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An Application of MS-Excel to Solve Optimisation Problems – Exam Study Optimiser

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Abstract—*Many students often find themselves in the panicky and stressful situation where they have too much to learn but too little time to accomplish it because the exams are fast approaching. They then need to choose which topics to study in the limited time available before the exam, so that their efforts will yield the best possible result in terms of marks gained in the exam. This paper explains how to use the Solver tool in the Data menu of MS-Excel to solve this combinatorial optimization problem instantaneously, saving precious time which can now be better utilized for exam preparation. This also provides the student with a clear action plan and protects the student from wasting time due to 'freezing' caused by panic on the final day before the exam*

1. INTRODUCTION

Many students will be familiar with the following situation – there are only 2 more days to go before the final exam. Ten chapters will be assessed for the exam, but the student remembers almost nothing. The student does a reality check and estimates the amount of time required to 'master' each chapter, which totals up to 30 hours. But the student can only study for a maximum of 16 hours until the start of the exam. Assuming that the student knows the marks distribution (weightage) of each chapter to be tested in the exam, and assuming that the student can maximize the chances of securing the marks allotted for a particular chapter only if he devotes the entire amount of time required to 'master' the chapter according to his original estimate, which chapters must he choose to study in the limited time available before the exam, in order to enable him to score the maximum possible marks in the exam?

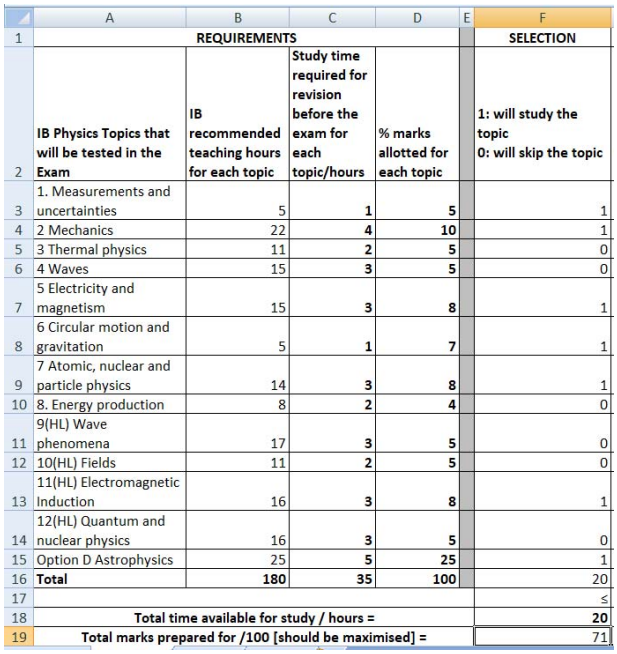
This is a Combinatorial Optimization problem, which can be solved very easily and automatically after constructing a Linear Programming Model by using the Solver tool that is available as an extra Add-In called the Analysis Toolpak in MS-Excel. It can be loaded in MS-Excel by following the instructions given by Niels Weterings (refer the Appendix).

2. FORMULATING THE MODEL

This decision-making problem can be generalized as follows:

Suppose there are n tasks T_1, T_2, …., T_i, …, T_n to be completed and each task will take time t_i where i = 1,2,3,….n. The total time *available* for completing ALL the tasks, A becomes the constraint, since A is less than the total time *required* to complete ALL the tasks, R which is calculated as $R = \sum t_i$. The completion of each task generates a particular profit, P_i. The goal is to maximize the total profit P which is the sum of the profits of all the tasks that will be chosen for completion in the available time.

For illustrative purpose, the list of topics is taken from the IB Physics HL curriculum, and the estimated time required to master/revise each topic is calculated by taking $1/5^{th}$ of the recommended teaching hours for each topic prescribed by the IB subject guide. Assuming that the student is preparing for the final summative exam in which he/she will be tested on all the topics, and assuming a more or less uniform coverage of all the topics in the exam, marks distribution for the summative assessment was done. All this information is added in the REQUIREMENTS section of the table in the EXCEL spreadsheet as shown in Figure 1.



	A	B	C	D	E	F
1	REQUIREMENTS					SELECTION
2	IB Physics Topics that will be tested in the Exam	IB recommended teaching hours for each topic	Study time required for revision before the exam for each topic/hours	% marks allotted for each topic		1: will study the topic 0: will skip the topic
3	1. Measurements and uncertainties	5	1	5		1
4	2 Mechanics	22	4	10		1
5	3 Thermal physics	11	2	5		0
6	4 Waves	15	3	5		0
7	5 Electricity and magnetism	15	3	8		1
8	6 Circular motion and gravitation	5	1	7		1
9	7 Atomic, nuclear and particle physics	14	3	8		1
10	8. Energy production	8	2	4		0
11	9(HL) Wave phenomena	17	3	5		0
12	10(HL) Fields	11	2	5		0
13	11(HL) Electromagnetic Induction	16	3	8		1
14	12(HL) Quantum and nuclear physics	16	3	5		0
15	Option D Astrophysics	25	5	25		1
16	Total	180	35	100		20
17						≤
18	Total time available for study / hours =					20
19	Total marks prepared for /100 [should be maximised] =					71

Figure 1 Implementing the model in MS-Excel

The total time available for study (in hours) is determined by the user and is set as the constraint for the model. It will depend on how late the student starts the preparation for the exam, and how much study-time is available before the commencement of the exam.

The values in the SELECTION column and 'Total marks prepared for' will be populated automatically by MS-Excel on using the SOLVER tool based on the information provided in the REQUIREMENTS section.

The following three questions must be answered in order to formulate this linear programming model:

1. What are the decisions to be made? In this problem, we need Excel to choose the topics to be studied (1 = study the topic, 0 = skip the topic).
2. What are the constraints on these decisions? Each topic has to be either chosen (1) or not chosen (0) for study, which makes it a binary output variable. These decisions will determine the total time spent studying the selected topics, which must be less than or equal to the total time available for studying.
3. What is the overall measure of performance for these decisions? It is the total marks that can be prepared for based on the topics chosen for study. The goal is to maximize this quantity.

To make the model easier to understand and to manipulate the data for calculation using formulae, the range of cells containing the different data were named as follows (right click on the selection of cells to be named, and select 'Name a Range' in the pop-up window):

Figure 2 Variables used in the model

Range Name	Cells
required_time	C3:C15
marks_allotted	D3:D15
total_required_time	C16
total_allotted_marks	D16
total_available_time	F18
topics_selected	F3:F15
time_spent	F16
Marks_prepared_for	F19

The functions were entered in the cell addresses as shown in Figure 3 to perform the calculations.

Figure 3 Functions used to evaluate the variables

Functions inserted	Cell Address	Variable calculated
=SUM(B3:B15)	B16	Total IB recommended teaching hours for all the topics
=SUM(C3:C15)	C16	total_required_time
=SUM(D3:D15)	D16	total_allotted_marks
=SUMPRODUCT(required_time,topics_selected)	F16	time_spent
=SUMPRODUCT(marks_allotted,topics_selected)	F19	marks_prepared_for

The SUM function adds all the numbers in a range of cells, while the SUMPRODUCT function returns the sum of the products of the corresponding ranges or arrays. Thus, total time spent studying the selected topics is calculated by the sum of the products of the time required for each topic and the corresponding binary value of the topic selection status (0 or 1). The total marks prepared for as a result of choosing the topics is calculated by the sum of the products of the marks allotted for each topic and the corresponding binary value of the topic selection status (0 or 1).

The optimal solution (selection of topics which will maximise the total marks prepared for) was found by using the Solver in the Data menu of MS-Excel as follows.

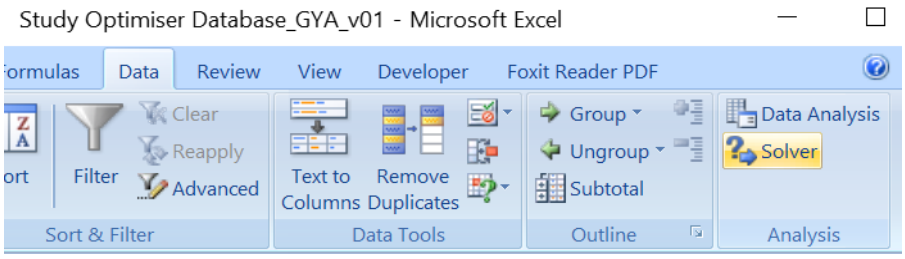


Figure 4 Click on Solver in the Analysis group of Data tab

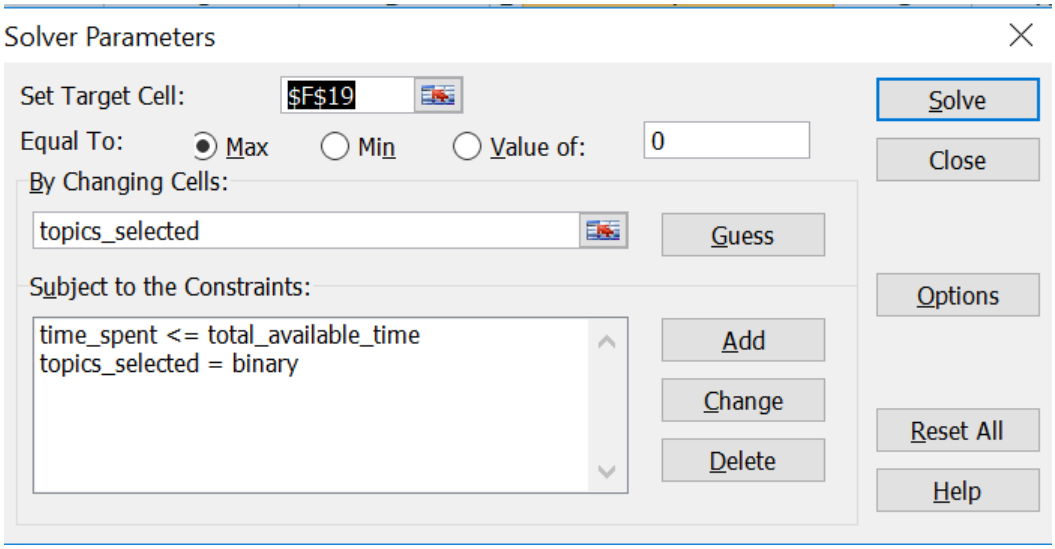


Figure 5 Enter the Solver Parameters in the Pop-Up window as shown

'marks_prepared_for' (cell F19) was selected for 'Set Target Cell', and the condition was set as 'Equal To' 'Max' (selected the Max radio button). This condition was achieved 'By Changing Cells' to 'topics_selected'. The constraints were set one by one by clicking on the 'Add' button.

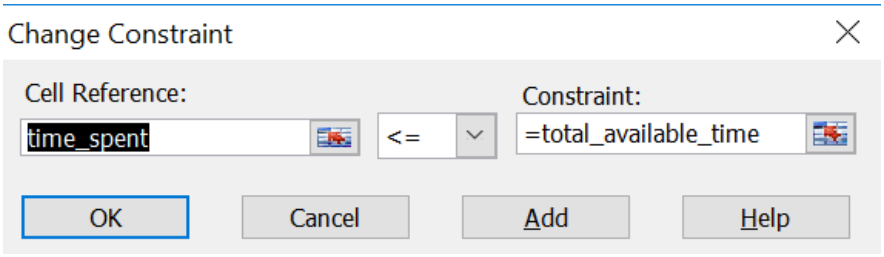


Figure 6 Setting the constraint for time_spent

'time_spent' was set to be less than or equal to 'total_available_time', and

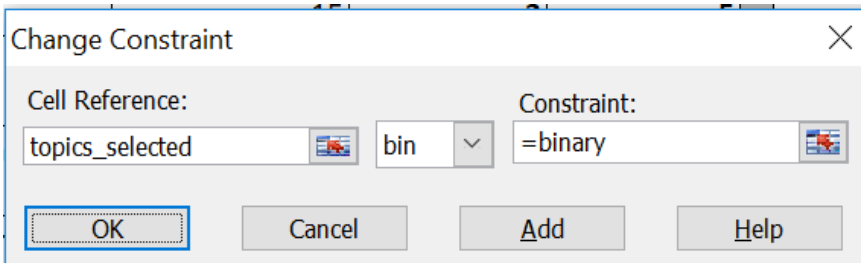


Figure 7 setting the oonstraint for topics_selected

'topics_selected' was set as binary variable so that it can take only 0 or 1 as values. Next, 'Options' button was clicked and 'Assume non-negative' checkbox was selected in the Solver Options popup window.

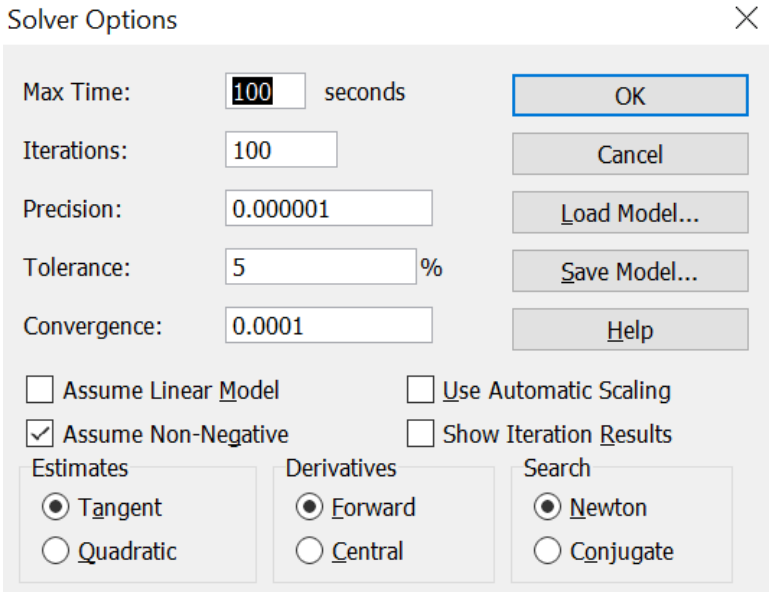


Figure 8 Selecting 'Assume Non-Negative' in the Solver Options

Finally, the Solve button was clicked to see the optimal solution for the current value of total available time for study. By changing the value of 'total_available_time' (cell F18) from 1 to the maximum possible value of 'total_required_time' in increments of 1, and clicking on the Solve button each time, one can obtain the optimal solution for all the possible values of total available time. The % marks prepared for was found to increase almost linearly with the % of required time which was available for study, as expected.

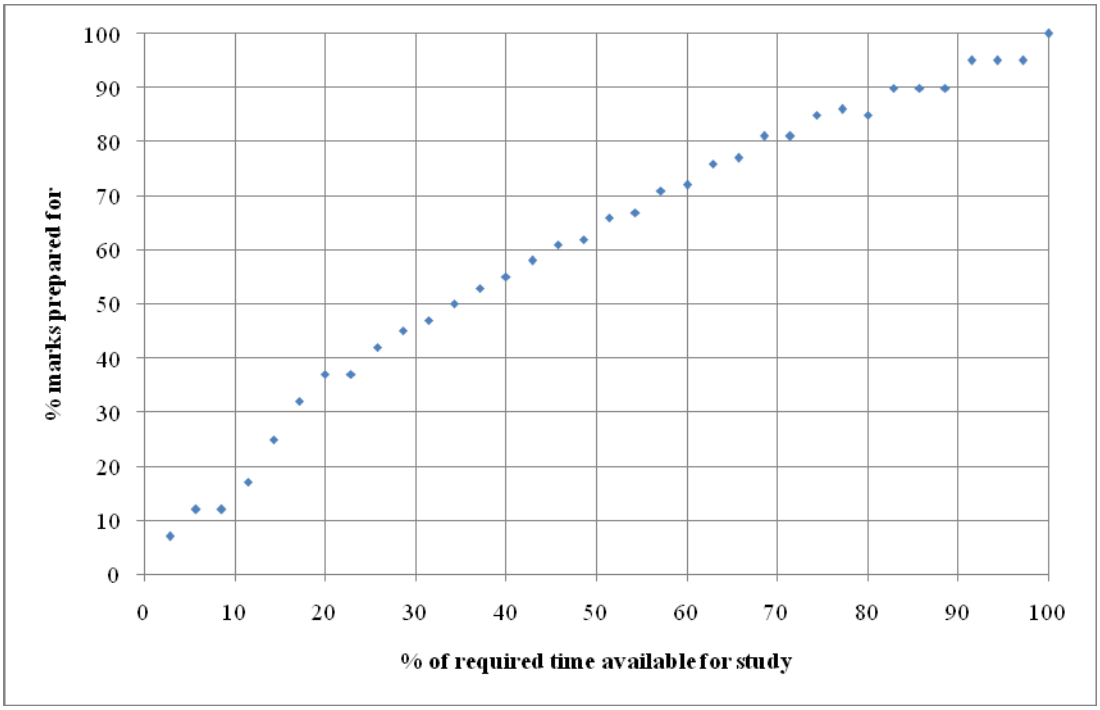


Figure 9 % marks prepared for vs % of required time available for study

3. CONCLUSION

The Solver tool of MS-Excel can be used to instantaneously decide which topics to be studied out of a collection of topics if the estimated time required to complete each topic and the approximate marks distribution or weightage for each topic in the exam is known, along with the total time available for study. This automation of the decision-making process can save precious time for the student when he/she is preparing for the exam and very little time is left. By showing a clear plan of action as to which topics to study and which topics to skip for the optimum utilization of the available scarce time to maximise the gain in terms of possible marks that can be scored in the exam, it reduces and/or prevents the onset of stress and panic for the poorly prepared student when the exam is fast approaching. The Solver tool of MS-Excel is a very powerful and versatile tool which can be used to solve many such decision-making optimization problems easily and quickly.

REFERENCES

[1] *Weterings, N. Assignment Problem in Excel. (n.d.). Retrieved December 25, 2017, from* http://www.excel-easy.com/examples/assignment-problem.html

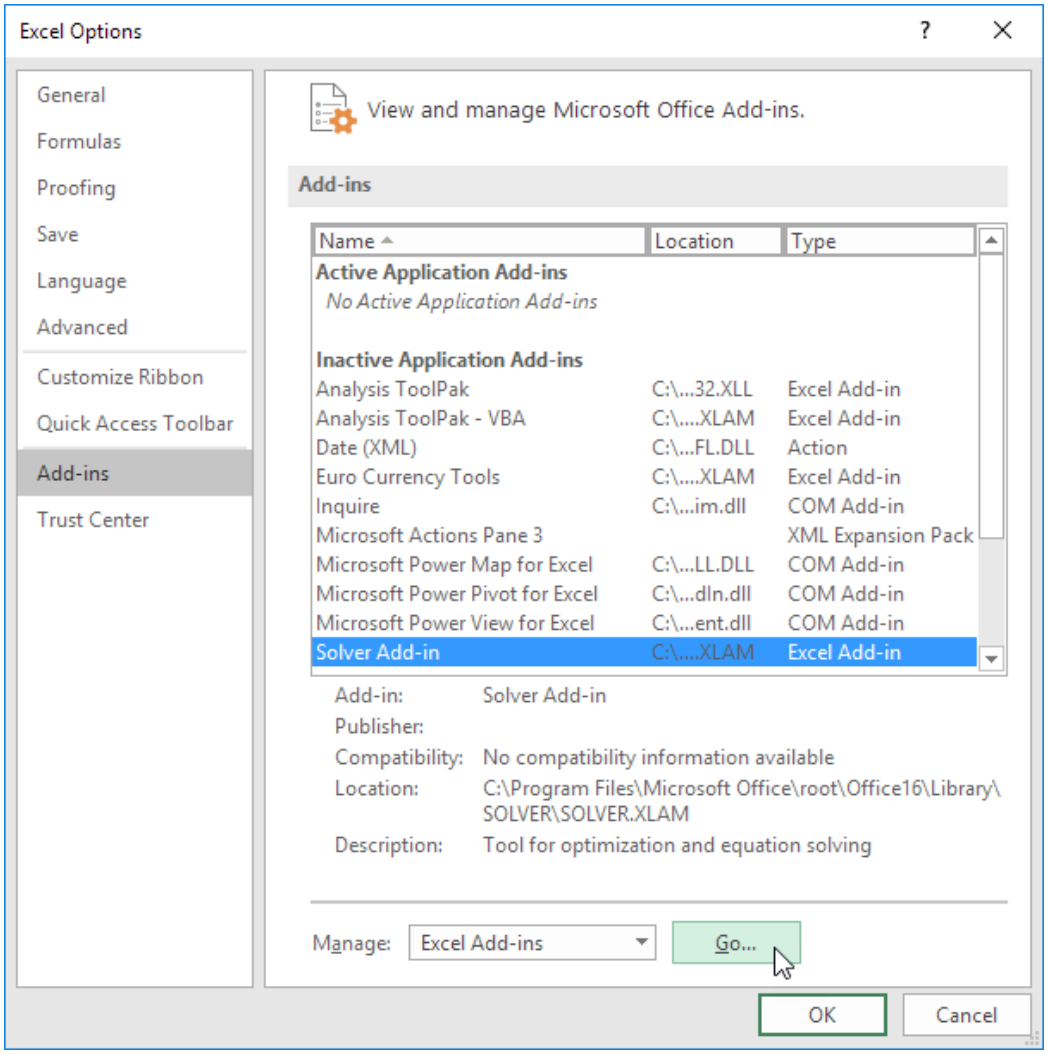
[2] *Weterings, N. (n.d.). Solver in Excel. Retrieved December 25, 2017, from http://www.excel-easy.com/data-analysis/solver.html#load-solver-add-in*

Appendix

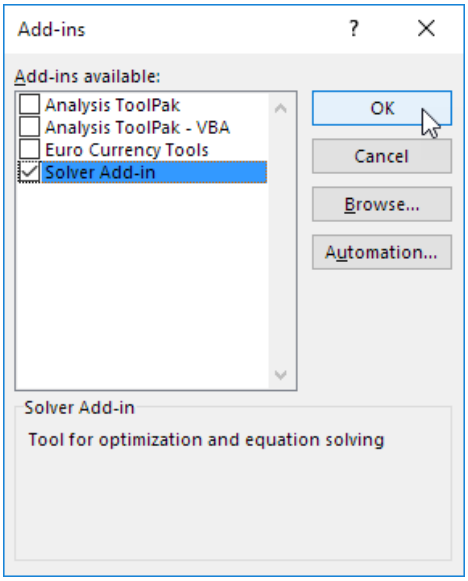
How to load Solver in MS-Excel (Niels Weterings, 2010)

"1. On the File tab in MS-Excel, click Options.

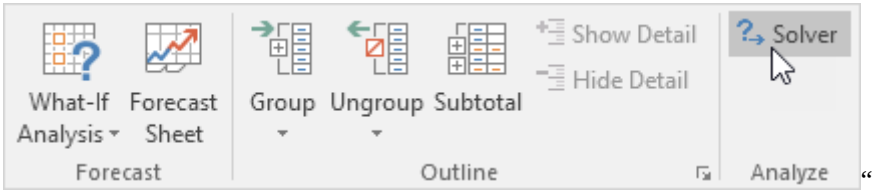
2. Under Add-ins, select Solver Add-in and click on the Go button.



3. Select Solver Add-in checkbox and click OK.



4. You can find the Solver on the Data tab, in the Analyze group.



Link to download Exam Study Optimiser (customised MS-Excel Spreadsheet developed in this research)
https://tinyurl.com/yaaqhxgo