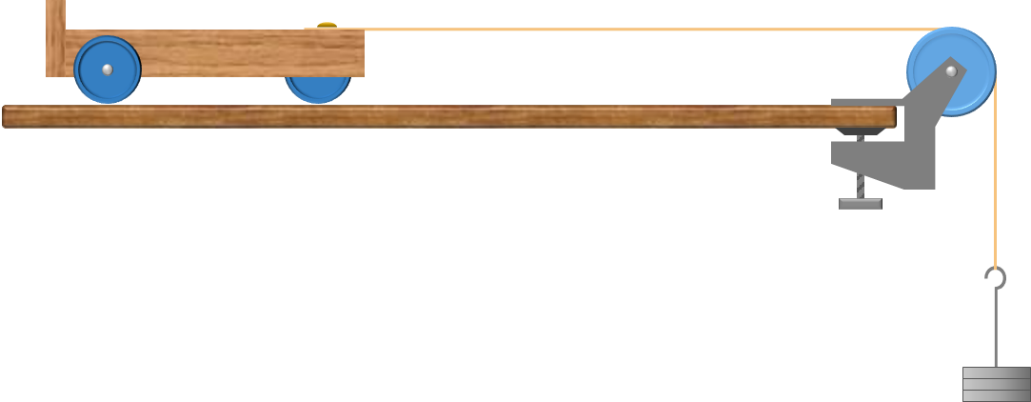
**Trolley pull**

A dynamics trolley is pulled along a bench by a falling weight.

The size of the force pulling it is equal to the size of the weight.



**Predict**

What do you think will happen if the mass of the trolley and the force pulling it are both doubled?

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**Explain**

Why do you think this will happen?

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| --- |
| **Observe what happens when mass and force are doubled.** |

**Observe**

Describe how the trollies move. (How do their speeds and accelerations compare?)

**Explain**

Were your prediction and explanation correct?

Try to improve your first explanation to explain what happens more clearly.

*Physics > Big idea PFM: Forces and motion > Topic PFM6: Forces make things change > Key concept PFM6.2: Force, mass and acceleration*

|  |
| --- |
| **Response activity** |
| **Trolley pull** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | The acceleration of an object is proportional to the resultant force acting on it and inversely proportional to its mass. An object accelerates in the direction of the resultant force acting on it. |
| Observable learning outcome: | Describe the effect of a resultant force on objects of different mass.  Describe the relationship between the resultant force on an object and its acceleration. |
| Activity type: | Predict, explain; observe, explain (PEOE) |
| Key words: | Resultant force, acceleration, mass, dynamics trolley |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic questions:

* Diagnostic question: Loaded lorry
* Drag race II

**What does the research say?**

Students struggle to understand forces and motion, and use a system of ‘gut dynamics’ based on everyday experience in their reasoning. Understanding motion in Newtonian terms is a major task for students, and students of all ages, including physics undergraduates, fail to understand Newtonian concepts of motion (Driver et al., 1994).

Students have intuitive theories about forces and motion that resemble mediaeval ‘impetus’ theory (McCloskey, 1983). They may not see force as an interaction between two objects but rather as something that resides in a single object. They may use the terms ‘energy’ and ‘force’ in an undifferentiated way (Twigger et al., 1994) and may use ideas about force in a way that resembles what a physicist means by momentum (Watts and Zylbersztajn, 1981). They may believe that a force is required to maintain motion at a constant velocity, and that a greater force is required to maintain motion at a greater velocity, so that force is seen as being proportional to velocity rather than to acceleration as in the Newtonian view.

**Ways to use this activity**

Students should complete this activity in pairs or small groups, and the focus should be on the discussions. It is through the discussions that students can check their understanding and rehearse their explanations.

To begin, each group should discuss the activity and use their scientific understanding, firstly to predict *what* they think will happen, and then to explain *why* they think they are going to be right. If students in any group cannot agree, you may be able to direct them with some careful questioning.

Students now carry out the practical, or watch a demonstration. You will need to decide whether it is better for each group to carry out the practical and risk some unexpected observations, or to demonstrate the activity so that everyone *observes* the same thing.

* It is relatively straight forward to demonstrate, approximately, that when the force pulling the trolley is doubled it accelerates at twice the rate.
* A steady count of 3, 2, 1, go, 1, 2, 1, 2 is sufficient.
* At ‘go’, the hanging mass is released and the trolley starts to move forwards. On each of the 2s, a marker is placed to mark the position of the trolley.

(The count should be at a rate that reaches the final 2 before the weight pulling the trolley reaches the ground.)

* This is repeated with two times the pulling force and two times the mass.

(Mass is easily doubled by placing an upturned dynamics-trolley on top of the first.)

* If the pulling force and mass are both doubled, it will be apparent that after two seconds, the trolley moves about the same distance in the following two seconds. In other words, it is moving at about the same speed and its speed has increases by the same amount as the other trolley over the same period of time.

N.B. the speed measured here is the average speed of the trolley after a count of 3.

* It can be instructive to repeat this demonstration with twice the mass and the original force, and with twice the force and the original mass.

This method is usually good enough to convince students of the relationships, and if repeated for a range of different masses and forces (doubling or tripling either or both) it can be even more convincing. Especially, if students are encouraged to predict what will happen for different force – mass combinations.

After the practical each group should be given the opportunity to change, or improve their explanation. A good way to review your students’ thinking might be through a structured class discussion. You could ask several groups for their *explanations* and put these on the whiteboard. Then ask other groups to suggest which explanation is the most accurate and the most clearly expressed, and through careful questioning work up a clear ‘class explanation’.

A useful follow up is for individual students to then write down explanations in their own words – without reference to the class explanation on the board (i.e. cover it up).

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in each group. For example, you may choose to select a student with strong prior knowledge as a scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

**Equipment**

For the class (or for each student/pair/group):

* Dynamics trolley (x2)
* Bench pulley
* Set of (x10) 1 N hanging weights (see technician notes)
* String
* Cushioning below falling weights (e.g. a piece of upholstery foam)

**Technician notes**

The motion of the trolley should only be measured over the distance that it is being pulled.

Weights should be chosen so that the trollies move at a reasonable pace along the bench: not so slow that friction becomes an issue; and not so fast that counting has to be very quick.

A friction compensated ramp could be used to enable more reliable motion whilst using smaller masses.

N.B. The force is accelerating both the trolley **and** the hanging masses. Using this set up, the mass of both is exactly doubled. Other variations of force and mass may not satisfy this requirement for taking accurate measurements.

**Health and safety**

Mass hangers falling onto the floor can break.

There is likely to be rapid movement to mark the trolley’s position.

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Expected answers**

Doubling the mass and the pulling force will result in the trolley accelerating at exactly the same rate – its movement will not change.

Doubling the force will double acceleration, but doubling its mass will make it two times harder to accelerate. The two changes will have equal and opposite effects on the acceleration.

**Acknowledgments**

Developed by Simon Carson (UYSEG) and Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG)

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