Reaction forces for a loaded beam

Physics > Mechanics > Forces, work, power & energy

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

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Teacher information

Application

Test setup for determining support reactions

If a beam is supported by means of two supports, the support reactions in both bearings are the same if the mass of the beam is constant over its cross section and the beam is subjected to an external load which acts exactly in the middle of the beam. However, if this or several forces are applied outside the centre, the support reactions are different. In the normal case - the statically determined case - a beam is supported by means of a classic fixed/loose bearing arrangement. In this case, the fixed bearing can transmit two bearing reactions and is therefore a two-valued bearing, whereas the floating bearing carries one bearing reaction and is a monovalent bearing.

The degree of freedom of the locating bearing is therefore 1 and that of the floating bearing is 2.

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Other teacher information (1/2)

Prior

Before carrying out this experiment, it is advisable that the students have already acquired basic knowledge about 'force and counterforce' and have experience in measuring forces and their effects. In addition, it would be an advantage if the students have already learned about the processes and moments at a lever.

Scientific

If a beam is supported at both ends and loaded L_i at intervals l_i on support A is loaded, the support reactions in the bearings are A and B usually not of the same size. The support forces here each have only one vertical component ($F_{A,y}$ and $F_{B,y}$), which can also be calculated with the help of force and moment equilibria or measured directly.

$$\Sigma\, M_A = F_{B,y} \cdot l_{Bar} \pm \Sigma\, L_i \cdot l_i = 0 \;,\; \Sigma\, F_y = F_{A,y} + F_{B,y} \pm \Sigma\, L_i = 0$$

Other teacher information (2/2)

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Learning

The students should extend their acquired knowledge about the unloaded beam and now examine the loaded beam in a similar way. This should give the students a first basic understanding of the laws of leverage.

Tasks

1. Provide a beam suspended in two bearings with an additional load.
2. Gradually vary the position of the load and the resulting support forces F_1 & F_2 determine.

Note: Make sure that the beam itself is hooked into the loops and not just the marker pins.

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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

Swing whose cross member is loaded with two forces (swings)

Beams, girders and other load-bearing elements are a central component of many structural engineering structures. Properly designed, they are capable of bearing very heavy loads or distributing them to the so-called supports (support points) of the beam. If the beam is additionally loaded with external forces, these must be taken into account during construction.

Just think, for example, of the steel beams used in a high-rise building, crossbeams in the roof truss of a pitched roof, the axles of trains or trucks, or even the suspension for swings.

In this experiment, you examine the supporting forces of a loaded beam as a function of the respective load and its distribution.

Tasks

Determine the support reactions of a beam with an additional load.

Proceed as follows:

1. Provide the beam with an additional load.
2. Vary the position of the load gradually.
3. Determine the supporting forces F_1 & F_2.

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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	Lever	03960-00	1
6	Weight holder, 10 g	02204-00	1
7	Slotted weight, black, 10 g	02205-01	2
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	Fishing line, l. 20m	02089-00	1

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Additional equipment

Position	Equipment	Quantity
1	Scissors	1

Set-up (1/3)

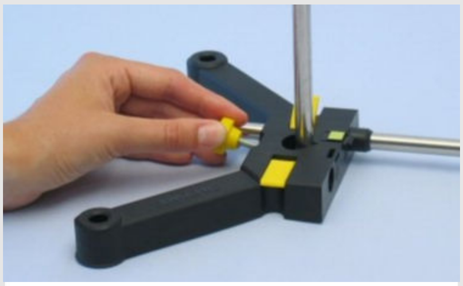
First, screw the divided support rods together to form long support rods.

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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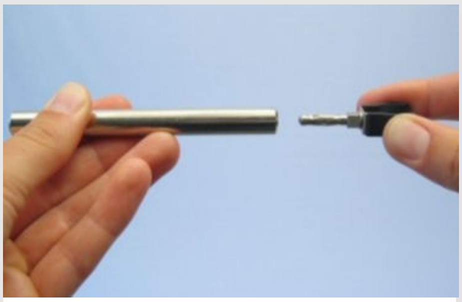
Set-up (2/3)

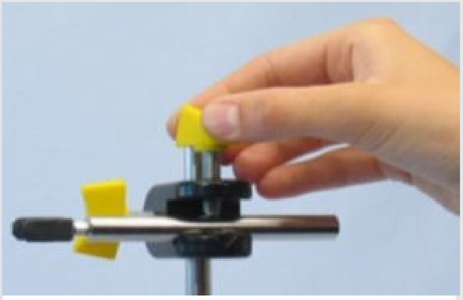
Insert the two dynamometer holders into the 100 mm tripod rods with hole.

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 vertical position of use with the screw.



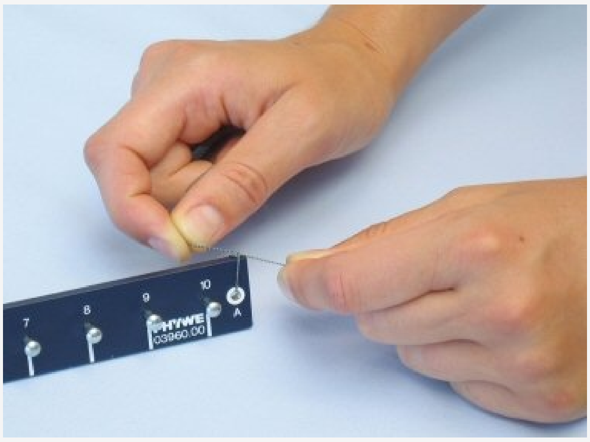
Insert the force gauge holder into the stand rod



Fixing the support rods to the double socket

Inserting and adjusting the force gauges

Set-up (3/3)



Fixing to the beam

- Cut two threads of about 10 cm each from the fishing line.
- Fasten each of these with a loop as shown in the picture to the two outer holes of the beam.
- Knot another loop at the open ends and hang the beam in the eyelets of the two dynamometers.

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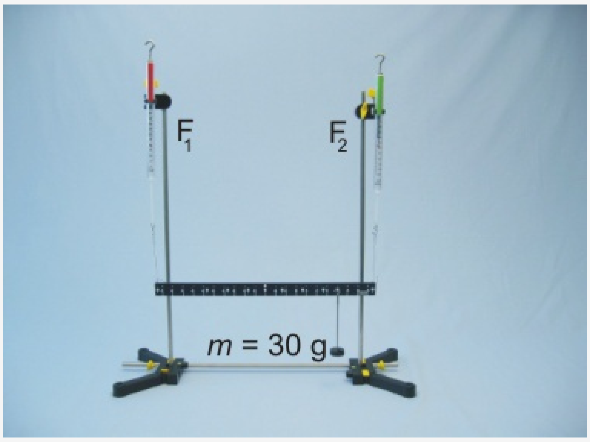
Procedure (1/3)

Steps of the beam

- Adjust the height of the dynamometer so that the beam hangs horizontally.
- Read now the powers F_1 and F_2 without additional load and note the measured values in the protocol.

Procedure (2/3)



Loading the beam and measuring the forces F_1 & F_2

- Hang the slotted weight plate with two weights 10 g ($m_{total} = 30\,g$) to the right marker '9'.
- Read the resulting forces F_1 and F_2 and record them in Table 1 of the results.
- Hang the mass stepwise from the right starting at the marks '7', '5', '3', '1' and further to the left at '1', '3', '5', '7' and '9'.
- Enter the respective measured values for F_1 and F_2 in Table 1.

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Procedure (3/3)

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Determining the weight force F_W of the beam

- Determine the weight force F_W of the beam.
- To do this, hang the beam centrally on a 2 N dynamometer and note the measured value.

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Report

Table 1

Carry the value for the weight of the beam F_W and those of the load F_{Load} in one.

$F_W =$ ______ N $F_{Load} =$ ______ N

Note the values for the forces F_1 and F_2 without additional load and calculate F_{total}.

$F_1 =$ ______ N

$F_2 =$ ______ N

$F_{total} =$ ______ N

Table 2

Enter your measured values in the table.

Calculate the sum of the forces $F_{total} = F_1 + F_2$ and enter them into the table as well.

Marking No.	$F_1\ [N]$	$F_2\ [N]$	$F_{total}\ [N]$	Marking No.	$F_1\ [N]$	$F_2\ [N]$	$F_{total}\ [N]$
-9				9			
-7				7			
-5				5			
-3				3			
-1				1			

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Task 1

Compare F_{total} from Table 2 with the weight forces F_W and F_{Load}.

What's your conclusion?

- $F_{total} > F_W + F_{Load}$
- $F_{total} < F_W + F_{Load}$
- $F_{total} = F_W + F_{Load}$

Check

Task 2

Now take a sheet of (graph) paper and draw the coordinate cross on it according to the adjoining illustration:

- y-axis: 0 N ... 1 N ($F[N]$)
- x-axis: -10 ... 10 (mark)

Now enter here the measured values for F_1 and F_2 and connect the points to a curve.

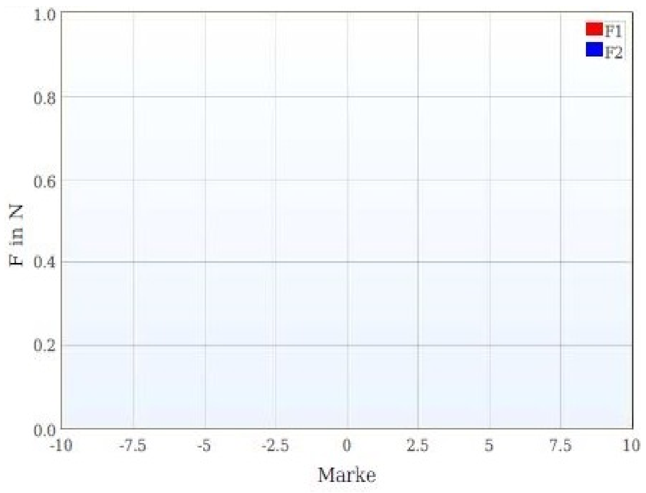

Diagram for entering the determined values

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Task 3

What tendency for the determined support forces do you notice in the diagram in relation to the position of the load?

- The bearing force of the support to which the load is closer has the higher value.
- The bearing force of the support to which the load is closer has the smaller value.

Check

Task 4

What role does the centre of gravity of the beam play in the relationship between bearing force and point of application of the load? Look at the graph of the measured values for F_1 and F_2 as a function of the position of the mass you created before.

- If the mass acts at the centre of gravity of the beam (in the middle), the forces at the supports on the left and right are equal and each amount to about half of F_{total}.
- If the mass acts at the centre of gravity of the beam (in the middle), the forces at the supports on the left and right are equal and are each approximately double the F_{total}.

Check

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Task 5

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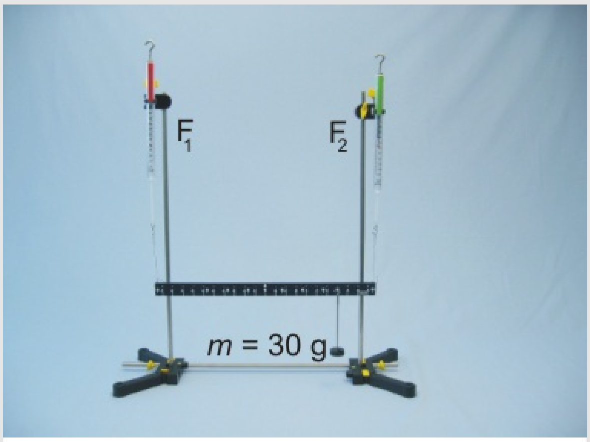

Beam with additional load

Measuring the forces F_1 & F_2

Complete the following statement:

If the mass m is moved from right to left, the force is F_2 ______ and the power F_1 ______.

bigger smaller

Check

Task 6

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How would the power F_1 (load-free end) be changed by an additional load, which is applied exactly at the right suspension point of the beam (at F_2)?

- ○ F_1 would increase by about 1/10 of the total load.
- ○ F_1 would take the same value as F_2.
- ○ F_1 would not change. ($\Delta F_1 = 0$)
- ○ F_1 would be about twice the value of F_2.

Check

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Task 7

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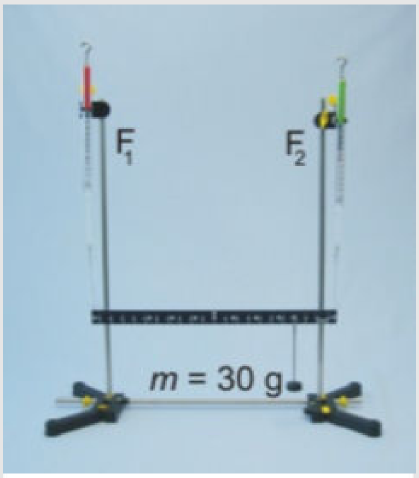

Experiment set-up

Where do the two curves for F_1 and F_2 cross?

- At the '0' marker or at the center of gravity of the bar.
- At the '10' mark at the left end of the bar.
- At the marker '10' at the right end of the bar.

Check

Slide	Score / Total
Slide 20: settlement of F_{ges} with F_G & F_{Last}	0/1
Slide 22: Support forces and position of the load 1	0/1
Slide 23: Support forces and position of the load 2	0/1
Slide 24: Variation of the position of the load	0/2
Slide 25: One-sided load	0/1
Slide 26: Point of intersection of the curves (centre of gravity)	0/1

Total amount 0/7

Solutions   Repeat   Exporting text

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