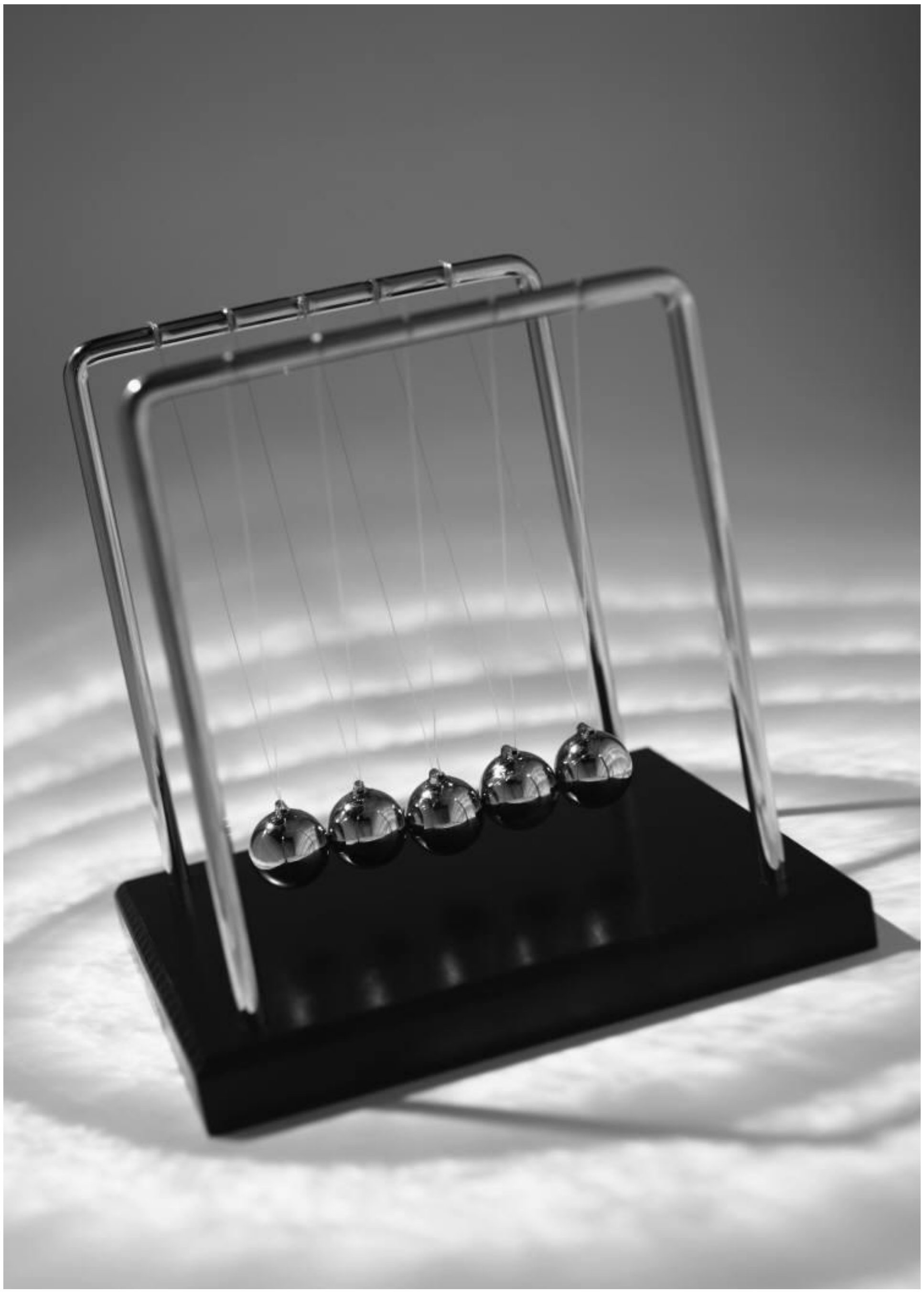
# Practical Mechanics Activities



Tricia Lunel
February2011

This booklet is intended as a list of suggested practical activities to accompany the MEI Mechanics 1 textbook, to encourage students to experience the laws they are learning about in a real context. They are the product of a Further Maths Knowledge Network I set up in 2010 funded by NCETM. My thanks go to all those who helped to contribute and try out the ideas and I hope they bring much enjoyment to you and your students!

| Activity | Description |
|---|---|
| 1 | Distance / displacement |
| 2 | Scalars and vectors |
| 3 | Reference points |
| 4 | Estimating measures |
| 5 | Displacement / time and velocity / time graphs |
| 6 | SUVAT equations |
| 7 | Memorising the SUVAT equations |
| 8 | Balancing the metre ruler |
| 9 | Playing in the lift |
| 10 | Design a system which is least ideal |
| 11 | Parachute designs |
| 12 | Connecting students |
| 13 | Masses on tables with pulleys |
| 14 | Vector chess |
| 15 | Right handed vector sets |
| 16 | Throwing things! |
| 17 | Stomp rockets |
| 18 | Forces on a slope |
| 19 | Strings and weight |

## Chapter 1 – Motion

1. Distance / displacement

Go for a walk around the school! Set the threshold of the classroom as your reference point. Go to the Hall, say, counting steps. Compare the number of steps you've taken – discuss the need for standardized units of measurement. Note that distance and displacement are equal at this point. Retrace your steps – at intervals say out loud your distance travelled and your displacement relative to the classroom door. Note when you are back that just because your displacement is zero does not mean that you have not travelled any distance.

2. Scalars and vectors

Put a metre ruler on the floor. Set this as your reference line and decide which way is positive. Show the students positive displacement, negative displacement, positive velocity, negative velocity. Contrast with distance and speed which don't need direction.

Let the students have a go. When they are fluent, give them a card to demonstrate, say, negative displacement but positive velocity (see Appendix 1 for some suggestions). Get the others to say what is being demonstrated.

When they are really good you can bring in acceleration and deceleration too. Or you can shift the game into the vertical plane and show motion with their hand instead with a reference line on the board or wall.

3. Reference points

Hold an item in your hand. What is its position relative to your hand, the floor, the playground downstairs? Throw it up – what height does it reach relative to the reference point or some new reference like the ceiling? Once it hits the floor, what is its new displacement? What if you introduced another item, this time dropping from the ceiling – how does that fit in?

You could ask students to draw the displacement / time or distance time graph to go with this motion too.

4. Estimating measures

Ask the students to hold their hands apart one metre – measure it and see how well they estimate. You can do the same with the height of the building, how far it is across the playground, the length of a calculator…It's good to have a feel for measurements so you can see when your answers are a little crazy!

Now try with mass – estimate the mass of different items in the classroom and then check with scales. How about the mass of a car (internet is good for checking this!) or a lorry?

It will not be long before they are driving. See if they can spot speeding motorists outside school. If you are travelling somewhere together, stopping distances and how far they look like would be a useful conversation. Make sure you include talk about reaction times and how that will change if you've been drinking or have your mates in the car with you. You could also talk now about why it's 30mph in town…

On the same topic, throw a ball across the playground – using a stopwatch, see if you can throw it at say $3ms^{-1}$. What's the fastest / slowest you can throw it? How about speeds for a car – covert 30mph to $ms^{-1}$. Do the same for 70mph so they have a feel for SI units of velocity. Ask them to find out the maximum acceleration for different types of car in SI units.

## 5. Displacement / time and velocity / time graphs

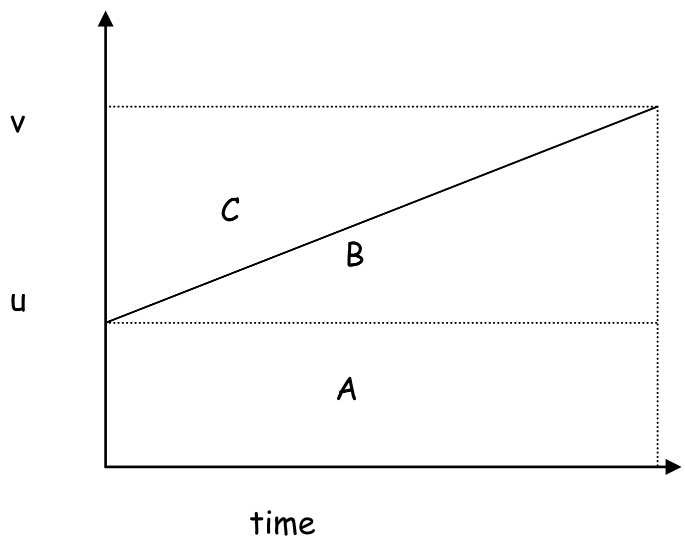
Draw the axes for the two graphs above each other. Get two students at the board; one drawing the displacement graph, the other drawing the velocity one. Put one of them in charge – they decide what happens next. As one draws, the other has to interpret how that affects their graph and draw appropriately. As they get better at this, get a third student to give instructions – you can move from no acceleration to constant acceleration to variable acceleration to make it more stretching, and add the acceleration / time graph as well.

Repeat for distance / time and speed / time graphs.

Chapter 2 – Modelling Using Constant Acceleration

6. SUVAT Equations

See if your students can come up with the three s= equations just by considering the area under the velocity time graph below.




They come from A+B as a rectangle plus a triangle or A+B as a trapezium or the rectangle including C then subtract that C part.

The last two come from the gradient of the graph being the acceleration and the last from the difference of two squared velocities expressed as (v+u)(v-u).

7. Memorizing SUVATs

See how fast they can write the 5 equations on the board either on their own or as teams in a relay. Or two students in a play off at the board, fastest stays on to challenge the next, champion gets a prize. Or last one to arrive has to say the equations in fewer than 45 seconds or they buy the biscuits next lesson…. The choice is yours! These are the only equations they have to learn for M1 so they need them learnt properly.

Chapter 3 - Forces and Newton's laws of motion

8. Balancing the metre ruler

Get a student to balance a metre ruler on two fingers at the ends of the ruler. Ask the class to predict what will happen when they bring their two fingers together and write down their responses on the board. Ask the student to do this quickly – usually the ruler tips and falls on the floor. Repeat more slowly – with good control the ruler should balance better but often ends up on the floor again. Discuss the forces involved.

9. Playing in the lift

This may have to be half term homework if you don't have a lift at school. Stand in the lift without it moving – you just feel normal. Press the up button and notice the sensation as the lift accelerates – do you feel heavier or lighter? Just before the lift stops, while it is decelerating, notice if you feel lighter or heavier again. Repeat on the way down. Why do you feel like that – can you explain it with diagrams, considering acceleration and reaction forces? Not that I ever said this, try jumping just as the lift goes up or just as it goes down – which one is more difficult and why? Even more fun done as a group activity…Please don't break the lift!

If you are lucky enough to have a lift at school you could try the same experiments standing on scales so you can check whether you are heavier or lighter as the lift starts and stops. You could also carry a bag attached to a spring balance and note the readings as you accelerate and decelerate.

Why is everything "normal" when you are in the middle of the ride?

10. Design the system which is least "ideal"

We spend a lot of time in mechanics pretending that we have negligible mass, inextensible strings, smooth surfaces, uniform bodies…See if you can design a mechanics display which counters as many of these as you can. You could use an elastic string to drag a lumpy object with most of its mass at one side up a slope covered in sandpaper…prizes for the most modeling simplifications countered!

11. Parachute designs

Give students newspaper, string, selotape and plastic carrier bags. Ask them to design a parachute which will stay in the air as long as possible (i.e. maximizing use of air resistance) carrying a load. If each group has the same load (breakfast bars are handy and can be eaten at the end) the task is made fairer. While they make their parachute you can discuss the pros and cons of their designs and look at real parachutes using the computer. The parachutes can be released at the same time to test how effective they are – a group release from a set of windows at the same height or from a mezzanine floor makes for easy comparison.

## Chapter 4 Newton's second law applied to connected objects

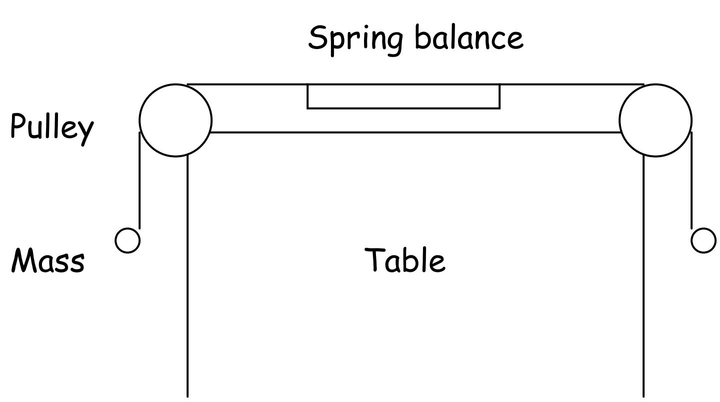
### 12. Connecting students

You need your students to agree to be gentle before you start this! Pair them up with someone a similar size and ask them to hold hands – the first one pulls the second. How much force do you feel in your arm if the second one complies? What happens to the force if you try to accelerate the second person? In a large space, what happens when the connection suddenly breaks? Now swap – the second one is pulling now and the first is going to resist (without accidents occurring!). Repeat the two activities – what happens to the forces?

I'm sure they will have tried this one in PE….Sit two students back to back on the floor with their arms folded. They have to stand up using each other to lean against. Talk about the forces involved. Then pair up two students who are different in size to repeat the exercise – what do they need to do differently?

### 13. Masses on tables with pulleys

Many students don't know how a pulley works – it's worth having a play with string and masses to see what happens when you have the masses on either side of the pulley balanced or unbalanced. You can also set up a system where you have two masses dangling on either side of a table connected by a string going over two pulleys. Put a spring balance in the middle of the table – what will it read? Why?



## Chapter 5 Vectors

### 14. Vector chess

If your pupils don't know how to play chess, this is a good time to learn! Set up the chess board for a game and decide on your reference point – White's left hand corner might be a good start – and which way is positive. You might start with a pawn moving 2j, or perhaps a knight moving -i + 2j. Black of course will have lots of negative vectors for his moves. Each move has to be said aloud and checked by the other player.

If this is too easy, move the reference point to the centre of the board, or get White alternately to make Black's moves for him and vice versa… This would be a nice homework in pairs.

### 15. Right-handed vector sets

For those who struggle to visualize 3d coordinates, three pea sticks stuck at mutual right angles into a piece of blutac might be helpful. A discussion about where (2, 4, 7) is in this 3d space might help clear up misunderstandings.

Or you could use your thumb, forefinger and second finger of your right hand to demonstrate a right-handed vector set. If positive x and y directions are as they normally are on a graph, which way is the positive z direction? Lots of 3d objects have a right angled set (tables, chairs, corners of textbooks…Decide which axis must be which to form a right handed set.

## Chapter 6 Projectiles

### 16. Throwing things!

Start with some ordinary small balls – tennis balls are ideal. In pairs, get them to throw and catch, observing the path of the ball. Get the students to decide that the path is a parabola (like the $-x^2$ graphs from GCSE) and that it is symmetrical when the students throw from the same height.

Then ask them to stand closer together and make the ball go higher as they throw it. What do you alter to achieve that effect? Then move further apart and throw the ball to make as horizontal a path as you can – what did you alter? Discuss angle of trajectory and horizontal and vertical velocity components and relate these to practical experience.

Variations on this can include throwing the ball from a height to someone below – here the trajectory is part of the parabola. You can alter how much of a parabola by altering the velocity components again.

If you have some air balls (plastic shell balls with holes to increase air resistance) these are good for demonstrating how air resistance slows the ball down and the ball lands more quickly. You could have a competition to see how far you can throw one…

### 17. Stomp Rockets

Stomp rockets cost about £10. By "stomping" on the bellows you launch a foam rocket into the air – an ideal projectile for use in the playground. The angle of launch and the force used are variables to alter the flight pattern of the rocket.

You could start by getting students to hit a target from a fixed starting position so they realize the link between angle of projection and range and the force used and range of the rocket.

Now, for those who have access to a video camera you can do some flight path analysis. At http://www.cabrillo.edu/~dbrown/tracker/ or by Googling Douglas Brown, tracker, Cabrillo you can download software to turn the video of your rocket launch into an analysis to find the equation of motion for your stomp rocket flight. From there you could check whether modeling assumptions for projectile motion are good, what the angle of projection / initial horizontal and vertical components of velocity are, what the predicted and actual ranges are….. You can get lots of good maths from this fun outdoor activity.

Chapter 7 Forces and motion in two dimensions

18. Forces on a slope

It is helpful to have a piece of equipment to represent a slope for many of the problems in this chapter. Perhaps your D&T department could make one up, especially if you can alter the angle of the slope. It's even better if you can also alter the surface of the slope for different coefficients of friction. A roll of cling film or sand paper could be used to give a good demonstration here. Alternatively a table propped up on books is just as good. Textbooks are often useful as the mass involved.

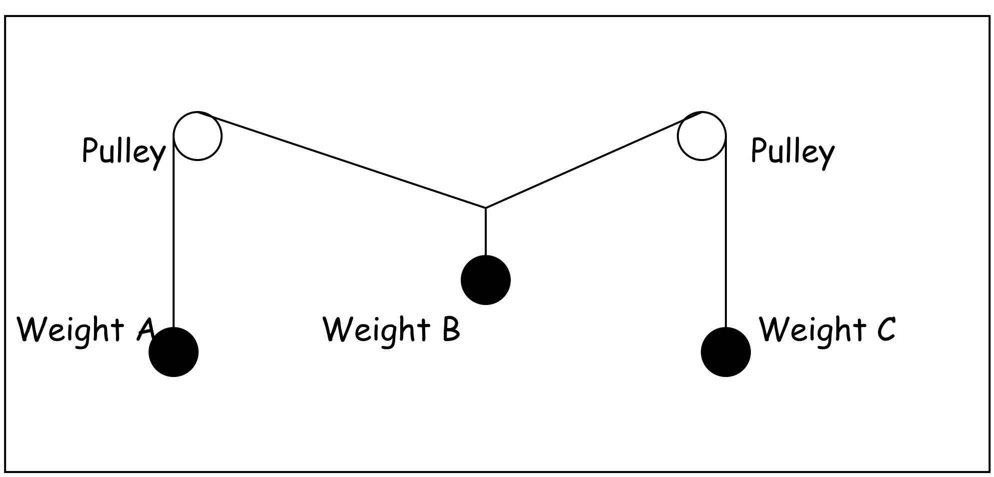
You can represent the forces involved using pea sticks again or coloured kebab sticks and attach them to your apparatus with blutac. Each force can be split into two components parallel and perpendicular to the slope by using the pea stick as the resultant force.

So many of the problems in this chapter can be physically modeled – getting the students to design their mock-up of a problem can be the key to them understanding how to solve force problems in two dimensions.

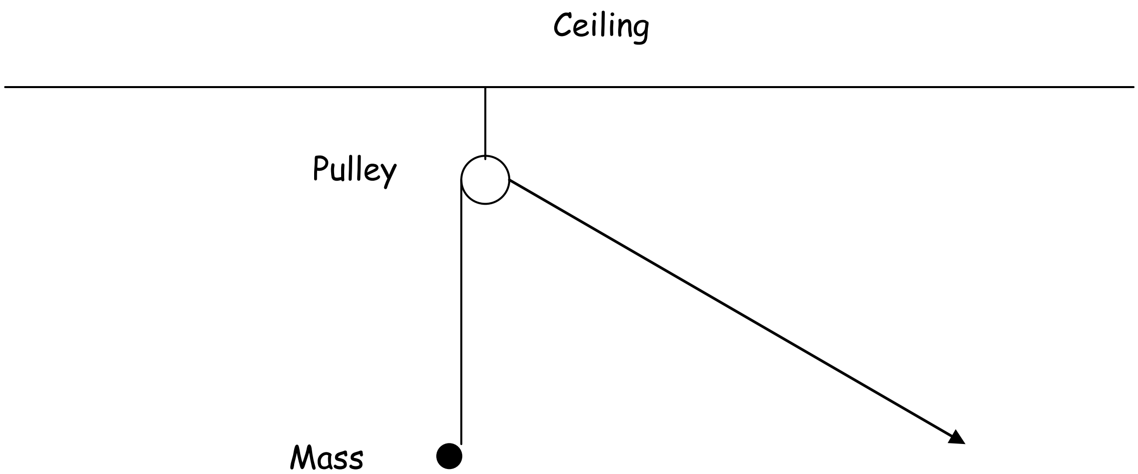
19. Strings and weights

Another useful piece of equipment is a board with two pulleys attached a distance apart. This can be set up with strings and weights to model some of the more usual problems of this sort.

Mounted vertically, the angles of the strings can be measured to show Lami's theorem.



Mounted between two tables a distance apart, you can model pulleys hanging from a ceiling.



Appendix 1 – Scalars and vectors cards

| | |
|---|---|
| Show me a distance travelled of 10 paces. Then show me a different one. And then a third ….. | Show me a displacement of -3 paces. Show me another way of ending at that same end displacement. And another… |
| Show me positive displacement with positive velocity. Now make the positive velocity slower…. | Show me negative displacement with positive velocity. Now increase the positive velocity…. |
| Show me negative displacement and negative velocity. Make the magnitude of the velocity lower…. | Show me positive displacement and negative velocity. Gradually increase the velocity until it is positive…. |
| Show me positive displacement and velocity with negative acceleration. Shout "Now" when the velocity starts to be negative….. | Show me negative displacement and velocity with positive acceleration. Shout "Now" when the displacement is no longer negative…. |