Force reduction (Item No.: P6104400)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Natural Sciences	Age 11-14	Nature and technology	Mechanical devices in daily use	Force reduction

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Easy	10 Minutes	10 Minutes	2 Students

Additional Requirements:

- Scissors

Experiment Variations:

- Digital measurement data recording with a tablet PC and Cobra4 sensor

Keywords:

Moving pulley, Block and tackle

Information for the teacher

Educational objective and competences

During this experiment, the students observe the force that needs to be applied when lifting a mass with the aid of a moving pulley. They notice that the force that needs to be applied when using a moving pulley is less than the force that needs to be applied for lifting the mass straight up. They also notice that this method directly reduces the force that needs to be applied if the pulley that is used is not heavier than the load that needs to be transported. However, the force must be applied over a longer distance.

Standard experiment set-up

Experiment set-up for measurements with a tablet PC

Competences

Process-related competences:

K: Knowledge gain
C: Communication
A: Assessment

The students can...

K02 – develop problem-related questions and formulate hypotheses.
K06 – execute simple experiments independently based on written instructions.
K08 – recognise technical concepts in examples from everyday life.
K09 – plan, execute and document simple experiments by themselves.
K10 - describe relationships with the aid of geometrical representations.
K12 – make assumptions about connections and causes.

C02 – describe the technical connections and relationships in everyday language.
C03 – acquire measurement data and extract them from age-appropriate representations.
C05 – present their results with the aid of specified media.
C06 – express and accept criticism.
C07 – work in groups on their own initiative.
C09 – read age-appropriate, relevant texts and relay the content thereof.

A01 – appraise their own results based on a comparison with other groups.
A02 – recognise the role of scientific phenomena in their everyday life.
A03 – evaluate arguments, take up a position and substantiate their point of view.
A06 – explain the areas of application in which scientific knowledge is of importance.
A08 – distinguish between the desired and undesired characteristics for the application of scientific effects.

Content-related competences:

The students can...

S: Specialised knowledge

S13 – distinguish between weight and mass.
S14 – use the unit of force (1 N).
S16 – set up simple "machines" and "devices".
S17 – demonstrate, in an experimental manner, that simple machines can be used to reduce the required forces.

Material

Position No.	Material	Order No.	Quantity
1	Spring balance,transparent, 1 N	03065-02	1
2	Weight holder,	02204-00	1
3	Slotted weight, black, 10 g	02205-01	8
4	Measuring tape, l = 2 m	09936-00	1
5	Support rod, l = 600 mm, d = 10 mm, split in 2 rods with screw threads	02035-00	1
6	Boss head	02043-00	1
7	Fishing line, l. 20m	02089-00	1
8	Holding pin	03949-00	1
9	Pulley,movable,dia.65mm,w.hook	02262-00	1
10	Support base, variable	02001-00	1
Additional required			
11	Scissors		1

Additional material for measurements with a tablet PC

In order to perform the experiment with digital measurement data recording via a tablet PC, the following additional material is required.

The spring dynamometer is not required for this variant.

Position No.	Material	Order No.	Quantity
1	Cobra4 Wireless/USB-Link	12601-09	1
2	Cobra4 Sensor-Unit Force, ±10 N	12646-00	1
3	Apple iPad		1
4	PHYWE measure App		1

Download on the App Store

Saefty information

- For this experiment, the general notes and instructions concerning safe experimentation in science classes apply.
- Prior to performing the experiment, you should warn the students that a loaded spring dynamometer may rebound when it is unloaded.
- Inform the students that a high support stand can tip over easily when they pull on it high at the top.

Didactic notes

Procedure

- If the set-up is changed, the string may slip off the pulley. It is important that the students ensure the string always passes over the pulley during the execution of the experiment.
- The students will realise that the effort (or force) that needs to be applied for transporting a load can be reduced if suitable devices are used. However, this is only possible if the distance over which the force must act is extended. This means that the resulting work is the same (if not more). Ask your students whether they realise this "disadvantage" of the new method.

Technical terms

It is important that the students are familiar with the concept of "mass" and that they use this term in science classes instead of "weight" when they talk about mass. Mass is a material property while weight is a force. In a simplified manner, "mass" is what can be measured in kg or g by way of a scale.

Tablet PC option

In addition to the classic variant, you can also let the students perform the experiment with the Cobra4 equipment and tablet PCs. The digital measurement data recording method enables the students to quickly acquire the measurement data, understand them more readily and to evaluate them in a particularly comfortable way.

- Remove the spring dynamometer from the set-up and replace it with the Sensor-Unit "Force" connected to the Cobra4 Wireless/USB-Link. The students perform the same measurements with the Sensor-Unit. They record the values directly in the form of a diagram. As a result, they can observe the development of the force over the entire duration of the movement, identify fluctuations and average them. If the students save their measurement series for each part of the experiment, they can view them repeatedly and use them for the questions in the experiment report.

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Force reduction (Item No.: P6104400)

Experiment (standard)

Introduction

Surely, you have already tried to lift a heavy object and failed because you were not strong enough. Maybe an adult has helped you. However, even adults are often not strong enough.

You have already learned that it is possible to reduce the force by using a lever. However, what can you do if it is impossible to use a lever? Maybe a rope would be a solution. Is it possible to reduce the necessary force by using a rope?

Application

If you need to lift a heavy load, you can use a moving pulley.

- Hiking accident: If hikers fall into a crevasse, they can be saved easily by their fellow hikers. The person who has fallen into the crevasse hangs from a rope and moving pulley and the other hikers pull on the other end of the rope.

Rope team hiking in the mountains

Task

Lift a load with the aid of a moving pulley and a string. However, this time, let the pulley run over the string and lift it together with the load. Measure the force that you need to do so.

Experiment set-up

Assumption

What is the purpose of the pulley?

Initial question

During this experiment, you lift the weight holder and the pulley.

Do you think that you will need a reduced amount of force with this set-up compared to a set-up where you would lift only the weight holder?

- ☐ Yes, the pulley reduces the necessary force because it runs on the string.
- ☐ No, actually more force is necessary because the pulley also has a certain weight.
- ☐ No, the required force is identical.

Material and procedure

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10	Support base, variable	02001-00	1
Additional required			
11	Scissors		1

Set-up

First screw the two parts of the support rod together (Fig. 1). Set up a support system like the one shown in Figs. 2 and 3 with the aid of the support base and support rod.

Fig. 1

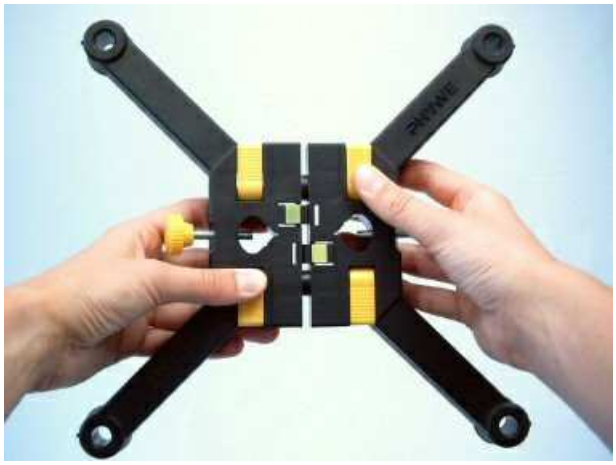

Fig. 2

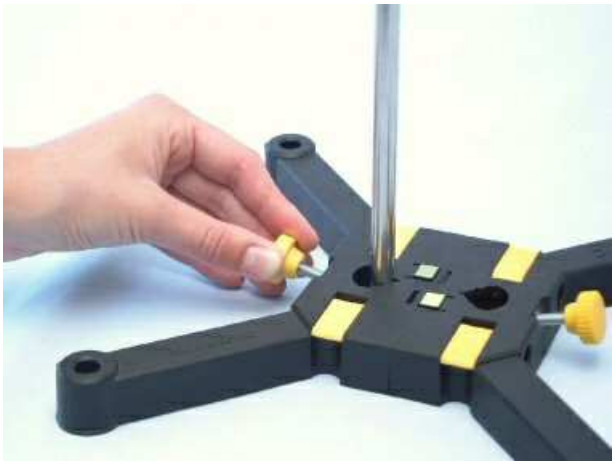

Fig. 3

Fasten the right-angle clamp to the very top of the support rod.

Take piece of string of approx. 60 cm and tie a little loop at the end. Thread the other end of the string through the eyelet of the holding pin and make a tight knot.

Screw the holding pin into the right-angle clamp as shown in Fig. 4.

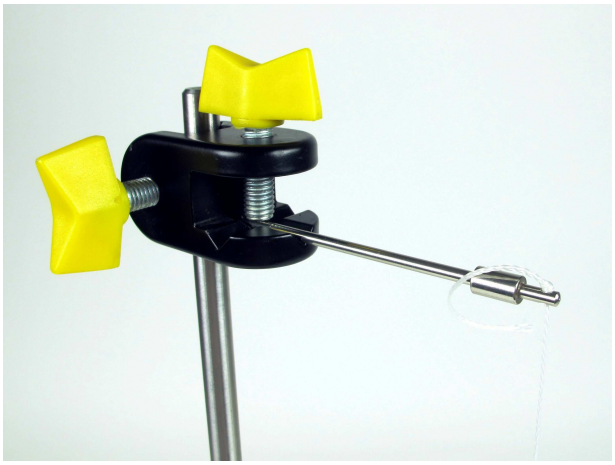

Fig. 4 a

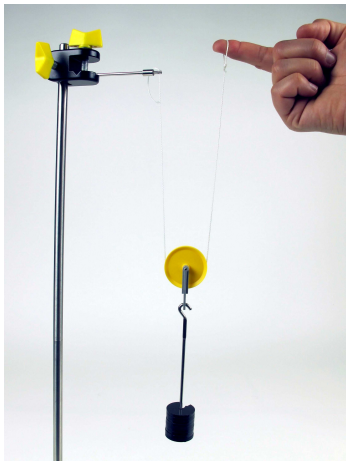

Fig. 4 b

Before the measurements, set the dynamometer (spring dynamometer) to zero. To do so, let the hook on the spring hang down (Fig. 5).

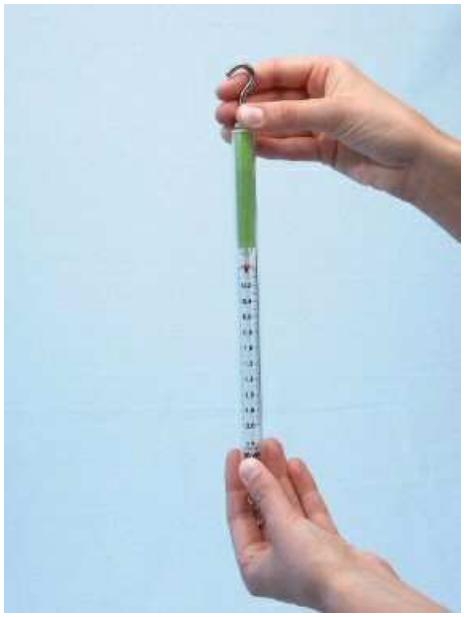

Fig. 5

Procedure

1. Place 8 slotted weights on the weight holder.

   Fasten the small pulley to the stem of the weight holder with the weights as shown in Fig. 6.

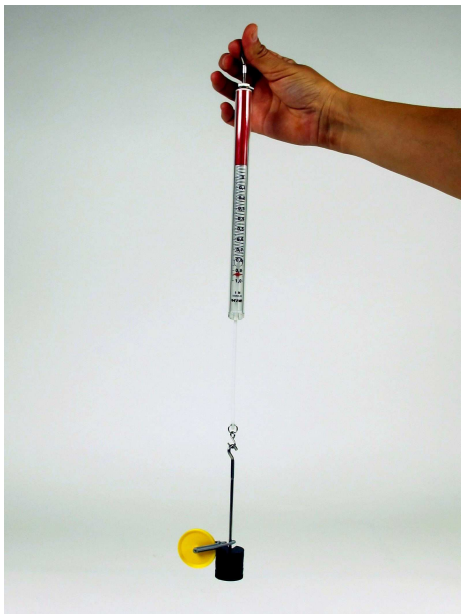

Fig. 6

   Use the spring dynamometer to measure the weight of the entire weight holder and note it down in the experiment report.

2. Remove the pulley but leave the 8 slotted weights on the weight holder.

   Suspend the weight holder from the hook of the pulley.

   Guide the string along the lower end of the pulley (between the pulley and hook) and hold the other end of the string upwards. The pulley sits on the string.

   Connect the loop of the string to the spring dynamometer. Hold the spring dynamometer so that the pulley and the weight holder are located above the tabletop as shown in Fig. 7.

Fig. 7

Move the spring dynamometer slowly upwards and observe the movement of the weight holder and pulley. Measure the force with the aid of the spring dynamometer while moving it upwards.

Move the load upwards by approx. 10 cm. Compare the length of string that you need to pull to accomplish this. Measure both lengths with the measuring tape.

Evaluation

During this experiment, you have examined how you can lift a load with a reduced amount of force by way of a pulley.

Go to the experiment report and answer the questions about the experiment.

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Experiment (with a tablet PC)

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Application

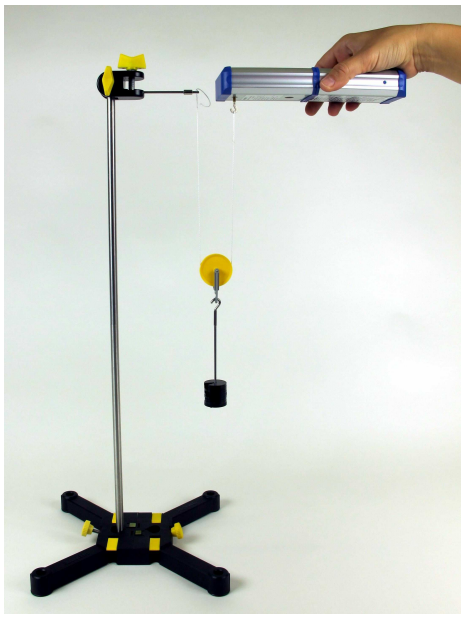
If you need to lift a heavy load, you can use a moving pulley.

- Hiking accident: If hikers fall into a crevasse, they can be saved easily by their fellow hikers. The person who has fallen into the crevasse hangs from a rope and moving pulley and the other hikers pull on the other end of the rope.

Rope team hiking in the mountains

Task

Lift a load with the aid of a moving pulley and a string. However, this time, let the pulley run over the string and lift it together with the load. Measure the force that you need to do so.



Experiment set-up

Assumption

What is the purpose of the pulley?

Initial question

During this experiment, you lift the weight holder and the pulley.

Do you think that you will need a reduced amount of force with this set-up compared to a set-up where you would lift only the weight holder?

- ☐ Yes, the pulley reduces the necessary force because it runs on the string
- ☐ No, actually more force is necessary because the pulley also has a certain weight.
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Material and procedure

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11	Cobra4 Sensor-Unit Force, Kraft 10 N	12646-00	1
12	Apple iPad		1
13	PHYWE measure App		1
Additional required			
14	Scissors		1

Set-up

First screw the two parts of the support rod together (Fig. 1). Set up a support system like the one shown in Figs. 2 and 3 with the aid of the support base and support rod.

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Fig. 1

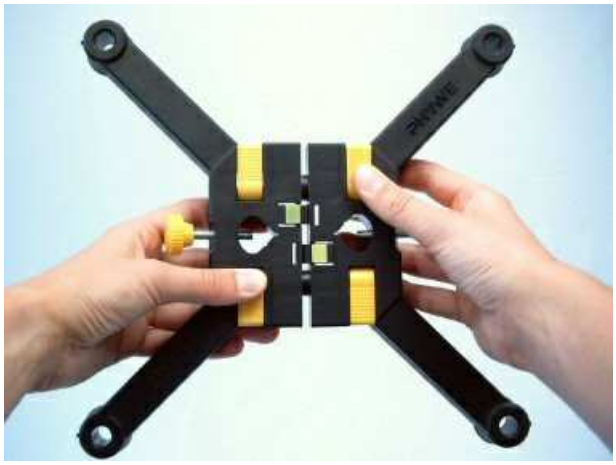

Fig. 2

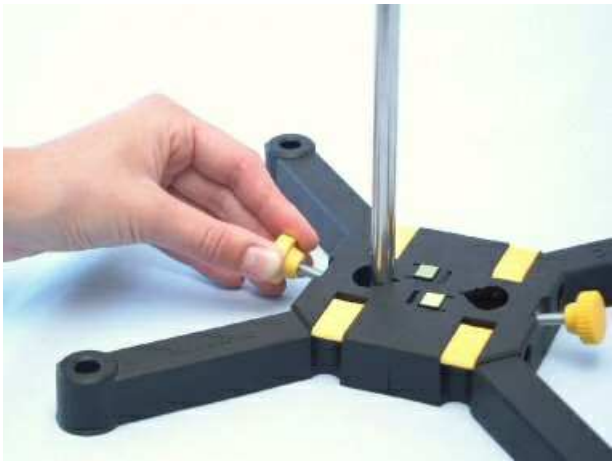

Fig. 3

Fasten the right-angle clamp to the very top of the support rod.

Take piece of string of approx. 60 cm and tie a little loop at the end. Thread the other end of the string through the eyelet of the holding pin and make a tight knot.

Screw the holding pin into the right-angle clamp as shown in Fig. 4.

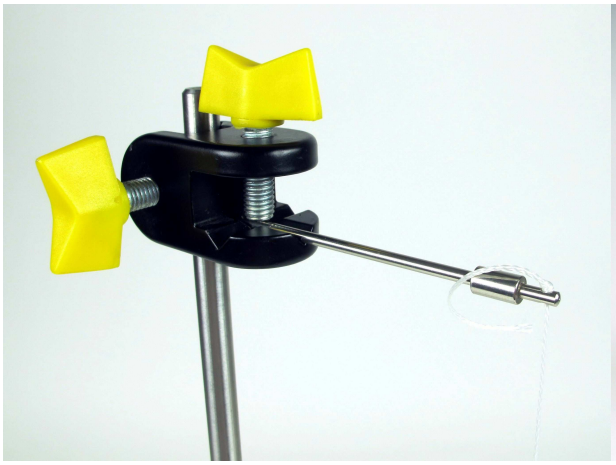

Fig. 4 a

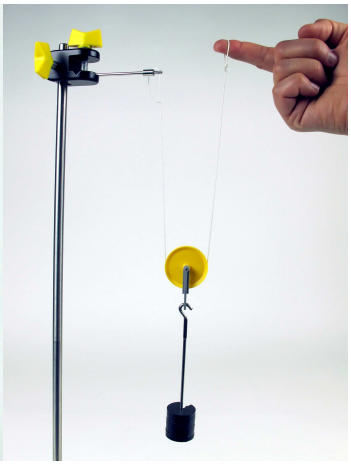

Fig. 4 b

Procedure

Connect the ''Wireless/USB-Link" and the sensor and switch the device on.

Connect your tablet PC with the "Wireless/USB-Link" and open the "measure" app .

Select the connected sensor.

Hold the force sensor with the hook down and select "Set to zero".

Deactivate "Repeated measurement" and open the window with the analogue display.

1. Place 8 slotted weights on the weight holder.

   Fasten the small pulley to the stem of the weight holder with the weights as shown in Fig. 5.

   Use the force sensor to measure the weight of the entire weight holder and note it down in the experiment report.

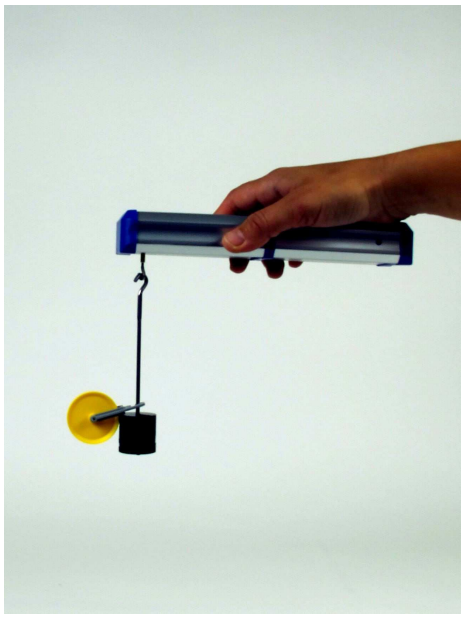

Fig. 5

2. Remove the pulley but leave the 8 slotted weights on the weight holder.

   Suspend the weight holder from the hook of the pulley.

   Guide the string along the lower end of the pulley (between the pulley and hook) and hold the other end of the string upwards. The pulley sits on the string.

   Connect the loop of the string to the force sensor. Hold the force sensor so that the pulley and the weight holder are located above the tabletop as shown in Fig. 6.

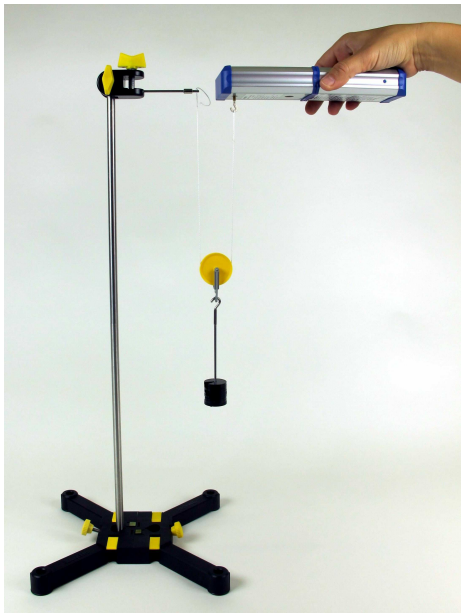

Fig. 6

   Open the diagram window.

   Start the measurement.

   Move the force sensor slowly upwards and observe the movement of the weight holder and pulley.

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Stop the measurement when the weight holder reaches the pulley.

Observe the measured force while pulling.

Move the load upwards by approx. 10 cm. Compare the length of string that you need to pull to accomplish this. Measure both lengths with the measuring tape.

Evaluation

During this experiment, you have examined how you can lift a load with a reduced amount of force by way of a pulley.

Go to the experiment report and answer the questions about the experiment.

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Report: Force reduction

Observation - Table (2 points)

What is the force that you have measured?

	Force in N
Direct lifting:	1 ±0.1
Pulling with the moving pulley:	1 ±0.2

Observation - Question 1 (1 point)

Do the measured values differ from one another? If so, how?

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Evaluation - Question 1 (1 point)

Why did you weigh the pulley as well?

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Evaluation - Question 2 (1 point)

What are the properties that the pulley needs to have so that you can reduce the amount of force that is needed for lifting the load?

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Evaluation - Question 3 (1 point)

You have lifted the load by 10 cm with the aid of the pulley. What is the length of the string that you had to pull?
Enter the length in cm.

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Evaluation - Question 4 (1 point)

What is the disadvantage of trying to reduce the necessary force by way of a moving pulley?

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Initial question (repeated) (1 point)

During this experiment, you lift the weight holder and the pulley.

Do you think that you will need a reduced amount of force with this set-up compared to a set-up where you would lift only the weight holder?

- [ ] Yes, the pulley reduces the necessary force because it runs on the string.
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