4 Mechanical Measurements

4.1 Distance

To compare your measurements with your calculations you will need to measure distances: the diameter of the Himalaya or a merry-go round, the height of a roller coaster or a Ferris wheel. Ordinarily you can't just walk up to the rides and put a measuring tape on them, so some advanced preparation is necessary. You will need a tape measure or a calibrated string. Otherwise determine the length of your pace before you go. Sometimes you can take advantage of the fact that many rides have repeating equally-spaced supports. You can often use the process of triangulation to measure horizontal distances as well as vertical distances at the fair. To measure the height of a ride you need a protractor, soda straw, string, and weight as shown in Fig. C1. Tape the straw to the protractor and tie on the weight with the string. The same arrangement – minus the soda straw – can be used as a horizontal accelerometer.

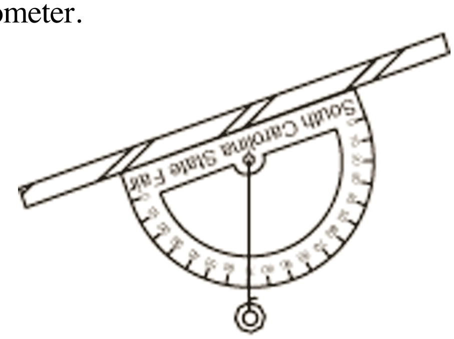


Figure C1

Sight through the straw as shown in Fig C.2 to find the angle θ.

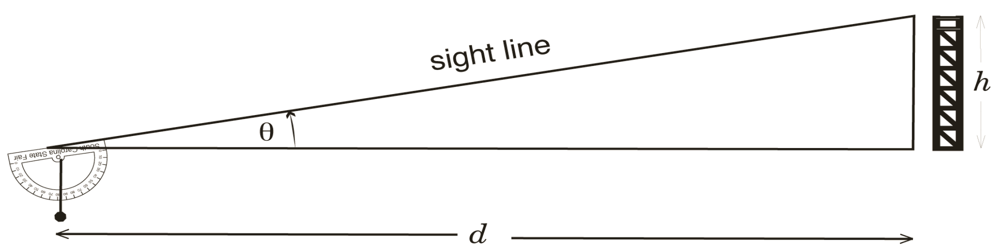


Figure C2

Measure the distance d. Then calculate the height h from $h = d \times \tan(\theta)$. Remember to add the distance from the protractor to the ground to get the total height.

In some cases you can not go – or reliably estimate – the distance to the base of a ride. In that case you must measure two angles, θ_1 and θ_2, and a distance D to find the height H. (Fig C.3)

$$H = D\frac{\sin\theta_1 \sin\theta_2}{\sin(\theta_1 - \theta_2)}.$$

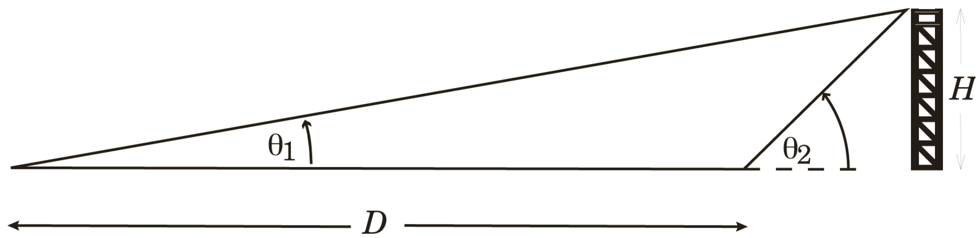


Figure C3

4.2 Speed

You may need to measure both average speed and instantaneous speed. In some cases they are the same, as for the riders on the Round Up. For other rides, such as roller coasters and The Scorpion, the average speed and the instantaneous speed are not the same.

To measure the average speed v, use

$$v_{\text{average}} = \frac{\text{total distance traveled for one trip}}{\text{time for one trip}} = \frac{D}{T}.$$

You will need to measure the distance D – directly or by one of the methods described above – and the time T. It is helpful to have a digital watch with a stop-watch function for measuring time.

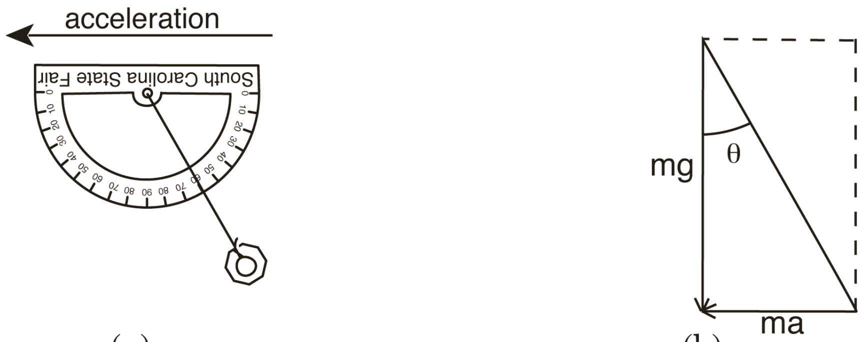
Instantaneous speeds can be a little harder to measure, especially when the speed is changing rapidly. Try to measure over shorter distances ΔD, thereby covering shorter times and satisfying

$$v_{\text{instantaneous}} = \lim_{\Delta t \to 0} \frac{\Delta D}{\Delta t} = \frac{\text{short distance}}{\text{time to go the short distance}}.$$

4.2 Acceleration

Horizontal Acceleration

The same protractor, string and weight used to measure distances can be used to measure the horizontal component of acceleration (horizontal accelerometer). If the protractor is held as in Figure C4(a) and moved with acceleration to the left, the weight will not hang straight down, but will make an angle θ with the vertical direction. We can use the value of this angle to tell us how much horizontal acceleration the protractor is undergoing. The weight swings away from the direction of the acceleration.



(a) (b)

Figure C4

There are two forces on the weight W in Fig. C4(a), the downward force of gravity (weight) of the bob mg, and the horizontal force F that we apply when we accelerate the bob to the left. This force to change the horizontal motion is connected to the horizontal acceleration we give it through Newton's second law $F = ma$. We see from Fig. C4(b)

$$\tan\theta = \frac{ma}{mg} \quad \text{or} \quad a = g\tan\theta.$$

We often measure the accelerations in multiples of the acceleration of gravity, g. Here the horizontal component of the acceleration may be written as

$$\frac{a}{g} = \tan\theta.$$

Thus in the example shown in Fig C4, $\theta = 30°$, so $a/g = \tan(30°) = 0.577$ and we say the rider experienced 0.577 gs.

Note that your readings will only be accurate if you hold the base line of the protractor horizontal.

Another style of horizontal accelerometer can be made by bending a hollow tube to fit the curved side of a protractor. When the curved side is downward and the tube has one or two small balls in it, the position of the balls shows the angle, just as does the string in Fig. C4(a). This type of accelerometer has some advantage in that it is less disturbed by the wind.

Vertical Acceleration

The simplest vertical accelerometer is a spring scale. You can tape a weight to the hook and, holding the scale vertical, read off the weight under various conditions. The number of "gs" you experience in a given situation is the scale reading in that situation divided by the scale reading when you are not moving.

You can make a vertical accelerometer similar to those sold in kit form (Fig. C5). You need a clear plastic tube (3/4" to 1" is best), some small weights (fishing weights are good), some rubber bands or weak springs, some duct tape and glue, and a pencil or pen. You can make the caps from chair-leg caps or anything else that will fit.

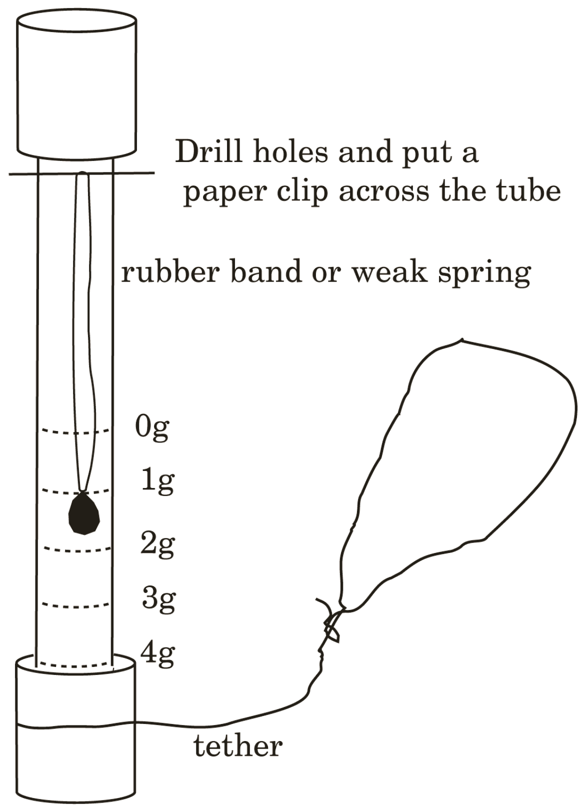


Figure C5

First assemble the accelerometer as shown in the figure without the bottom cap. Hang one weight on the rubber band and mark "1 g" at the position at which the weight hangs in the tube. Now hang another identical weight under the first one and mark "2 g" at that position. Continue until you have marked 3 or 4 g. Remove all but the first weight and permanently attach the bottom cap and tether.

These notes are only intended to guide you if you chose make your own accelerometer. Use your ingenuity and devise an instrument that will do the job.