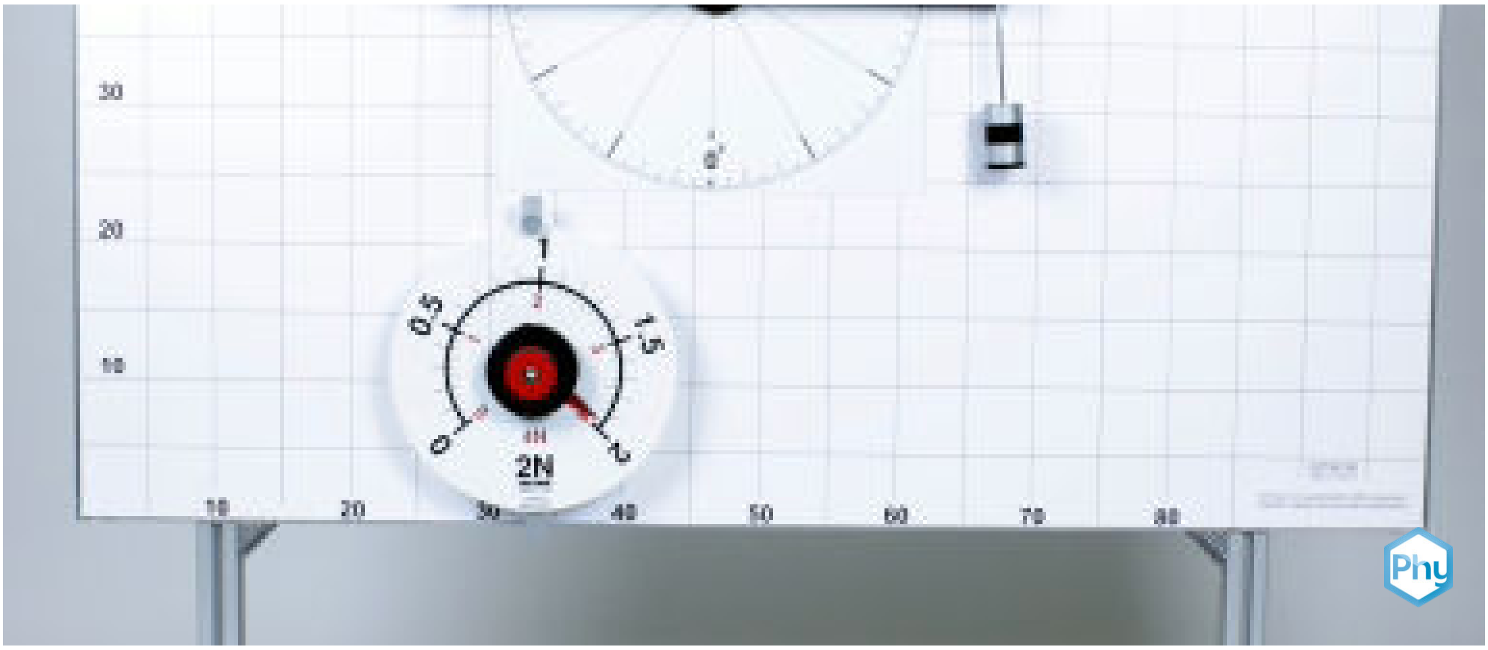
Torque



P1253500

Physics > Mechanics > Forces, work, power & energy

Applied Science > Engineering > Applied Mechanics > Statics

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/66334b3341778100023363ab

PHYWE

General information

Application

PHYWE

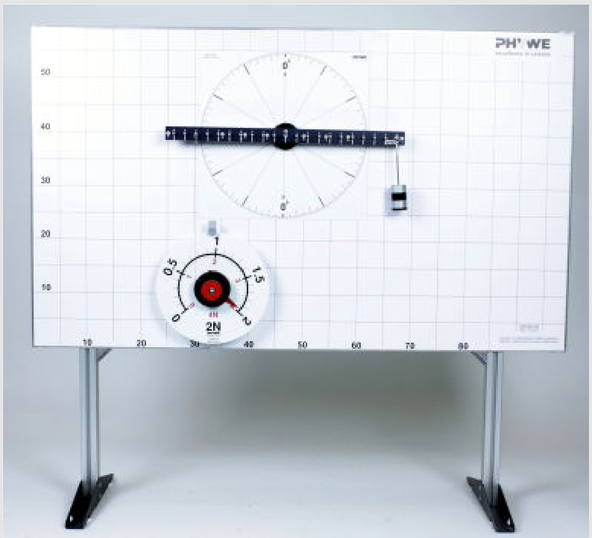


Fig. 1: Experimental setup

A torque is the externally applied force at the radius at which the point of application of the force is at its maximum distance from the centre of rotation. The torque indicates how strongly a force acts on a rotatably mounted body.

Torque is used in many different areas, e.g. robotics, mechanics, electrical engineering and the automotive industry. In everyday life, torque is used everywhere, e.g. when tightening screws or with motor shafts. When you ride a bike, you need to apply torque to the pedals to move the bike forwards. A higher torque allows you to go faster or climb a steeper incline.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Other information (1/2)

PHYWE

Prior knowledge

The students need prior knowledge of torque. It is also important to know the torque equilibrium.

Principle

The aim is to prove that a body rotating about an axis, on which forces act eccentrically, remains at rest if the torques caused by the forces compensate each other (torque equilibrium).

Other information (2/2)

PHYWE

Learning objective

In this experiment, the students are supposed to understand the torque and the torque equilibrium as an example.

Tasks

The task of this experiment is to determine the weight force F_1, the force measured by the dynamometer F_2 and the power arms l_1, l_2 and compare them in order to discover the underlying relationships.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Safety instructions

PHYWE

The general safety instructions for experimentation in science lessons apply.

Theory (1/2)

PHYWE

A torque is the externally applied force and the radius with which the point of application of the force is distanced from the centre of rotation. This indicates how strongly a force acts on a rotatably mounted body.

One force $\overrightarrow{F}$ at a vertical distance $\overrightarrow{s}$ from a fixed axis of rotation, it generates a torque $\overrightarrow{M}$ for which applies:

$$\overrightarrow{M} = \overrightarrow{s} \cdot \overrightarrow{F}$$

and

$$M = s \cdot F \cdot sin\alpha$$

α denotes the angle between the direction of force and the connecting line from the centre of rotation to the point of application of the force.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Theory (2/2)

In the experiment, a body rotating around an axis is in equilibrium, i.e. all the torques acting on it balance each other out.

If the sum of all torques acting on a specific point as a fixed axis of rotation is not equal to zero, the body rotates about this axis of rotation.

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

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	Torsion dynamometer	03069-03	2
4	Scale for demonstration board	02153-00	1
5	Weight holder, 10g	02204-01	2
6	Slotted weight, silver-bronze, 10 g	02205-03	4
7	Slotted weight, silver-bronze, 10 g	02205-03	4
8	Slotted weight, silver-bronze, 50 g	02206-03	2
9	Slotted weight, silver-bronze, 50 g	02206-03	2
10	Lever	03960-00	1
11	Optical disk, magnet held	08270-09	1
12	Marker, black	46402-01	1
13	Screw clamp	02014-01	2

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Setup and procedure

Setup

Structure 1

- Place an optical disc on the demo board.
- Using the ruler, draw lines through the centre of the disc that form angles of 15°, 30°, 45° and 60° with the horizontal line and - seen from the centre - are about 22 cm long (see Fig. 2).

Structure 2

- Place the axle and lever as in experiment 1.

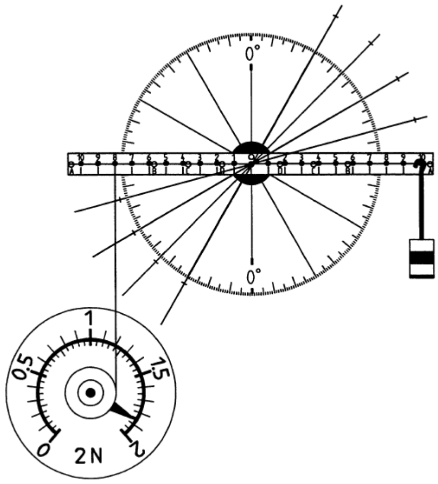


Fig. 2: Experimental setup

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Execution 1 (1/2)

PHYWE

- Load a weight holder with slotted weights (3 x 50 g), place the dynamometer on the demo board and measure the weight force F_1 for the loaded weight holder; note F_1 in table 1.
- Place the rod on fixing magnet on the optical disc so that the axle is exactly in front of the centre of the disc.
- Place the lever on the axle so that it can rotate around its centre of gravity.
- Demonstrate that the lever can remain in any position (is in equilibrium).
- Hook the weight holders onto mark no. 10 on the right and the pull cord of the dynamometer onto mark no. 8 on the left.
- Move the dynamometer until the lever is horizontal and the pull cord of the dynamometer is perpendicular to the lever (Fig. 2).

Realisation 1 (2/2)

PHYWE

- Note the force displayed by the force gauge F_2.
- Also note the length of the force arms $l_1 = l_{W1}$ and $l_2 = l_{W2}$.
- Turn the lever in the intended steps of 15°, not changing the marks at which $\overrightarrow{F_1}$ and $\overrightarrow{F_2}$ apply.
- Move the dynamometer so that its pull cord runs perpendicular to the force arm when each F_2 is to be measured; note the forces F_2.

  (Note: The angle between the force $\overrightarrow{F_2}$ and its force arm is a right one exactly when the value displayed by the dynamometer is a minimum.)
- Remove all devices except for the optical disc.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Execution 2 (1/2)

PHYWE

- Use the ruler to mark the respective points of application of the forces $\overrightarrow{F_1}$ on the lines passing through the centre of the optical disc , use the triangle to drop the plumb lines onto the horizontal line and thus determine the end points of the effective force arms $\overrightarrow{l_{W1}}$.
- Measure the force arms l_{W1} for the respective angles α (angle between force arm and force!) for F_1 and enter them in Table 1.

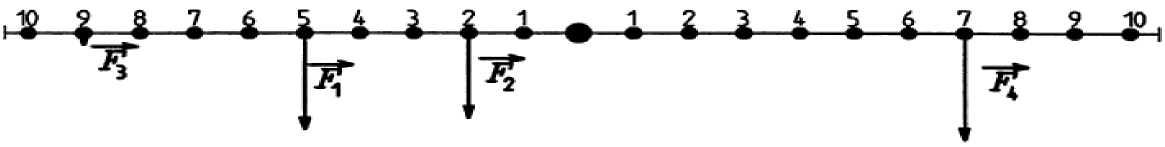


Fig. 3

Realisation 2

PHYWE

- Load the second weight holder (8 x 10 g + 1 x 50 g) and measure the weight force F_2.
- Note F_2 and weight force F_1 for the other loaded weight holder (1.54 N) in Table 2.
- Place both dynamometers on the demo board.
- Hook the pull cords of the dynamometers and both weight holders onto suitable marks on the lever (see Fig. 3 and Table 2, column 2).
- Move the dynamometer until the lever is horizontal and the pull cords are perpendicular to it.
- Measure and note F_3 and F_4 and the associated force arms.

PHYWE Robert-Bosch-Breite 10
37079 Göttingen Tel.: 0551 604 - 0
Fax: 0551 604 - 107 info@phywe.de
www.phywe.de

PHYWE

Report

Observation 1

PHYWE

$\alpha/1^\circ$	F_1/N	F_2/N	l_{W1}/N	l_{W2}/N	$\frac{F_1 \cdot l_{W1}}{N \cdot cm}$	$\frac{F_2 \cdot l_{W2}}{N \cdot cm}$
90	1,54	1,86	20,0	16,0	30,8	29,8
75	1,54	1,79	19,3	16,0	29,7	28,6
60	1,54	1,69	17,3	16,0	26,6	27,0
45	1,54	1,40	14,3	16,0	22,0	22,4
30	1,54	1,00	20,2	16,0	15,7	16,0

Table 1

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Evaluation 1 (1/2)

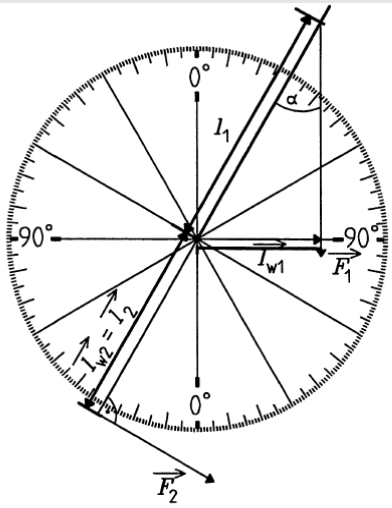


Fig. 4

Table 1 initially shows that at constant force F_1 the products $F_1 \cdot l_{W1}$ are the smaller, the smaller the angle between the force and its force arm and the smaller the (perpendicular) distance between the lines of action of $\overrightarrow{F_1}$ to the centre of rotation of the body at which $\overrightarrow{F_1}$ applies.

This distance is called the effective length l_W of the force arm l the product $F \cdot l_1$ is called torque.

This is explained by completing the sketch on the demo board (see Fig. 4; explanation for the case α = 30°).

Evaluation 1 (2/2)

Due to the torque that the force $\overrightarrow{F_1}$ exerts, the lever would be turned clockwise, i.e. to the right. This torque is counteracted by the one caused by $\overrightarrow{F_2}$. If the body (the lever) is at rest, both torques are equal. By forming the products $F_1 \cdot l_{W1}$ and $F_2 \cdot l_{W2} = F_2 \cdot l_2$ this is confirmed (see columns 6 and 7 of Table 1).

A body that is rotatable around an axis and on which forces act eccentrically remains at rest when the torques caused by the forces are cancelled out. It is then said that torque equilibrium prevails on the body.

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Observation and evaluation 2

PHYWE

Power	Mark no.	F/N	l/cm ($l = l_W$)	$\frac{F \cdot l}{N \cdot cm}$	$\frac{F \cdot l}{N \cdot cm}$
F_1	5, left	1,54	10	15,4	
F_2	2,left	1,37	4	5,5	
F_3	9,left	0,19	18	3,4	
F_4	7,right	1,72	14	24,1	24,1

Table 2

The result of experiment 1 also applies to more than two torques acting on one body.

Note 1 (1/2)

PHYWE

In experiment 2, the special case α = 90° was only selected for all forces in order to simplify the determination of the force arms. If sufficient time is available, for example $\overrightarrow{F_3}$ and $\overrightarrow{F_4}$ can apply at a different angle on the lever or the particularly complex case can be created in which the lever is at an angle and the forces $\overrightarrow{F_3}$ and $\overrightarrow{F_4}$ do not act on the lever at right angles. The torque is a vectorial quantity, namely the cross product of force and vectorial force arm:

$$\overrightarrow{M} = \overrightarrow{F} \cdot \overrightarrow{l}$$

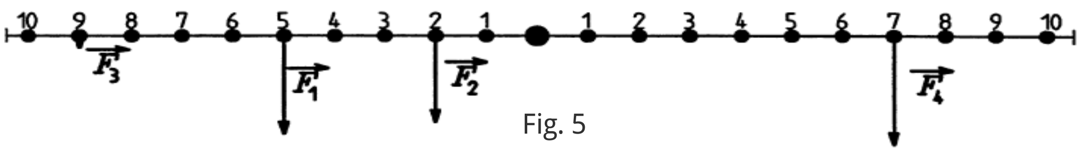


Fig. 5

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Note 1 (2/2)

The following applies to the amounts:

$|\vec{M}| = M = |\vec{F} \cdot \vec{l}| = F \cdot l \cdot sin\alpha$,

whereby α is the angle that $\vec{F}$ and $\vec{l}$ include. $\vec{F}$ and $\vec{l}$ build a vector parallelogram on which the vector $\vec{M}$ stands perpendicular.

Analysing the experiments is much easier if the students have the relevant knowledge of trigonometry. Then l_w can be calculated through $l_W = sin\alpha$. However, the auxiliary lines through the centre of the optical disc should still be drawn because they facilitate the exact setting of the angles α.

Task

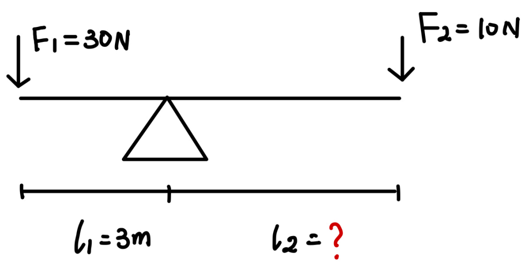
$F_1 = 30N$

$F_2 = 10N$

$l_1 = 3m$

How big is l_2 so that the lever remains balanced?

- l_2 = 9 m
- l_2 = 7 m
- l_2 = 10 m



PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Slide	Score / Total
Slide 22: Levers in balance	0/1

Total score 0 / 1

Show solutions Repeat