What frame of reference is your smartphone accelerometer in?

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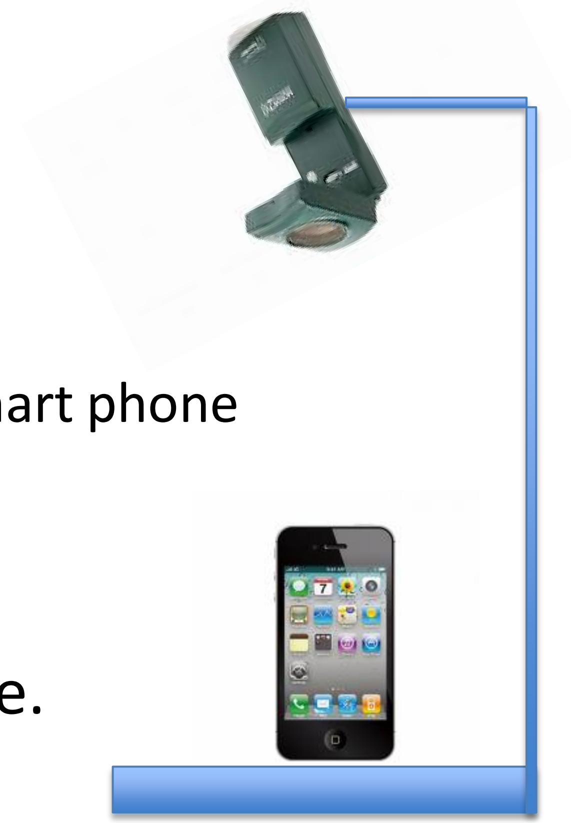
2014 Winter Meeting
Orlando, Florida

Question #1:



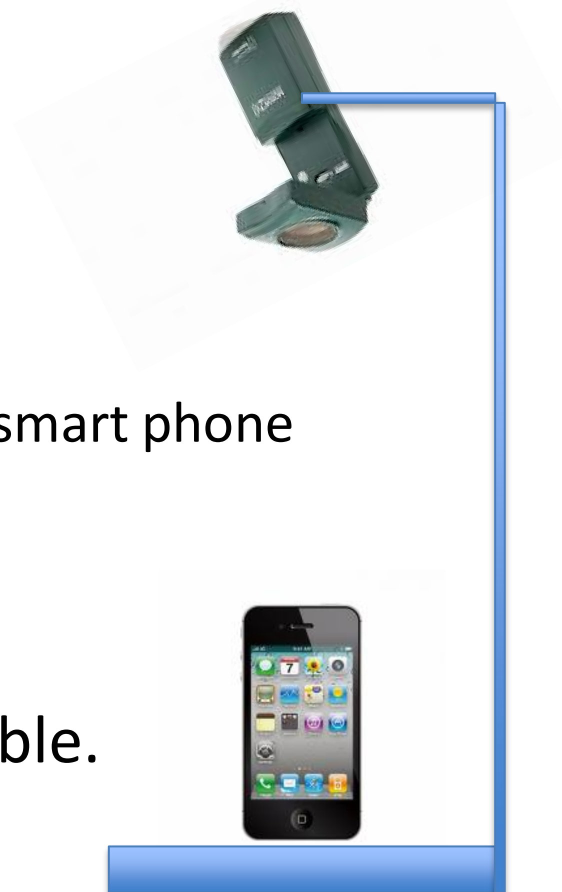
- A “smartphone” has an accelerometer.

- You also measure the acceleration of the smart phone
with a motion sensor that measures position
with sound waves.

- The smartphone is at rest on the table.

- The accelerometer reading = ?
(magnitude and direction)
- The acceleration measured by the motion sensor = ? (magnitude and direction)

Question #1:



- A smartphone has an accelerometer.

- You also measure the acceleration of the smart phone with a motion sensor that measures position with sound waves.

- The smartphone is at rest on the table.

- The accelerometer reading = +g (up)

- Acceleration measured by the motion sensor = zero

Question #2:

- A smartphone has an accelerometer.

- You also measure the acceleration of the smart phone with a motion sensor that measures position with sound waves.

- The smartphone is in free fall.

- The accelerometer reading = ? (magnitude and direction)
- The acceleration measured by the motion sensor = ?(magnitude and direction)

Question #2:

- A smartphone has an accelerometer.

- You also measure the acceleration of the smart phone with a motion sensor that measures position with sound waves.

- The smartphone is in free fall.

- The accelerometer reading = <u>zero</u>

- Acceleration measured by the motion sensor = g (down)

http://www.devx.com/wireless/Article/44799

- **Understanding the Accelerometer**
- <u>The accelerometer in iPhone and iPod Touch measures the acceleration of the device relative to freefall.</u> (Correct!)
- *A value of 1 indicates that the device is experiencing 1 g of force exerting on it (1 g of force being the gravitational pull of the earth, which your device experiences when it is stationary).*

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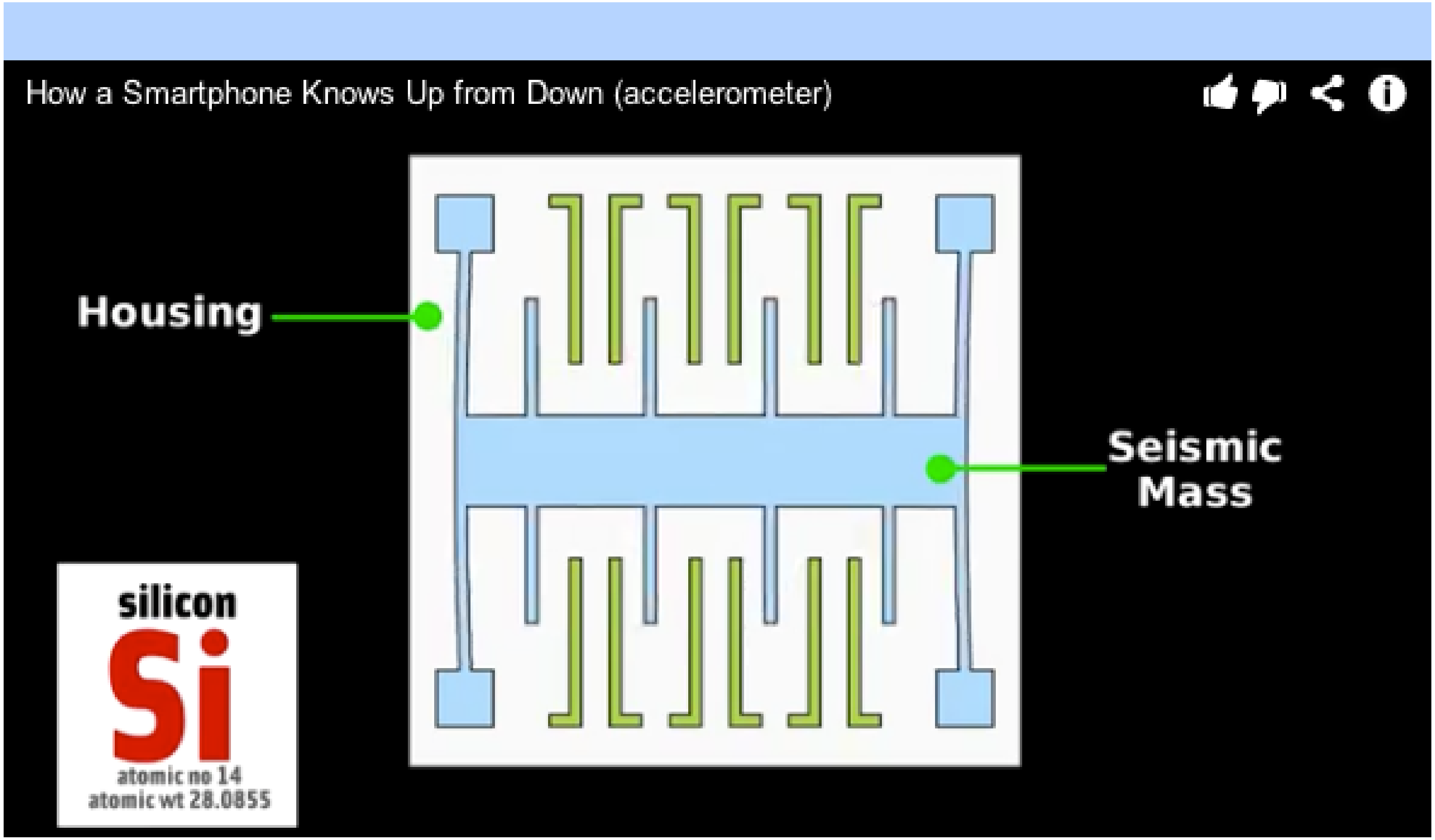
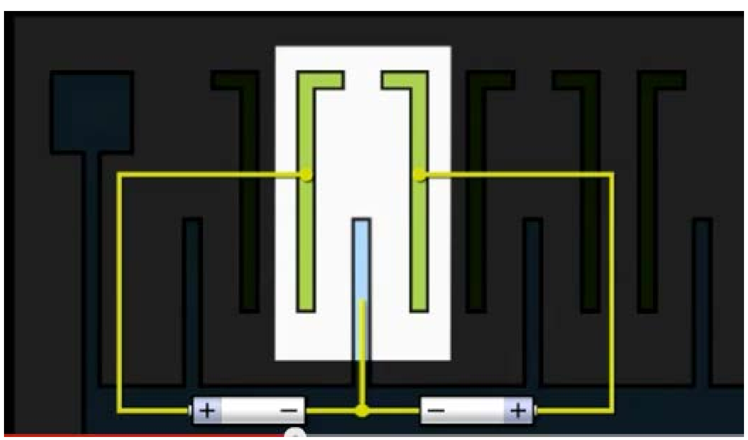
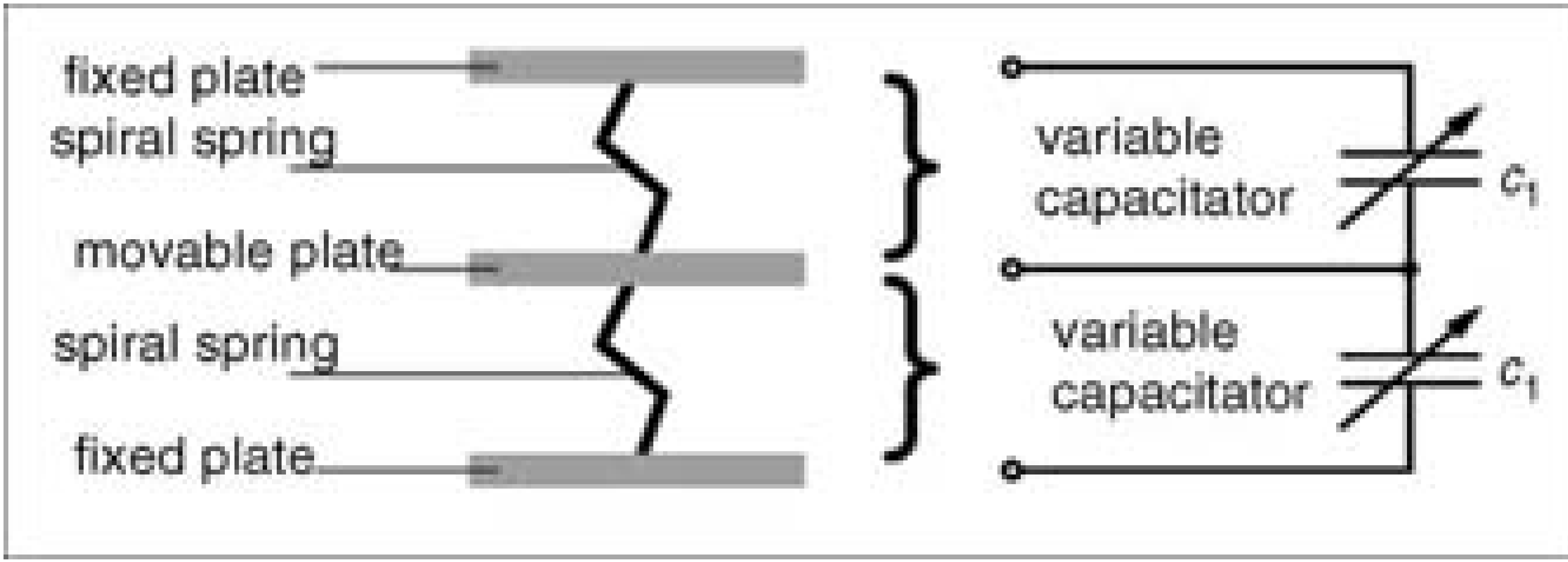




Capacitive Spring Mass Base Accelerometer

Analyzing free fall with a smartphone acceleration sensor
Patrik Vogt and **Jochen Kuhn,** The Physics Teacher –
March 2012 – Vol. 50, Issue 3, pp. 182



Equivalence principle of general relativity –
To device, acceleration = gravitational field intensity

FIG. 2. Design and mode of operation of acceleration sensors.

Phys. Teach. 50, 182 (2012)

Accelerometer Reading
(in the vertical direction)

- In an inertial (Newtonian) reference frame, accelerometer reading =

gravitational field intensity g + acceleration

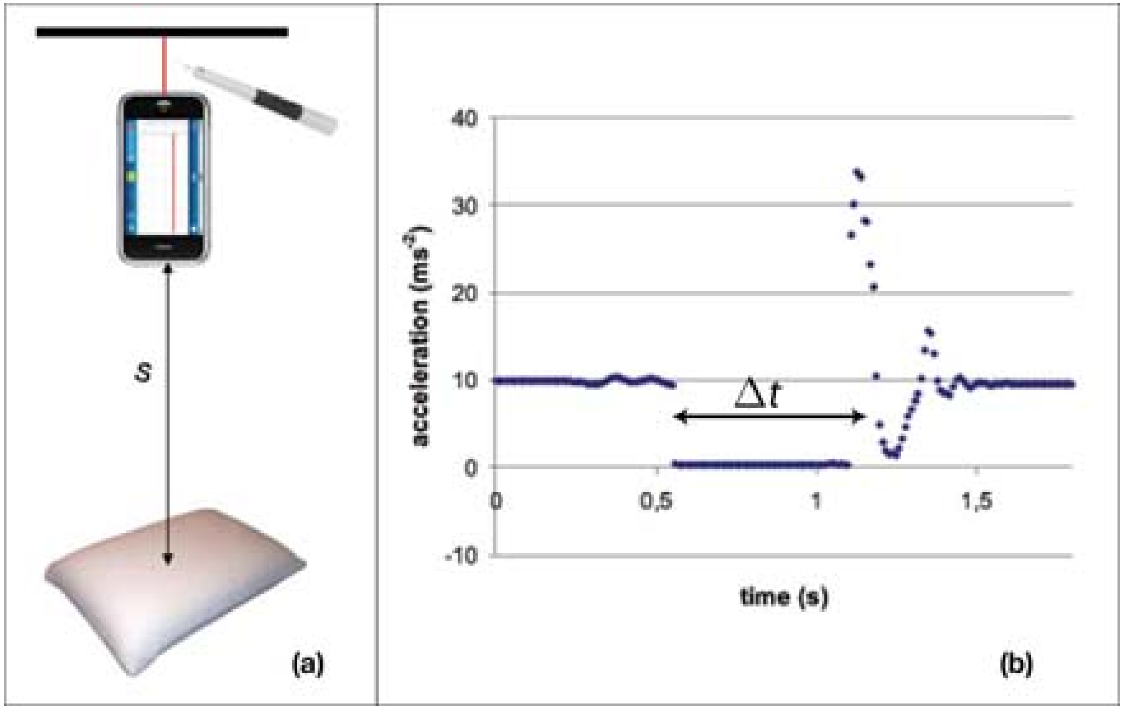
- In a general relativistic reference frame

(free fall), where gravity is <u>NOT</u> a force,

Accelerometer reading = acceleration

Which reference frame is "assumed" in introductory physics?
Do we consider gravity to be a force?

“Analyzing free fall with a smartphone acceleration sensor”
Patrik Vogt and **Jochen Kuhn,** The Physics Teacher – March 2012 – Vol. 50, Issue 3, pp. 182



“At first, the smartphone is suspended from the string and the acceleration of gravity of 9.81 ms^{-2} takes effect”

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Free fall: (a) Experimental setup and acceleration process, (b) Presentation of measurements after the export of data from the smartphone into MS Excel.

Response to “iPhysicsLabs” column

Jochen Kuhn, Patrik Vogt *University of Kaiserslautern, Department of Physics/Didactics of Physics*

iBlackBox? Jonathan Hall

The Physics Teacher -- May 2012 -- Volume 50, Issue 5, pp. 260

The acceleration when at rest = zero,

Acceleration = g down when in free fall.

Accelerometer reading needs to be “tared” to zero when not accelerating.

P. Vogt and J. Kuhn, “Analyzing simple pendulum phenomena with a smartphone acceleration sensor,” [Phys. Teach. **50**,439–440 (Oct. 2012)]

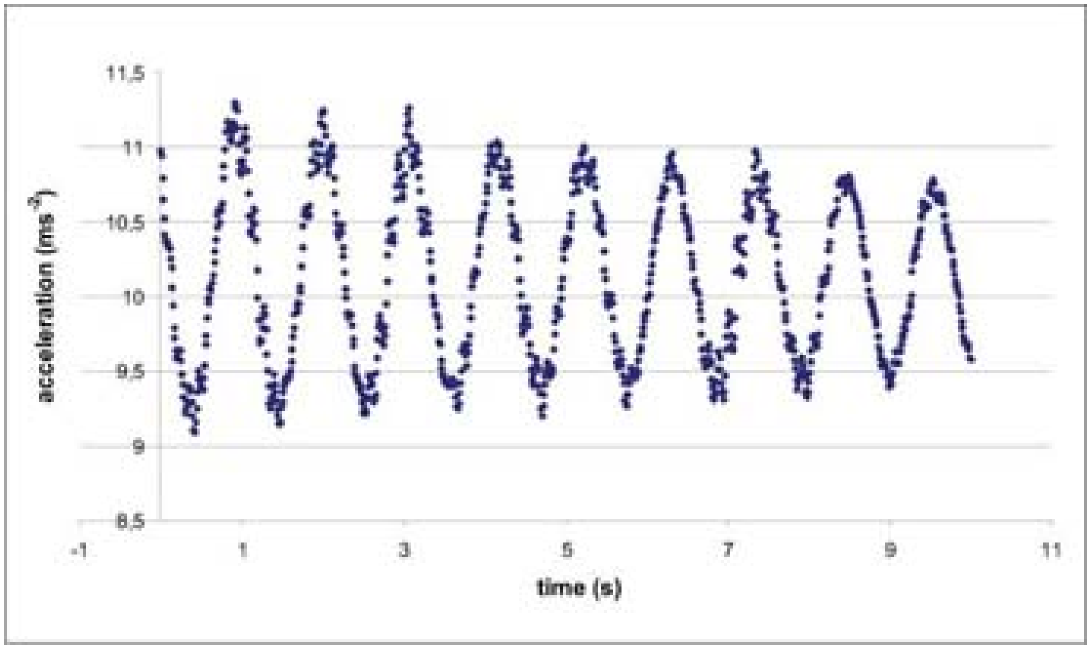

Fig 2

Acceleration process for a mathematical pendulum (l = 1.15 m); presentation of measured values after the export of data from the smartphone into MS Excel.

Accelerometer reading = g•cosθ + radial acceleration

P. Vogt and J. Kuhn, “Analyzing simple pendulum phenomena with a smartphone acceleration sensor,” Phys. Teach. **50**,439–440 (Oct. 2012)

Regarding a), the acceleration in the direction of the string is given by the sum of the centrifugal force apparently taking effect and the pendulums mass in the direction of the string. As velocity is briefly zero at the turning point, the pendulum's mass only takes effect in the direction of the string, so the acceleration of small *g* is measured. The minima are thus located at the turning points on the acceleration curve (Fig. 2). When passing through the rest point, the pendulum is moving at its highest velocity and, as a result, at maximum centrifugal acceleration. In addition, the acceleration of gravity needs to be completely added to this, i.e., the accelerations at the zero crossing point are higher than *g* and correspond to the maxima in Fig. 2

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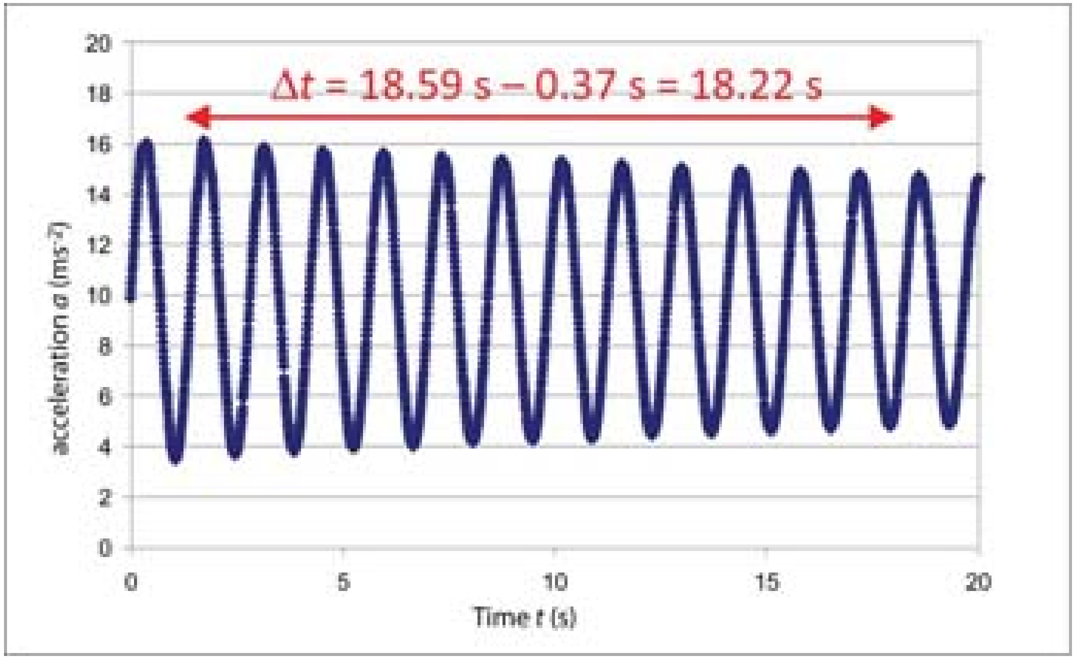
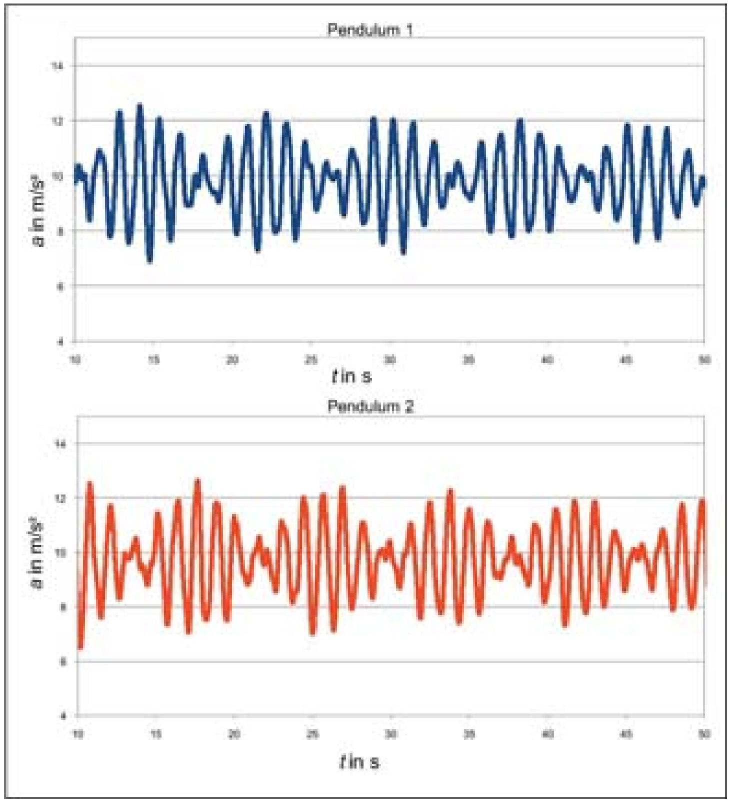
Analyzing spring pendulum phenomena with a smart-phone acceleration sensor . Jochen Kuhn[1] and **Patrik Vogt**[2]

The Physics Teacher -- November 2012 -- Volume 50, Issue 8, pp. 504



Dynamic determination of spring constants: chronological acceleration process for a spring pendulum (Presentation of measured values after the export of data from the smartphone into MS Excel).

"Analyzing spring pendulum phenomena with a smart-phone acceleration sensor." Jochen Kuhn[1] and **Patrik Vogt**[2]
The Physics Teacher -- November 2012 -- Volume 50, Issue 8, pp. 504



"When the acceleration values, and therefore the amplitudes, of one pendulum reach a maximum, the accelerations of the other pendulum correspond approximately to the acceleration of gravity, which equals a state of rest."

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More smartphone acceleration **Jonathan Hall**

The Physics Teacher -- January 2013 -- Volume 51, Issue 1, pp. 6

Authors' response **J. Kuhn** and **P. Vogt**

The Physics Teacher -- January 2013 -- Volume 51, Issue 1, pp. 6

We thank Mr. Hall for his comments. He is completely right and we already discussed exactly those same points in one of our earlier publications [that we cited in the article to avoid just such misconceptions; see Ref. 1, P. Vogt and J. Kuhn, "Analyzing Free Fall with a Smartphone Acceleration Sensor," *Phys. Teach*. **50**, 182–183 (March 2012)]. Teachers should certainly discuss these points with their students to avoid misconceptions, and the technical requirements always have to be taken into account (the app has no option to include offset or tare, so this has to be handled manually).

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Questions #3 and #4 –

3. Have I become a grumpy old man?

4. How do we teach acceleration to our students, and to each other?

Please send comments to:

jch12@psu.edu

Jack Lemmon was born in an elevator. The elevator was in a gravitational field, but it is unknown whether or not it was accelerating at the time.

“Thumbing Through *The Physics Teacher* “
Steve Iona

The Physics Teacher -- April 2013 -- Volume 51, Issue 4, pp. 203

“Among the “Letters to the Editor” is one from a senior lecturer at Penn State Erie who comments on a 1981 *AJP* article by David Trowbridge and Lillian McDermott that deals with student understanding of acceleration, in reference to a *TPT* article on using smartphones to analyze spring pendulum phenomena.”