

# A Method of Setting Examination Papers and Generating the Solutions

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**Abstract** – A method of setting examination papers and automatically generating the corresponding solutions is described which is based on the use of MS Word and MS Excel. Questions are automatically selected from a pool of questions and both the question data and the order in which the question is to appear in the examination paper is specified. Both the paper and the corresponding solutions are then generated using Ms Word with the numerical information being supplied from Excel to Word through mailmerge. The method described allows a record of each examination paper to be captured in terms of the questions selected, the data employed and the order of appearance of the question in the paper. The questions selected can then be linked back to the subject material being tested and the learning outcomes for the module ensuring that quality standards are maintained. Setting up the question pool requires initial effort, however the time expended is then quickly recouped by the subsequent speed with which examination papers can be set, the quality of the papers produced and the elimination of any errors in the solutions. The method gives the possibility of examination papers being generated by non-academic staff, though the production of the questions and the solution methodology would remain an academic function. This could free up academic time at key periods in the academic cycle. Whilst the method has evolved and been applied within an engineering discipline it could easily be used in any discipline requiring numerical answers to be generated and some of its features would easily lend themselves to disciplines in which more essay type questions are deployed.

**Index Terms** – Assessment, Learning Outcomes, Quality standards, Efficiency gains

## INTRODUCTION

Managing the link between learning and assessment is a challenge. The conflicts presented in balancing the needs of academics and their Institutions, students and professional accrediting bodies requires careful consideration, this is clearly discussed in [1]. Getting the correct balance between summative and formative assessment is crucial. In the present work formative assessment has been addressed by using in-class questions delivered through a personal response system, [2], and also through on-line tests presented through a virtual learning environment, [3]. Experience shows that many students enjoy the stimulus of on-line and in-class testing and are motivated to learn through such assessment mediums. In [4] the conclusion is drawn that assessment methods and requirements have a greater influence on how and what students learn than any other factor.

Summative assessment is usually associated with end of module assessment, here the freedom for Institutions of Higher Education to set their own examination and assessment procedures distinguishes tertiary education from secondary where examinations are set and moderated by distinct external examining bodies. This rests the onus for assuring quality standards at tertiary level with the Institution which will ultimately award degrees and other qualifications based upon its assessment criteria. Whilst it is customary for Universities to appoint an external examiner, a senior academic from another Institution, to oversee the academic procedures on each degree programme the principal responsibility lies with the academic staff involved in teaching the degree programme. Whilst forms of assessment have widened beyond the traditional set examination to include continuous assessment through coursework and assessment of oral presentations the end of module examination still dominates the assessment methods deployed in most numerate subjects.

However, frequently the requirement for academic staff to set examination papers falls at a very busy time in the semester. Consequently, examination papers are frequently set in a hurry without adequate time to fully reflect on the content of the paper and its relationship with the learning outcomes of the module. The need to produce worked solutions to papers is an additional burden. Increasingly it is the case that administrative support for academic staff is dwindling so that in addition to setting the paper and producing the solutions a typed paper must be submitted. Within this demanding remit there is considerable scope for errors to creep in, these may occur in the paper itself or more commonly in the solutions where numerical errors can easily be introduced.

A means of streamlining the production of examination papers was therefore sought which held the prospect of reducing the pressures on academic staff which could automate the production of examination papers. In the method described in this paper the questions used formed a question pool from which selections of questions could be made to generate a complete examination paper. Since the question pool would be prepared well in advance of any requirement to

produce an examination paper the questions, and the solutions, would be prepared without the time pressures otherwise occurring and the pool could be extended over time.

## THE METHODOLOGY ADOPTED

In order to produce a workable system some means of identifying questions and the topics in the syllabus to which the questions were linked was necessary. Thus the starting point of the question paper design was the syllabus for the module being assessed which was split into distinct topics, topic1, topic2, topic3 etc.... For an examination paper to give full coverage of the syllabus, ideally, at least one question from each topic would be required, though in certain circumstances there may be more topics than there are questions. For example if the convention was to provide an examination paper containing 5 questions but the syllabus contained 6 distinct topics one topic would remain uncovered on that particular paper. In such a situation it would be important to ensure that the same topic was not omitted on a regular basis.

A number of questions relating to each topic were set with each question being assigned a distinct alphabetical character, QuestionA, QuestionB, QuestionC ...etc. The questions were written in MS Word so that a set of files named QuestionA.doc, QuestionB.doc, QuestionC.doc....etc were generated in Office 2003 whilst in Office 2007 the file extension .docm was used enabling the use of macros within the documents.

The numerical data for the questions was supplied from MS Excel by means of a table exported from Excel to Word through mailmerge. All the variables associated with each question were prefixed by the same alphabetic character i.e. For QuestionA all variables started with A, for Question B all variables started with B...etc. Within the Excel spreadsheet one worksheet was associated with each question, SheetA, SheetB, SheetC ...etc, and one cell of each of those worksheets, cell A5, identified which topic in the syllabus the question was linked to.

Two folders were created one named Paper and the other Solutions both of which contained copies of the MS Word files, the distinction being that the question Word files in the Paper folder consisted of the question only, whilst those in the Solutions folder contained both the question and step by step solutions to the question with the convention being adopted that the question text appeared in black whilst the solution text was in blue. The numerical information to generate the solutions was exported from the Excel spreadsheet though the same table via mailmerge.

To generate an examination paper ideally a question on each topic was required and clearly with a number of questions on each topic to choose from a number of possible combinations existed. One variable would be the order in which the selected questions appeared in the examination paper. Thus for an examination paper containing 5 questions with 5 possible questions on each topic there would be 125 different ways in which the paper could be collated. Another variable is the numerical data used in the selected questions, in the method used here the data was generated using a random number generator within the Excel spreadsheet based on previously set minimum and maximum values for each variable and the number of decimal places that the variable needed to be specified to. The combination of number of different paper layouts, which question from the pool was deployed and the order in which the question then appeared in the paper together with the change in numerical question data and hence solutions, ensured that no duplication of examination papers occurred.

Figure 1 shows a schematic diagram of the structure of the method used to produce either the paper or the paper together with the solutions. The data for the questions was set and the calculations performed within the Excel spreadsheet which had one Worksheet associated with each question these were labelled SheetA, SheetB, SheetC ...etc. An additional Worksheet to the spreadsheet named the Analysis sheet made a random choice of a question on each topic and also a choice of where that question was to appear within the examination paper. With those choices determined the worksheet then collated the information from the question worksheets used and stored all the information in a single table, this table was finally used to Mailmerge with the question and solution Word files to generate the examination paper and the paper together with the solutions.

As an example for a paper containing 5 questions based on a syllabus with 5 topics in which there were 5 different questions on each topic to choose from both the Paper folder and the Solutions folder would contain 25 different word files names QuestionA.doc through to QuestionY.doc. However only 5 of those Word files would be required to produce the final paper and these would be specified from within the Excel spreadsheet. Thus one set of information which must form part of the Excel table deployed in the mailmerge is the names of the Word files needed. To simplify the specification of those files the Excel spreadsheet contained information about the directory structure being deployed and the drive and subfolder location in which the Paper folder and Solutions folder were held. Using this information once the questions had been selected it was possible to identify the names of the files which were necessary to put together either the paper or the paper and the solutions. The identification of those files was facilitated by the chosen naming convention of the files and folders which were linked to the alphabetic notation.

The paper was generated using an MS Word file named MasterPaper.doc which linked to the Excel spreadsheet through the Mastertable produced within the Analysis worksheet in Excel. This two row table contained a header row which held the generic names for the question files and also the names of the variables associated with those questions with the second row containing the corresponding values. A similar file Mastersolutions.doc was used to generate the paper and the solutions, this also linked to the same Excel table as illustrated in figure 1.

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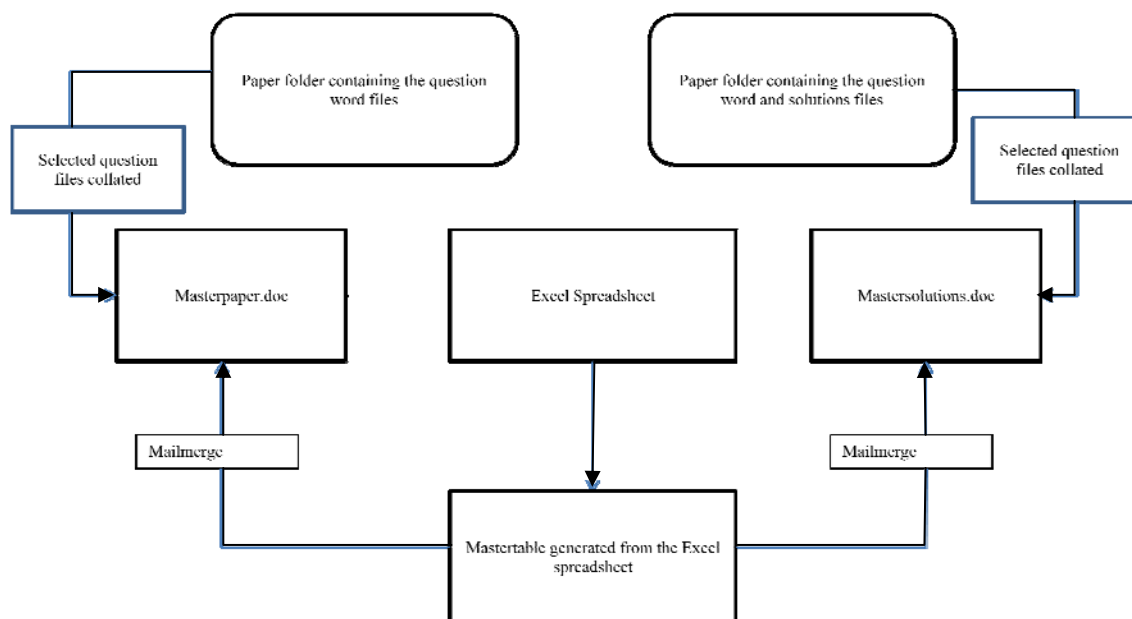


FIGURE 1  
SCHEMATIC ARRANGEMENT OF METHOD USED

The layout of the Masterpaper.doc file and Mastersolutions.doc file was similar giving instructions to combine the question files selected. Combining the question files was carried out using the MS Word facility Includetext. This is activated in MS Word simply by combining the keystrokes Control and F9. This throws up a pair of chevrons and within the chevrons it is necessary to type Includetext "filename.doc". This instruction inserts the file filename.doc within the merged Word document. Taking the merge filenames from the Excel Mastertable it was then possible to combine all the question files in a single document which formed in the case of Masterpaper.doc the examination paper and for Mastersolutions.doc the examination paper and the solutions to the actual questions. Allowance was made for the inclusion of a header file at the start of the document which contained the paper details, for example the subject and date, length and time of the examination and provision was also made for the inclusion of an Appendix file which would contain any supplementary information needed to be supplied with the examination paper, for example a formulae sheet.

Table 1 shows the layout of the Masterpaper.doc file and Mastersolutions.doc file both files link to the designated Excel spreadsheet and are supplied with mailmerge information from the Mastertable generated within the spreadsheet.

In Table 1 the information relating to the files to be combined occurs in the form of merge fields with the actual file names being supplied through the Mastertable from within MS Excel. In this way as the selection of questions changed the file names and associated variables also changed and different questions were inserted in their allocated positions within the examination paper.

Table 2 shows an example of part of the Mastertable generated within Ms Excel. From this table using mailmerge the examination paper and solutions are generated, in this case combining questions C,S,X, B and D. To allow more of this table to be listed the table has been printed as a 2 column table rather than the two rows which would appear in MS Excel. For this case the remainder of the Mastertable would contain the variables needed to form the questions and solutions for Questions C, S, Z, B and D respectively.

{includetext "<Headerp>"}	{includetext "<Headers>"}
{includetext "<Filep1>"}	{includetext "<Files1>"}
{includetext "<Filep2>"}	{includetext "<Files2>"}
{includetext "<Filep3>"}	{includetext "<Files3>"}
{includetext "<Filep4>"}	{includetext "<Files4>"}
{includetext "<Filep5>"}	{includetext "<Files5>"}
{includetext "<Appendixp>"}	{includetext "<Appendixs>"}
<b>Layout for MasterPaper.Doc</b>	<b>Layout for MasterSolutions.doc</b>

TABLE 1  
STRUCTURE OF MASTERPAPER AND MASTERSOLUTIONS FILES

Headerp	O:/Paper/Header.doc
Filep1	O:/Paper/QuestionC.doc
Filep2	O:/Paper/QuestionS.doc
Filep3	O:/Paper/QuestionX.doc
Filep4	O:/Paper/QuestionB.doc
Filep5	O:/Paper/QuestionD.doc
Appendixp	O:/Paper/Appendix.doc
Headers	O:/Solutions/Header.doc
Files1	O:/Solutions/QuestionC.doc
Files2	O:/Solutions/QuestionS.doc
Files3	O:/Solutions/QuestionX.doc
Files4	O:/Solutions/QuestionB.doc
Files5	O:/Solutions/QuestionD.doc
Appendixp	O:/Solutions/Appendix.doc

TABLE 2  
A SECTION OF THE MASTERTABLE FROM THE EXCEL SPREADSHEET

## PREPARING THE QUESTIONS

As already stated the questions have been prepared using MS Word. It was found easier to handle the questions if the text of the questions was in a table layout. Within each question the numerical data was added as a mergefield generated from within the Excel spreadsheet. Within the spreadsheet these variables were created as names and since the data for each question began with a different alphanumeric character there could be no confusion in allocating the variables to the correct question.

## THE LAYOUT OF THE EXCEL SPREADSHEET

As previously explained each question was linked to a particular worksheet within the Excel spreadsheet and a consistent method of performing the calculations was adopted. Cell A5 on a question worksheet, contained the topic name and cells A6 and B6 held the question letter and its corresponding number, this would be between 1 and 5 if the question was selected for inclusion within the paper or otherwise set to 6 in which case that question would be ignored. The column of cells from A7:B7 downwards held the names of the variables and their corresponding values with the last column containing information about the total number of variables associated with each question not including cell A5. This could either be added manually or calculated within the spreadsheet using the command Count. It was necessary to specify the total number of variables associated with each question so that when collating an examination paper using the Analysis worksheet it was possible to assess when all the information for a particular question had been added to the Mastertable so that the information for the next question could then be included.

The data for the questions was supplied using a random number generator which took the form  $\text{round}(\text{Rand}() * (\text{max} - \text{min}) + \text{min}, \text{ndp}) * \text{scf}$  where max, min, ndp and scf were previously set as the maximum value, minimum value, number of decimal places to be used and the scale factor to be applied to the variable. The scale factor was introduced to allow for the possibility that certain variables needed, for convenience, to be multiples of particular values, for example, angles may be restricted to 30°, 45° and 60° to achieve this max, min, ndp and scf would be set to 4, 2, 0 and 15 however in many situations the scale factor would be 1.

With the data for the questions generated using the random number formula the remaining variables were those needed to generate the solutions. These variables were listed immediately following the last data element in column A with the corresponding column B listing the formulaic link between the solution and the data variables. To execute the calculations in Excel all that was then necessary was to highlight the cells in columns A and B from A6 onwards (to include all non-blank cells) and create the cells as names this made the solution variable values automatically available within the individual worksheet as the formulae could then be executed. Unfortunately however it is not possible to use these values to execute the mailmerge since the number of decimal places to which the values are calculated would be excessive when merged in MS Word. Thus before forming the values to be supplied to the Mastertable a means of fixing the number of decimal places each variable should be output to was necessary. This was achieved by writing a module in Visual Basic which took each variable and established the number of decimal places it contained, for calculated values the convention of 3 decimal places was used. Fixing the number of decimal places was then achieved by copying the non-blank cells in columns A5 onwards to the first row in the worksheet and the cells in column B5 onwards to the third row of the worksheet. The second row of the worksheet was then formed by fixing the variables in the third row of the sheet using the Visual Basic module. The first two rows of the worksheet were then used to form a table in Excel with the naming convention that SheetA generated TableA etc... Having the values for each individual question associated with

a particular table gave the advantage that each question could be tested separately. Mailmerging QuestionA.doc from the Solutions folder with TableA from SheetA in the Excel spreadsheet would allow the question and solutions for Question A to be generated and similarly for all of the individual questions in the pool.

Table 3 shows part of QuestionC.doc showing the merge fields appearing in both the question and solutions rows and Table 4 shows the contents of the columns A6:B6 downwards. The question data was calculated from information relating to the data variables which is entered directly into the worksheet and the solution variables are calculated using the formulae appearing in the appropriate column B cell. It would be possible to prepare this information in an Ms Word file and simply paste it into Excel with the calculations and fixing of the data being automatically performed within Excel once the variables had been declared as names. Thus the method could be used by someone with only a limited command of Excel since all that is necessary would be to produce a Word table and the ability to cut and paste it into the Excel question worksheet.

(ii)	<p>A fuel pump delivers «CQ» litres/s of a paraffin fuel (<math>\rho = \text{«CDensity» kg/m}^3</math>, <math>\mu = \text{«cdynv» } \times 10^{-3} \text{ Pa.s}</math>), down a circular cross-section fuel-line with an internal diameter of «CDiameter» mm. which can be taken to be smooth. Determine the Reynolds' number of the flow and using this information deduce the state of the flow.</p> <p style="text-align: right;"><b>(6 marks)</b></p>
(ii)	<p>The flow rate = Area x velocity so that the velocity = Flow rate/pipe area The pipe cross-sectional area is «carea» m<sup>2</sup> so the velocity is «cvelocity» m/s</p> $\text{Re} = \frac{\rho DV}{\mu} = (\text{«CDensity»} \times \text{«CDiameter»} / 1000 \times \text{«cvelocity»}) / (\text{«cdynv»} \times 10^{-3}) = \text{«CRe»}$ <p>The flow is laminar when the Reynolds number is less than 2000 and turbulent for values greater than 2500 so the flow is «CTest».</p> <p style="text-align: right;"><b>(6 marks)</b></p>

TABLE 3  
PART OF THE MS WORD FILE TO PRODUCE THE SOLUTIONS FOR QUESTION C

Flow in Pipes	
C	1 (Question number)
CQ	<p>Question data calculated from random number generator:</p> <p>Round(Rand()*(max-min)+min),ndp)*scf</p>
Cdensity	
Cdynv	
Cdiameter	
Cpipelength	
Carea	= ATAN(1) * Cdiameter ^ 2 * 10 ^ -6
Cvelocity	= CQ * 10 ^ (-3) / Carea
CRe	= Cdensity * Cdiameter / 1000 * Cvelocity / Cdynv
CTest	= If Cre < 2500 Then Ctest = "laminar" else Ctest = "turbulent"
Cdynamicp	= 0.5 * Cdensity * Cvelocity ^ 2
Cdynamicpkpa	= Cdynamicp / 10^3
Cf	= If Ctest = "laminar" Then Cf = 16 / Cre else Cf = 0.3125 / Cre ^ 0.25
CK	= Cf * Cpipelength / Cdiameter * Cdynamicp
Ctotalnumber	15

TABLE 4  
CELLS A5:B21 OF SHEETC

When the mailmerge for this part of the question has been executed the output would appear as shown in Table 5 showing the question together with the solutions.

(ii)	<p>A fuel pump delivers 210 litres/s of a paraffin fuel (<math>\rho=780 \text{ kg/m}^3</math>, <math>\mu=1.140 \times 10^{-3} \text{ Pa.s}</math>), down a circular cross-section fuel-line with an internal diameter of 194.5 mm. which can be taken to be smooth. Determine the Reynolds' number of the flow and using this information deduce the state of the flow.</p> <p style="text-align: right;"><b>(6 marks)</b></p>
(ii)	<p>The flow rate = Area x velocity so that the velocity = Flow rate/pipe area The pipe cross-sectional area is 0.030 m<sup>2</sup> so the velocity is 7.068 m/s</p> $\text{Re} = \frac{\rho DV}{\mu} = (780 \times 194.5 / 1000 \times 7.068) / (1.140 \times 10^{-3}) = 940.588$ <p>The flow is laminar when the Reynolds number is less than 2000 and turbulent for values greater than 2500 so the flow is laminar.</p> <p style="text-align: right;"><b>(6 marks)</b></p>

TABLE 5  
A SAMPLE OF THE MERGED SOLUTION FILE

## FORMING THE COMPLETE EXAMINATION PAPER

Whilst it would be possible to collate an examination paper manually by selecting which questions were to be used and executing an individual mailmerge for each question and then slotting the questions together and typing in the individual question numbers a means of automating this process was sought. The solution arrived at was to add an additional worksheet to the Excel spreadsheet, the Analysis worksheet. This sheet picked up all the information in cells A5 on each of the individual question sheets and sorted out which of the questions related to which topic on the module syllabus. A random choice of a question on each topic was then made, again using a simple random number generator, and a second random number choice positioned the question within the paper. The filenames necessary to form the selected questions and both the data and solution variables for each question were then formed into a single two row table on the Analysis worksheet generating the Mastertable to be used for the mailmerge process.

With the Mastertable generated it was then a simply matter of executing the mailmerge with the MasterPaper.doc file to generate an almost complete examination paper or executing the mailmerge with the MasterSolutions.doc file to produce the paper and solutions. It is important however that before the mailmerge is executed the residual information left over from a previous examination paper collation is cleared. Following the mailmerge it would appear that both the Masterpaper.doc file and Master solutions.doc file contained the examination paper or paper and solutions. To restore the merge fields to these documents it is necessary to open and select the entire document (achieved by the keystrokes Ctrl+A) and then press the keys Shift+F9, the mailmerge with new Mastertable can now be correctly executed.

The only manual intervention necessary following mailmerge would be to ensure that for those questions complemented by figures or tables the figure and table numbering was correct as this would necessarily change dependent on the position of a particular question within the examination paper. To flag up that some manual editing is required the figure and table numbers used appeared in the question word files printed in red.

Table 6 gives an example of an examination paper selection made within the Analysis worksheet. In this case the examination paper has been composed of questions D, N, T, S and E. Within the worksheet the individual worksheets from which the question and solution data need to be collected are formed and also the total number of variables associated with each question together with the name of the question files which then form part of the Mastertable information. These selections would change automatically each time the Analysis sheet is accessed. Within the Analysis worksheet the syllabus topics on which the selected questions are based is also generated. Thus at a glance it is possible to identify what part of the syllabus is being examined.

## EXTENDING THE RANGE OF APPLICATION TO OTHER MODULES

Whilst the method described here has required the use of some advanced Excel features it can readily be adapted to other questions and syllabi and be used by others who have only a rudimentary knowledge of Excel. All that is necessary to change one question for another is to change the columns A5:B5 onwards in the worksheet for a particular question to the

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appropriate variables for the new question and to create these variables as names in Excel and to change the topics on the module syllabus and the directory location for the Paper and Solutions folders. Thus there is only a need for one generic Excel spreadsheet.

Selected Examination Paper Layout		Question Selection				
Ary5		Number of questions 5	Question position	Excel worksheet	Number of variables	Question file
1	Topic5	D	1	SheetD	21	QuestionD
2	Topic4	N	2	SheetN	22	QuestionN
3	Topic3	T	3	SheetT	15	QuestionT
4	Topic2	S	4	SheetS	17	QuestionS
5	Topic1	E	5	SheetE	14	QuestionE

**TABLE 6**  
**AN EXAMPLE OF THE PAPER SELECTION FROM THE ANALYSIS WORKSHEET**

The method can be used by anyone with an ability to create a table in MS Word which lists the variables associated with a question as shown in Table 4. For the data variables a maximum and minimum value must be specified and the number of decimal places and the scale factor to be used must be given. For the solution variables the names of the variables and the formulae linking those variables to the data variables must be specified. This Ms Word table can then be cut and pasted into the Excel spreadsheet and the solutions for the new question would be generated.

Whilst the method has been used here to produce examination papers it could equally be used to produce a variety of tutorial questions or to vary worked examples appearing in student notes.

The integration of Word and Excel as described in this paper is a powerful means of performing calculations giving scope to present students with a variety of exercises to encourage their development in numerate subjects with little effort required on the part of the academic.

## CONCLUSIONS

A method of setting examination papers and automatically generating the corresponding solutions has been described which is based on the use of MS Word and MS Excel integrated through the facility of mailmerge. The method allows an examination paper together with solutions to be generated automatically from a bank of previously developed questions freeing up valuable academic time at pressured times in the academic cycle. The method allows each question in a pool to be tested separately allowing scope for errors to be eliminated. The use of a random number generator to produce the question data and also to select the questions to be used and also their position within the examination paper ensures that no duplication of examination papers can occur. The ease with which students could be presented with sample papers prior to the examination where different numerical data could be used offers a means of encouraging students to learn and feedback on sample papers could be given encouraging students to improve their performance and learning techniques.

The Excel spreadsheet developed as part of this work can be adapted to a wide range of questions and topics with only minor changes necessary to change from one question to another or to change the module syllabus. This makes the method of potential value to others who could pick up its use easily needing very little knowledge of MS Excel. Central to the method is the consistent naming convention for folders, files and variables which enables named variables to be linked with the appropriate question and solutions.

The method could also be used to generate problem banks, tutorial questions or worked examples saving valuable academic time and offering scope to present students with a multitude of questions to work on with only a marginal outlay in academic time.

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