Acceleration due to Gravity*

Object

To measure the acceleration due to gravity (g).

Theory

In principle, the measurement of acceleration is quite straightforward. One measures the positions (y) of the accelerating object at several instants of time (t) and plots a smooth graph. The second derivative, d^2y/dt^2, is the acceleration. As we are measuring close to the surface of the Earth, the acceleration due to gravity (g) is expected to be a constant. Hence, the y vs. t graph is expected to be a parabola. So, we fit the best parabola to our data. The fitted equation is:

$$y = v_0 t + \frac{1}{2} g t^2, \tag{1}$$

where v_0 is the initial velocity and we have chosen $y = 0$ at $t = 0$. To find g from this, one uses the known y and t at two distinct points on the graph and writes down equation 1 for each. The two resulting equations can be solved simultaneously to find the two unknowns – v_0 and g.

The measurement method

However, in reality, the above procedure can get tricky. A freely falling object moves too fast for us to measure its position accurately at given instants of time. So we use infrared sensors connected to a computer to accurately measure the time of fall. Even with the computer doing the timing, it would be a little easier if g were somewhat smaller. We cannot make g smaller, but we can do the next best thing – measure a component of g at some known angle (θ). So that

$$g = a / \cos\theta, \tag{2}$$

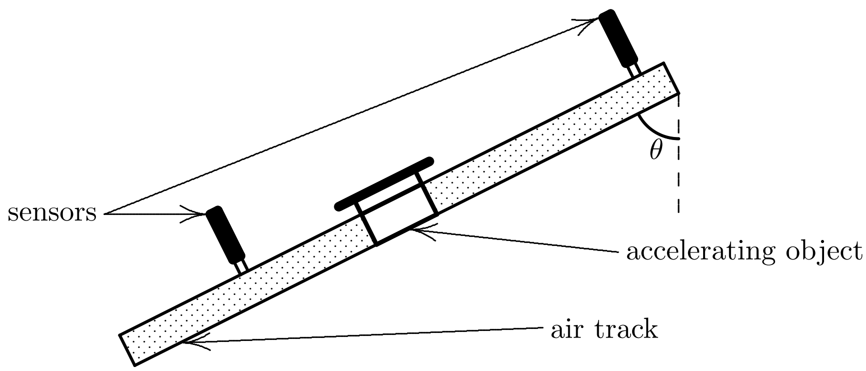
where the component a (of g) is the measured quantity and the fitted equation 1 is replaced by:

$$y = v_0 t + \frac{1}{2} a t^2. \tag{3}$$

To measure such a component of g, we let the object fall along a plane inclined at an angle of θ to the vertical. However, if the object slides along a plane with friction, there will be large errors. So, we create a frictionless surface – an air track.

An air track is a metal track that has many tiny holes through which air is forced out under pressure. The falling object is a metal rider that rides on the track. The air blown through the holes lifts the rider slightly off the surface thus eliminating friction for our purposes.

We tilt the air track at some angle θ to the vertical and measure a, the acceleration of the object sliding down the track. Then we use equation 2 to compute g.



Now, to measure a, look for the “GenPhy1” folder on your computer desktop. In it there is a file named “Acceleration”. Open this file. Click the “connect” button twice to connect the two infrared sensors that are placed on the air track. Then click the green “Collect” button. Now the falling object (rider) can be allowed to fall from the top of the track and run through the two sensors. The software displays the time taken. The distance between the sensors must be measured manually and entered next to the time recorded. This gives one data point. Now, leaving the top sensor in place, move the bottom sensor to a different position and drop the object from the same height as before. This will give the second data point. Collect at least three data points. Then use the “Curve Fit” button to fit equation 3 to the data[†]. The fitted value a is the measured acceleration. Now you can use equation 2 to compute g.

Some trials

For a small angle θ find a using about four data points for the graph. Devise your own method for measuring the angle. Find g and see how close it is to the expected value. What do you think is the greatest source of error?

Try various angles of tilt (of the air track) and find ways of reducing experimental error.

[†]Choose the form of equation 3 from the list of choices. Note that the software uses x instead of t for the independent variable.