Combination of forces; parallelogram of forces

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

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Test setup for determining the parallelogram of forces

Two forces F_1 and F_2 which act in different directions generate a resulting counterforce in a force parallelogram F_{res} which compensates for the forces. The direction of action of the forces can be chosen arbitrarily. With the help of the force parallelogram, the graphic determination of these forces is possible.

The forces can be determined analytically with the aid of the angle functions.

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Other teacher information (1/2)

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Prior

Students need a basic understanding of forces and the relationship between mass and weight force. In addition, students should also have a sound knowledge of the ways in which unidirectional and counter-directional forces interact.

Scientific

With the help of a force parallelogram the resulting force F_{res}, determine with amount and direction of action

Other teacher information (2/2)

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Learning

The students should learn how to determine a force resulting from two acting forces with magnitude and direction without the aid of the angular functions.

Tasks

The students should be able to determine the resulting force F_{res} from the direction and magnitude, which compensates two different forces F_1 and F_2 in different directions.

Remark: The evaluation can be done graphically by means of the force parallelogram without knowledge of the angular functions or can be done mathematically as an additional task if the angular functions are known. The circular disk with angular division required for evaluation is attached as a copy template. The copies should be given to the students before the experiment is carried out.

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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

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Cable-stayed bridge

As you know, forces in the same direction add, while forces in the opposite direction subtract. In a bridge, the weight is 'distributed' over a few pillars. This distribution is based on the distance between the sections of the bridge and the pillars. The design is such that the resulting forces F_{res} act vertically downwards on the pillar and are thus supported by it.

This can be described with the help of the so-called force parallelogram, which provides information about the amount and direction of the resulting force. In this experiment you will learn how to create and evaluate a force parallelogram.

Tasks

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Investigation of how the weight of a mass is absorbed by two dynamometers, which are at a certain angle to each other and relative to the vertical.

The results should be presented graphically.

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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	Weight holder, 10 g	02204-00	1
6	Slotted weight, black, 10 g	02205-01	4
7	Slotted weight, black, 50 g	02206-01	1
8	Spring balance,transparent, 1 N	03065-02	1
9	Spring balance,transparent, 2 N	03065-03	1
10	Spring balance holder	03065-20	2
11	Measuring tape, l = 2 m	09936-00	1
12	Fishing line, l. 20m	02089-00	1

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Additional equipment

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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)

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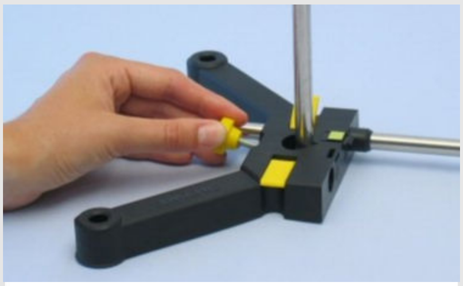
First, screw the divided support rods together to form long support rods.

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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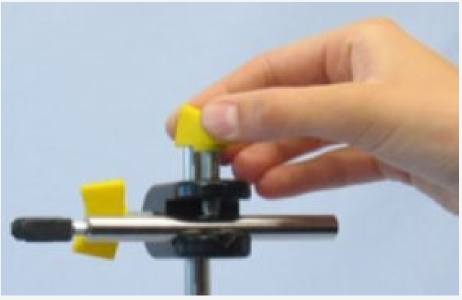
Set-up (2/3)

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)

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Load aligned force gauges with weight plate

Knot a piece of fishing line (approx. 35 cm) exactly in the middle and a loop at each end. Hang the weight plate on the middle loop of the line between the two dynamometers and load it with a total of $m = 100\,g$.

To load the weight plate with the slotted weight, the slotted weights are placed on the narrow part of the weight plate and then pushed down.

Weight plate provided with weights

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Procedure (1/4)

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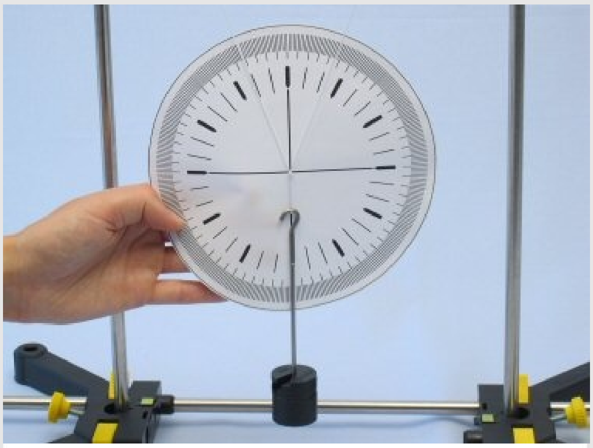

Positioning and alignment of the angle disk

- Adjust the two double sockets to the same height with the force gauges.
- Hold the angle disc so that the centre of the circle coincides with the suspension point of the mass (node on the loop in the middle of the chute) and turn the angle disc so that the direction of the weight force coincides with one of the main axes.

Procedure (2/4)

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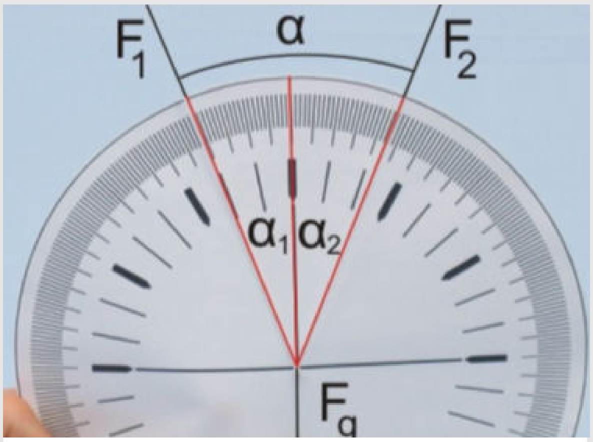

Adjusting the force gauge in the force gauge holder

- Adjust the force gauge holder of the 1 N force gauge so that the two angles α_1 and α_2, so that the forces F_1 and F_2 with the vertical are equal in size.
- In each step described below, make sure that the knot in the middle of the fishing line, and thus the suspension point of the weight force, is in the middle of the angle scale and that the direction of the weight force continues to coincide with the main axis.

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Procedure (3/4)

Extending the tripod feet

- For the following measurement the two angles should be set to the same value: $\alpha_1 = \alpha_2$.
- Set the two angles to 20°, 30°, 40° and 50° one after the other. Pull the two halves of the tripod foot apart step by step. The vertical position of the force gauge holders should not be changed.
- Check the angles each time $\alpha_1 = \alpha_2$ correspond to the specified value and then read the resulting forces F_1 and F_2. Note the values in Table 1 in the protocol.

Procedure (4/4)

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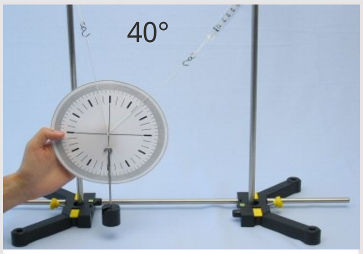
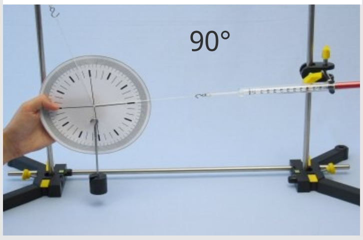


Vary the position of the force gauge (step by step)



- Now go back to the starting position.
- Move the dynamometer 1 N down step by step.
- Set the following angles for α_1 as shown in the adjacent figures : 40°, 55°, 70°, 90° and 115°.
- Read both angles and forces at each step and note the values in Table 2.

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Report

Table 1

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Enter your measured values in the table. ($m = 100\,g$, $F_g = 1\,N$)

Calculate $\alpha_{res} = \alpha_1 + \alpha_2$ and complete the table. For F_{res} see task 1.

$\alpha_1\ [^\circ]$	$\alpha_2\ [^\circ]$	$\alpha_{res}\ [^\circ]$	$F_1\ [N]$	$F_2\ [N]$	$F_{res}\ [N]$
20	20				
30	30				
40	40				
50	50				

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Table 2

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Enter your measured values in the table. ($m = 100\,g$, $F_g = 1\,N$)

Calculate $\alpha_{res} = \alpha_1 + \alpha_2$ and complete the table. For F_{res} see task 1.

$\alpha_1\ [^\circ]$	$\alpha_2\ [^\circ]$	$\alpha_{res}\ [^\circ]$	$F_1\ [N]$	$F_2\ [N]$	$F_{res}\ [N]$
40					
55					
70					
90					
115					

Task 1

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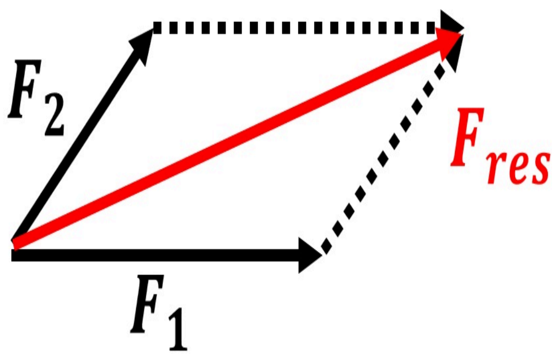

Parallelogram of forces

Draw a force parallelogram for all measured values from Table 1 and Table 2 on a sheet of paper (Table 1: same angles, Table 2: different angles). Define a scale for the force, e.g. $1\,N : 1\,cm$.

Determine the resulting forces from the diagram by drawing F_{res} and enter the values in the respective table.

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Task 2

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Compare the graphically determined values 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

Additional task

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Calculate according to $\sqrt{F_1^2 + F_2^2 + 2F_1F_2cos(\alpha)}$ the resulting force F_{calc} for some measurements and compare the values obtained with the values determined from the diagrams F_{res} for the resulting force from the drawing method.

- $F_{res} \ll F_{calc}$
- $F_{res} \approx F_{calc}$
- $F_{res} \gg F_{calc}$

Check

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Slide	Score / Total
Slide 22: Comparison \(F_{res}\) & \(F_g\)	**0/1**
Slide 23: Angular functions	**0/1**

Total amount 0/2

Solutions Repeat Exporting text

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