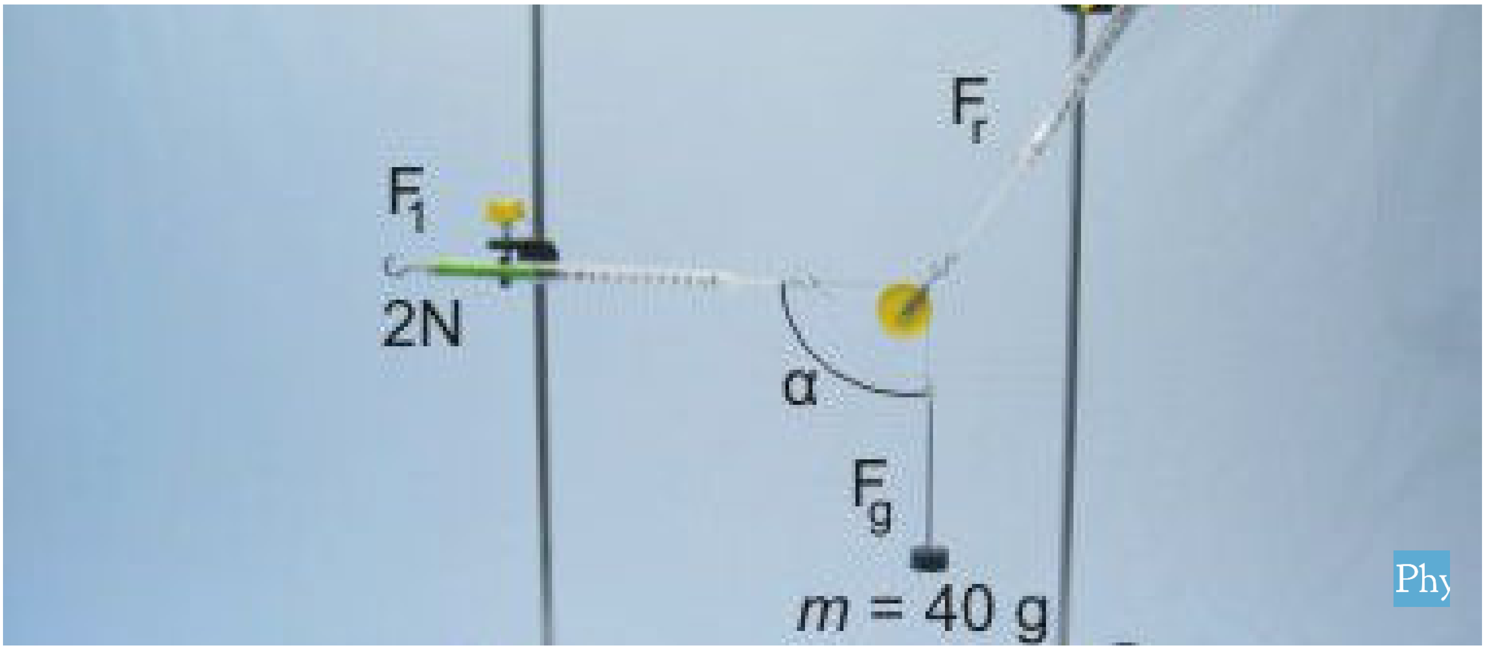
Force on a pulley mounting



Physics → Mechanics → Forces, work, power & energy

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

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Teacher information

Application

Test setup for determining the resulting force at the deflection roller

If a pulley is used to deflect a rope which is subjected to a force, this pulley can be considered as frictionless in a simplified way. Under this assumption, the forces in the rope are then equally high at both ends.

If these forces are also known, the resulting force in the support of the roller F_{res} can be determined. This force can be determined either by measuring it with a dynamometer or by calculating it with the aid of the angular functions.

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Other teacher information (1/2)

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Prior

Students should have a basic understanding of forces. In particular, they should understand how a parallelogram of forces is created and how forces in the same direction and in opposite directions work. The students should have a feeling for how the force resulting from external forces F_{res} arises. In addition, it would be an advantage if the students have already learned the theory of angular functions.

Scientific

The reulting force F_{res} can in this case either be measured directly or calculated using the angle functions.

Other teacher information (2/2)

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Learning

Students should learn how to determine the resulting force that loads a roll both experimentally and mathematically.

Tasks

1. Using a roller to deflect a weight force and measure the resulting force on the roller support F_{res}.
2. Determine the resulting force F_{res} depending on the angle α between the weight force F_G and the redirected force F_1.

In an additional task, students who know the angular function can calculate the resulting force F_{res} from F_1, F_G and the angle α.

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Safety instructions

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

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Student Information

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Motivation

Pulleys of a sailing yacht

In many technical applications, pulleys are important components for changing the direction of action of the respective loads on the ropes as required. To simplify the calculation of the acting forces, it is often assumed that the pulley is frictionless. The consequence of this simplification is that the rope forces are equally high at both ends of the rope.

In this context, rollers are often installed in pulleys. If these are cleverly designed and built, the forces required to lift heavy loads can be kept very small.

In this experiment you learn which forces occur at the holder of a roller.

Tasks

1. Using a roller, deflect a weight force and measure the resulting force on the roller support F_{res} .
2. Change the angle α between the weight force F_G and the redirected force F_1 and again measure the resulting force .

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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	3
3	Support rod with hole, stainless steel, 10 cm	02036-01	2
4	Boss head	02043-00	2
5	Spring balance,transparent, 1 N	03065-02	1
6	Spring balance,transparent, 2 N	03065-03	1
7	Spring balance holder	03065-20	2
8	Weight holder, 10 g	02204-00	1
9	Slotted weight, black, 10 g	02205-01	3
10	Pulley,movable,dia.40mm,w.hook	03970-00	1
11	Fishing line, l. 20m	02089-00	1

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Additional equipment

Position	Equipment	Quantity
1	Angle plate (copy template)	1
2	Scissors	1

Under the following link you can download the template with the angle disc:

Angle plate (copy template)

Set-up (1/3)

First, screw the divided support rods together to form long support rods.

Connect the two halves of the tripod foot with a long tripod rod and attach the locking levers.

Insert the two remaining long tripod rods into one half of the tripod foot and fix them.

Connecting the support rods

Connecting the tripod feet

Fixing the support rods

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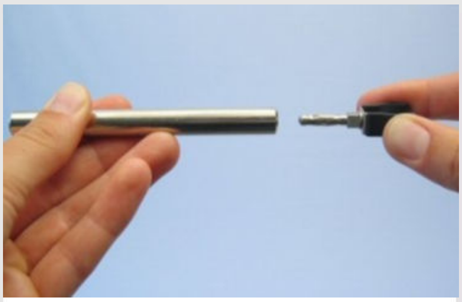
Set-up (2/3)

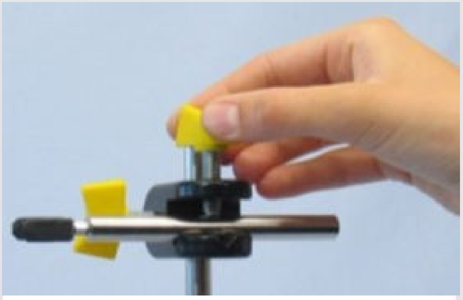
Insert the two dynamometer holders into the 100 mm tripod rods with the hole.

Attach the double sleeves to the long support rods and clamp the force gauge holders into them.

Insert the two force gauges and adjust them in the position of use with the screw.



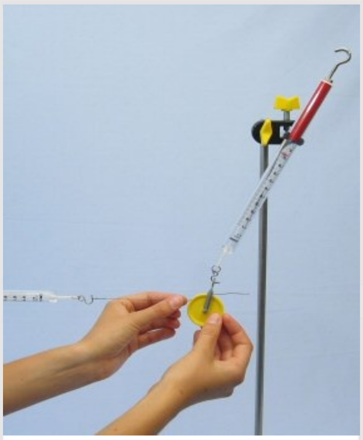
Insert the force gauge holder into the stand rod



Fixing the support rods to the double socket

Inserting and adjusting the force gauges

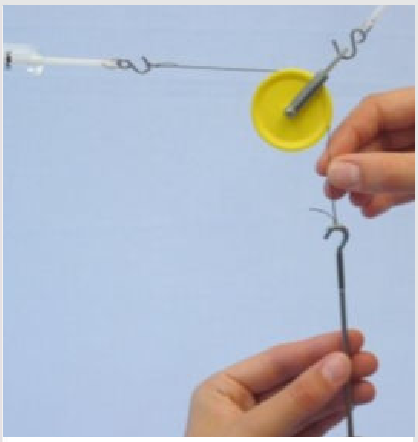
Set-up (3/3)



Attach the force gauge to the stand rod

Attach the 1 N dynamometer with the dynamometer holder at the top of one of the support rods. Hang the roll in the eyelet of the 1 N dynamometer.

Fix the dynamometer 2 N with the dynamometer holder in horizontal position to the other support rod. Connect the dynamometer 2 N to the weight plate with a piece of string.



Fastening the weight plate to the deflection roller

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Procedure (1/4)

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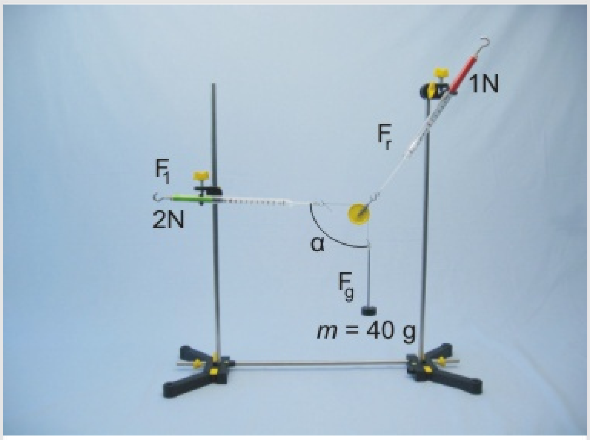

Applying the load (weights) and aligning the dynamometer

- Load the weight plate with three 10 g weights ($m_{ges} = 40\ g$) and align the dynamometer 2 N so that it is exactly horizontal ($\alpha = 90^{\circ}$).
- To place the slotted weight on the weight plate, the slotted weights must be attached to the upper end of the weight plate.
- Make sure that the mass hangs freely.
- Read the two force gauges and note the measured values for the redirected force F_1 and the resulting force F_{res} on the role in Table 1 in the log.

Procedure (2/4)

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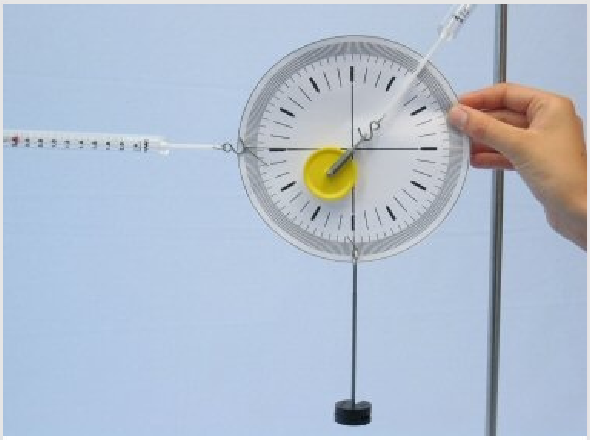

Positioning of the angle scale in the experimental setup for angles $\alpha = 90^{\circ}$

- Change the angle α between the weight force F_G and F_1 by moving the force gauge holder 2 N from the horizontal position first upwards and then downwards. Adjust the angles 105°, 120°, 70° and 50° one after the other.
- Hold the angle disk so that its center is at the intersection of the force axes.
- Read for every angle α forces F_{res} and F_1 and enter the measured values in Table 1.
- On the following page you can see an example of the modified test setup.

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Procedure (3/4)

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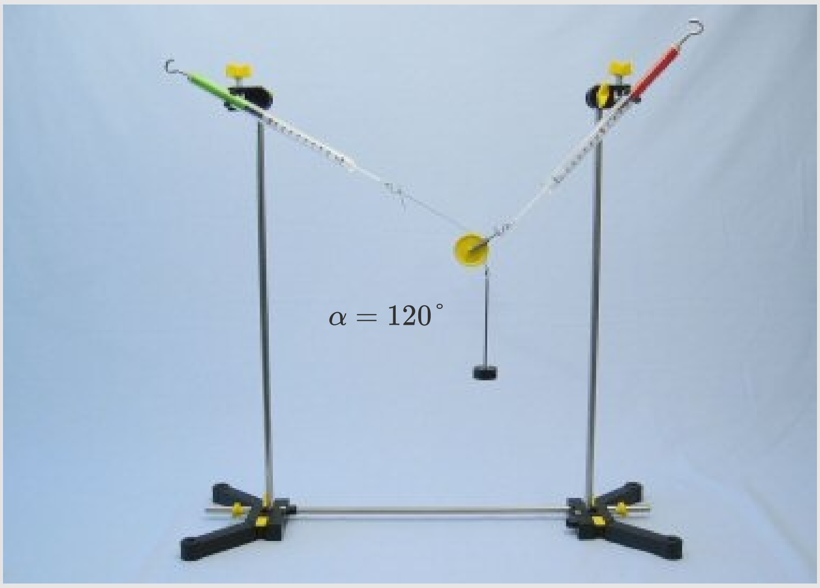

Procedure (4/4)

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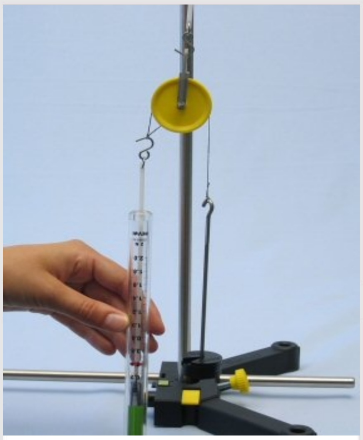
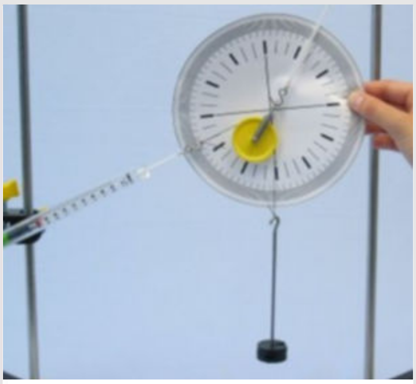


Vertically aligned force gauge ($\alpha = 0^\circ$)

- Now take the dynamometer 2 N out of the holder and pull it parallel to the F_G down ($\alpha = 0^\circ$)
- Also note the corresponding values in Table 1 of the protocol.
- All set angles should always be checked using the angle scale before reading the values.



Check the set angle with the aid of the angle plate

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Report

Table 1

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Enter your measured values in the table. Calculate the weight force F_G for $m = 40\,g$ and enter them.

$\alpha\,[^\circ]$	$F_1\,[N]$	$F_{res}\,[N]$
90		
120		
105		
70		
50		
0		

$F_G =$ ______ N

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Task 1

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Compare the values determined for the resulting force F_{res} by the force of gravity F_g. What do you find?

- ○ $F_{res} < F_g$
- ○ $F_{res} = F_g$
- ○ $F_{res} > F_g$

Check

Task 2

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Do you have to consider the weight of the roller?

- ○ No, the weight of the roller does not have to be taken into account due to the geometry.
- ○ Yes, the weight of the roller must be taken into account for accurate measurements.

Check

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Task 3

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What is the weight force of the roller $F_{G,Roller}$? Measure with a dynamometer.

$F_{G,Roller} =$ [ ] N

What is therefore the weight of the roller m_{Roller}? Calculate this using the acceleration due to gravity ($g = 9,81\, m/s^2$).

$m_{Roller} =$ [ ] g

Task 4

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At which angle α is the power F_{res} the biggest?

- ○ F_{res} is greatest at $\alpha = 90^\circ$.
- ○ F_{res} is greatest at $\alpha = 50^\circ$.
- ○ F_{res} is greatest at $\alpha = 120^\circ$.
- ○ F_{res} is greatest at $\alpha = 0^\circ$.

Check

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Task 5

At which angle α is the power F_{res} smallest?

- F_{res} is smallest at $\alpha = 0^{\circ}$.
- F_{res} is smallest at $\alpha = 90^{\circ}$.
- F_{res} is smallest at $\alpha = 120^{\circ}$.
- F_{res} is smallest at $\alpha = 50^{\circ}$.

Check

Task 6

How do you explain this?

- As F_1 changes proportionally depending on the angle α, the diagonal of the force parallelogram always remains the same even with increasing angle α, whereby F_{res} becomes larger at larger angles. Physically speaking, with increasing angle, an ever greater proportion of the total force is transformed from F_1 to F_{res}
- As F_1 remains unchanged, the diagonal of the parallelogram of forces becomes larger with increasing angle α smaller and smaller, F_{res} then also becomes smaller at larger angles. Physically speaking, the force F_1 with increasing angle, a smaller and smaller portion of the force is placed on the roller and thus F_{res}.

Check

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Additional task 1

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Draw a parallelogram of forces for the angles 70° and 120° on a sheet of paper, from the measured values in Table 1. Define a scale for the force, e.g. $1\,N = 1\,cm$. Determine the resulting force from the diagram F_{res} and compare with the measured values from the table.

Calculate F_{res} for the two angles α according to the following formula from the forces F_1 and F_G:

$$F_{res} = F_G - F_1 \cdot sin(\alpha - 90^\circ) = F_G + F_1 \cdot cos(\alpha)$$

$\alpha\,[^\circ]$	120	70
$F_{res}\,[N]$		

Additional task 2

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Compare the results with each other. What do you find?

- [ ] The calculated values are slightly smaller than the measured values because the weight of the roll was not taken into account in the calculation.
- [ ] You can calculate the resulting force on the roller as a function of the angle α from both the measurements and the drawing.
- [ ] The calculations differ very much from the results of the measurements and the drawings.
- [ ] The calculations correspond relatively well with the measurement results.

Check

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Slide	Score / Total
Slide 20: Comparison \(F_{res}\) & \(F_g\)	**0/1**
Slide 21: Weight force of the roller	**0/1**
Slide 23: Context \(\alpha\) and \(F_{res}\)	**0/1**
Slide 24: Context \(\alpha\) and \(F_{res}\) - 2	**0/1**
Slide 25: Justification for the link \(\alpha\) and \(F_{res}\)	**0/1**
Slide 27: Comparison of the results	**0/3**

Total amount 0/8

Solutions Repeat Exporting text

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