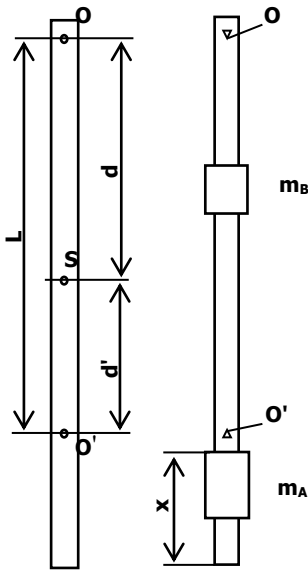


## 2 - SIMPLE HARMONIC VIBRATIONS: REVERSIBLE PENDULUM AND TORSION PENDULUM

### I. Determination of acceleration due to a reversible pendulum

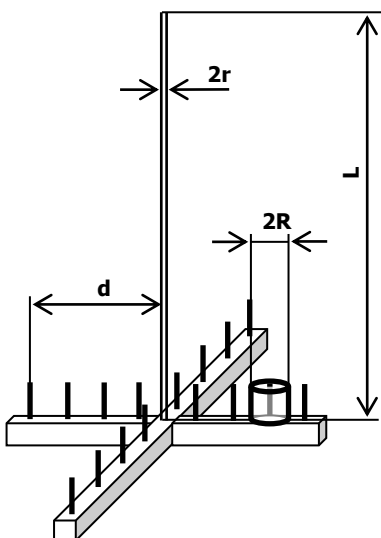


1. The weight  $m_B$  (located between the axes) should be approximately halfway between the axes. Do not change its position during the measurement. First, check that its position is correct:
  - a. We make four measurements of twenty periods of oscillation of a pendulum in four configurations:
    - $m_A$  weight near the  $O'$  axis, rotation about the  $O'$  axis
    - $m_A$  weight near the  $O'$  axis, rotation about the  $O'$  axis
    - $m_A$  weight at maximum distance from  $O'$  axis, rotation about the  $O'$  axis
    - $m_A$  weight at maximum distance from the  $O'$  axis, rotation about the  $O'$  axis
  - b. Plot the measured periods of vibration for both positions of the weight and both axes of rotation on the graph and check whether the predicted curves intersect in the measuring range. If so, measurements may be taken; if not, the position of the weight  $m_B$  should be changed, but only with the agreement of the experimenter.
2. We start the measurements. Place the  $m_A$  weight closest to the  $O'$  axis.
3. We swing the pendulum and measure the time of twenty periods of oscillation about the axis  $O$ .  
The pendulum must be tilted by the same angle each time.
4. Turn the pendulum over and measure the time taken for 20 oscillations about the  $O'$  axis (two or three times).
5. The pendulum will move the  $m_A$  weight by 3 cm, measure the time of 20 oscillations about the  $O$  and  $O'$  axes again, and proceed until the  $m_A$  weight is at the end of the pendulum. Record the measurement results in the table.

|                        |   |   |   |   |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|------------------------|---|---|---|---|-----|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| $L =$                  |   |   |   |   |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $x$ [cm]               | 0 | 3 | 6 | 9 | ... |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $t_0$                  |   |   |   |   |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $T_0 = t_0 / 20$       |   |   |   |   |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $t_{O'}$               |   |   |   |   |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $T_{O'} = t_{O'} / 20$ |   |   |   |   |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

6. After measuring and determining the periods of oscillations of the pendulum suspended on the axis  $O'-T_{O'}$  and the axis  $O-T_0$  as a function of the position of the moving mass  $m_A - x$ , we make a graph of two relations  $T_0 = T_0(x)$  and  $T_{O'} = T_{O'}(x)$  (dependence of the periods of oscillations of the pendulum from the distance of the moving mass from the selected axis of rotation).
7. Find the point of intersection of the curves  $T_0(x)$  graphically and  $T_{O'}(x)$  (these are not lines!!!) - the point  $(x_0, T)$ .
8. Measure the distance  $L$  between the axes (the reduced length).
9. Base the determined value of  $T$  and the measured value of  $L$  on the formula  $g = 4\pi^2 L / T^2$ , from which we calculate the value of acceleration due to gravity.
10. Calculate the combined uncertainty  $u_c$  of the measured quantity. Calculate the expanded uncertainty  $U_c$ .
11. Compare the measured value with the table value and evaluate the correctness of the measurement method used.

### II. Determination of modulus of elasticity using a torsion pendulum



1. Use a micrometre screw to measure the diameter of the test rod ( $2r$ ) several times (ideally 10) at various points.
2. Measure the length of the test rod ( $L$ ) with a linear tape measure.
3. Measure the diameters of  $n$  additional weights ( $2R$ ).
4. Weigh  $n$  additional weights.
5. Measure the distance between the pins where you place these weights ( $2d$ ).
6. Make the vibrator move, either unloaded or with a "preload". Measure the time  $t_1$  of twenty periods of vibration (five times).
7. After placing the weights on the pins, vibrate the vibrator again. Measure time  $t_2$  of twenty periods (five times).
8. Once all measurements have been taken, determine  $T_1$  and  $T_2$ , and calculate the mean values of  $r$ ,  $L$ ,  $R$ ,  $m$ .
9. Determine the magnitude of  $G$  from the formula given in the instructions.
10. Determine the standard uncertainties of all quantities measured directly. Determine whether the uncertainty is of the Type A or Type B method for each uncertainty.
11. Determine the combined uncertainty and the expanded quantity uncertainty  $G$ . Correctly record the results.
12. Compare the determined value of  $G$  with the tabulated value (is the found quantity within the uncertainty range).