How to mark markers?

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***Abstract**: In an attempt to improve the way in which students presented their work in examinations a first year class was given a quiz that involved marking some previous solutions submitted by students in an exam. This exercise produced many interesting outcomes not the least being the question of, " how to mark markers?". This paper describes the quiz and the main outcomes but in particular addresses the question of assessing markers. This has also caused the authors to reflect on how they mark.*

Introduction

Experience in teaching first year students an introductory mechanics course has indicated that in recent years students present their work less well. This has resulted in very frustrated markers who find it extremely difficult and time consuming to see where a student has gone wrong because of poor presentation skills. It seems at times that students give no thought to how an examiner will comprehend their solutions. As a result it has been the practice to make use of an 'Examiners Revenge' described by Scott and Stone (2000). This involves marking, in front of the class, some student solutions to an exam question. The solutions have all identifying marks removed. In this way students see common errors and to some extent how poorly laid out solutions can be. Feedback on this process has shown that the students find it useful. However it has not been found that this has improved the presentation skills of students. As a result some thought has been given to developing other means of positively affecting the way students present their solutions.

As markers the authors have been aware that marking exam scripts requires not only a knowledge of the topic and the expected solution but also the ability to comprehend alternative solution strategies and methods. This leads to deeper insights of the topic and of student thought processes. As a result the possibility was considered of getting students to mark exam scripts as a means of improving presentation skills and gaining deeper insights of the topic.

There is a growing trend in education to use students and the work they produce as a learning resource. This encompasses a range of initiatives, from student self-assessment (Read, 2004) to peer assisted study sessions (Miller, 2004). A traditional application of this approach has a student marking their own work, or that of another student. We may all have memories of switching papers in primary school and marking our neighbour's maths test. In a more sophisticated form, this type of exercise can develop critical thinking and improve learning outcomes (Pinkerton, 2005). Exam papers are not usually marked in this manner; however, they have been used as a research resource to determine student misconceptions (Tang, 2000), and a strong relationship has been measured between a student's ability to develop a comprehensive model exam paper and their final mark in a course of study (Brink 2004). These studies did not allow the students themselves to analyse and learn from the exam scripts.

At the University of Western Australia a recent development has been the introduction of a Teaching Fellowship Scheme. 'The Teaching Fellowship Scheme, introduced in 2005 by the Teaching and Learning Committee, provides five $20,000 Fellowships across the University. The Scheme is designed to support the University's teaching and learning priorities as identified in the Operational Priorities Plan, and will be offered on an annual basis.' As a result in 2006 an application was made to the scheme to develop the idea of getting students to mark old exam solutions.

The Proposal

When the proposal was formulated it stated:

The aim of the proposal is to evaluate whether student solutions (both incorrect and correct) from past exam scripts can be used as an effective learning resource by current students.

Published (correct) solutions to past exam questions are commonly available to students, and students often assume that by simply reviewing these they will master the methods used to answer the questions. This is seldom the case. Mistakes are part of the learning process. In the proposed project students will be asked to analyse a group of solutions taken from past exam scripts and to report on the errors made in these solutions. The task will expose students to good and bad examples of problem solving, and in doing so deepen their understanding of the methods used to solve a particular problem. It will also strengthen their critical thinking as they identify erroneous methods and common mistakes. This will assist them to reflect more fully on their own work. It will also highlight important non-technical issues such as legibility, logical layout of a solution, and so forth.

A brief literature review has shown no previous studies that deal directly with the proposed project, although a number of authors have used exam scripts as a research resource. A more thorough review will be conducted to investigate how student generated learning resources have been used in the past and whether this have been successful in improving learning outcomes.

Students studying Engineering Dynamics (AMEC1401) in second semester will participate in this project. In this unit students learn different methods for analysing the dynamics (force and motion) of rigid bodies and mechanisms. Exam assessment involves the students applying these methods to solve a number of problems.

A range of solutions produced by students will be selected from past exam scripts and then collated to produce collections that comprise 2-3 different solutions to the same question. Some of these solutions may be correct and some incorrect. Incorrect solutions will be chosen to illustrate common student misconceptions and errors. Only discrete sections will be taken from past exam scripts, and any student identifiers and examiner comments will be removed. Scripts from repeating students will not be used.

As part of an assessment task each current student will be given a marking guide and asked to analyse and assess a particular collection of past solutions. They will also report on what errors have been made in the solutions. Distributing a number of different collections to the class will reduce the risk of students copying from each other and will encourage class discussion. The aim of this task is to expose students to a range of solutions methods, which have been correctly or incorrectly applied to a particular problem, thus encouraging them to think more deeply about these methods. It will also highlight common errors and misconceptions, and reinforce the importance of presenting a clear and logical written solution.

The student assessment of the solutions will be compared with the actual marks the solutions obtained in the exam. This will show whether students understand the weighting placed on each step of the solution process and allow feedback to be given in class. It is also planned to prepare an exam question that will reveal if the students have learned from the proposed assessment task. The question would have the possibility of the same errors as in the solutions the students have assessed. This should give some indication of the effectiveness of the proposed assessment task.

A mechanism will be designed to obtain meaningful feedback from the students about their perception of the assessment task and whether they found reviewing other students' work assisted in their understanding of the course material.

The application was successful and the implementation of the proposal was put in hand. However the detailed application of the ideas/suggestions presented in the proposal needed to be developed. The major issue was how was a marker to be marked?

Implementation

It was decided to use a quiz as the basis for the exercise as this would ensure the serious participation of students. Historically two quizzes were conducted during the semester and each counted for 10% of the unit. These quizzes involved the solution of an exam type problem. One of these quizzes was replaced by the marking exercise. As this was a new situation for the students it was decided to produce material based on an exam question and a solution that would indicate what was expected of students. To ensure that the students obtained the most benefit from the quiz the problem chosen for the example was from a different topic in the unit. The one chosen and the 'proof' solution prepared by the examiner is as follows:

Given, $y^2 = 7x^3 + 2x$ where x and y are in metres and y is always positive, what is the normal component of acceleration when,

$$x = 3\text{m};\ \frac{dx}{dt} = 4\,\text{m/s};\ \frac{d^2x}{dt^2} = 6\,\text{m/s}^2$$

WORKED SOLUTION

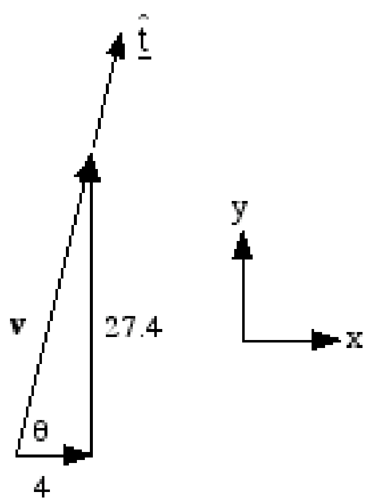
$$y^2 = 7x^3 + 2x \qquad \text{...} \quad (1)$$

Since we are given x = 3m we may find y from (1) remembering y is positive

$$y = \sqrt{7x^3 + 2x} = \sqrt{7x3^3 + 2x3} = \sqrt{195} = 13.96\,\text{m}$$

Now differentiate (1) with respect to time

$$2y\frac{dy}{dt} = 21x^2\frac{dx}{dt} + 2\frac{dx}{dt} \qquad \text{...} \quad (2)$$



and substituting values

$$2x13.96\frac{dy}{dt} = 21x3^2x4 + 2x4$$

Hence $\dfrac{dy}{dt} = \dfrac{764}{27.9} = 27.4\,\text{m/s}$

From velocity components the tangential direction can be found. Define x-y axes and draw diagram.

Thus $\tan\theta = \dfrac{27.4}{4}$

and $\theta = 81.7^o$

Now differentiate (2) with respect to time

$$2y\frac{d^2y}{dt^2}+2\frac{dy}{dt}\frac{dy}{dt}=21x^2\frac{d^2x}{dt^2}+42x\frac{dx}{dt}\frac{dx}{dt}+2\frac{d^2x}{dt^2}$$

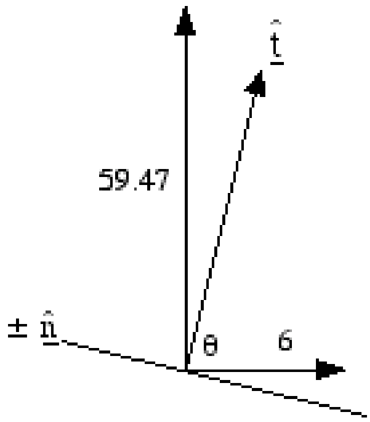
rearranging

$$\frac{d^2y}{dt^2}=\frac{21x^2\frac{d^2x}{dt^2}+42x\frac{dx}{dt}\frac{dx}{dt}+2\frac{d^2x}{dt^2}-2\frac{dy}{dt}\frac{dy}{dt}}{2y}$$

and substituting values

$$\frac{d^2y}{dt^2}=\frac{21x3^2x6+42x3x4^2+2x6-2x27.4^2}{2y}=59.47\,\text{m/s}^2$$

Knowing the tangential direction the normal direction is perpendicular to this. The positive n direction has to be such that a_n is positive.



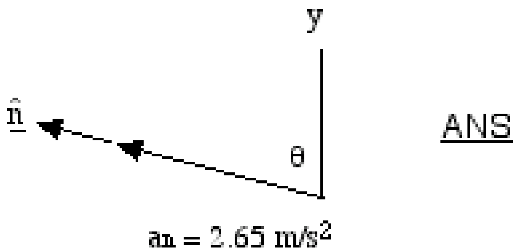
As a_n has to be positive

$$a_n=\left|\frac{d^2y}{dt^2}\mathbf{cos}\,\theta-\frac{d^2x}{dt^2}\mathbf{sin}\,\theta\right|$$

Substituting values

$$a_n=\left|59.47\,\mathbf{cos}\,81.7-6\,\mathbf{sin}\,81.7\right|=2.65\,\text{m/s}^2$$

Check sign of the calculation inside absolute brackets to find correct direction of n. Thus,



The marking scheme adopted by the original examiner was as follows.

2 marks: Determine y value

7 marks: Velocity analysis to determine $\dot{y}$, and t direction

5 marks: Determine $\ddot{y}$

6 marks: Determine n direction and the normal component of acceleration

It was then necessary to determine how students should be instructed so that they in turn could be marked. This was developed by considering a student solution with errors. The example chosen is shown in figure 1 with the marking scheme superposed and the use of E1, E2, etc. to indicate errors.

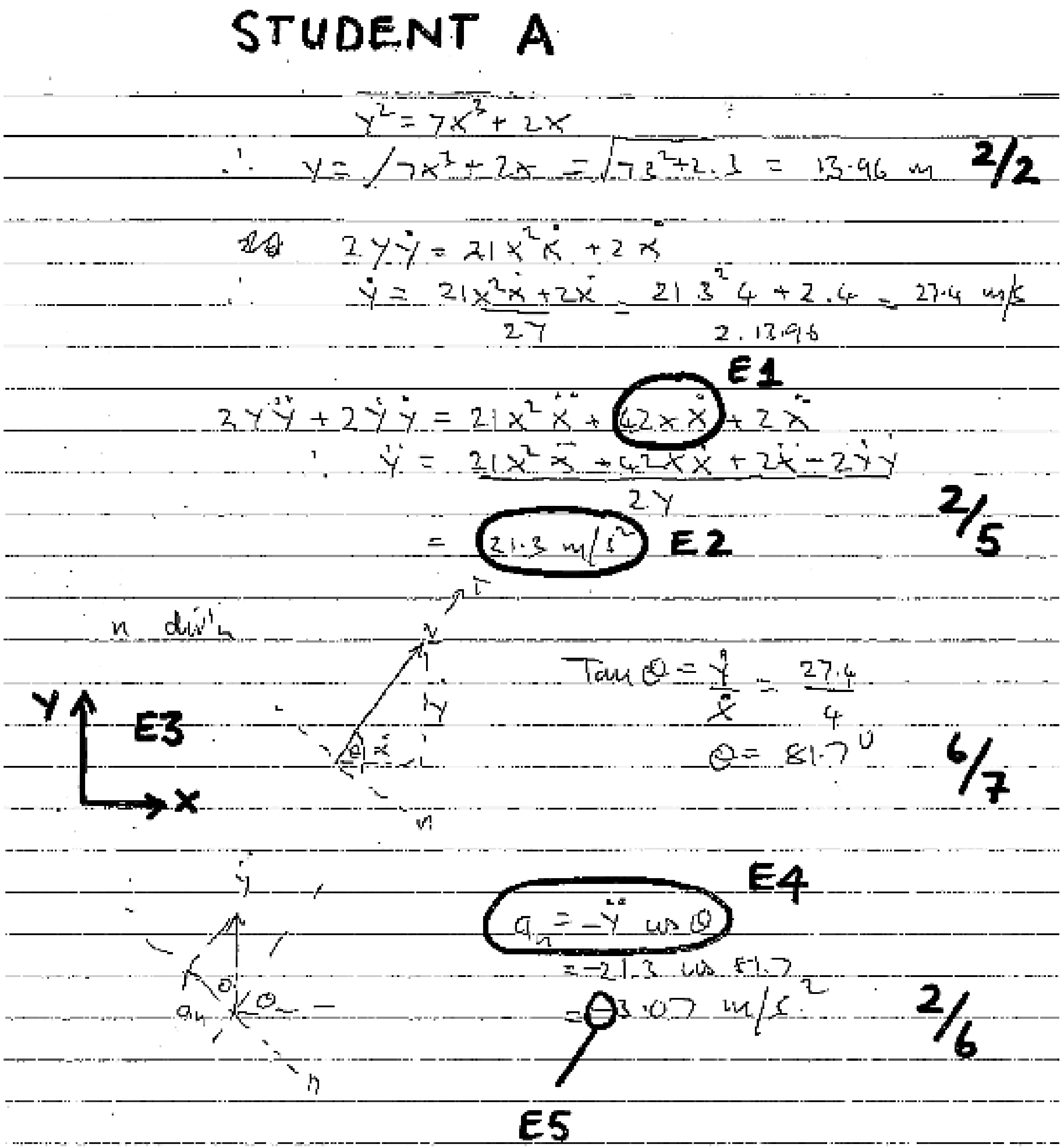


Figure 1: Typical solution with marking superposed

It was found useful to describe the errors and expect the student markers to do the same. The exercise of deducting marks depending on the level of error was also considered to be a useful required task. Thus the students were eventually required to give a final mark for the solution. The list of errors and the final mark produced for this example problem that was given to students a day before the quiz is shown in figure 2. While undertaking this development, the authors were forced to be reflect on how they had marked and with what consistency. It was going to be interesting to see if the student markers produced the same final mark.

E1: Did not differentiate $21x^2\dot{x}$ correctly
E2: Numerical error (wrong answer for equation given)
E3: x-y axes not defined
E4: Forgot to include x component of acceleration
E5: normal acceleration cannot be negative. Therefore direction shown for +n is not correct.
MARK: 12/20

Figure 2: List of errors with final mark

The final pre-quiz handout is shown below

GUIDE TO TEST 2

PLEASE USE BLUE OR RED PEN ONLY TO MARK SCRIPTS.

You will be given:

- A past exam question on planar kinematics.
- A worked solution to the question, including a general marking scheme for each section of the solution.
- Four student scripts for the question, each with a cover sheet.

For each student script provided you are required to use the worked solution to,

1. Indicate the first error (numerical or method) in the student's solution by circling the error and writing E1 next to it on the script. The first error usually means that the numbers in the solution will be wrong, however parts of the method may still be correct.
2. Indicate all subsequent errors in the solution by circling them and writing E2, E3 … etc. Note that diagrams and equations sometimes have more than one error.
3. On the cover sheet for the student write each reference number and briefly explain the error made.
4. Give the student solution a mark (out of 20).

   You may assign part marks for a section. For example, if a section of the solution is worth 5 marks, you may give the student a mark between 0/5 to 5/5 for that section.

An example question and 'marked' student script are attached.

The example is not on planar kinematics.

ASSESSMENT OF TEST 2

Your marking of the student scripts (10%)

Your mark for this part will be the sum of all the correctly identified errors, plus two marks if your final mark for a solution is within $\pm$2 of the examiner's mark or one mark if it is within $\pm$4 of the examiners mark.

The example given above was then attached with the addition of,

A general comment to students: This student script has no sentences explaining each step in the solution. For a simple question you may be able to do this without penalty. For more complicated problems marks can be lost for unclear reasoning or incomplete working. Do not be afraid of explaining each step of your solution.

It will be observed that in the time for the quiz (45 mins) the expectation was that the students would see the question and solution for the first time and then mark four scripts with varying numbers of errors. As this was a novel quiz for the students the lecturer gave the students the topic of the quiz (planar kinematics) one week before and worked through the example given above and the way it was marked one day before the quiz.

Results

The results of the test and the subsequent analysis of what the students did is the topic of a report by Hesterman (2007). The major outcomes are listed below:

- Students found it difficult to complete the task in the required time.
- Students expressed a new-found sympathy for staff who have to mark hundreds of solutions.
- Students said it was a useful experience but one which they would not wish to do again.
- The average of the students' mark for each solution marked was very close to that of the original marker.
- The time taken to mark the student markers was much greater than for a normal quiz.

One of the major objectives was the hope/expectation that students would appreciate the importance of the use of words, diagrams and a clear layout and that this would be evident in their next exam. How this was quantified is described by Hesterman (2007). It was possible to find previous exam scripts of many of the students for a unit with a similar content and compare their presentations before and after exposure to the quiz. It has proved difficult to demonstrate a significant improvement in exam results or layout as determined by numbers of words and diagrams used. However, the examiners were conscious that their effort in marking the final exam was significantly reduced.

Conclusions

The use of peer marking to enhance the presentation of student solutions in exams has been discussed and an implementation described. The whole exercise has caused the authors to reconsider how they mark and how to mark markers. The final outcomes of the project are yet to be fully analysed, but the first run resulted in the concern expressed in the introduction '*This has resulted in very frustrated markers who find it extremely difficult and time consuming to see where a student has gone wrong because of poor presentation skills.*' being alleviated.

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