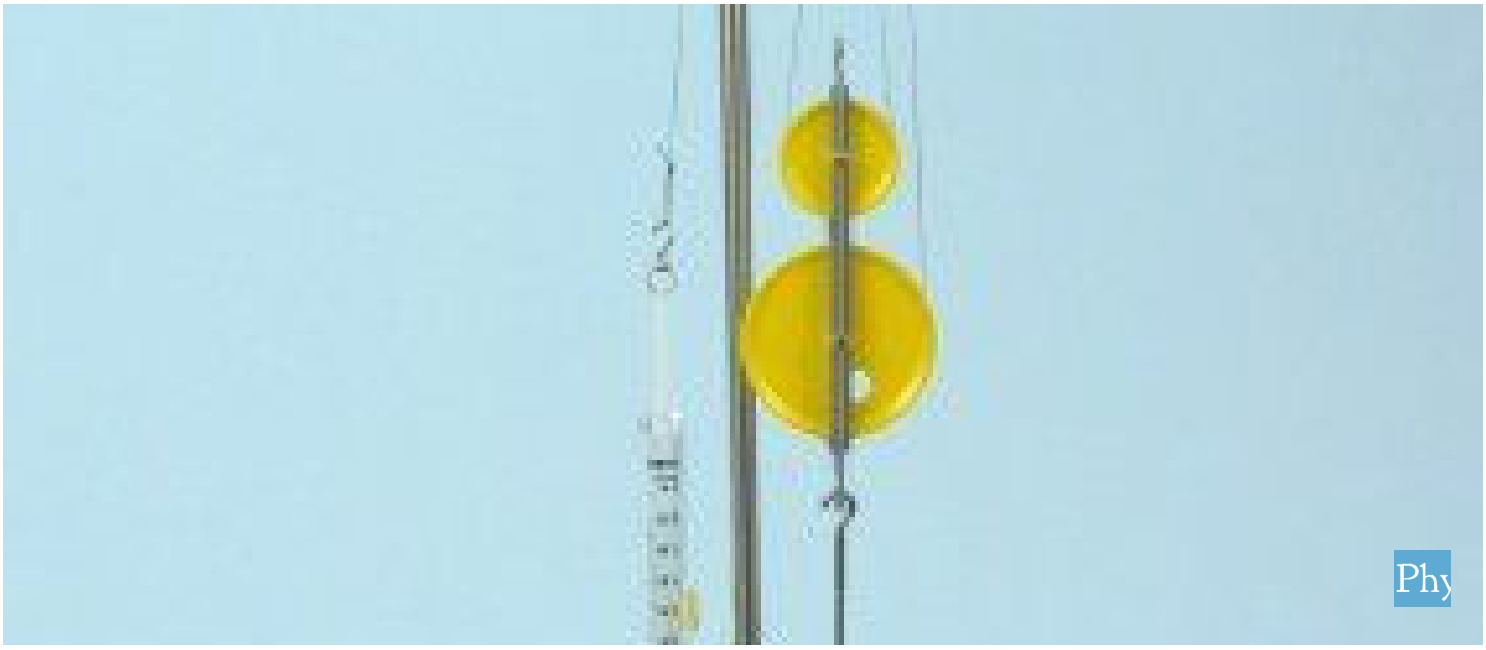
Block and tackle with four pulleys



Physics | Mechanics | Forces, work, power & energy

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	20 minutes

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Teacher information

Application

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Test setup of the pulley block

The work required to lift a load W results from the product of the force F and the way s:

$$W = F \cdot s \; [Nm]$$

If you want to reduce the required force, you can do this with the help of a pulley block. This multiplies the distance required for lifting, while the force is reduced in the same proportion.

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Other teacher information (1/2)

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Prior

Students should have a basic understanding of forces and be able to determine the weight of a body using a spring force meter. Ideally, students should already have a basic understanding of the forces and paths on a fixed/loose pulley and even have carried out initial experiments with simple pulleys with two rollers.

Scientific

Since the work done W to the product of force F and way s the required force can be reduced to the same extent by increasing the distance.

If, for example, the distance is doubled with the help of a pulley block, the force is reduced by exactly half.

Other teacher information (2/2)

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Learning

Using the example of a pulley block, the students should recognise that the force required to lift a given load decreases in the same proportion as the number of rollers.

Tasks

1. Determine the ratio of load and force in balance.
2. Determine whether the number of pulleys of the pulley block is related to this.
3. Examine whether the path of the load differs from that of the force.
4. Examine whether differences for the products $F \cdot s$ exist.

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Safety instructions

The general instructions for safe experimentation in science lessons apply to this experiment.

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Motivation

Crane with pulley block

Deflection pulleys are often used wherever heavy loads have to be lifted. The reason for this is that the ropes to which the load is attached can often only carry a certain, smaller load in order to be flexible enough to be wound onto a winch.

By deflecting at several fixed and loose pulleys (e.g. on a crane with pulley block) the load is distributed over several sections of the rope. As a result, lifting usually takes longer, while the rope can be pulled with less force, the rope's travel distances become longer.

In this experiment you will learn about the forces at work and the ways of a pulley block.

Tasks

A pulley block usually consists of a combination of several fixed and loose pulleys.

- In the following, examine a pulley block with two fixed and two loose pulleys.
- Determine experimentally what force is required to lift a load with the pulley block.
- Investigate how large the force path must be in order to lift a load by a certain distance (load path).

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Equipment

Position	Material	Item No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
3	Support rod with hole, stainless steel, 10 cm	02036-01	1
4	Boss head	02043-00	2
5	Weight holder, 10 g	02204-00	1
6	Slotted weight, black, 10 g	02205-01	4
7	Slotted weight, black, 50 g	02206-01	3
8	Pulleys, double in line	02266-00	2
9	Rod for pulley	02263-00	1
10	Spring balance,transparent, 2 N	03065-03	1
11	Spring balance holder	03065-20	1
12	Measuring tape, l = 2 m	09936-00	1
13	Fishing line, l. 20m	02089-00	1

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Additional equipment

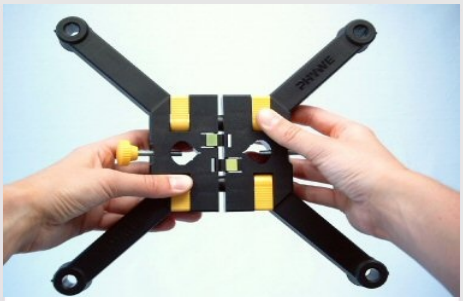
Position	Equipment	Quantity
1	Scissors	1
2	Felt marker	1

Set-up (1/5)

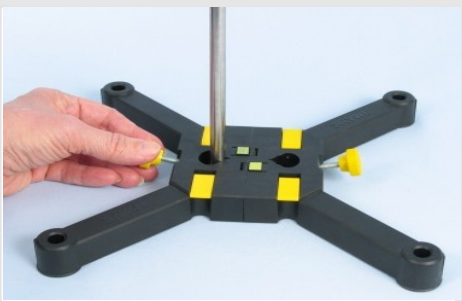
First screw together the split stand rod and put the two stand foot halves together.

Fix the long stand rod vertically in the stand foot.

Screwing the support rods



Mounting the half of the tripod foot



Fasten the stand rod in the foot

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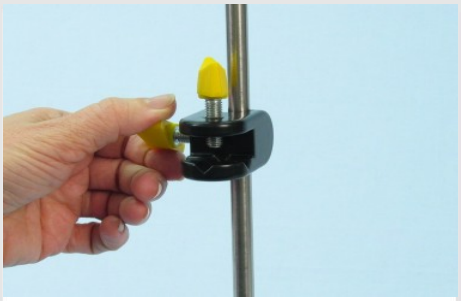
Set-up (2/5)

Clamp one double socket each in the lower area and at the upper end to the long stand rod.

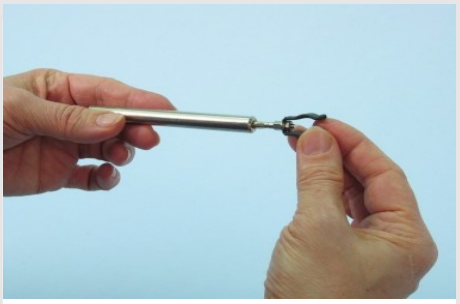
Attach a double pulley to the "pulley-handle" and clamp the handle in the upper double socket.

Insert the force gauge holder into the short support rod and clamp it into the lower double socket.



Fasten double sleeve to stand rod

Fastening the roller to the "handle"



Insert force gauge holder into stand rod

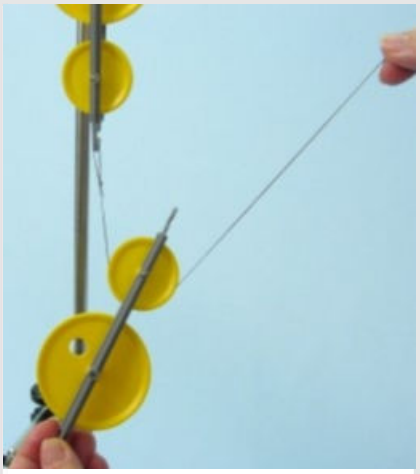
Set-up (3/5)

Fasten fishing line to the fixed reel

Take a piece of fishing line about 110 cm long and knot one loop at each end.

Attach one loop of the fishing line to the lower free hook of the upper fixed reel.

Then guide the line over the first of the four pulleys (the small upper pulley of the loose double pulley) as shown in the adjacent figure.



Running the cord over the first reel

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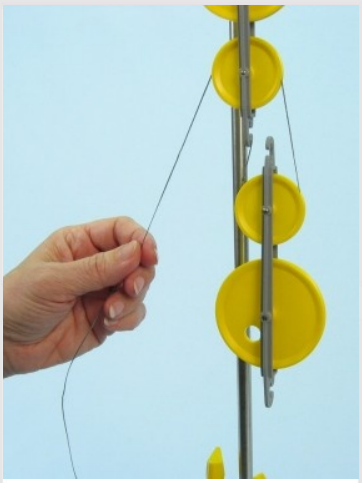
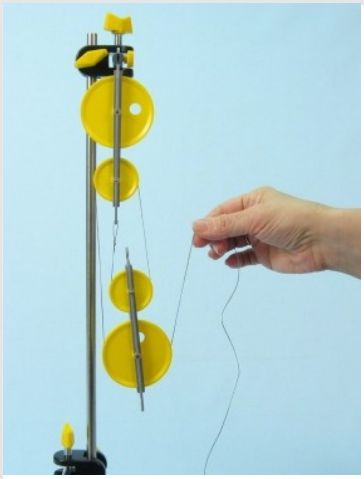
Set-up (4/5)



Running the cord over the second pulley

Now lead the line over the second pulley: the small pulley of the fixed double pulley above.

Next, run the line over the third pulley: the big pulley of the loose double pulley below.



Running the cord over the third pulley

Set-up (5/5)

Running the cord over the fourth pulley

Finally you lead the line over the fourth and last pulley: the big pulley of the fixed double pulley above.

Hang the loop at the end of the line on the upside down zero force gauge and clamp it into the force gauge holder.

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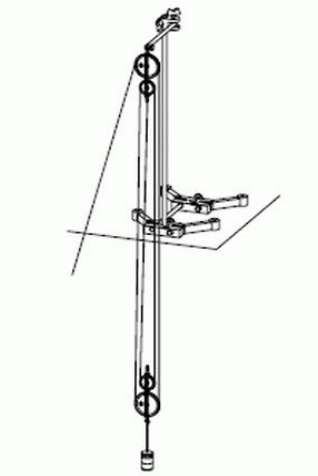
Procedure (1/3)

Determination of the weight force $F_{W,Pulley}$

- The weight force of a double pulley is $F_{W,Pulley} = 0,2\ N$. Convince yourself of this after the experiment using the force gauge.
- Load the pulley block with a mass of 50 g (weight plate with 4 mass pieces 10 g) and read the force F on the dynamometer.
- Repeat the force measurement for masses of 100 g, 150 g and 200 g.
- Enter all your measured values in Table 1 in the protocol.

Determination of F

Procedure (2/3)



Experimental set-up with long fishing line

- Now replace the 110 cm long fishing line with a piece of fishing line with a length of about 4-5 m.
- Make sure that the line runs over the four pulleys in the same way as in the first test part.
- Position the entire test setup close to the edge of the table so that the load can be moved past the table top without obstruction.
- Load the pulley block with a total of 150 g and let the line run so far that the load is on the ground.

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Procedure (3/3)

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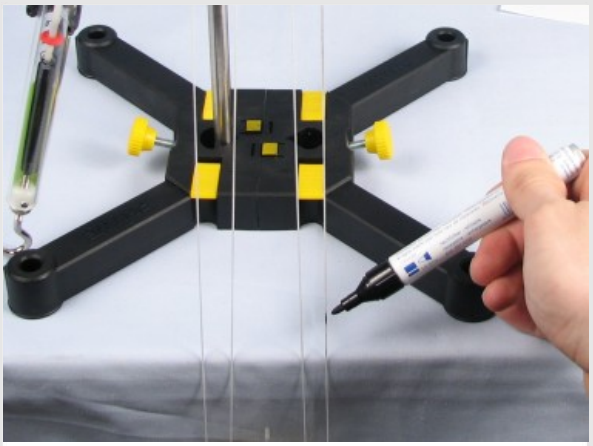

Marking the cord

- Mark the beginning of the string at a certain point of the setup, e.g. the tripod foot, with a line.
- Pull the cord until the load reaches the edge of the table and mark the cord with a line at the same place on the body as before.
- Measure the power F as in the previous experimental part.
- Measure the distance from the floor to the edge of the table that the load has travelled (load path s_l) and the length of the cord between the two marks (force path s_f).
- Enter all measured values into table 2 in the protocol.

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Report

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Table 1

Calculate F_G according to the formula

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Enter your measured values in the table and calculate from the mass m, taking into account the weight of the double pulley $F_{W,Pulley}$ the weight force F_W and complete the table.

$m\ [g]$	$F\ [N]$	$F_W\ [N]$	F_W/F
50			
100			
150			
200			

Enter the weight of $F_{W,Pulley}$.

$F_{W,Pulley} = N$

$$F_W = m \cdot g + F_{W,Pulley}$$

Form the quotients F_W/F and enter the results in the table as well.

Table 2

Calculate F_G according to the formula

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Enter your measured values in the table. Enter the value for F_W from Table 1.

Calculate the quotient s_l/s_f ($Loadpath/Forcepath$) and enter the result.

$m\ [g]$	$F_W\ [N]$	$s_l\ [cm]$	$s_f\ [cm]$	s_l/s_f	$F\ [N]$
150					

$$F_W = m \cdot g + F_{W,Pulley}$$

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Task 1

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Test setup for lifting the load

Is it easier to lift the load directly or by means of a pulley block?

- ○ It is easier to lift the load by means of the pulley block.
- ○ It is easier to lift the load directly.

Check

Task 2

Is there a difference between the quotient F_W/F and the number of pulleys, and if so, which one?

- ○ $F_W/F = No.\,Pulleys$
- ○ $F_W/F = 1/No.\,Pulleys$
- ○ $F_W/F = 2 \cdot No.\,Pulleys$

Check

What can you say about the power F that is required to lift the load?

- ○ $F > F_W$
- ○ $F < F_W$
- ○ $F = F_W$

Check

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Task 3

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Experiment set-up

Calculate the following products:

$F \cdot s_f = [Ncm]$ $F_W \cdot s_l = [Ncm]$

What do you notice when comparing the products?

- $F \cdot s_f = F_W \cdot s_l$
- $F \cdot s_f > F_W \cdot s_l$
- $F \cdot s_f < F_W \cdot s_l$

Check

Task 4

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Experiment set-up

Does the relationship also apply here?

$Load \cdot Loadpath = Force \cdot Forcepath$

- Yes, the condition also applies here.
- No, the condition does not apply here because of the four pulleys.

Check

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Task 5

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On one (different from in our experiment) pulley block, the force to be applied is six times smaller than the load. How large is the quotient of force travel/load travel for this hoist?

- $\frac{Forcepath}{Loadpath} = \frac{1}{6}$
- $\frac{Forcepath}{Loadpath} = 6$

Check

How many pulleys must such a pulley block have?

- $No.\,Pulleys = 12$
- $No.\,Pulleys = 6$
- $No.\,Pulleys = 9$

Check

Slide	Score / Total
Slide 22: Lift load with or without pulley block	0/1
Slide 23: Multiple tasks	0/2
Slide 24: Comparison of the products of force and displacement	0/1
Slide 25: Relationship $Last \cdot Lastweg = Kraft \cdot Kraftweg$	0/1
Slide 26: Multiple tasks	0/2

Total amount 0/7

Solutions | Repeat | Exporting text

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