Using smartphone portrait-landscape transitions to teach inclined-plane physics

Today's students are increasingly immersed in a landscape of screens and handheld digital devices through which a good deal of their interactions with the world around them are mediated. Physics educators, meanwhile, continue to rely on traditional human interactions with the physical world, such as sliding down a ramp or throwing a baseball, in order to illustrate fundamental concepts in physics. Regrettably, these interactions are decreasingly representative of the kinds of everyday activities that our students engage in, reducing their degree of engagement with the material. A new opportunity lies in the behaviour of smartphones in response to sustained tilted orientations, which has for some time become a familiar mechanism of interaction between students and many of the mobile apps that they engage with on a daily basis. Here we demonstrate how a methodical investigation of this digital-era mechanism can be used to introduce the inclined plane, a standard topic in most introductory mechanics courses.

The activity begins by inviting the students to choose, on their own smartphone, any app featuring portrait-landscape tilt transitions, such as a photo viewer or a texting app. They are asked to tilt their device so as to ensure that its initial state is landscape mode and then place it flat on a table. They slowly lift the short edge until the app transitions into portrait mode. We refer to the minimal angle at which this occurs as the critical angle, and require the students to measure it carefully.

This and subsequent angle measurements can be accomplished in a number of satisfactory ways; a simple method involving nothing more than a flat board and a protractor is illustrated in Fig. 1. It is strategic to defer a review of theoretical notions until this point in the procedure: There is considerable hope that the students' curiosity has now been awakened and that this will strengthen their resolve to engage with and appreciate the significance and applicability of the theory.

Once the preliminary critical-angle investigation is completed, we move to a more methodical examination of tilted orientations by using an accelerometer app, an increasingly widely-used strategy for physics experiments[1,2] including those involving inclined planes[4,3]. When the device is stationary in any given orientation, such apps provide a graphical display that can be interpreted in terms of the components of the gravitational acceleration along each of the device axes[5]. Fig. 2 depicts the accelerometer coordinate system labelling convention used by our smartphone (an Android device).

Once the students have set the accelerometer app in recording mode, they hold their smartphone at a variety of pre-determined angles, including the previously-established critical angle. The students transfer the resulting data to a PC and produce graphs such as the one seen in Fig. 3. They then calculate, for each angular position, averaged values for the acceleration components.

At this point, there are a number of options. One is to recover the angle of tilt based on the acceleration components, such as in Table I. Another option is to do the reverse: have them compute, for a given angle, the expected component values and compare them against the experimentally measured values, as in Fig. 4.

Although the analysis remains rudimentary, it does expose students to the typical elements in a modern data-analysis workflow. They discover that mastery of basic vector skills can bring insight into some of the under-the-hood technological aspects of their beloved handhelds. The work represented in Table I, for example, illustrates the kind of calculations that programmers code into their apps; and the graph in Fig. 4 can lead to a discussion of the accuracy and calibration of accelerometer sensors and how engineers visualize and evaluate their performance.

In terms of pedagogical fundamentals, we find that this activity provides a refreshing and enticing introduction to the material that is traditionally presented in lecture format as the topic with the rather austere title of ”the inclined plane”. It covers, minimally, the gravitational acceleration vector, the appearance of vectors in different frames of reference and, of course, vector decomposition and reconstruction. At the teacher's discretion the coverage can be easily extended to include the consideration of vector forces, including gravitational, normal and frictional.

---

[1] C. Fahsl and P. Vogt ”Determination of the drag resistance coefficients of different vehicles,” Phys. Teach. **56**, 5 (2018).

[2] ”Direct Visualization of Mechanical Beats by Means of an Oscillating Smartphone,” M. H. Gimnez, I. Salinas, J. A. Monsoriu and J. C. Castro-Palacio **55**, 424 (2017)

[3] ”Acceleration sensors of smartphones,” P. Vogt and J. Kuhn **2**, (2014)

[4] R. Ochoa, F.G. Rooney, and W.J. Somers, ”Using the Wiimote in Introductory Physics Experiments,” Phys. Teach. **49**, 16 (2011).

,

[5] In static situations, the components of the gravitational acceleration are equal and opposite to the corresponding acceleration components reported by the accelerometer.

FIG. 1. A low-cost apparatus for carrying out static inclined-plane experiments with smartphones

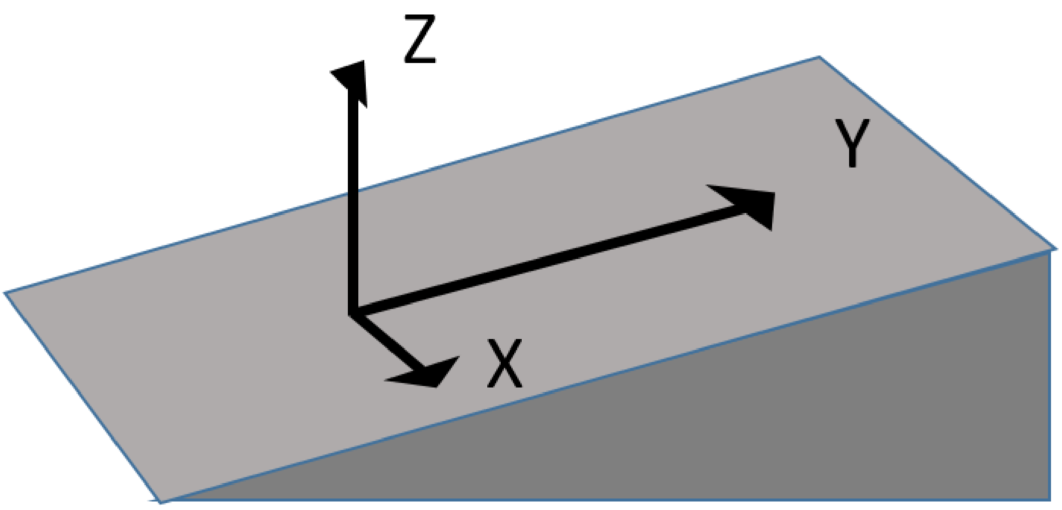

FIG. 2. Smartphone coordinate system. The phone is placed on the incline as per Fig. 1

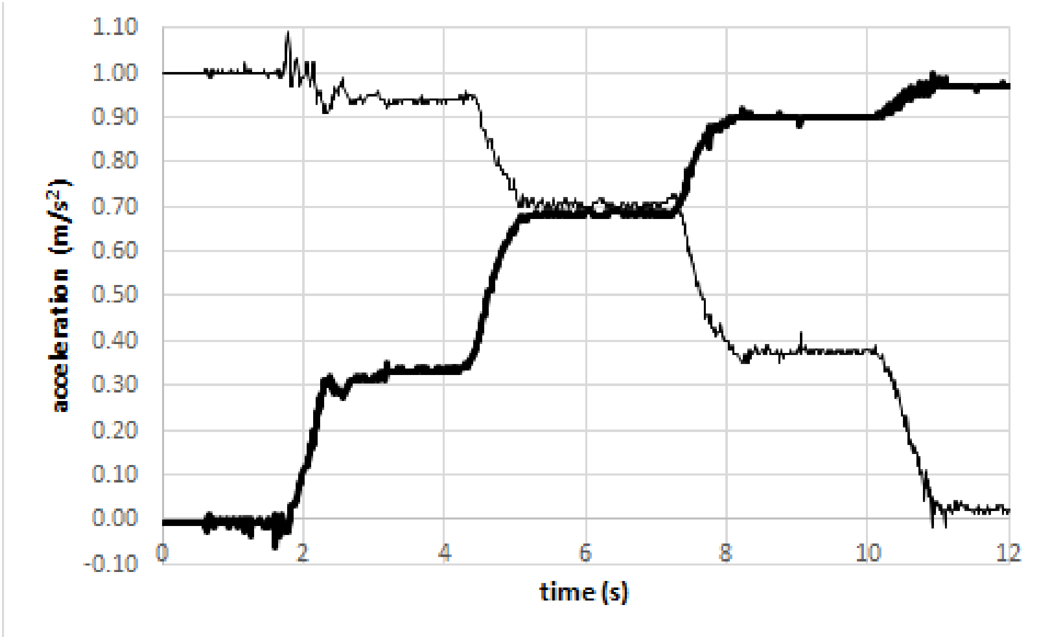

FIG. 3. Qualitative exploration of the behavior of the acceleration components using a Samsung Galaxy Express 3 smartphone. The device is consecutively held at angles of zero, 20, 45, 70 and 90 degrees. The thick line represents g_y and the thin one g_z.

TABLE I. Determination of angle of incline from accelerometer components

experimental angle (degrees)	g_y $(\frac{m}{s^2})$	g_z $(\frac{m}{s^2})$	calculated angle (degrees)
0	0.00	1.00	0.04
20	0.33	.94	20.3
45	0.68	0.71	44.1
70	0.90	0.38	67.3
90	0.97	0.02	88.8

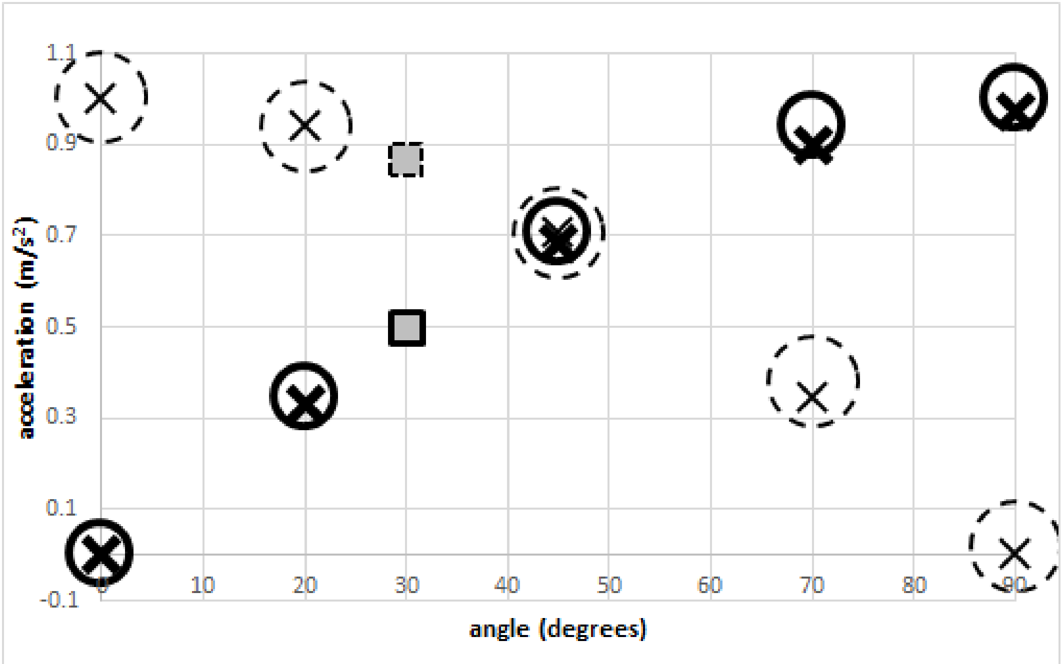

FIG. 4. Results: X marks are the averaged values from the flat portions of the previous graph (the thick X are g_y values and the thin X are g_z values). Circles mark the theoretical values using basic trigonometry (the thick circles are g_y values and the thin circles are g_z values). The squares mark the theoretical values for the 30-degree portrait-landscape critical angle of the smartphone.