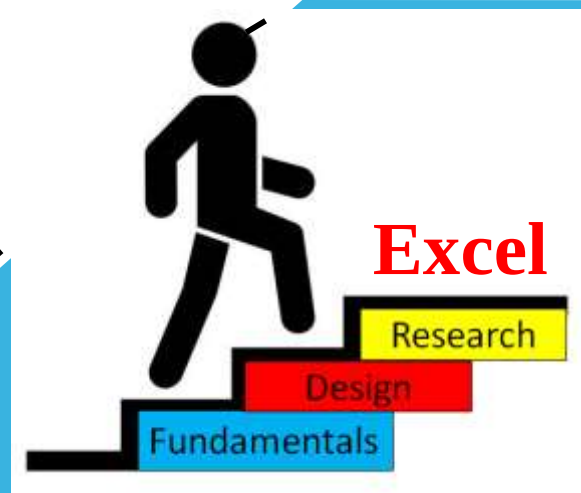




THERMAX 1-2-3 A MODELLING PLATFORM FOR OPTIMISATION ANALYSES OF FLUID- THERMAL SYSTEMS USING MS EXCEL



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Khartoum – December 19, 2024

Outlines

- Objective, method, and tools
- The Excel-based platform for thermo-fluid analyses
- Highlights
 - Examples of basic analyses
 - Examples of design optimisation analyses
 - Examples of research analyses
- About Thermax
- A Solver-TOPSIS technique for MOO analyses
- Course material

OBJECTIVE, METHOD, AND TOOLS

Objective, method, and tools

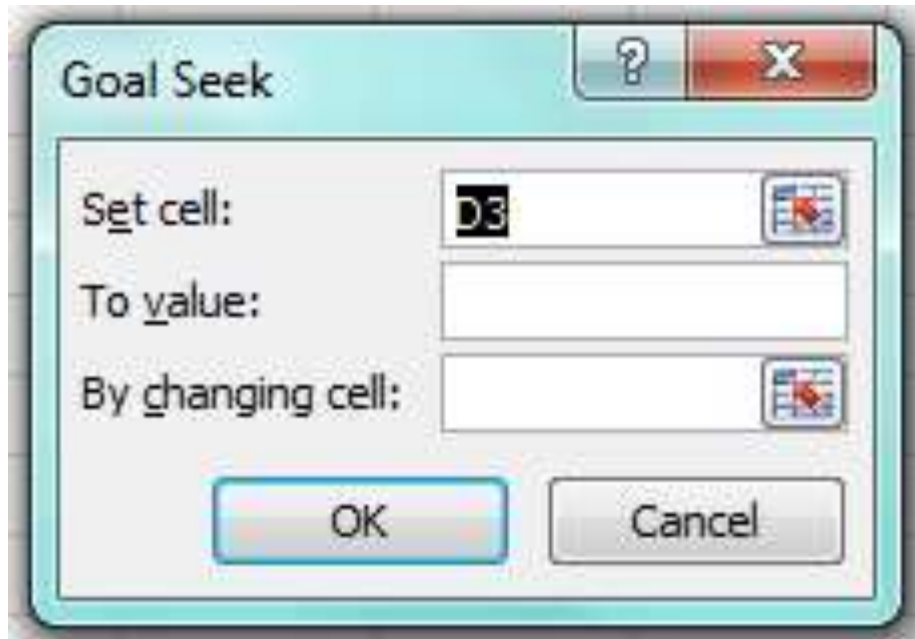
- To describe an effective learning/teaching method for energy-related undergraduate subjects:
 - Thermodynamics
 - Fluid-dynamics
 - Heat-transfer
- Method and tools:
 - Encourage computer-aided analytical methods
 - Enable design analyses of fluid-thermal systems
 - Adopt problem and project-based learning (PBL)
 - Facilitate student research

THE EXCEL-BASED PLATFORM FOR THERMO-FLUID ANALYSES

Excel's Built-in capabilities

- Graphical display of data and analyses results
- Numerous built-in mathematical functions, e.g. statistical, financial, etc.
- Solution of linear systems of equations by the matrix inversion method (**MMULT**, **MINVERSE**)
- Iterative solutions and solution of non-linear equations:
 - Internal solver (the iterative calculations option)
 - **Goal-Seek**

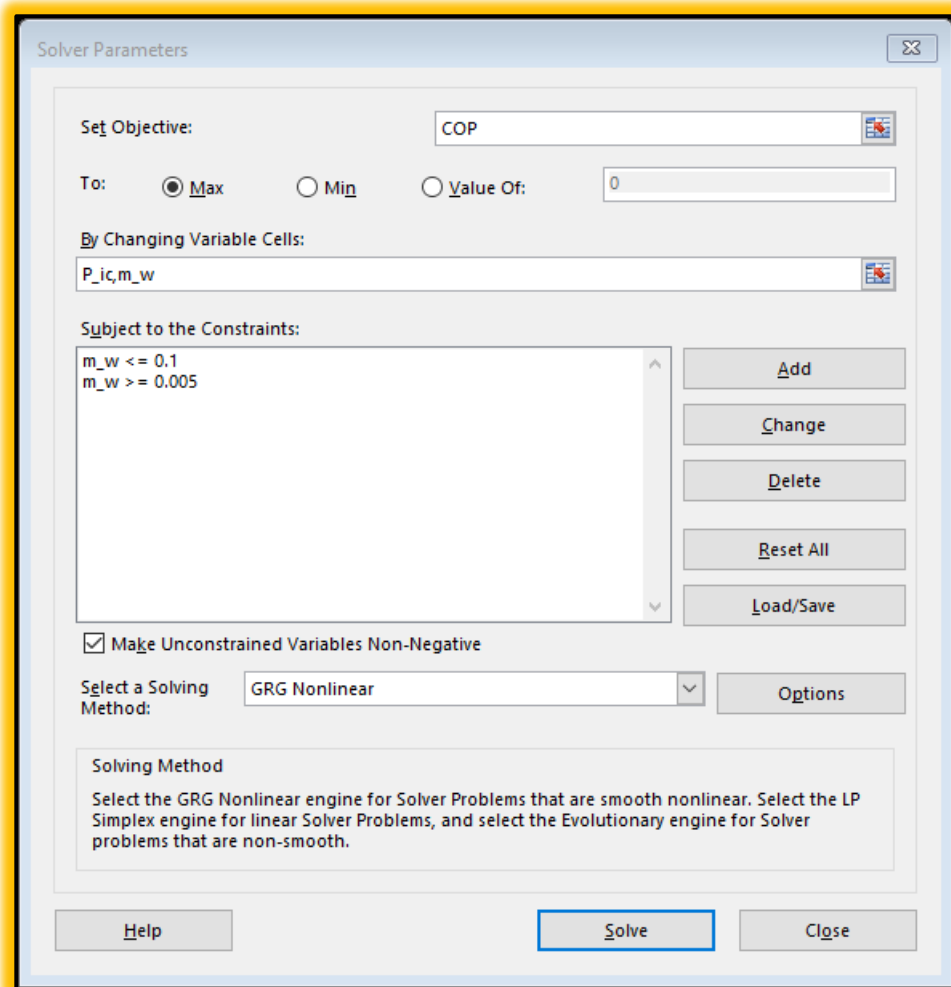
Goal Seek



Tools for thermo-fluid analyses

- Single-objective optimisation (**Solver**)
- Multi-objective optimisation:
 - The **MIDACO** solver
 - **Solver+TOPSIS**
- Various add-ins for fluid properties (e.g. REFPROP, **Thermax**)
- Visual Basic for Applications (**VBA**) for the development of user-defined functions

Solver for S-O and M-O optimisation



The image shows the 'Solver Parameters' dialog box in Microsoft Excel. The 'Set Objective:' field is set to 'COP'. The 'To:' section has three radio buttons: 'Max' (selected), 'Min', and 'Value Of:'. The 'Value Of:' field is set to '0'. The 'By Changing Variable Cells:' field is set to 'P_ic,m_w'. The 'Subject to the Constraints:' list contains two constraints: 'm_w <= 0.1' and 'm_w >= 0.005'. To the right of this list are buttons for 'Add', 'Change', 'Delete', 'Reset All', and 'Load/Save'. Below the constraints list is a checked checkbox labeled 'Make Unconstrained Variables Non-Negative'. The 'Select a Solving Method:' dropdown is set to 'GRG Nonlinear', with an 'Options' button next to it. A text box at the bottom explains the solving methods: 'Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.' At the bottom of the dialog are 'Help', 'Solve', and 'Close' buttons.

Solver Parameters

Set Objective: COP

To: ☒ Max ☐ Min ☐ Value Of: 0

By Changing Variable Cells: P_ic,m_w

Subject to the Constraints:

m_w <= 0.1
m_w >= 0.005

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method: GRG Nonlinear

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Help Solve Close

Thermax

- Thermodynamic analyses require evaluation of the thermodynamic properties of working fluids at different phases, pressures and temperatures.
- Excel itself doesn't have built-in function for this purpose.
- Thermax has been developed for education purposes.

Thermax functions for fluid properties

#	Substance(s) of the group	Prefix
1	Ideal gases (29)	Gas...
2	Water and steam	Wat...
3	Refrigerants (32)	Ref...
4	Water lithium-bromide solution	Lib...
5	Ammonia-water solution	Nh3...
6	Psychrometry	Psy
7	Fuels and reacting substances (18)	Chm...
8	Air at atmospheric pressure	Air...

Visual Basic for Applications (**VBA**)

- VBA
- Availability and ease of use
- Development of user-defined functions, e.g. for fluid properties
- Development of Macros and user forms for user-friendliness of developed applications
- Examples:

Function GWP(Ref\$)

```
Function GWP(Ref$)
If Ref$ = "R23" Then
GWP = 14800
ElseIf Ref$ = "R404A" Then
GWP = 3920
ElseIf Ref$ = "R4104A" Then
GWP = 89
ElseIf Ref$ = "R134a" Then
GWP = 1300
ElseIf Ref$ = "R744" Then
GWP = 1
ElseIf Ref$ = "R152a" Then
GWP = 140
ElseIf Ref$ = "R290" Then
GWP = 5
ElseIf Ref$ = "R717" Then
GWP = 0
End If
End Function
```

Function Schedule40(Diam, index)

```
Function Schedule40(Diam, index)
```

```
'Dim A, B, C, D, E, F
```

```
a = Array(0.405, 1.029, 0.02242, 0.683, 0.0003947, 0.3664)
```

```
b = Array(0.54, 1.372, 0.03033, 0.924, 0.0007227, 0.6706)
```

```
c = Array(0.675, 1.714, 0.04108, 1.252, 0.001326, 1.233)
```

```
D = Array(0.84, 2.134, 0.05183, 1.58, 0.00211, 1.961)
```

```
e = Array(1.05, 2.667, 0.06867, 2.093, 0.003703, 3.441)
```

```
F = Array(1.315, 3.34, 0.08742, 2.664, 0.006002, 5.574)
```

```
G = Array(1.66, 4.216, 0.115, 3.504, 0.01039, 9.643)
```

```
h = Array(1.9, 4.826, 0.1342, 4.09, 0.01414, 13.13)
```

```
.
```

```
.
```

```
If (Diam <= a(index)) Then
```

```
Schedule40 = a(index)
```

```
Elseif Diam <= b(index) Then
```

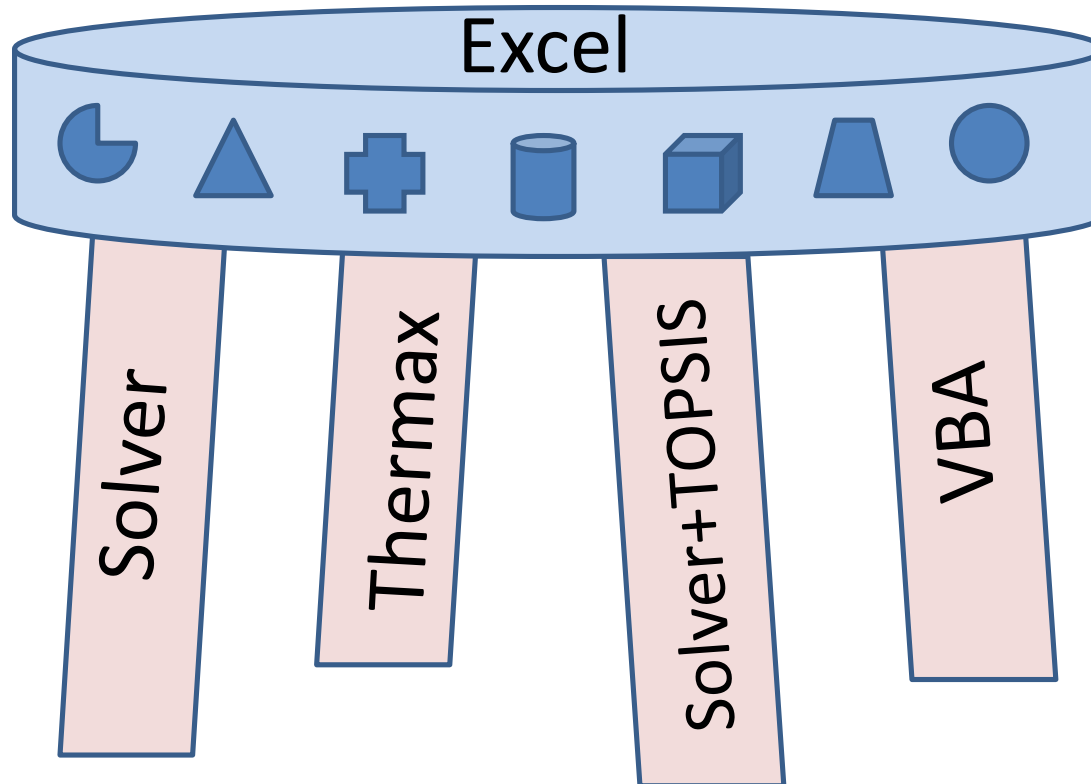
```
.
```

```
.
```

```
End If
```

```
End Function
```

The Excel-based modelling platform

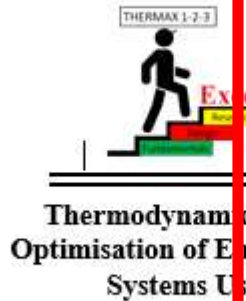


Features

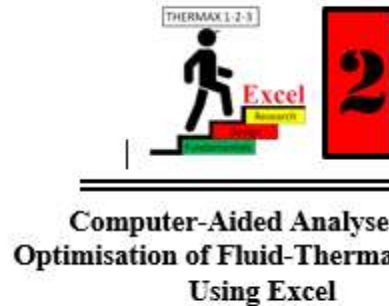
- An Excel-based modelling platform
- An Excel add-in for fluid properties that is adequate for most thermo-fluid analyses (Thermax)
- A technique for using Solver and TOPSIS for multi-objective optimisation analyses
- Three books that can be used at three levels

COURSE MATERIAL AND SUGGESTED COURSES

Three books (*unpublished*)



Mohamed M.



Mohamed M. El-Awad



Mohamed M. El-Awad

Three books (*unpublished*)

- Thermodynamic Analyses and Optimisation of Energy-Conversion Systems using Excel - (3rd year - **Thermodynamics II, Applied thermodynamics**)

[https://www.academia.edu/24381392/Thermodynamic Analyses and Optimisation of Energy Conversion Systems Using Excel?email_work_card=view-paper](https://www.academia.edu/24381392/Thermodynamic_Analyses_and_Optimisation_of_Energy_Conversion_Systems_Using_Excel?email_work_card=view-paper)

- Computer–Aided Analyses and Optimisation of Fluid-Thermal Systems using Excel - Excel (4th year – **Computer applications, Elective subject**)

[https://www.academia.edu/40015718/Computer Aided Analyses and Optimisation of Fluid Thermal Systems using Excel?auto=download&email_work_card=download-paper](https://www.academia.edu/40015718/Computer_Aided_Analyses_and_Optimisation_of_Fluid_Thermal_Systems_using_Excel?auto=download&email_work_card=download-paper)

- Multi-Objective Optimisation and Exergoeconomic Analyses of Energy-Conversion Systems by Using Excel – (5th year UG- **Elective subject**, 1st year PG- **Elective subject**)

[https://www.academia.edu/41316679/Multi Objective Optimisation and Exergoeconomic Analyses of Energy Conversion Systems by Using Excel?auto=download&email_work_card=download-paper](https://www.academia.edu/41316679/Multi_Objective_Optimisation_and_Exergoeconomic_Analyses_of_Energy_Conversion_Systems_by_Using_Excel?auto=download&email_work_card=download-paper)

References

1. L. W. Anderson and D. R. Krathwohl, eds. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Longman, 2001.
2. M. Hofmann, F. Witte, M. Fritz, J. Freissmann, I Tuschy, G. Tsatsaronis. *Free and Open-Source Teaching: Understanding Exergy using Thermal Engineering Systems in Python (TESPy)*, Proceedings of ECOS 2023 - the 36th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental impact of energy systems, 25-30 June, 2023, Las Palmas de Gran Canaria, Spain
3. MIDACO-Solver, <http://www.midaco-solver.com/>