Moment of rotation (torque) (Item No.: P1253500)

Curricular Relevance

Area of Expertise: Physics

Education Level: Age 14-16

Topic: Mechanics

Subtopic: Forces, simple machines

Experiment: Moment of rotation (torque)

Difficulty

Intermediate

Preparation Time

10 Minutes

Execution Time

10 Minutes

Recommended Group Size

1 Student

Additional Requirements:

- Triangle (set square)

Experiment Variations:

Keywords:

Principle and equipment

Principle

Demonstrate that a body which can be rotated about an axis on which forces act eccentrically remains at rest if it is counterbalanced by the torques induced by the forces (equilibrium of torques).

Equipment

Position No.	Material	Order No.	Quantity
1	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 for slotted weights	02204-00	2
6	Slotted weight, black, 10 g	02205-01	4
7	Slotted weight, silver bronze, 10 g	02205-02	4
8	Slotted weight, black, 50 g	02206-01	2
9	Slotted weight, silver bronze, 50 g	02206-02	2
10	Lever	03960-00	1
11	Optical disk, magnet held	08270-09	1
12	Marker, black	46402-01	1
Additional material:			
13	Triangle (set square)		

Robert-Bosch-Breite 10
D - 37079 Göttingen

Tel: +49 551 604 - 0
Fax: +49 551 604 - 107

info@phywe.de
www.phywe.com

Set-up and procedure

Set-up

Procedure

Procedure 1

- Load one weight holder with slotted weights (3 x 1 50 g). Place a dynamometer onto the demonstration board and measure the weight F_1 of the loaded weight holder. Record F_1 in Table 1.
- Place the axle on fixing magnet onto the protractor disk in such a manner that the axle is located directly at the centre of the disk.
- Place the lever onto the axle such that the former can be rotated about its centre of gravity.
- Demonstrate that the lever can remain in any position (is in equilibrium).
- Hang the weight holder in the hole at the right #10 index mark and the traction cord of the dynamometer at the left #8 index mark. Shift the dynamometer until the lever is horizontal and the traction cord of the dynamometer is perpendicular to the lever (Fig. 1).
- Record the force F_2 indicated by the dynamometer.
- Also note the length of the power arms $l_1 = l_{W1}$ and $l_2 = l_{W2}$.
- Rotate the lever by the intended intervals of 15°; do not change the index marks on which $\overrightarrow{F_1}$ and $\overrightarrow{F_2}$ act. In each case move the dynamometer such that its traction cord is perpendicular to the force arm when F_2 is to be measured. Record the respective forces F_2 .

  Note: The angle between the force $\overrightarrow{F_2}$ and its power arm is exactly a right angle when the force indicated by the dynamometer is at its minimum.
- Remove all devices except for the protractor disk.
- With the scale on the lines which pass through the centre of the protractor disk mark the respective points of application of the forces $\overrightarrow{F_1}$. Using the triangle, drop a perpendicular to the horizontal line, thus determining the end point of the effective power arms l_{W1}.
- Measure the effective power arms l_{W1} for F_1 for the angle α (angle between power arm and force); record the values in Table 1.

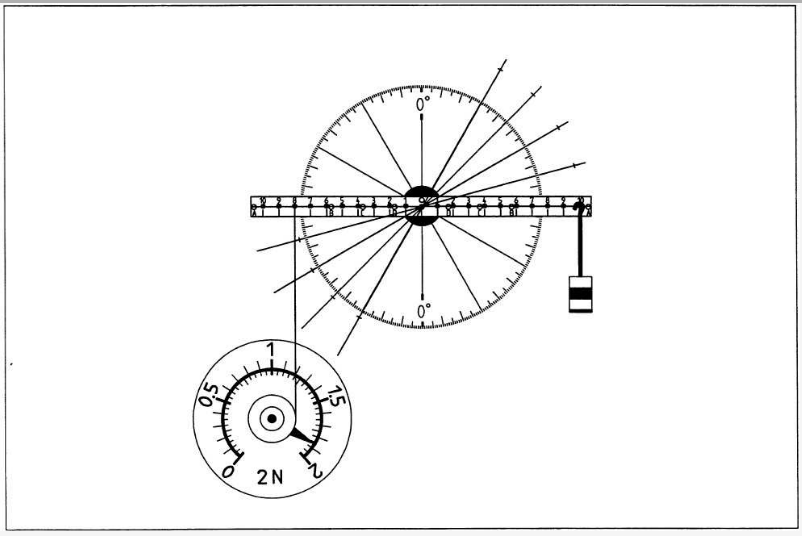

Fig. 1

Procedure 2

- Load the second weight holder (8 x 1 0 g + 1 x 50 g) and measure its weight F_2 .
- Record F_2 and weight F_1 for the other loaded weight holder (1.54 N) in Table 2.
- Place both dynamometers onto the demonstration board.

- Hook the traction cords of the dynamometers and the two weight holders into appropriate holes (index marks) on the lever (cf. Fig. 3 and Table 2, column 2).
- Change the positions of the dynamometers until the lever is horizontal and the traction cords are perpendicular to it.
- Measure and record F_3 and F_4 as well as the respective power arms.

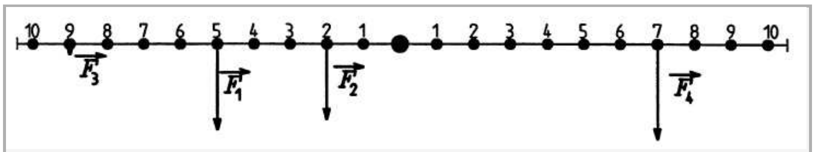

Fig. 2

Observation and evaluation

Observation

Evaluation

Evaluation 1

From Table 1 , it first follows that for a constant force F_1 , the smaller the angle between the force and its power arm - and thus the smaller the (vertical) distance between the lines of action of $\overrightarrow{F_1}$ and the fulcrum of the body on which $\overrightarrow{F_1}$ acts - the smaller the products $F_1 \cdot I_{W1}$. This distance is termed the effective length I_w of the power arm I; the product $F_1 \cdot I_{W1}$, the moment of rotation (torque).

This is to be explained while the drawing on the demonstration board is being completed (cf. Fig. 2; explanation for the case where α= 30°).

As a result of the torque produced by the force $\overrightarrow{F_1}$, the lever is turned clockwise, i.e. to the right. This torque acts against the one resulting from $\overrightarrow{F_2}$: . If the body (the lever) is at rest, the moments of rotation (the torques) are equal. If the products $F_1 * l_{W1}$ und $F_2 * l_{W2} = F_2 * l_2$, are formed, this fact will be confirmed (cf. columns 6 and 7 in Table 1).

A body which can be rotated about an axis and on which forces act eccentrically remains at rest if the moments of rotation produced by the forces counterbalance each other. It is then said that the body is in moment-of-rotation (torque) equilibrium.

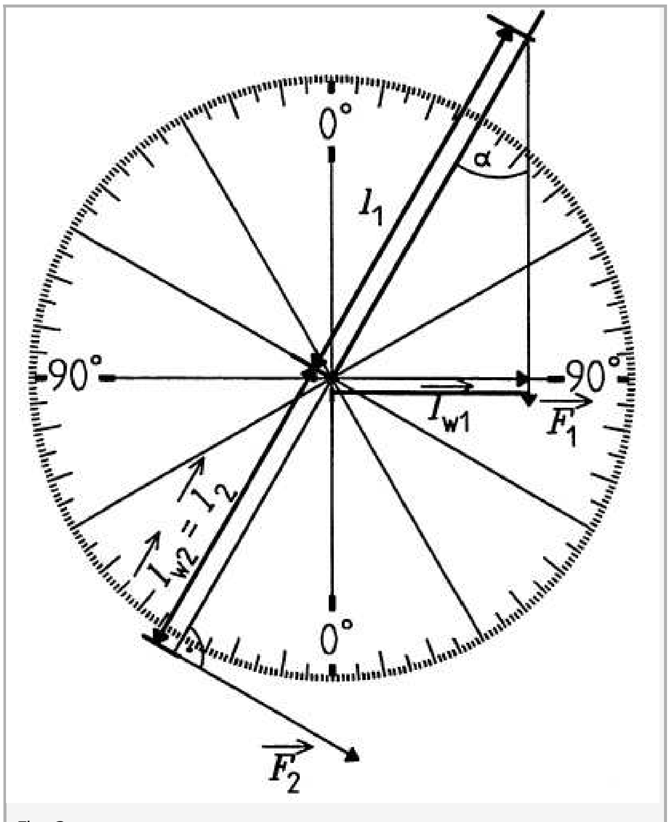

Fig. 3

Evaluation 2

The results of Experiment 1 also apply for more than two moments of rotation which act on a body.

Remarks

$\overrightarrow{F_3}$ and $\overrightarrow{F_4}$

The special case where α = 90° for all forces was chosen in Experiment 2 solely because it simplifies the determination of the power arms. If there is sufficient time available, one can, e.g., allow $\overrightarrow{F_3}$ and $\overrightarrow{F_4}$ to act on the lever at another angle or prepare the particularly involved case in which neither the lever is horizontal nor do the forces $\overrightarrow{F_3}$ and $\overrightarrow{F_4}$ act at a right angle to it.

The moment of rotation (torque) is a vectorial quantity; indeed, it is the cross product of force and vectorial power arm: $\vec{M} = \vec{F} * \vec{l}$.

For the values obtained here, the following is true:

$$\left|\vec{M}\right| = M = \left|\vec{F} * \vec{l}\right| = F * l * \sin\alpha ,$$

where α is the angle enclosed by $\vec{F}$ und $\vec{l}$. $\vec{F}$ and $\vec{l}$ define a vector parallelogram, to which the vector $\vec{M}$ is perpendicular.

The evaluation of the experiments will be greatly facilitated if the students have appropriate knowledge of trigonometry. In that case, one can calculate /w according to l_w according to $l_W = \sin\alpha$. The guide lines through the centre of the protractor disk should however also be drawn in this case because they facilitate the exact definition of the angle α.

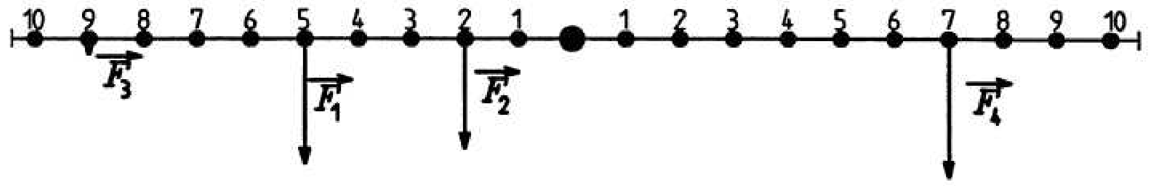

Fig. 3