Restoring force on a displaced pendulum

Using a thread pendulum, investigate how large the force with which the displaced pendulum approaches its resting position is.
In addition, investigate how this force, which is termed the restoring force, depends on the angle of displacement of the pendulum and how one can calculate it.

Equipment

Demonstration board for physics	02150.00	1
Axle on fixing magnet	02151.02	1
Torsion dynamometer, 2 N/4 N	03069.03	1
Scale for demonstration board	02153.00	1
Weight holder for slotted weights	02204.00	1
Slotted weight, 10 g, black	02205.01	2
Slotted weight, 10 g, silver	02205.02	2
Slotted weight, 50 g, black	02206.01	1
Slotted weight, 50 g, silver	02206.02	2
Protractor disk, magnet held	08270.09	1
Fish line, 1 m from	02090.00	1
White board pen, water soluble		

Set-up

— Prepare a piece of fish line which is approximately 40 cm long and has two terminal loops.

— Arrange the slotted weights on the weight holder as shown in Fig. 1. Determine the centre of gravity of this body which is intended to be the pendulum bob (it lies approximately between the second and the third 50-g slotted weight, starting from the weight holder).

— Place the protractor disk onto the demonstration board in such a manner that the line $\overline{00}$ is vertical and the disk extends beyond the upper edge of the board.

— With the white board pen extend the line $\overline{00}$ almost to the lower edge of the board.

— Place the axle on fixing magnet in the centre of the protractor disk.

Procedure

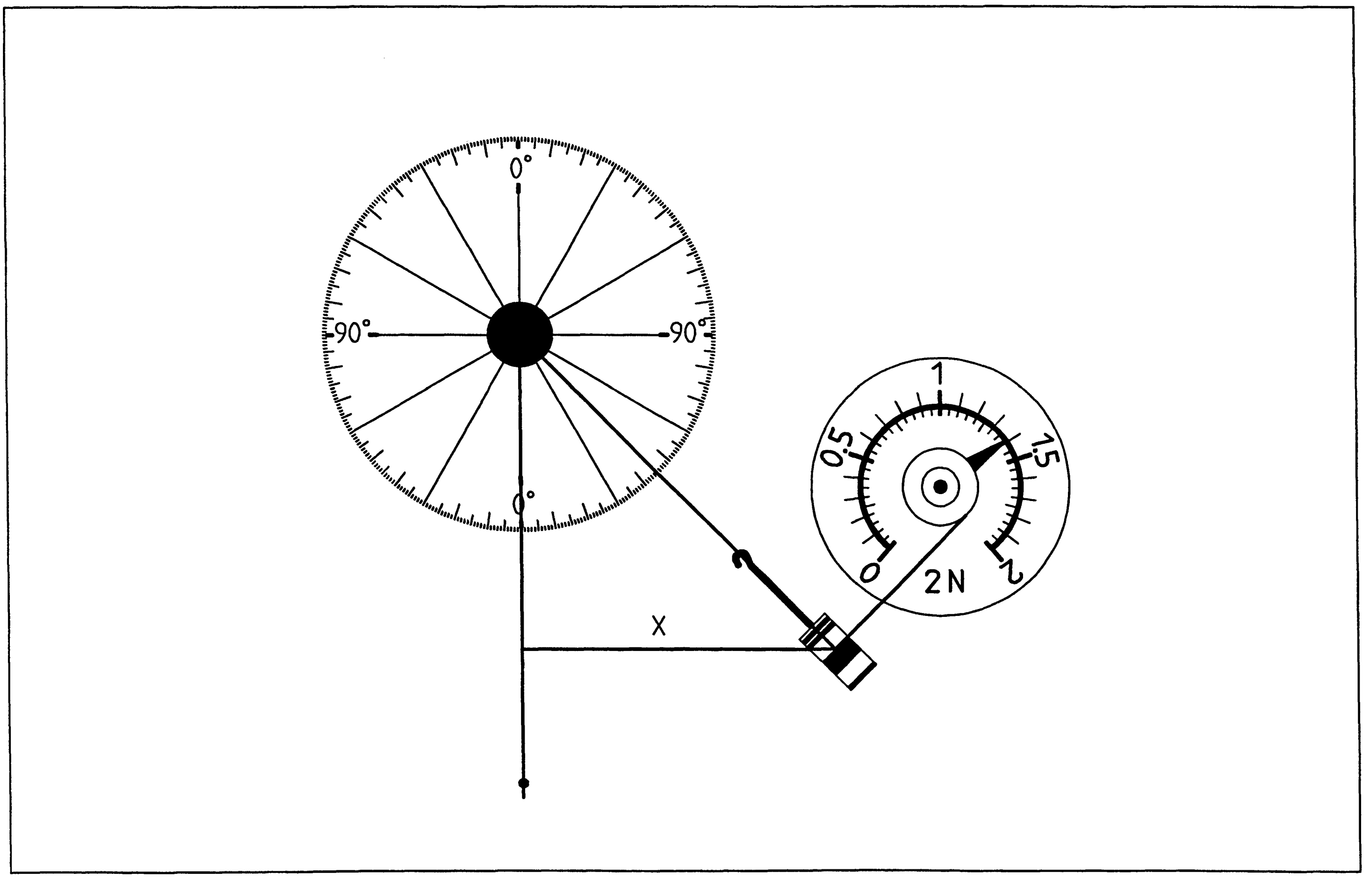
— Measure and note the weight F_G of the pendulum bob.

— Hang the pendulum bob on the axle with the prepared cord.

— Mark the position of the pendulum bob's centre of gravity on the vertical line on the demonstration board (Fig. 1).

— Measure and record the length of the pendulum l.

Fig. 1



— Displace the pendulum and allow it to oscillate; note your observation.
— Stop the pendulum.
— Place the dynamometer onto the demonstration board and hook the traction cord at the centre of gravity of the pendulum bob.
— Set the dynamometer to 0 and shift it until the pendulum has been displaced by 15° and the traction cord of the dynamometer forms a right angle with the pendulum's thread.
— Mark the position of the centre of gravity of the displaced pendulum bob on the board.
— Read the indicated force F_r; then measure the distance x between the pendulum bob's centre of gravity and the drawn perpendicular line. Record F_R and x in Table 1.
— Repeat the measurements in steps of 15° each and record the measured values.

Results

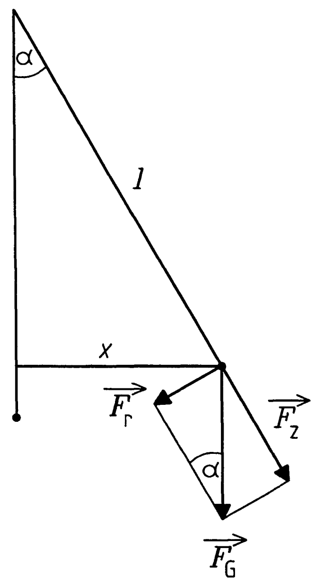
F_G = 1.94 N
l = 48.5 cm

Observation: After the displaced pendulum is released, it oscillates around its resting position.

Table 1 (sample measurement)

α / 1°	F_r / N	x / cm	F_r / F_G	x / l
15	0.51	12.6	0.26	0.26
30	0.97	24.0	0.50	0.49
45	1.39	34.2	0.72	0.71
60	1.65	42.0	0.85	0.87

Fig. 2



Evaluation

The pendulum which has been displaced to the right is accelerated to the left by the restoration force $\vec{F}_r$ back to its resting position; due to its inertia it swings beyond this position. The restoration force is equal to zero in the resting position, then however it again becomes larger and swings the pendulum to the right in the direction of the resting position.

As the students can predict, the larger the distance x or the angle α is, the larger F_r is. This is confirmed by the measurements.

The calculation of the quotients $F_r/F_G = x/l$ (cf. Table 1) demonstrates the following: $F_r/F_G = x/l$ or $F_r = F_G \cdot x/l$.

This result is corroborated by the completion of the diagram on the demonstration board (cf. Fig. 2 and Fig. 3). In the process, the student's knowledge of the similarity of triangles is used.

Remarks

If the students have knowledge of trigonometry, then the result can also be written in the form $F_r/F_G = \sin\alpha$ or $F_r = F_G \cdot \sin\alpha$. And in this case, the measurement of x can be omitted, if desired.

In connection with the discussion of the relationship between F_r and F_G, the second component of $\vec{F}_G$ should also be interpreted: it is a tractive force (in Fig. 2 designated $\vec{F}_Z$), which spans the pendulum.

Fig. 3