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Incorporating simple practicals into your mechanics lessons

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Session description

Mechanics helps us model the real world but it can be difficult to incorporate practical activities into our mechanics lessons. This session will offer practical demonstrations which are easy to set up and use, and which help expose misconceptions and deepen understanding of mechanics principles.

Aimed at teachers who are new to teaching mechanics or those who want to incorporate practical activities and demonstrations into their lessons.

Barriers to using practicals

- How frequently do you carry out practicals in your mechanics lessons?
- What prevents you from carrying out practicals?
- What barriers do you face when you consider doing a practical?

Common barriers

- Time
- Lack of / access to equipment
- Cost
- Accuracy of measurements
- Complexity of scenarios
- The practical not working
- Fear?
- …

Pulleys

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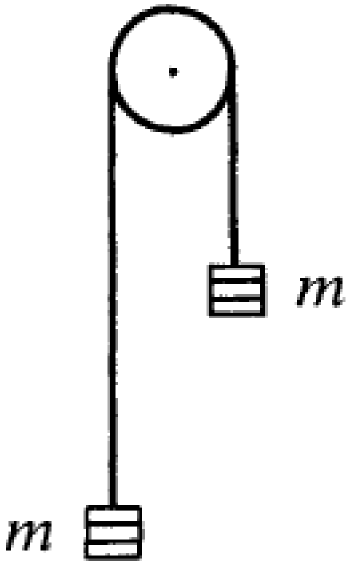
Equilibrium?



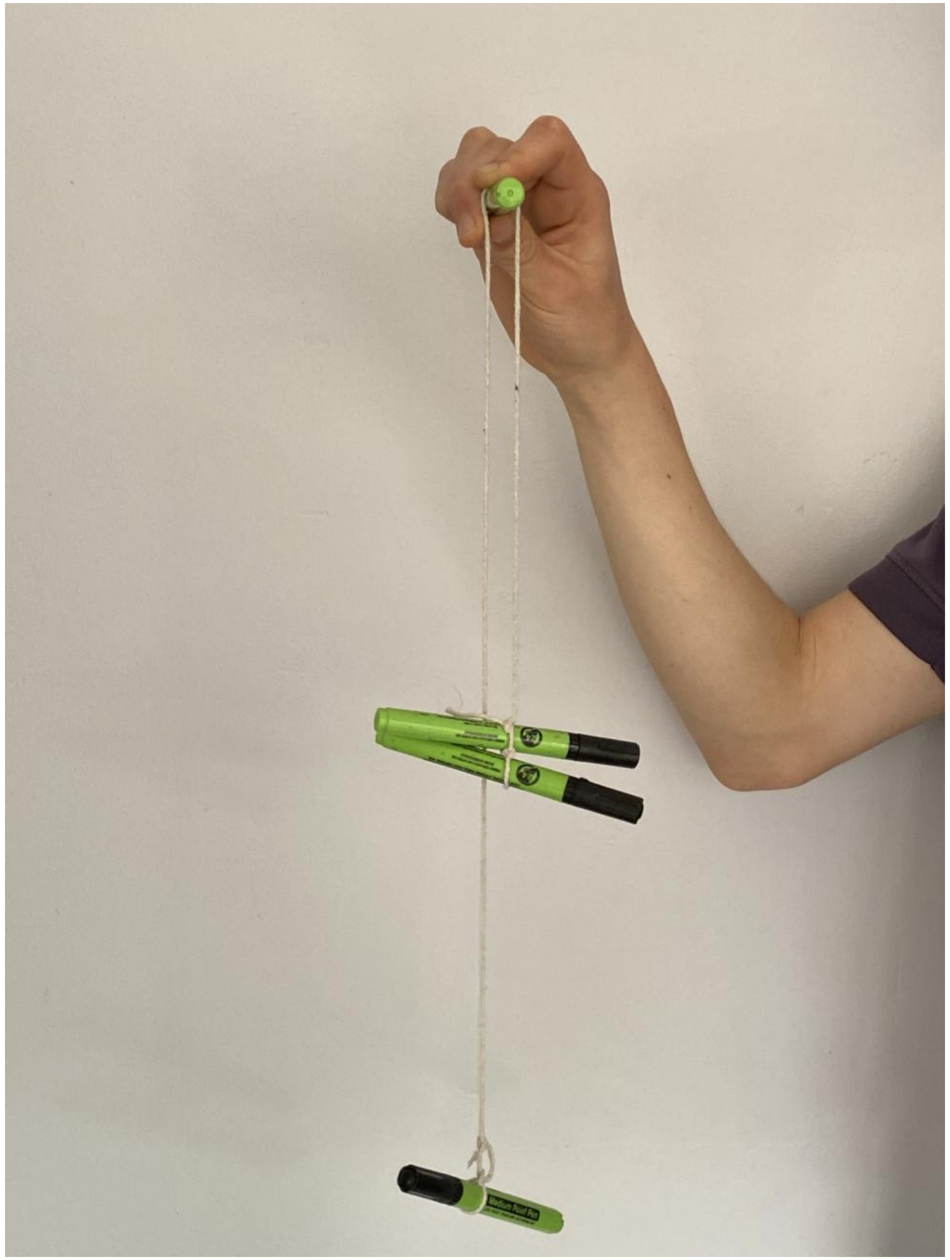
- What might students think will happen?
- What assumptions are being made?
- What will happen if the system is set to be moving?

Image taken from Savage & Williams (1990), Mechanics in Action, CUP

Observations

Practical activity	What are the key learning points? e.g. What misconception might be addressed?	How might my students respond? What might they notice?

Make-your-own-pulley



Exam preparation?

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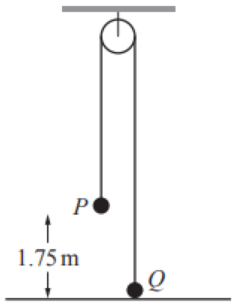


Particles P and Q, of masses 4 kg and 6 kg respectively, are attached to the ends of a light inextensible string. The string passes over a smooth fixed pulley. The system is in equilibrium with P hanging 1.75 m above a horizontal plane and Q resting on the plane. Both parts of the string below the pulley are vertical (see diagram).

(a) Find the magnitude of the normal reaction force acting on Q. **[1]**

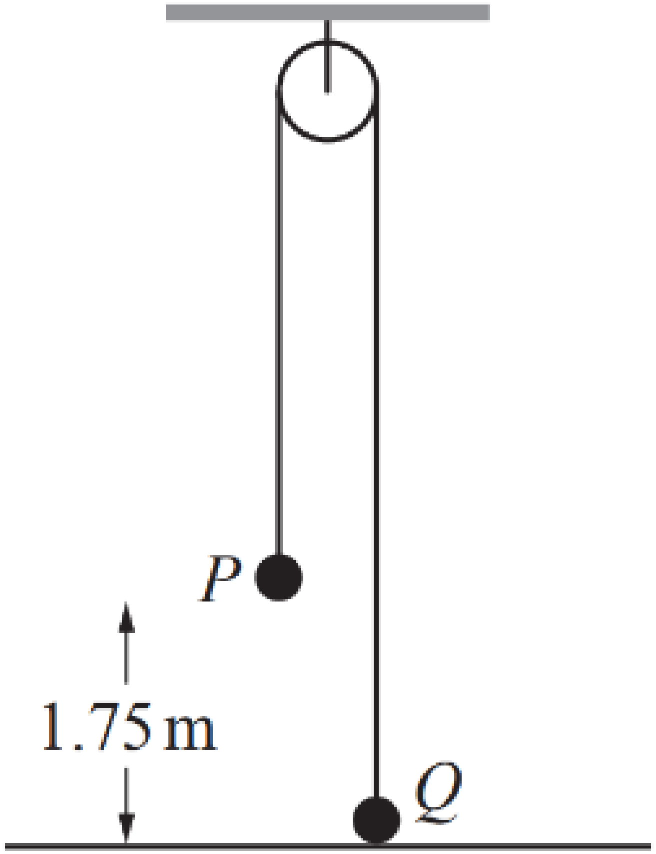
The mass of P is doubled, and the system is released from rest. You may assume that in the subsequent motion Q does not reach the pulley.

(b) Determine the magnitude of the force exerted on the pulley by the string before P strikes the plane. **[5]**

(c) Determine the total distance travelled by Q between the instant when the system is released and the instant when Q first comes momentarily to rest. **[4]**

When this motion is observed in practice, it is found that the total distance travelled by Q between the instant when the system is released and the instant when Q first comes momentarily to rest is less than the answer calculated in part **(c)**.

(d) State **one** factor that could account for this difference. **[1]**



Friction

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Friction

- With the table flat, what forces are acting on the board rubber?

- If we lift the table just enough so that the object doesn't move,

what forces will be at play?

Have the forces changed at all?

- What questions might you want

students to ask at this point?

On the point of slipping – practical activity

Fill out the grid in your handout, thinking about the key learning points, misconceptions and observations.

- Consider the table flat.
- Consider the table lifted at an angle so the rubber doesn't move.
- Gradually incline the table so that the board rubber starts to slip.
- Turn object over and repeat inclining of surface. Do you think it will slip at a bigger or smaller angle? What explanation could your students give for this?

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Increasing the mass

- What happens when the mass of the object is increased?

- Does this increased mass impact the point of slipping? What will students think will happen?

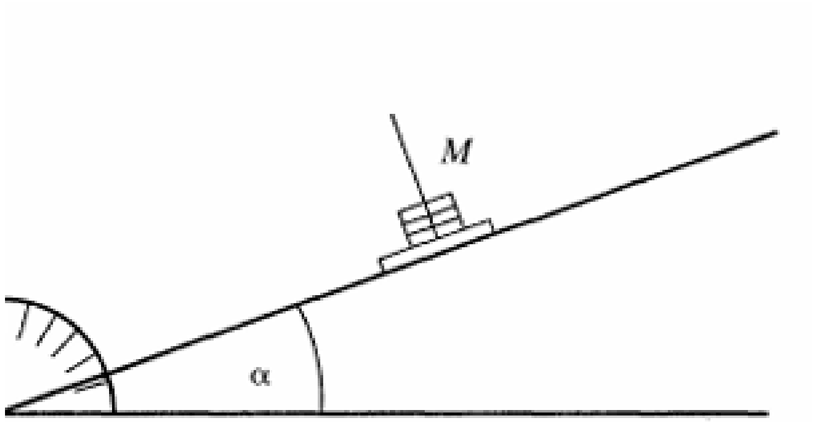


Image taken from Savage & Williams (1990), Mechanics in Action, CUP

Exam question 1

A rough plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$

A brick P of mass m is placed on the plane.

The coefficient of friction between P and the plane is μ

Brick P is in equilibrium and on the point of sliding down the plane.

Brick P is modelled as a particle.

Using the model,

(a) find, in terms of m and g, the magnitude of the normal reaction of the plane on brick P **(2)**

(b) show that $\mu = \frac{3}{4}$ **(4)**

For parts (c) and (d), you are not required to do any further calculations.

Brick P is now removed from the plane and a much heavier brick Q is placed on the plane.

The coefficient of friction between Q and the plane is also $\frac{3}{4}$

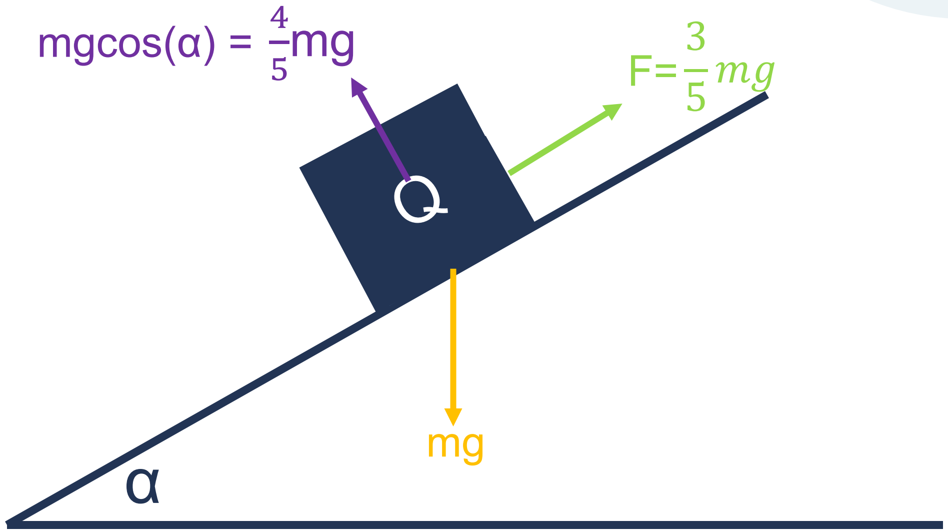
(c) Explain briefly why brick Q will remain at rest on the plane. **(1)**

Brick Q is now projected with speed $0.5\,\text{m s}^{-1}$ down a line of greatest slope of the plane.

Brick Q is modelled as a particle.

Using the model,

(d) describe the motion of brick Q, giving a reason for your answer. **(2)**



What misconceptions do you think students made in answering this question?

How might our previous experiment have helped the understanding of this?

Edexcel, GCE Mathematics, Paper 9MA0/03, Oct 2020, Q1.

The first part was well done by the majority of candidates who resolved perpendicular to the plane to give a correct expression for the normal reaction. In part (b), most resolved parallel to the plane and then used $F=\mu R$ to derive the given answer for μ. There was occasional sin/cos confusion seen in the relevant equations but this was fairly rare. Horizontal resolution was an alternative valid approach. The third part was found to be much more challenging. Those who realised that m cancels out of the resolution equation parallel to the plane achieved the one mark available very easily but such instances were rare. Most attempted to explain the situation in words. A common response was that as m increases, R increases and so F increases to a larger value than before, meaning that the brick will remain in equilibrium, with no consideration of the component of weight acting down the plane. It was essential to the argument that **either** the friction and the force pulling it down the plane increase by the same amount **or** that the friction and weight component increase in the same proportion; just stating that both increase was not deemed sufficient. In part (d), few were able to relate their earlier work to help them answer this question and the majority of candidates failed to realise that the brick would continue to move down the plane with a constant speed since there would be no resultant force. Most thought it would move with acceleration because of weight/gravity or with deceleration because of friction. A few just stated it would move slowly down the plane.

"the third part was found to be much more challenging…a common response was that as m *increases, R increases and so F increases to a larger value than before,… with no consideration of the component of weight acting down the plane."*

Edexcel, GCE Mathematics, Paper 9MA0/03, Oct 2020, Q1.

For the latest examiners' reports, please also refer to the Edexcel website.

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Exam question 2

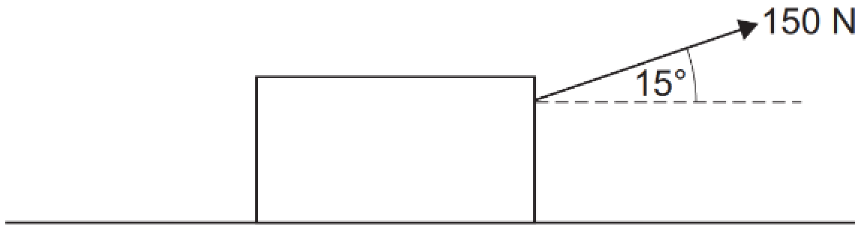
13 **In this question use $g = 9.8\,\text{m s}^{-2}$**

A boy attempts to move a wooden crate of mass 20 kg along horizontal ground. The coefficient of friction between the crate and the ground is 0.85

13 (a) The boy applies a horizontal force of 150 N. Show that the crate remains stationary.

[3 marks]

13 (b) Instead, the boy uses a handle to pull the crate forward. He exerts a force of 150 N, at an angle of 15° above the horizontal, as shown in the diagram.



Determine whether the crate remains stationary.

Fully justify your answer.

[5 marks]

Consider looking for past exam questions that you can easily recreate as a practical.

AQA, GCE Mathematics, 7357/02, June 2018, Q13

For the latest examiners' reports, please also refer to the AQA website.

Exam question 2

Question 13

Nearly all students made good progress with part (a), with over half scoring full marks. Nearly all students successfully found the maximum possible friction and made a comparison with the applied horizontal force. The most frequently seen error was when students wrote a statement that was incorrect, often along the lines of "friction is greater than 150N so there is equilibrium". This showed a misunderstanding of the friction model and could not be overlooked.

Part (b) was also well answered, but a lack of detail often meant that students had not fully justified their answer. Several impressive and detailed answers were seen, where students explained clearly that the horizontal component of the applied force was greater than the maximum friction so that the crate would not remain stationary.

Resolving of forces was generally successful.

AQA, GCE Mathematics, 7357/02, June 2018, Q13

Key Takeaways?

- Practicals don’t need complicated equipment.
- 5–10 minutes is enough.
- Students will understand the algebra better if they have experienced the models.
- Practicals are an easy to draw out common misconceptions that are highlighted by examiners.

Download a copy of ‘Mechanics in Action’ from the STEM Centre e-library.

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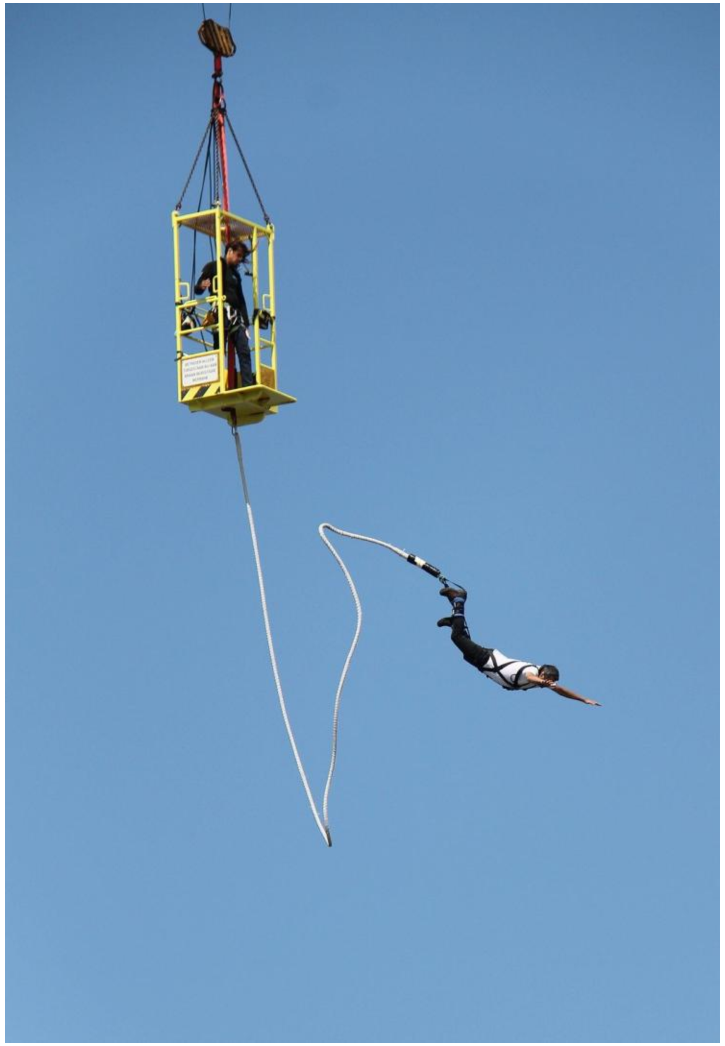
Reflection

Which practical will you try next time you teach Mechanics?

Teaching Mechanics 1 & 2

- Extended courses to improve subject knowledge and pedagogy
- TM1 covers the mechanics content of A level Mathematics
- TM2 covers the mechanics in A level Further Maths
- A mixture of online sessions and two in-person study days



amsp.org.uk/events/extended-pd-courses

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Incorporating simple practicals into your mechanics lessons

Mechanics lessons should have a practical element, and the topics included in A-level Mathematics provide opportunities for students to develop shared experiences through full-scale experiments, short practicals, teacher demonstrations and thought experiments. The activities listed below offer ideas for simple practicals that will illustrate concepts and spark discussion.

1. Pulleys

Objects which are connected via a string around a pulley are often encountered by students, who need to understand the forces acting both on individual objects and the whole system.

a) Equal masses connected over a pulley. What happens when the string is free to move?
b) Make-your-own pulley. Attach board pens to each end of a piece of string. Pass the string over your finger which can then act as the pulley. You might find that the pulley does not move, even if the masses are unequal. How can you explain this?
c) For a smooth make-your-own-pulley, the string can be passed over a board pen.
d) Allow the masses to move freely. Use a long enough string so that one mass hits the surface underneath e.g. table or floor. Observe what subsequently happens to the motion of both objects.

2. Friction

Students need to understand the variable nature of the force of friction when two surfaces are in contact, and how it depends on both the surfaces and the normal reaction.

a) Place an object on a table. Slowly raise one end of the table and increase the angle of incline. What happens?
b) Repeat (a) with a different object. What happens? What is the effect of the object being heavier or made of a different material?
c) Repeat (a) with the other surface of the object in contact e.g. shiny and cork sides of a coaster. What do you notice?
d) Slide an object across different surfaces e.g. carpet, lino, etc. What do you notice?

3. Connected particles

In addition to pulleys, students encounter objects which are connected via strings, towbars, etc.

a) Two people pull either end of a bungee cord. Compare the extension to two people pulling on one end with the other attached to a door/wall. How can we achieve the same extension?
b) Attach two tables with a bungee cord. Pull the first table using another bungee cord. Which cord will stretch more?
c) How does a child move a toy train and its carriages?

4. Forces on stationary objects

Students need to be able to identify the forces acting on stationary objects and understand their combined effects.

a) Stand up and feel the forces on your feet. What forces are acting on you?
b) Lift one foot off the floor. What happens to the forces?
c) Push down on the table whilst stood up. What happens to the forces?
d) With a partner hold the end of a piece of string and then pull. What do you feel?
e) With a partner hold a pen or ruler and push. What do you feel? How does this compare to the string in (d)?
f) Stand with one foot in contact with the floor and one on a bathroom scales, or both feet on the scales and pushing down on a table. What is your maximum/minimum "weight" on the scales?
g) How can you make a set of scales show more than your weight?
h) What happens if you stand on a set of scales in a lift?

5. Force and motion

Motion is often easy to observe but only the effects of forces acting are observable. This can lead to interesting discussions with students.

a) Throw a ball vertically upwards. What is the resultant force at different points in its motion?
b) Throw a ball to another person. What is the resultant force at different points?
c) Drop a paper cone from a particular (measured) height. How long does it take to hit the floor? What is its acceleration?
d) Drop an object. Now drop an object whilst walking fast and observe its vertical motion. What about its horizontal motion?
e) Stand up and imagine you are on a moving train. What would happen if the train accelerates/decelerates/turns? Compare this to when it is not turning or accelerating.

6. Moments

Not all objects can be modelled as particles and students need to understand what happens when forces act on rigid bodies.

a) Why are handles placed where they are on a door?
b) What happens when you hang heavy shopping bags on a pushchair? What if you remove the child from the pushchair?
c) Place a sucker on a door in different places and try opening the door. What do you notice?
d) Attach a string to the door handle. Try to open the door when the string is perpendicular to the door, or in line with the door, or...

Practical activity	What are the key learning points? e.g. What misconception might be addressed?	How might my students respond? What might they notice?