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Analyzing radial acceleration with a smartphone acceleration sensor

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This paper continues the sequence of experiments using the acceleration sensor of smartphones (for description of the function and the use of the acceleration sensor, see Ref. 1) within this column, in this case for analyzing the radial acceleration.

Radial acceleration is investigated in several experiments with smartphones: One experiment is performed with experimental apparatus in a physics laboratory; the other experiment is carried out with pupils at a children's playground. This second example provides a means of exploring radial acceleration using an everyday object—in this particular example a merry-go-round. In this contribution the same apps described in previous articles about the use of acceleration sensors installed in smartphones[1–3] are used (SPARKvue[4] with an iPhone or an iPod touch, Accelogger[5] for an Android device). The values measured by the smartphone are also subsequently exported to a spreadsheet application (e.g., MS Excel) for analysis.[1]

Radial acceleration in the physics laboratory

In this example, a roof slat with a length of almost two meters is fixed to an electric motor—as is often found in physics collections, e.g., for experiments with a "Kugelschwebe" (semi-circular channel) (Fig. 1). With the help of cable fixers, the smartphone is then fixed onto the wooden slat at a defined distance from the rotation center r so that the axis is pointing in the direction of radial acceleration.[6] Figure 2 shows a measurement example for a distance from the rotation center of 86.5 cm. When the measurement is started, the motor is switched off; the measured radial acceleration is close to zero (small deviations can arise because the smartphone is not positioned perfectly horizontally). After approximately five seconds, the motor is switched on. From this time onward, the iPhone moves with a constant track speed v.

If the acceleration values recorded at an interval of 12 s and 59 s are averaged, the value is calculated to be 8.69 ms^{-2}. This result can be compared with a conventional measurement, in which radial acceleration a is indirectly determined using the formula

$$a = \frac{v^2}{r}. \qquad (1)$$

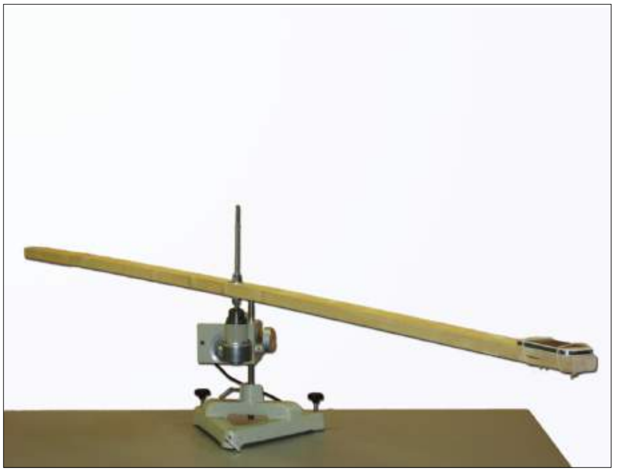

Fig. 1. Experiment setup to investigate radial acceleration.

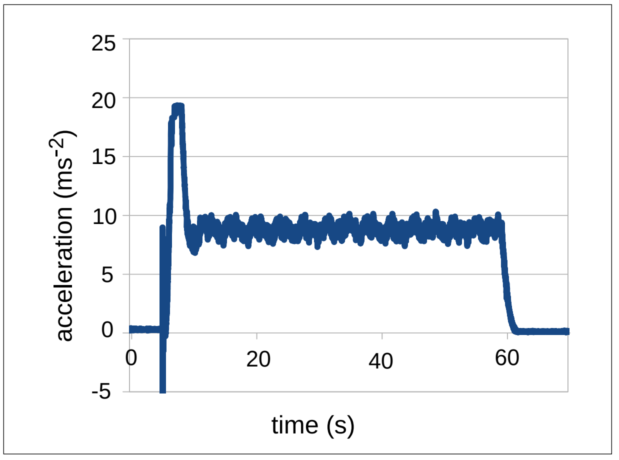

Fig. 2. Measurement example for a distance from the rotation center of r = 0.865 m and a duration of circulation of t = 38.2 s for 20 revolutions.

For this, the time t is measured for a given number of revolutions n. For the measurement example in Fig. 2, 20 revolutions occurred in 38.2 s. Taking into consideration the formula for the circumference and Eq. (1), radial acceleration is calculated to be

$$a = \frac{n^2 4\pi^2 r}{t^2} = \frac{20^2 \cdot 4\pi^2 \cdot 0.865\ \mathrm{m}}{(38.2\ \mathrm{s})^2} \approx 9.36 \frac{\mathrm{m}}{\mathrm{s}^2}, \qquad (2)$$

which matches well with the result of the smartphone measurement.

Alongside individual measurements of radial acceleration, the setup makes it possible to verify Eq. (1) in an experiment. Namely, by recording a series of measurements, it is possible to confirm the proportionalities $a \sim v^2$ (for r = constant) and $a \sim 1/r$ (for v = constant). However, when selecting the velocity, it is advisable to limit the measurement range of the acceleration sensors installed in the smartphone to $\pm 2g$.

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Fig. 3. Experimental setup to examine centripetal acceleration of a merry-go-round.

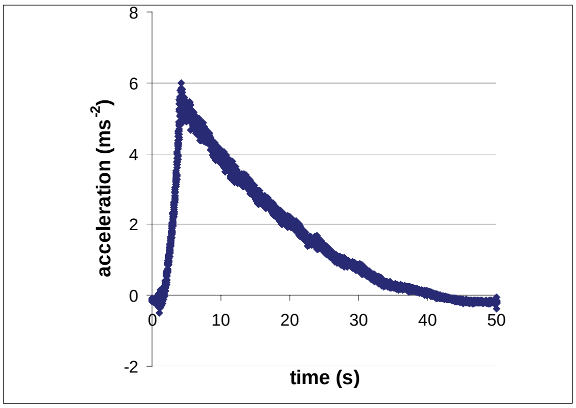

Fig. 4. Measurement example from the merry-go-round.

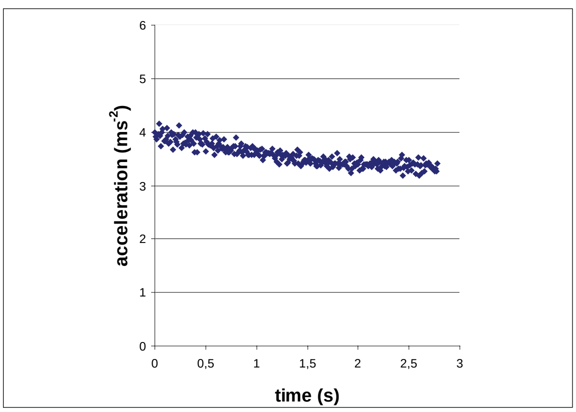

Fig. 5. Analysis using an iPhone.

Centripetal acceleration of a merry-go-round

In the second example, the radial acceleration of a merry-go-round, typically found at children's playgrounds, is examined (see Fig. 3). In order to make the carousel rotate, it is necessary to step onto it and apply force tangentially to the circular disc in the middle of the merry-go-round. Before the merry-go-round starts rotating, the smartphone is fixed at a given distance *r* from the rotation center either on the outside railing or the seating area of the merry-go-round so that an axis is pointing in the direction of radial acceleration. Similar to the previous example, this is performed with the help of cable fixers or adhesive tape, for example. Figure 4 shows a measurement example for a distance from the rotation center of 79 cm. After the measurement has been started on the app, the merry-go-round is accelerated from a complete standstill to a maximum value. In this example, the process lasts for approximately eight seconds. After this, the acceleration process is stopped and the merry-go-round slows as a result of friction until it reaches a complete standstill (see Fig. 4).

In order to obtain radial acceleration, several acceleration values recorded at a short interval are averaged at the end of the acceleration process (e.g., at 9 s and 14 s; see Fig. 5). In this case, it results in a value of approximately 3.52 ms^{-2}. This result can be compared to a conventional measurement in which radial acceleration a is indirectly determined by applying Eq. (1). Then Eq. (2) is applied, resulting in a = 3.73 ms^{-2} for T = 2.89 s and r = 0.79 m, so that the values from the experiments can also be considered acceptable with a relative error of approximately 6%.

References:

1. P. Vogt and J. Kuhn, "Analyzing free fall with a smartphone acceleration sensor," *Phys. Teach.* **50**, 182–183 (March 2012).
2. P. Vogt and J. Kuhn, "Analyzing simple pendulum phenomena with a smartphone acceleration sensor," *Phys. Teach.* **50**, 439–440 (Oct. 2012).
3. J. Kuhn and P. Vogt, "Analyzing spring pendulum phenomena with a smartphone acceleration sensor," *Phys. Teach.* **50**, 504–505 (Nov. 2012).
4. itunes.apple.com/de/app/sparkvue/id361907181 (temporary web address).
5. de.androidzoom.com/android_applications/tools/accelogger_bgq_download.html (temporary web address).
6. In order to obtain a very precise specification of the distance to the rotation center, information on the location of the acceleration sensors within the smartphone must be obtained from the manufacturer. In the iPod touch (4G) the sensors are located underneath the home button; a description of the location for the iPhone 4G can be found online at www.ifixit.com/teardown/iphone-4-teardown/3130/2 (temporary web address).