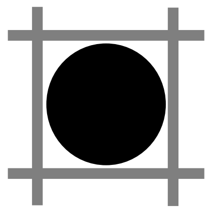
Understanding accelerometers

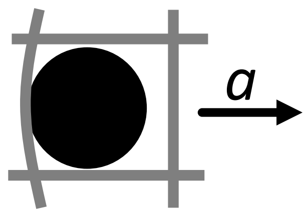
1. The ball-in-a-box model of an accelerometer

An accelerometer can be thought of as a small box with a solid ball sitting inside of it.



The box on a horizontal surface, viewed from above

When the box is accelerated to the right, the left wall makes contact with the ball and pushes it along.



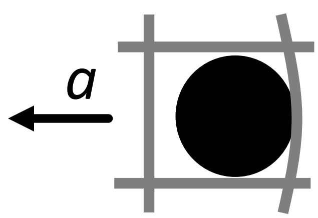
The wall bends slightly and an internal sensor measures this to deduce the magnitude F_{wall} . Knowing that a bigger force means a bigger acceleration, *i.e.*

$$F_{wall} = m_{ball} * a \ ,$$

the accelerometer reports the value of *a* using

$$a = \frac{F_{wall}}{m_{ball}} \quad .$$

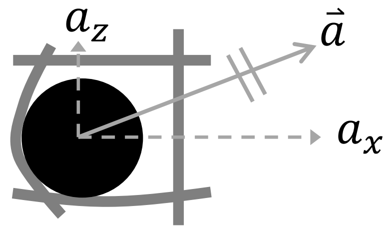
When the box is accelerated to the *left*, it is the *right* wall that ends up doing the pushing:



The accelerometer again reports the acceleration value, only this time it will have the opposite sign as the first acceleration.

The same idea applies to accelerations acting along the other directions (axes). The accelerometer always reports three values: a_x, a_y and a_z. Each value can be positive or negative, depending on the acceleration direction, or zero if there is no acceleration along a particular axis.

2. Vectors and accelerometers



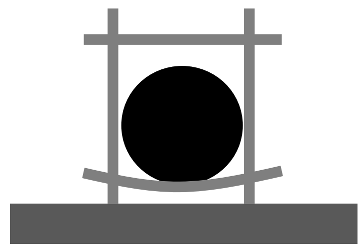
Ball-in-a-box on a tabletop, again viewed from above the table looking downwards. Bending of walls deliberately exaggerated!

Consider our ball-in-a-box being accelerated horizontally at an angle between two axes.

The "x" wall bends a lot because it is supporting a large acceleration a_x along the x direction. The "z" wall bends only the small amount needed to support the smaller acceleration a_z along the z direction. The vector combination of these two produces $\vec{a}$.

This means that, by examining each of the individual acceleration components reported by the accelerometer , we can deduce the magnitude and direction of the box's acceleration.

3. Gravity and accelerometers


Box resting on a horizontal surface, viewed from the side. The upwards force exerted by the lower wall is interpreted as a sign of an upward acceleration.

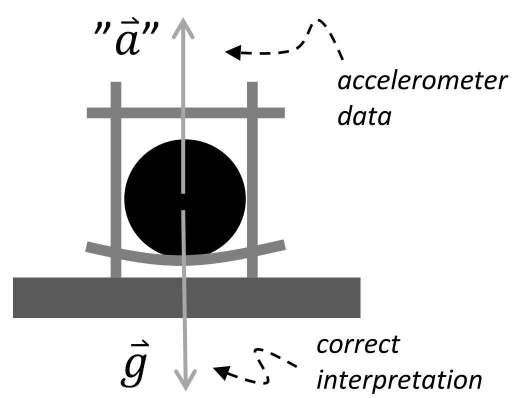
Consider now a side view of a motionless accelerometer. The left and right walls are in a relaxed state, but the bottom wall has bent slightly to receive the weight of the ball.

An internal sensor senses this bend and does the only thing it knows how to do: it reports an acceleration!

Since, $F_{wall} = m_{ball} * g$, the reported "acceleration" value will be equal to g:

$$a = \frac{F_{wall}}{m_{ball}} = \frac{m_{ball} \; * \; g}{m_{ball}} = g$$

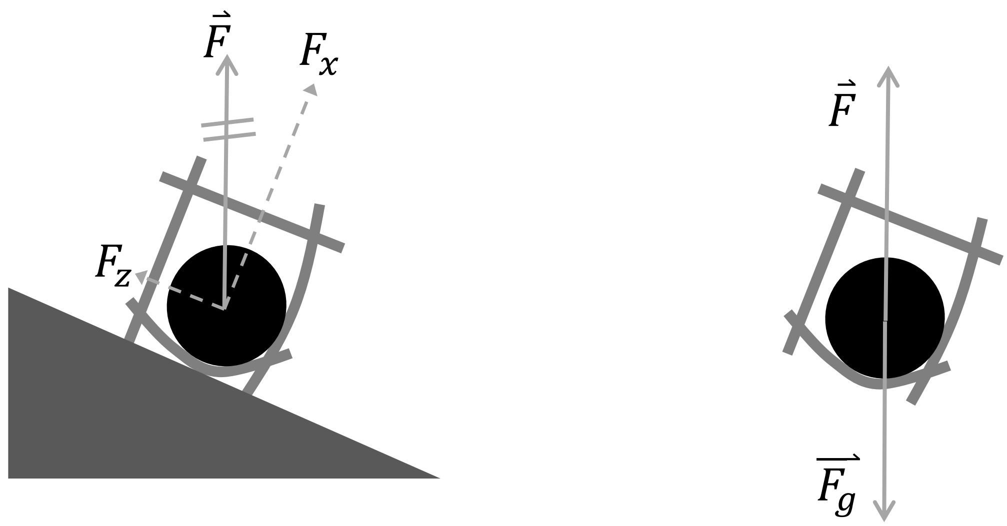
Furthermore, since all 3 axes of the accelerometer are programmed identically, the direction must follow the same rule as before, and is reported as upward!



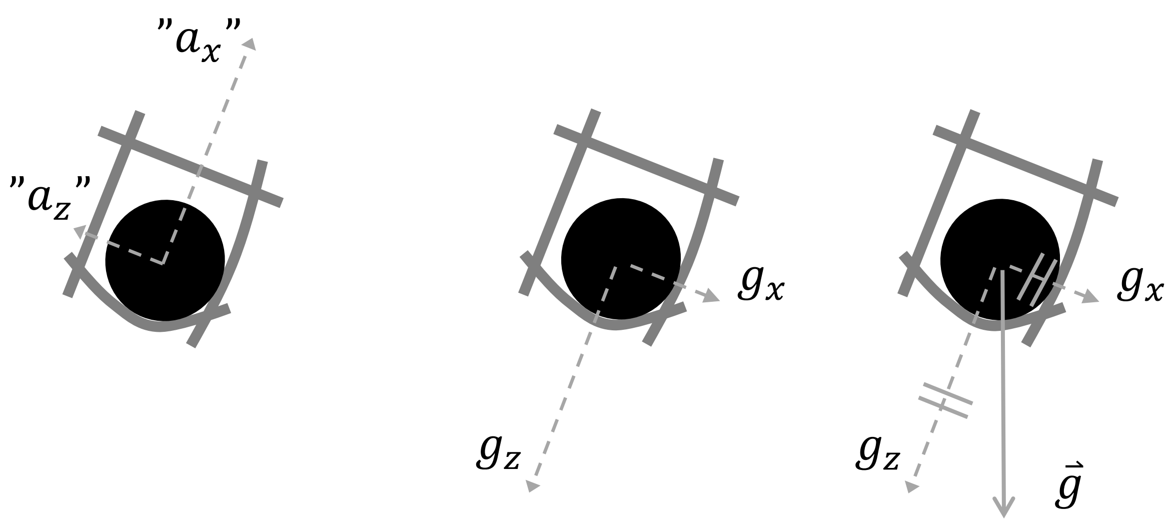
Accelerometers cannot tell whether a wall force is accelerating the ball or merely resisting its gravitational attraction. It is up to us to interpret the accelerometer data correctly.

4. Accelerometers on an inclined plane

Consider a ball-in-a-box that is immobile on a rough incline. There are two wall forces acting on the ball so as to prevent it from accelerating. These two forces, when added together as vectors, produce a net upwards force that exactly counteracts the downward force of gravity.



The accelerometer reports these wall forces as accelerations. Since we know the system is immobile, we interpret each accelerometer component as a measure of a <u>gravitational component in the opposite direction</u>, just like was done in the previous part 3.



accelerometer data *correct interpretation*

> ***Note:*** *the choice of "x" and "z" for axis labels is arbitrary, as it depends which side of the box was placed on the inclined surface.*