - Lower bound is always one for arrays from worksheet
  - Can use UBound to get sizes

Worksheet Array Example

```
Function getMean (Ain As Range) As Double
Dim A as Variant, m as Long, k as Long
Dim sum as double, cells as Long
Dim nRows as Long, nCols as Long
A = Ain   :   nRows = UBound(A,1)  : sum = 0
nCols = UBound(A, 2)  : cells = nRows * nCols
For k = 1 to nRows
   For m = 1 to nCols
      sum = sum + A(k,m)
   Next m
Next k
getMean = sum/cells   : End Function
```

Sum = 0 not needed

Call from worksheet e.g.: =getMean(C2:C35)

VBA Array to Worksheet

- VBA steps to return array to worksheet
  - Declare the function type as Variant
  - In the function or sub declare a working array for calculations
    - Use application.caller for dimensions
  - Write the code for values in working array
  - At end of function set <function name> = <working array name>
- To use the function: select cells; enter function in formula bar; Cont+Shift+Enter


```
Function array2wks(<arguments>) As Variant
   Dim userRows As Long
   Dim userColumns As Long
   Dim workArray() as Double
   'Statements below determine rows and columns
   userRows = Application.Caller.Rows.Count
   userColumns = Application.Caller.Columns.Count
   ReDim workArray(1 to userRows, 1 to userColumns)

      'Place code here to compute all
      'components of workArray

      array2wks = workArray
End Function
```


Passing by Reference/Value

- Consider the following function call

  Call mySub(a, b)

```
Sub mySub( x as Long, y as Long)
   x = 2 * x
   y = x / y
End Sub
```

Answer: The value of a will have the new value of x computed in mySub

- What happens to the value of a in the calling program because of the x = 2 * x?

Passing by Reference/Value 2

- By default VBA passes memory locations of variables to procedures
  - This is known as pass by reference
- Alternative is pass by value
  - This simply sends the procedure the value stored in the memory location
  - To use pass by value enter the keyword ByVal before the variable in the header

```
Sub mySub( Byval x as Long, y as Long)
```

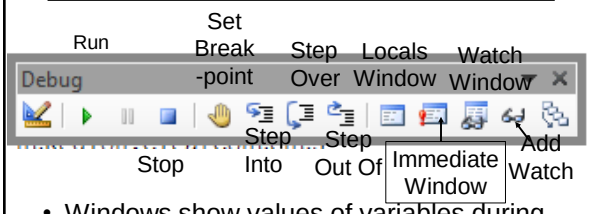

Strings

- Consider only variable length strings
- Use Dim str as String
- Use & or + as concatenation operator to join two strings
- Len(str) gives length of string
- Left, Right, and Mid give substrings in same manner as worksheet functions
- InStr function searches for substrings

Debugging

- Debugger allows you to step through a program and see intermediate values
  - Useful to find location of errors
- Items to use in debugger
  - Breakpoints stop execution at certain points
  - Step-by-step execution
  - Intermediate and Watch windows
  - Hover mouse over variable to get its value
  - Change statement to be executed next

Debugging Toolbar Icons



- Windows show values of variables during program execution
- Step commands allow you to step through individual statements

Help

- Help systems for Excel and VBA
- Search function does not always return what you are looking for
- If you know the keyword, type it, place the cursor in the keyword, and press F1
- Sometimes a Google search for "Excel VBA <subjectYouAreInterestedIn>" works better than Excel/VBA help

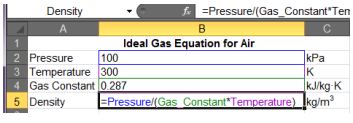
First Program

- Six different approaches to calculation of a trajectory, x(t), y(t) from 0 to t_{max}
  - Conventional cell formulas
  - Individual UDFs with "A1" cell references
  - Cell formulas with names
  - Individual UDFs with names
  - Array function
  - Macro
- Due Monday, February 3, 11:59 pm

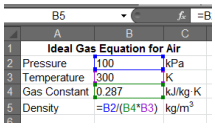
Range Names

- Can assign meaningful names to cells
- Names are used in formulas and show in name box when cell is selected
- Example below shows change with names

Worksheet Using Names



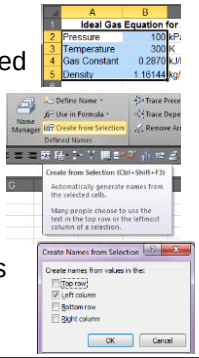
Without Names



Default cell names are absolute

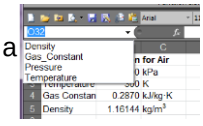
Getting Range Names

- Select cells with names adjacent to cells to be named
- Choose **Create from Selection** in **Defined Names** group of **Formula** tab
- In resulting dialog box make sure name location is correct and click **OK**



Name Box

- The name box, to the left of the formula bar, shows the currently selected cell
- When range names are defined, this box becomes a pulldown menu that shows all the defined names



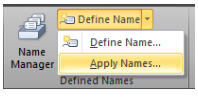
- Clicking on a name in this menu takes you to the named cell
- When entering formula, clicking on a named cell enters name into formula

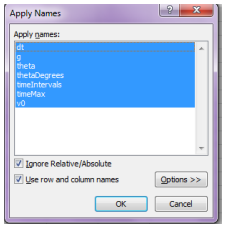
Name Manager

- Main tool for managing range names
  - Choose **Name Manager** in **Defined Names** group of **Formula** tab
  - Create, delete or edit names in Manager
- By default names have scope of entire workbook
- Name manager allows you to make name scope one worksheet
  - More instructions on first exercise

Names to Existing Formulas

- Click the down arrow next to **Define Names** and select **Apply Names** from the resulting submenu
- Select names in Apply names dialog and click OK
  - Can leave settings for checkboxes at bottom of dialog as set by Excel





Array Formula

- Array expressions: formulas that are entered into multiple cells at the same time
- Array functions: functions whose values are entered into multiple cells as arrays
- When entering an array formula or using an array function you must press **Control+Shift+Enter** instead of Enter
- You are asked to modify VBA code to use an array formula for the trajectory

Assignment One Code Structure

- Array function to return trajectory

```
Function trajectory(v0 As Double, _
        theta As Double) As Variant
```

- Macro to return trajectory

```
Sub getTrajectory()
```

- Common calculation function for both procedures above

```
Function calculateTrajectory(v0 As _
 Double, theta As Double, nRows As _
                    Long) As Variant
```

 You have to edit last function 41

Modify Calculate Trajectory

```
Function calculateTrajectory(v0 As Double, _
theta As Double, nRows As Long) As Variant
'Comments not shown
   Dim results() As Variant
   ReDim results(1 To nRows, 1 To 3)
  '(1) Use "Dim" statements to declare variables:
time, dTime and k
   results(1, 1) = "Time (s)"      'Comment …
   results(1, 2) = "x (m)"
   results(1, 3) = "y (m)"
```

nRows is total table rows including header row

What is nRows?

1	Initial velocity	10	m/s	
2	Initial angle	45	degrees	
3	g	9.80665	m/s^2	
4	Number of time intervals	5		
5	Maximum time	1.442096	s	
6	Time step	0.288419	s	
7				
8				
9		Time (s)	x (m)	y (m)
10		0	0	0
11		0.288419	2.039432	1.631546
12		0.576839	4.078865	2.447319
13		0.865258	6.118297	2.447319
14		1.153677	8.15773	1.631546
15		1.442096	10.19716	0

- nRows is the total number of rows including the header row
  - How is nRows related to the Number of time intervals?
- Previously found time step as maximum time divided by Number of time intervals

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Modify Calculate Trajectory II

```
'(2) Compute time step, dTime, from maxTime
function and number of rows, nRows.  How is
nRows related to number of time steps (NTS)?
    dTime =
'(3a) Complete coding of loop.  Set lower
and upper limits for k, the loop index
    For k = <What are my lim
        time = (k - 2) * dTime
        results(k, 1) = time
```

Hint: On worksheet you found $\Delta t = t_{max}/NTS$.

k is row index where first row is header row

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Modify Calculate Trajectory III

```
    results(k, 1) = time
(3b) Put statements here to compute x and y as
additional columns in the results array.  Use UDFs
for x and y.  results(k,m) is an array that has results
for time = (k-2)*dtime in the first column and the
corresponding x and y values for that time in
columns 2 and 3
    Next k
    calculateTrajectory = results
End Function
```

Hint: First/last time in loop must have $t = 0/t_{max}$

Suggestion: Make good guess about dTime equation and loop limits and check results

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