EXPERIMENT 4

Pendulum

GOAL

- Setting up a pendulum
- Measurement of the gravitational acceleration of Earth

THEORY

A pendulum is a physical system consisting of a pivot and a weight ("bob") suspended from the pivot by a cord/rope. We call this system as simple pendulum if the cord/rope is weightless. The simple pendulum is considered as an idealized model of pendulum.

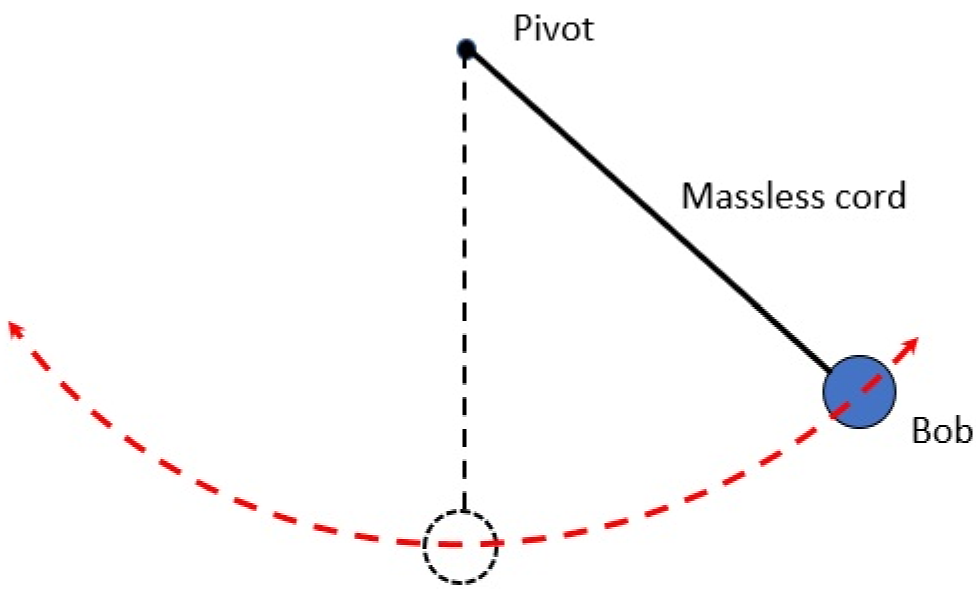

Fig. 1. Simple Pendulum

The pendulum is in equilibrium state (the dashed image on Fig. 1) while the cord is in vertical position. If we displace the bob from the equilibrium state and release it a restoring gravity force will accelerate it back, toward the equilibrium position. Then the bob will pass the equilibrium position and swing back and forth. The time required for one complete cycle is called ***period***. The period of the simple pendulum depends on the length of the cord and the gravitational acceleration of Earth at the location where the measurement is conducted. This dependence can be expressed by the following formula:

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad (1)$$

where l is the length, and g is the local gravitational acceleration of Earth.

To determine the gravitational acceleration, we will modify the formula using simple mathematical operations:

$$T = \frac{2\pi}{\sqrt{g}}\sqrt{l} \qquad (2)$$

The formula (2) remind us the equation of a line,

$$y = ax + b \qquad (3)$$

where a is the slope and b is the y-intercept of the line.

Comparing formulae (2) and (3), we can conclude that the graph of the dependence T vs. $\sqrt{l}$ will give us a line with the slope equal to $\frac{2\pi}{\sqrt{g}}$. We can determine the value of this slope from the best fitting line of the dependence T vs. $\sqrt{l}$ and then evaluate the gravitational acceleration as

$$g = \left(\frac{2\pi}{a}\right)^2 \qquad (4)$$

PROCEDURE

We cannot construct a simple pendulum in principle, because any cord has a mass. However, if the mass of the cord much less than the mass of the bob, we can use the pendulum to determine the gravitational acceleration within some accuracy. It is also recommended to use a small size object as a bob. This will let us to minimize the air resistance and ignore the rotation of the bob along its axis. Explanation of effect of these two factor is beyond of this manual.

Very often the time required for one cycle of the pendulum is too short, which makes the measurement of the period difficult. It is recommended to measure the duration t of a certain numbers of cycles, n, and then determine the period as $T = \frac{t}{n}$. The time t can be measured by a timer. If a special timer, you can use a timer of your cell phone.

Measurements

1. Construct a pendulum considering the recommendations provided above.
2. Perform measurements for various values of l and complete the following table:

l (meters)	$\sqrt{\boldsymbol{l}}$ ($\sqrt{\text{meters}}$)	***t*** (seconds)	***n***	***T*** (seconds)

3. Create a graph *T* vs. $\sqrt{l}$ using Excel program.
4. Based on the best-fit analysis and formula (4), determine the gravitational acceleration.