Home Experiments

This page describes two simple experiments that you can do at home to practise good research methods. Although the scientific content of these experiments is elementary, the task of doing them well and writing them up at a professional level is a skill that requires experience.

Doing the Experiments

When doing the experiments you should write complete notes on your work in a notebook. Write these notes *while you are doing the experiment*, not at a later time. Your notes will include the following items:

- A suitable title.
- A statement of the objective of the experiment.
- An account of the theory used.
- A description of the equipment used, including a sketch of the apparatus.
- A description of the experimental method.
- Notes on the precautions needed to ensure that the experiment is well done.
- A complete record of the measurements you make, plotted on a graph if appropriate.
- Estimates of the uncertainty of each individual measurement.
- Calculations of the results and their uncertainties. *Make these calculations immediately after recording the measurements*. You will then know whether a result was satisfactory, or the measurements should be repeated.
- The conclusions drawn from your measurements and calculations.
- A comparison of your results with the theory, or with the results published by other researchers.

Writing the Report

The contents of your final report will be taken from the items listed above. The report should be written in the professional style required for publications, *not like the simplified notes written by school children and undergraduates*.

Measurement of the Circle Constant

The **circle constant** is the circumference c of a circle divided by the radius r. It is written as the Greek letter tau $\tau = c/r = 6.2831853...$. Tau is irrational, so it is represented by an infinite non-recurring decimal number. There are good mathematical reasons for using tau instead of the more usual pi = circumference/diameter (see Michael Hartl, *The Tau Manifesto*, 2011, available online).

The Circumference Method

Take a variety of circular objects of different sizes. Measure the radius and the circumference of each object. Calculate c/r for each object.

Estimate the absolute values $|\Delta c|$ and $|\Delta r|$ of the uncertainties for each measurement. Calculate the estimated uncertainty in c/r by the formula

$$|\Delta(c/r)| = (|\Delta c|/c + |\Delta r|/r)(c/r).$$

Compare your results with the theoretical value of τ by seeing whether or not the theoretical value $\tau = 6.283...$ lies within the interval

$$c/r \pm |\Delta(c/r)|.$$

The value of tau given above is for a plane circle. If the circle is on a convex surface, such as a sphere, then the radius measured on the surface will be bigger than the radius on a plane and $c/r < \tau$. If the circle is on a saddle-shaped surface, then the circumference will be bigger than the circumference on a plane and $c/r > \tau$. If the shape of the object used is not a perfect circle, then c/r may be greater than or less than tau.

The Area Method

Let dc be a differential increment of the circumference of a circle. Then the triangle with base dc and apex at the center of the circle has height r and area $\mathrm{d}A = \frac{1}{2}r\mathrm{d}c$. The area A of the whole circle is given by

$$A = \int \mathrm{d}A = \tfrac{1}{2}r\int \mathrm{d}c = \tfrac{1}{2}rc = \tfrac{1}{2}\tau r^2.$$

Draw circles of different sizes on graph paper ruled in millimeter squares. Determine the areas of your circles by counting the number of millimeter squares that lie inside the perimeter of each circle. Millimeter squares more than half of which lie inside the perimeter should be counted. Millimeter squares more than half of which lie outside the perimeter should not be counted.

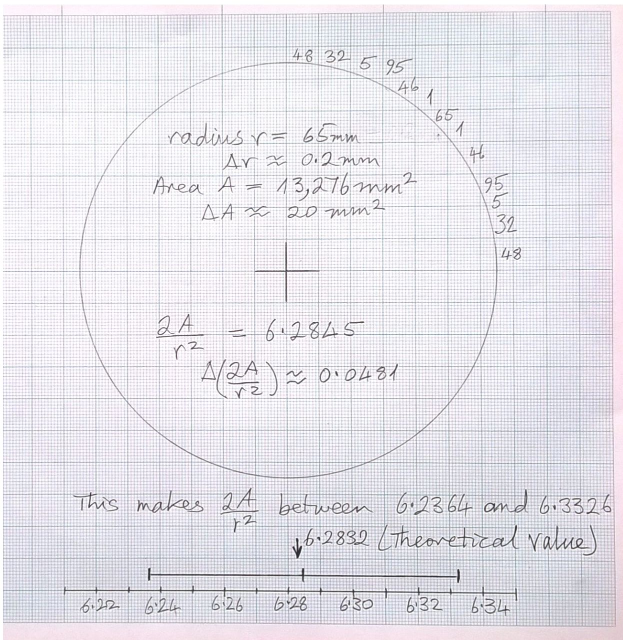
Calculate the value of $2A/r^2$ for each circle.

Estimate the absolute values $|\Delta r|$ and $|\Delta A|$ of the uncertainties for each measurement. Calculate the estimated uncertainty in $2A/r^2$ by the formula

$$|\Delta(2A/r^2)| = (|\Delta A|/A + 2|\Delta r|/r)(2A/r^2).$$

Compare your results with the theoretical value of τ by seeing whether or not the theoretical value $\tau = 6.283...$ lies within the interval

$$2A/r^2 \pm |\Delta(2A/r^2)|.$$



Example.

Measurement of the Acceleration of Gravity Using a Pendulum

The periodic time T of a simple pendulum with length L swinging in a gravitational field with acceleration g is given by

$$T = \tau\sqrt{(L/g)},$$

where τ is the circle constant, approximately 6.2832.

Make a simple pendulum by hanging a small heavy object on a thin string from a firm support. The heavy object should be small so that you can determine its center of gravity accurately. The thin string should be flexible but should not stretch. The firm support should not move when the pendulum swings.

Measure the length L of the pendulum from the point of suspension to the center of gravity of the heavy object. Use a stop watch to measure the periodic time T of the pendulum. The amplitude of the swings should be small, but you should time as many cycles as possible and divide by the number of cycles to get an accurate value for T. Do the experiment in still air with no wind.

Repeat the measurements with different lengths, approximately 0.5 m, 1 m, 1.5 m, and 2.0 m.

Graphical Plot

To test the theory that T is proportional to $\sqrt{L}$ plot a graph of your results with L on the horizontal axis and T^2 on the vertical axis. You should get a straight line through the origin. Find the value of $g = \tau^2 L/T^2$ from the slope of your graph.

Comparison of Result with Published Value

Calculate $\tau^2 L/T^2$ for each length of the pendulum.

Estimate the absolute values $|\Delta L|$ and $|\Delta T|$ of the uncertainties for each length of the pendulum. Calculate the estimated uncertainties in $\tau^2 L/T^2$ by the formula

$$|\Delta(\tau^2 L/T^2)| = (|\Delta L| + 2L|\Delta T|/T)(\tau^2/T^2).$$

Compare your result for g with the published value for Bangkok 9.783 ms^{-2} by seeing whether or not the published value lies within the interval

$$\tau^2 L/T^2 \pm |\Delta(\tau^2 L/T^2)|.$$

RHBE, August 2017.
