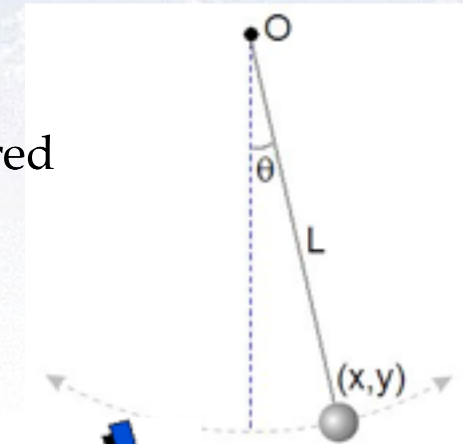
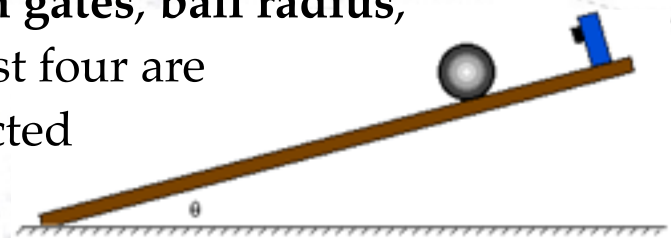
Applied Statistics - Project 1

The first project in Applied Statistics is to measure the gravitational acceleration, g, with the greatest possible precision, using two different experiments:



Simple pendulum:
Measure **length** and **period** of the pendulum. Length is measured with a measuring band and a laser, and time by your hand.

Ball rolling down incline:
Measure **incline angle**, **distance between gates**, **ball radius**, **rail distance** and **gate passage times**. First four are measured by hand, while timing is extracted from data files.

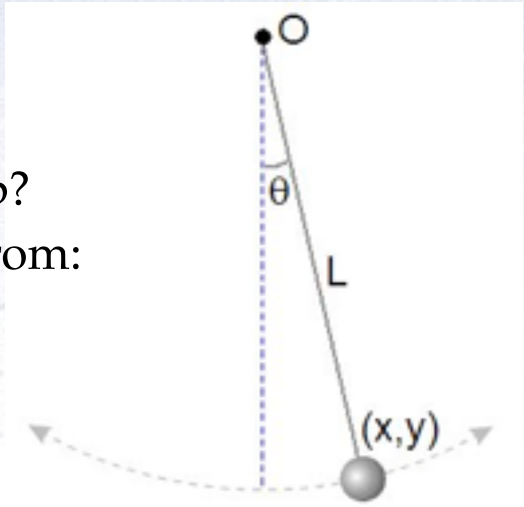


The project purpose is to learn how to **extract**, **minimise** and **propagate** errors. Before doing the experiments, please consider through error propagation, which of the measurements are going to be most challenging/limiting.

For more information, please look at the project 1 webpage.

Experiment objectives

In doing these experiments, you should make sure that you answer the following questions:

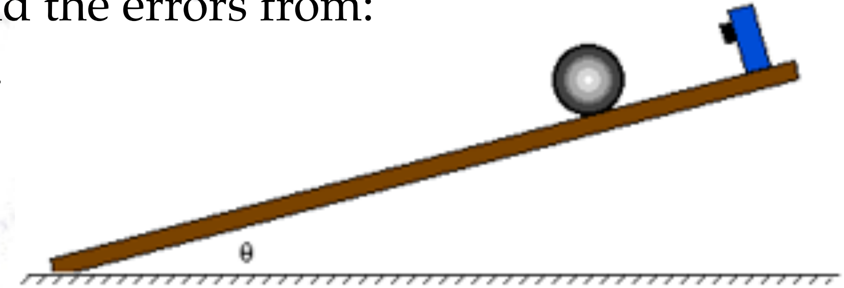


Pendulum:

- What is the timing precision of each person in the group?
- What is the gravitational acceleration g and the errors from:
  - ✦ Length of pendulum.
  - ✦ Period of pendulum.

Ball on an incline:

- What is the angle of the rail θ, and what is the angle of the table, Δθ?
- What is the gravitational acceleration g and the errors from:
  - ✦ Timing measurements in the five gates.
  - ✦ Distance between the gates.
  - ✦ Ball radius and rail distance.
  - ✦ Angle of rail.



Finally, perhaps you can eliminate some of your uncertainty by making $\theta = 90^o$?

Measurement situation

There are four possible situations in experimental measurements of a quantity:

One measurement, no error:

X = 3.14

Situation: You are f***ed!
You have no clue about uncertainty, and you can not obtain it!

Several measurements, no errors:

X1 = 3.14
X2 = 3.21
X3 = …

Situation: You are OK
You can combine the measurements, and from RMS get error on mean.

One measurement, with error:

X = 3.14 ± 0.13

Situation: You are OK
You have a number with error, which you can continue with.

Several measurements, with errors:

X1 = 3.14 ± 0.13
X2 = 3.21 ± 0.09
X3 = …

Situation: You are on top of things!
You can both combine to a weighted average and check with a chi-square.

Combining measurements

Given repeated measurements (by individual group members) of several quantities, that can be combined, what is the best way forward?

Combine at the end of analysis:

Measurements:
L1 = 3.543 ± 0.002 m
T1 = 3.942 ± 0.002 s
⇒ g1 = 9.821 ± 0.005 m/s^2

L2 = 3.545 ± 0.003 m
T2 = 3.940 ± 0.003 s
⇒ g2 = 9.827 ± 0.007 m/s^2

L3 = 3.523 ± 0.002 m
T3 = 3.944 ± 0.003 s
⇒ g3 = 9.771 ± 0.006 m/s^2

Combination:
g = 9.806 ± 0.004 m/s^2
Chi2 = 28.3, Ndof = 2
Prob(Chi2,Ndof) = 7.5 x 10^{-7}

Combine each quantity first:

Measurements:
L1 = 3.543 ± 0.002 m
L2 = 3.545 ± 0.003 m
L3 = 3.523 ± 0.002 m
⇒ L = 3.537 ± 0.002 m

Chi2 = 30.8, Ndof = 2
Prob(Chi2,Ndof) = 2.1 x 10^{-7}

T1 = 3.942 ± 0.002 s
T2 = 3.940 ± 0.003 s
T3 = 3.944 ± 0.003 s
⇒ T = 3.942 ± 0.002 s

Chi2 = 1.3, Ndof = 2
Prob(Chi2,Ndof) = 0.52

Combination:
g = 9.806 ± 0.004 m/s^2