MEI Insights 11: PD for Teachers New to Teaching Mechanics

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Introduction

Mathematics in Education and Industry (MEI) is an independent charity, committed to improving mathematics education. It works to support curriculum development and professional development for teachers, and to have a positive influence on national education policy. For a number of years MEI has offered professional development (PD) designed for teachers who have little or no experience of teaching the content of mechanics modules within AS/A level mathematics. In this article, the eleventh in the MEI Insights series, we outline our thoughts about what makes effective PD for teachers new to teaching mechanics, and in particular the challenges posed by the need to deepen specific subject knowledge and the pedagogical content knowledge required for mechanics to be taught effectively.

The Changing AS and A Levels in Mathematics

From September 2017 new AS/A levels in mathematics will be taught across the country. Among the changes is the requirement for all students to study mechanics and statistics alongside pure mathematics as part of both the AS and A level qualifications.

In light of these forthcoming changes we anticipate that the demand for PD in mechanics will increase as teachers will now be likely to be expected to teach mechanics having previously not done so. It is possible that many of these teachers will not have studied mechanics themselves. We describe some of the considerations we have taken into account when designing a PD course for teachers who are going to be new to teaching mechanics in 2017–19. These considerations are based on several years' experience in designing and presenting mechanics PD for the current A levels.

We organize the one-day course around the two key themes of motion and force. Our aim is to place the teachers in the shoes of their students by considering the subject knowledge with which students arrive, demonstrate how to build upon that starting point, and illustrate some of the distinctive features of mechanics teaching through the activities we use. We outline some of these features below.

Practical Activities

One of the key features of effective mechanics teaching is the use of practical activities and experiments as a teaching device. Throughout the course we use short practical activities and demonstrations in order to draw out key principles and show how to develop the theory on the basis of what is observed.

Activity 1: The opening activity of the course day involves the teachers being given a displacement–time graph shown in Figure 1 and being asked to, 'Walk out a journey which could be described by the graph.'

Fig. 1

A simple activity like this underlines the fact that mechanics is an essentially practical subject which attempts to describe the real world. Teaching motion by asking students to move seems to make sense!

After participants have 'walked out the journey' we go on to explore whether the motion suggested by participants

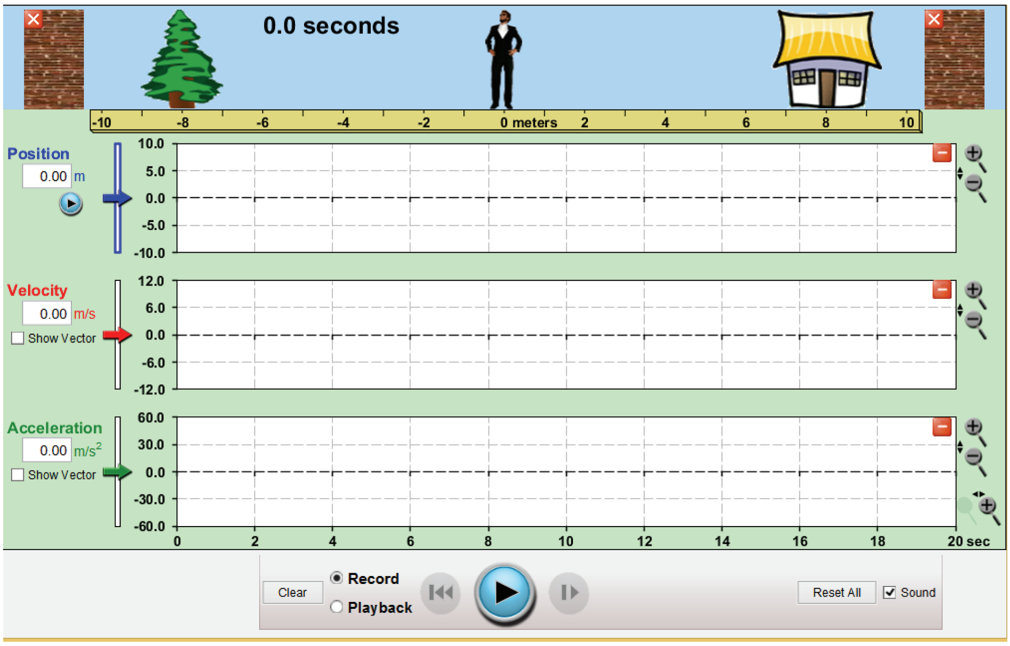


Fig. 2

does result in the required graph. This is done in one of two ways. Either we use another practical activity where a toy car tracked by a sensor is used to replicate the motion, or we use a simple applet such as 'The Moving Man' (see screenshot in Figure 2 and Note 1) to generate the original motion graph. These both link the motion of an object to a motion graph and provide immediate feedback on the suggestions that have been put forward by participants.

Practical activities motivate interest among students and through the use of simple experiments students are able to 'test' a particular idea in order to see if they were right. This provides a useful vehicle for exploring misconceptions, as well as providing a focal point for classroom discussion.

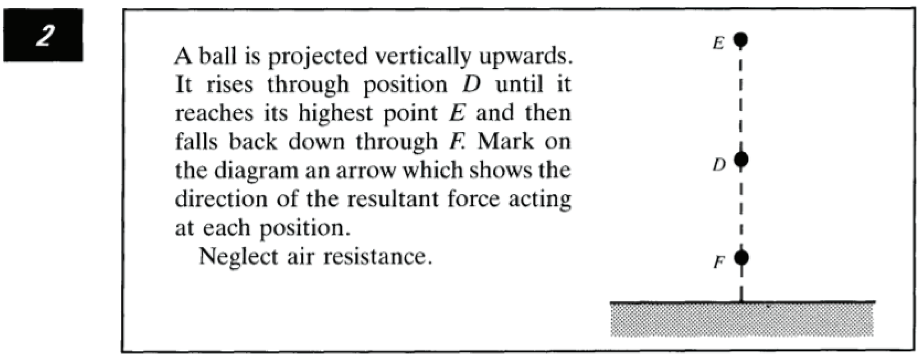
Misconceptions

Maybe more than any other area of A level Mathematics, mechanics exposes misconceptions commonly held by students. The seminal publication, 'Mechanics in Action' (Savage and Williams, CUP, 1990) devotes a whole chapter to misconceptions (Note 2). One such scenario we use on the course is to ask teachers to observe a ball being thrown vertically into the air before considering an extract from 'Mechanics in Action' (Fig. 3). The fact that a number of participants perceive that the direction of the resultant force is determined by the direction of motion illustrates how deeply held misconceptions can be.

Related to the previous section, practical activities can be useful in highlighting common misconceptions held by students, as this example shows:

Activity 2: During a session about connected particles we hold up a 'smooth' pulley with two equal masses at differing heights connected by a light inextensible string and ask participants to predict what their students believe would happen when the string is released.

Responses include suggestions that the mass closer to the floor will move downwards ('because it's already closer to the floor and therefore the pull of gravity is greater') and that the masses will move so as to be hanging at the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A ball is projected vertically upwards. It rises through position D until it reaches its highest point E and then falls back down through F. Mark on the diagram an arrow which shows the direction of the resultant force acting at each position.
Neglect air resistance.

Fig. 3

same height ('because that will make it fair and symmetry implies balance'). These sorts of responses provide a way of discussing what students really think is happening and exposing incorrect thinking.

One of the barriers teachers of mechanics have to overcome is the fact that our everyday language uses mechanics terminology in an informal sense. Students often have an understanding of concepts in A level mathematics such as weight, speeding up, slowing down, gravity, etc. which are drawn from them making sense of their own physical experiences. Drawing attention to this and equipping students with correct terminology while unpicking misconceptions is a skill developed by successful mechanics teachers.

Frequently, the work we do in highlighting and dealing with potential misconceptions is commented on by course participants. In answer to the question 'What were the most useful aspects of the event?' recent responses include:

'Having my own misconceptions dealt with.'
'Time to think like a student to address misconceptions.'
'How to deal with misconceptions.'
'Analysis of common misconceptions.'

These quotes illustrate the fact that misconceptions are an issue for some participants on the course. However, they also show that providing ideas for strategies for how student misconceptions can be exposed, discussed and corrected is valuable for these teachers.

Modelling

Mechanics is an attempt to model the real world using mathematics in order that we can then use the model to solve problems. The responses participants give in relation to Activity 2 (described above) naturally lead on to other areas of discussion, including that of developing a model. Use of the words *light*, *inextensible* and *smooth* routinely feature in A level mechanics questions and indicate some of the simplifying assumptions used when modelling a situation. Considering what would happen if these simplifying assumptions were not applied allows students to appreciate the importance of the simplifying assumptions within the model and the significance of such terms. Asking questions such as: What happens if the pulley is not 'smooth' and what effect, if any, would this have on the motion? How can we be sure that the tension in both parts of the string is the same? What happens if the string is not 'light'? Can you justify why it is acceptable to ignore air resistance? allows students to develop a deeper understanding of the modelling process.

One of the 'Overarching Themes' as described in the DfE subject content document (Note 3) is 'Mathematical Modelling' which has particular relevance to the study of mechanics. The modelling cycle is something both teachers and students need to be familiar with and we anticipate that there will be an increased focus on this compared to current specifications. Students therefore need to be comfortable with how to develop and use a mathematical model. Mechanics provides a useful vehicle for this.

Links Between Pure Mathematics and Mechanics

One of the most significant changes in the structure of the new A level mathematics is that it will be a linear course. Given that pure and applied topics will form a single course rather than separate modules, the links between different areas of mathematics can be exploited to help provide a richer, more cohesive experience for students. Obviously, this approach has always been an option for teachers. However, for those new to teaching mechanics one of the challenges is seeing how one area of mathematics relates to another. We therefore felt it worthwhile to give time on the course to thinking about some of the links between pure and mechanics topics and how this content could be taught. We use a couple of different activities to help illustrate this:

Activity 3: Figure 4 shows two questions which are produced on small cards and handed to individuals. People seated next to each other have different questions. Each teacher is instructed to work on the question they have been given. Once complete, they and the person next to them are asked to compare their questions and approaches.

A particle is travelling in a straight line with constant acceleration. After 1 second its velocity is $7\ ms^{-1}$ and after 2 seconds its velocity is $11\ ms^{-1}$. Find the initial speed and constant acceleration.	A line passes through the points A $(1, 7)$ and B $(2, 11)$. Find the equation of the line and state the gradient and y-intercept.

Fig. 4

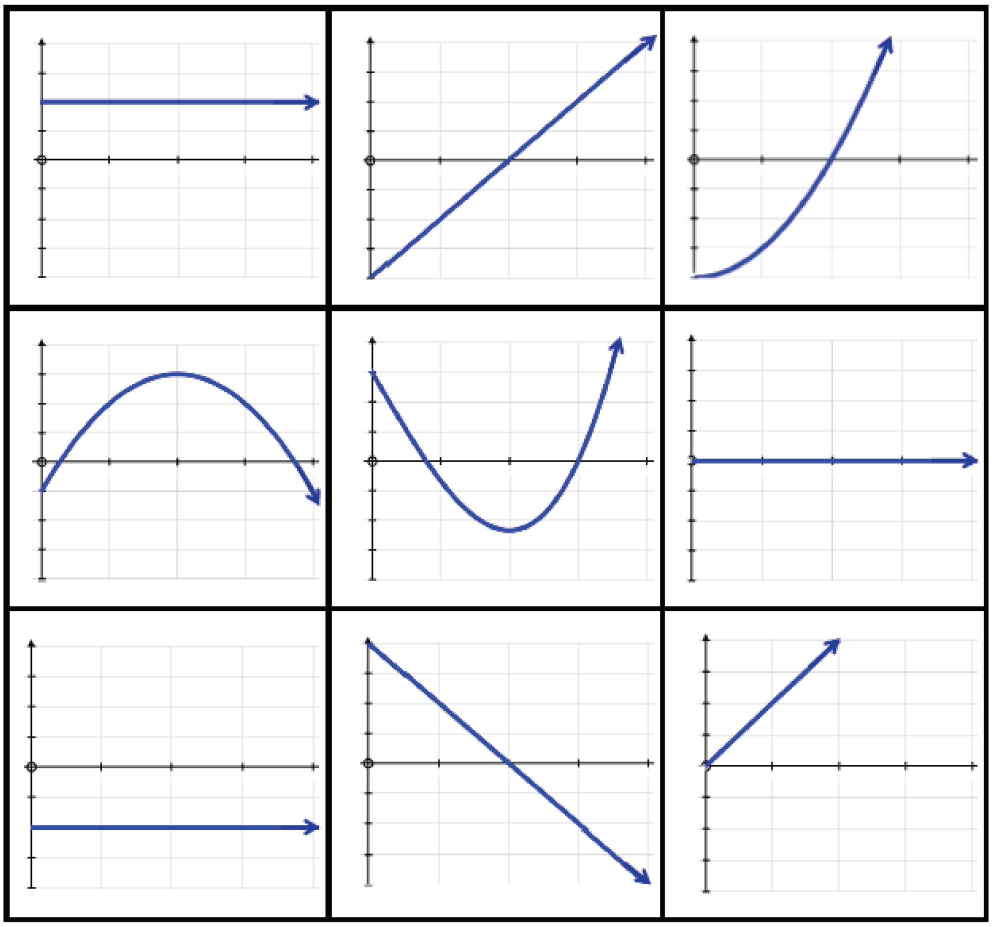

Fig. 5

Activity 4: This activity is a longer card-sorting activity. Designed to be used with students, it consists of nine cards showing pictures of graphs (Fig. 5) which have to be placed correctly on a 3 × 3 grid such that each column reads correctly. The labels on each row are given as either 'Displacement–time', 'Velocity–time' and 'Acceleration–time' or as 'function', 'gradient function' and 'gradient of the gradient function' (Fig. 6).

One of the key points teachers make after having worked on these two tasks is the observation that they switch between treating the task as a 'pure maths task' and as a 'mechanics task'. The implications for teaching are then drawn out in discussion. Students, too, will be expected to develop a set of mathematical problem-solving skills which can be applied in a number of different contexts and some students will find it easier to think in pure maths terms while others will thrive on applying the mathematics in a context.

Helping teachers see some of the connections between different areas of mathematics has proved valuable. Feedback from course participants in answer to the question includes comments such as the following:

'Resources presented in a very refreshing way; especially how calculus and physics are linked. Same with linking motion graphs with pure maths.'

'Making links between pure maths and its applications.'

'How we can bring in calculus and how it relates to mechanics.'

We feel that by linking less familiar mechanics content to more familiar pure content has helped to deepen the teachers' understanding. This more connected view of mathematics helps to build confidence in the participants' subject knowledge and illustrates some of the underpinning principles in both mechanics and pure topics.

So What Happens Next?

Clearly, preparing teachers to teach content they haven't taught before is a complex task and not something that can be achieved with a one-day course. We conclude the day by asking teachers to reflect on the main messages they will be taking away with them and encourage them to discuss with colleagues any questions that have been raised.

We therefore conclude this article by posing a few questions you might want to discuss in your department in order to review the mechanics teaching in the light of the forthcoming AS/A level changes:

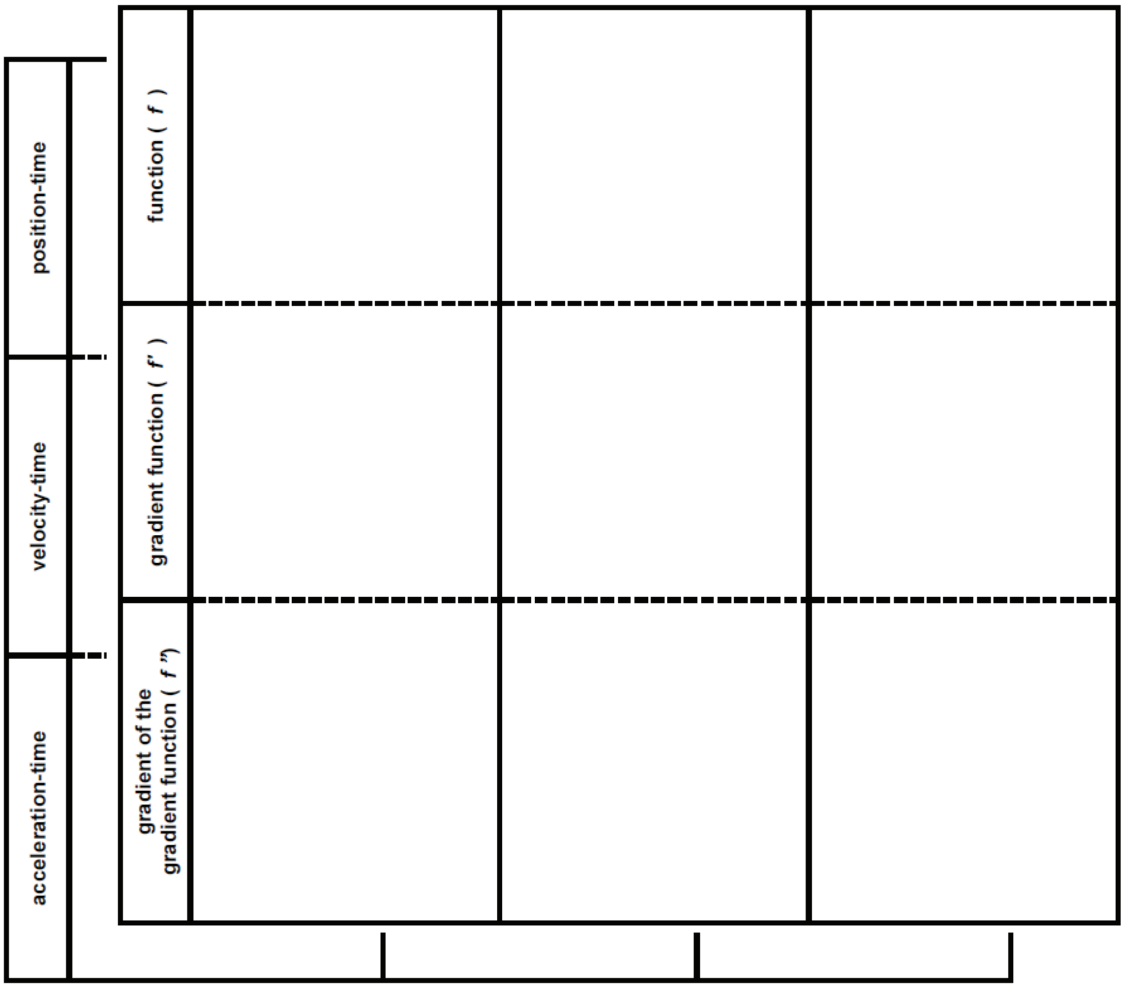

Fig. 6

Q: If we walked into a mechanics lesson in our department would we be able to tell it was a mechanics lesson rather than a pure mathematics lesson and why?

Q: Which of the emphases outlined above – practical activities, use of the modelling cycle, identification and use of student misconceptions – do we do well in our teaching of mechanics?

Q: What links between pure mathematics and mechanics do we feel are important to emphasize? What changes do we need to consider in order for these links to be made in a way that helps to create a more coherent picture of A level mathematics?

Q: Is every member of the A level teaching team ready for teaching the new specifications? Are there teachers new to teaching mechanics and, if so, what support is needed for them to become effective mechanics teachers?

Notes and References

1. PhET Interactive Simulations, accessed on 20/12/16, **https://phet.colorado.edu/en/simulation/legacy/moving-man.**

2. 'Mathematics AS and A level Content' 2014 DfE, pp 4,5, accessed 20/12/16 via **https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/516949/GCE_AS_and_A_level_subject_content_for_mathematics_with_appendices.pdf.**

3. Savage, M. and Williams, J. 1990 'Mechanics in Action', Ch. 4, pp. 44–57, Cambridge University Press, available as a free pdf download from the STEM Centre library following registration **www.stem.org.uk**.

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