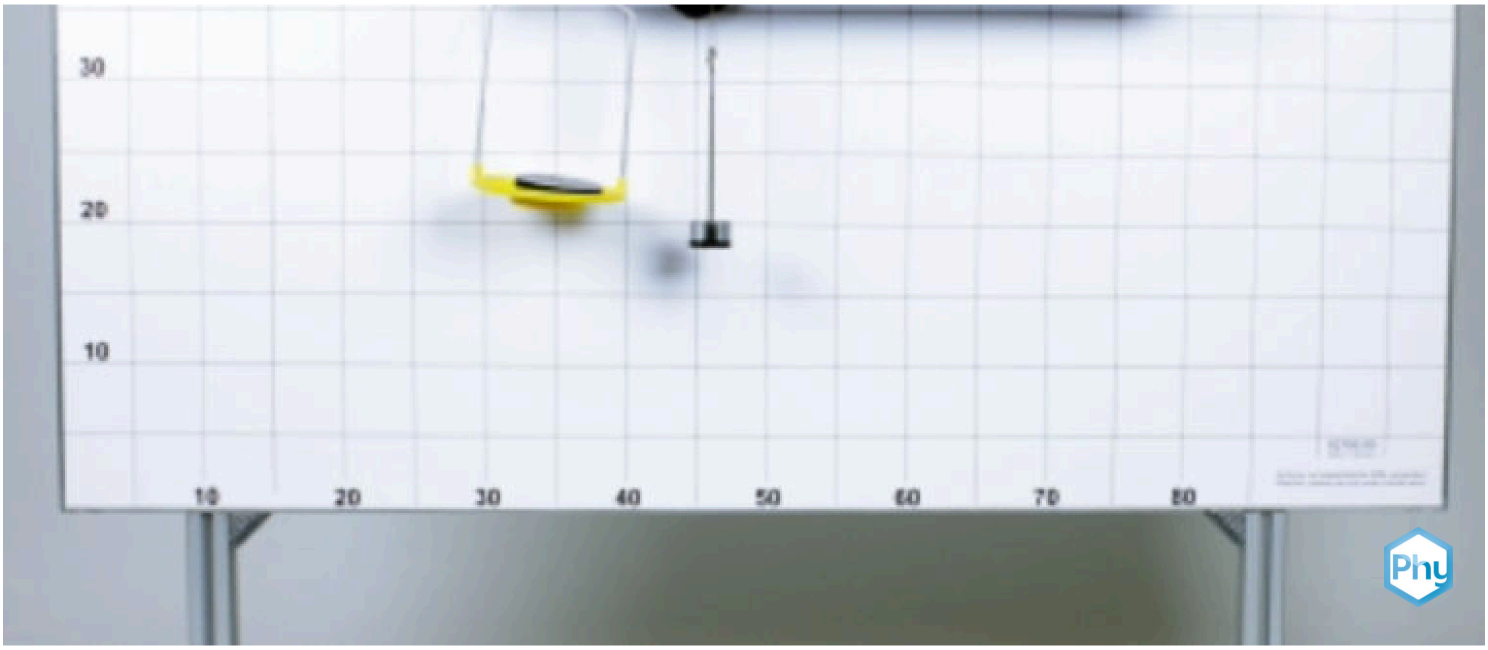
Steelyard



P1253700

Physics	Mechanics	Forces, work, power & energy

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

This content can also be found online at:

http://localhost:1337/c/663489020a117400026ef8ac

General information

Application

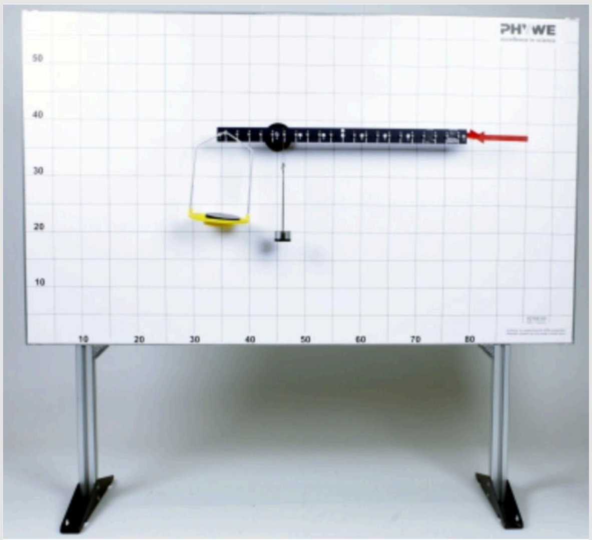


Fig. 1: Experimental setup

A steelyard consists of a pivoting suspended beam, similar to the beam scale. However, the two arms are not the same length and, unlike the beam scale, the pivot point is not exactly in the centre. The object whose mass is to be determined is hung on the shorter arm. On the longer arm, on the other hand, there is a specific weight that can be moved along this arm.

The running weight scale was already used by the Greeks, Romans and Chinese in pre-Christian times. This is why it has the nickname "Roman balance scale".

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Other information (1/2)

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Prior knowledge

The students need previous knowledge of steelyards. It is favorable if the students are already familiar with the "lever principle".

Principle

A model of a steelyard is to be built and used to determine the mass of bodies.

Other information (2/2)

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Learning objective

In this experiment, the students are supposed to understand the basics of the steelyard through examples. The students are supposed to deepen their understanding of the "lever principle".

Tasks

The students are supposed to measure and record the distances between the resting position and the centre of rotation under different loads, even if the scale is in equilibrium. Finally, a model of a steelyard is placed between the weight force F_G of the test object and the distances between the resting position and the centre of rotation.

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Safety instructions

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The general safety instructions for experimentation in science lessons apply.

Theory

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The steelyard consists of a pivoting suspended beam like the beam scale. However, the two arms are not the same length and, unlike the beam scale, the pivot point is not exactly in the centre. The object whose mass is to be determined is hung on the shorter arm. On the longer arm, on the other hand, there is a specific weight that can be moved along this arm.

The steelyard is based on the "lever principle". The lever principle is: "Effort times effort arm equals load times load arm". The lever principle relates to the torque equation.

$$\overrightarrow{M_1} = \overrightarrow{M_2}$$

and:

$$\overrightarrow{F_1} \cdot \overrightarrow{r_1} = \overrightarrow{F_2} \cdot \overrightarrow{r_2}$$

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Equipment

Position	Equipment	Item no.	Quantity
1	PHYWE Demo Physics board with stand	02150-00	1
2	Rod on fixing magnet	02151-02	1
3	Scale for demonstration board	02153-00	1
4	Pointers f. Demonst.Board, 4 pcs	02154-01	1
5	Weight holder, 10g	02204-01	1
6	Slotted weight, silver-bronze, 10 g	02205-03	4
7	Slotted weight, silver-bronze, 50 g	02206-03	2
8	Slotted weight, silver-bronze, 50 g	02206-03	2
9	Weight, 150 g, for 11060.00	11060-01	1
10	Balance pan, plastic	03951-00	1
11	Lever	03960-00	1
12	Fish line, l. 100m	02090-00	1
13	Marker, black	46402-01	1
14	Screw clamp	02014-01	2

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Setup and procedure

Structure (1/2)

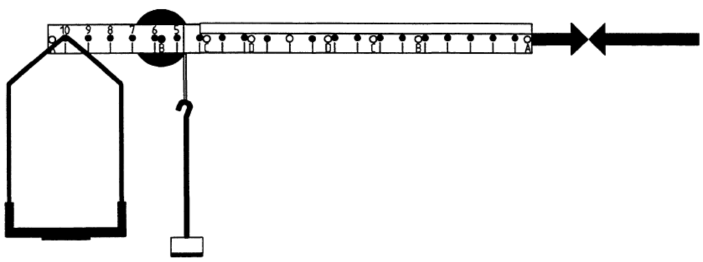

Fig. 2: Experimental setup

- Cover the upper part of the lever with an approx. 32 cm long piece of the adhesive tape; use the remainder to cut out an arrow similar to the pointer for the demo board and stick it onto the rear wall of the lever so that it protrudes sufficiently (see Fig. 2).
- Make a loop from approx. 10 cm of fishing line.

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Structure (2/2)

- Place the rod on the fixing magnet on the demo board and place the lever through the socket at point B onto the axle.
- Attach the balance pan with the 150g weight to mark no. 10 on the left, hang the weight holder loaded with a 50 g slotted weight over the right arm of the lever using the loop and move it until the lever remains horizontal.

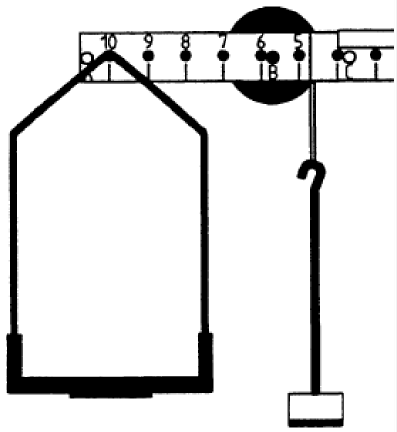

Fig. 3

Procedure

- Use the pointer for the demo board to mark the position of the arrow on the lever when the scale is balanced (see Fig. 2) and on the paper (right side of the lever) the position of the loaded weight holder that forms the moving weight (this determines the zero point of the scale for the steelyard); measure the distance l of the zero point from the pivot point (from the centre of the axle) and note it in Table 1.
- Hold the lever firmly, place a 10 g slotted weight on the balance pan and move the moving weight until the scale is in equilibrium, i.e. both arrowheads are exactly opposite each other; mark the point on the scale where the moving weight is now positioned; measure and note the distance of this point from the pivot point.
- Increase the load on the balance pan in steps of 10 g up to 200 g and proceed in the same way as before.
- Remove the slotted weights from the balance pan and use the now calibrated steelyard to determine the mass of suitable objects (measuring range 200 g, see Table 2)

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Report

Observation (1/2)

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m/g	l/cm	m/g	l/cm
0	1,2	110	17,3
10	2,7	120	18,6
20	4,2	130	20,1
30	5,6	140	21,5
40	7,1	150	23,1
50	8,5	160	24,5
60	9,9	170	26,0
70	11,4	180	27,4
80	12,8	190	28,9
90	14,3	200	30,4
100	15,7		

Table 1

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Observation (2/2)

Object on the scales	Distance of the moving weight from the centre of rotation l/ cm	Position of the moving weight on the scale in the range	Mass of the object m/g
Weight set	22,2	140...150	141
Shaft without	5,2	20...30	27

Tab. 2

Evaluation

The two-sided unequal-armed lever is in equilibrium when the clockwise and anti-clockwise torques compensate each other.

In the experiment, the acting forces are the weight forces of objects; therefore, the device, which is called a steelyard, can be used to compare weight forces and thus masses.

The unknown mass can be determined by comparing the unknown mass of a body with the known mass of standardised mass pieces.

With the steelyard, balance is achieved by changing the length of the force arm for the moving weight to the required length. Each length of the force arm corresponds to a certain mass of the object to be weighed. Based on this principle, the steelyard can be calibrated.

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Notes (1/2)

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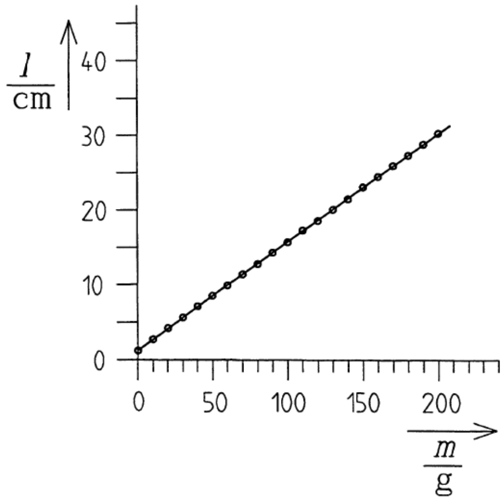

Fig. 4

Calibrating the steelyard in 10g increments results in many marks on the scale, but is very time-consuming. It is also possible to proceed in larger steps of 20g or 50g) and then subdivide the scale more finely.

The most rational way would be to define only the zero point and the end point (200 g) of the scale after measurement and then subdivide the scale linearly - as finely as desired. This is possible because a change in the counterclockwise force by the weight force F_G of the test object requires a change in the clockwise force arm proportional to this change in order to establish equilibrium on the scale:

ΔF_G Δl resp. Δl Δm (see Fig. 4).

Notes (2/2)

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The counterclockwise torque increases in proportion to the mass of the test objects (with a constant lever arm), the clockwise torque in proportion to the length of the force arm (with a constant force).

Determining the mass of the test objects (see Table 2) is only accurate to the extent that the scale divisions are small. If the mass is to be determined as accurately as possible, the required length l of the lever arm is measured and the mass is calculated using a known pair of measured values (e.g. 100 g = 15.7 cm). Otherwise, you can interpolate and obtain a good approximation of the mass, which corresponds better to the practical use of the scales.

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Task

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In which direction will the moving weight shift in this situation so that the balance is in equilibrium?

- Right
- No movement
- Left

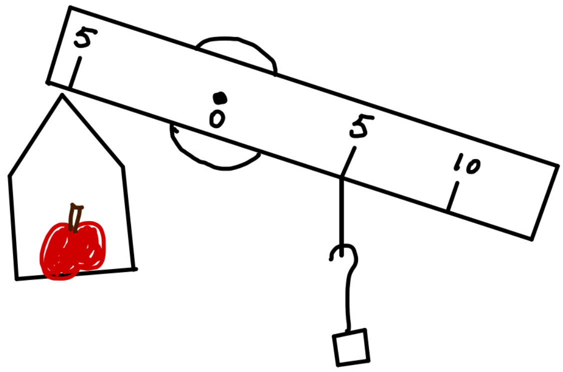

Fig. 5

Slide	Score / Total
Slide 18: Scales in balance	0/1

Total score 0 / 1

Show solutions   Repeat

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