ScienceCube

C38A
Triaxial Acceleration
User Guide

May 13 2010, Second Edition

WARNING:

For safety reasons and to avoid personal injury, read all operating guides and information in the product guide. Please check that this product is operating properly prior to when you intend to use it for educational purposes only. Use this device and sensors for teaching and learning. The information given in this electronic document shall not be regarded as a guarantee or warranty of physical characteristics and any conditions. We will not replace or cover the costs of a damaged sensor or probe due to negligent or destructive, improper use.

1. DO NOT attempt to modify Mentor device and sensors in any way. This may result in fire, injury, electric shock or severe damage to you or them.
2. DO NOT operate Mentor device and sensors with wet hands, this may cause an electric shock.
3. DO NOT use Mentor device and sensors in close proximity to flammable or explosive gases, or chemical vapors. Use this product in a well ventilated area.
4. DO NOT breathe the vapors in a chemical reaction. Be careful when you use a strong acid, strong base or other materials in an experiment.
5. For safety reasons keep this sensor out of reach of children or animals to prevent accidents, for example swallowing small size of the sensor. DO NOT allow children to play on or around the sensor.

CAUTION:

DO NOT use Mentor device and sensors in extreme conditions which are over the operating range and short-term exposure limit conditions. Stresses above input range may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade sensor reliability. DO NOT attempt to decompose, modify or repair the sensor in any other ways. This may cause permanent damage to the sensor.

Features and Specifications

Features

Item	Description
Feature	Measures the 3-axis acceleration in g. Sensing elements is mounted inside case (air box).
Dimension	37x18x16 (WxDxH) in mm
Usage	Use only in a dry place at room temperature below +40°C.

Specifications

Item	Description
Input range	Switchable[1] full scales: ±2g, ±4g or ±8g
Resolution (Sensitivity)	±0.004g /±2g, ±0.008g/±4g, ±0.016g/±8g
Uncertainty (Accuracy)	±0.01g in the ±2g range at 25°C with Zero-g state Max. Zero-g offset: ±0.06g at 25°C Typical: ±1.0% of full scale
Sampling rate	Default sampling periods: 0.2sec (5samples/sec) Max[2]. 750samples/sec
Response	Max. 750Hz with digital filter, specified 1.5kHz with analog filter. Wake up time is 1.0ms from standby

Additional equipment or application

Mentor device and MentorStart application software needed. If you are using Mentor application, consult your instructor for more information.

[1] You can select the measurement range in the MentorStart program or acceleration application for Mentor.

[2] Maximum sampling rate is specified with the 3-axis acceleration application software for Mentor.

CAUTION:

1. DO NOT use this sensor in close proximity to flammable or explosive gases. Chemical vapors may interfere with the polymer layers used for capacitive this sensor and high levels of pollutants may cause permanent damage to this sensor.
2. DO NOT use or expose this sensor at the maximum range under 1minute residence time (exposure limit with max. input range)
3. Prolonged direct exposure to extreme conditions may cause significant property damage.
4. DO NOT place sensor or cable in water, liquids, flame or on a hot plate.

Setup and Usage

1. Launch the MentorStart software and connect the sensor to the sensor port in your Mentor device. MentorStart will automatically detect the sensor. Place the sensor in a dry place.
2. You can view and measure the acceleration values of the Cartesian, Cylindrical or Spherical coordinates in the MentorStart or by using an application software for 3-axis acceleration.
3. If you want to measure the freefall or detect any motion interrupt, use the application software.

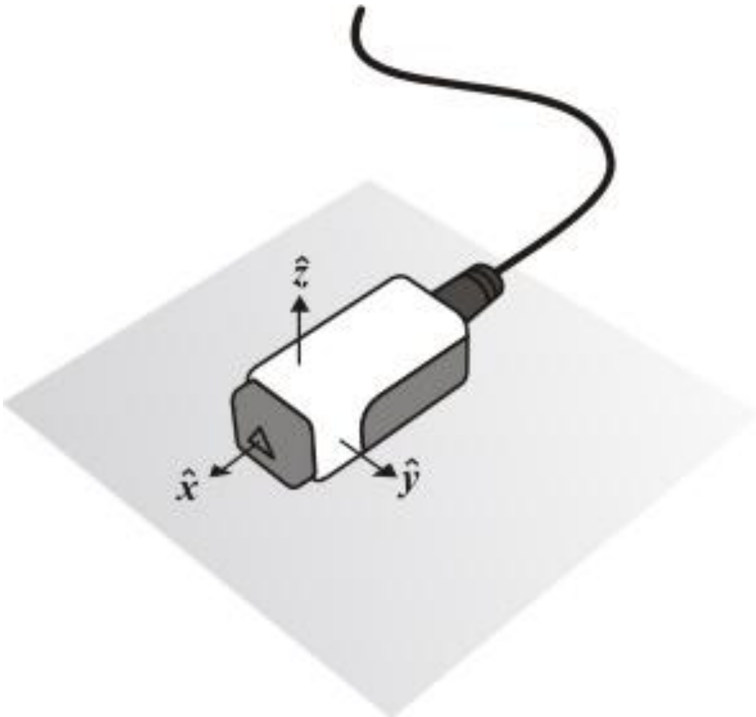

Fig.1 Measure the 3-axis acceleration values of the steady state motion in the laboratory table

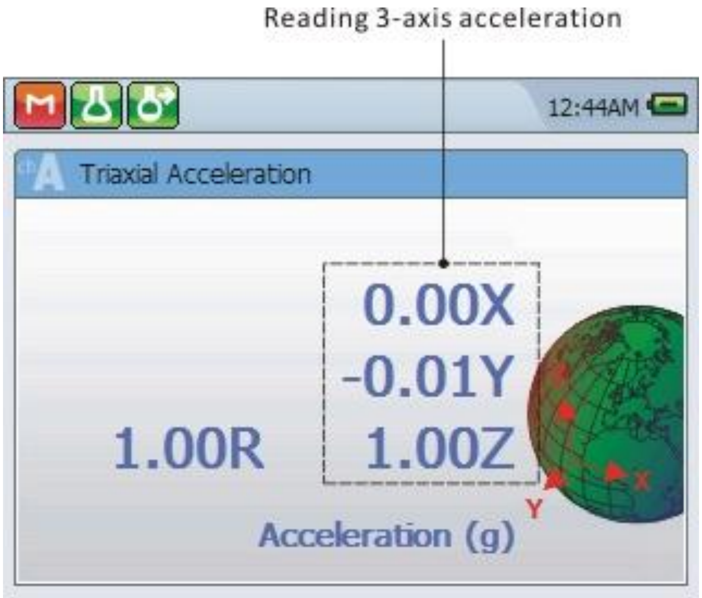

Fig.2 View the multidimensional values of 3-axis acceleration with the snapshot measurement.

How to analyze experimental uncertainty of acceleration

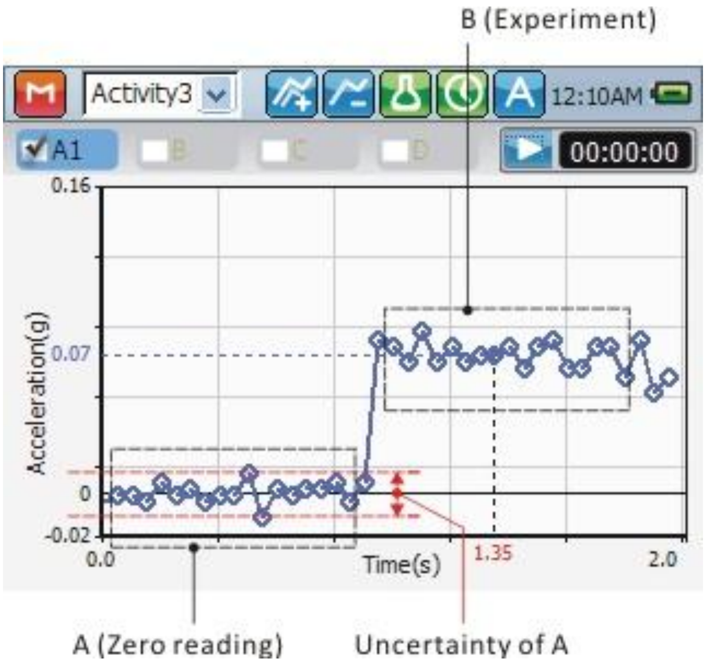

Fig.3 Measure the acceleration of the cart on the steady motion in a horizontal plane. After the zero-g reading A which is not moving-keep the cart from moving, B which is moving state due to constant force approach to steady motion.

The most straight forward way to report the uncertainty which has the systematic error related to accuracy and random error is to know how the results experimentally measured are averaged and propagated into the uncertainty of the derived values. For exploring this is that you calculate the averaged value of the acceleration and use the statistical values to report the experimental error. The table below show the statistics[3] results of the measurements for the steady motion as shown in Fig.2.

Table.1 Statistics of the zero reading[4] at the start of the experiment (Fig.3)

Parameters	Statistics
Maximum	0.011780
Minimum	-0.011658
Range (Maximum-Minimum)	0.023438
Mean	0.001103
Student's t-test ($p<0.05$, $\pm\mu$)	±0.002464
Detected systematic error[5]	±0.011719

According to the results of statistics, the measured values have random variation during the zero reading. The value of Student's t-test show random error presented in a measurement, and the systematic error can be detected from the range of the zero reading measurement. If you want to eliminate this systematic error, it needs to be allowed for by subtracting its maximum and minimum values from the readings, and you can take the Student's t-test value in assessing the error report of the measurement.

[3] In the Analyze screen of the MentorStart program, you can use the statistics function to analyze the measurement values.

[4] The zero reading is a measurement of a constant quantity as well as at the start of the experiment.

[5] It can be calculated with half value of the range (Maximum-Minimum) in Table.1.

Guide to Physics Experiments

Table.1 Advanced physics experiments using the Triaxial Acceleration sensor in the classroom laboratory.

Students' activity (Science Experiments)
Detect the mechanical properties of tilting, any motion or vibration
Measure the multidimensional values of 3-axis acceleration
Advanced physics practice of the force and acceleration in a horizontal or inclined plane
Amusement park physics about where students explore and measure various acceleration values on a ride such as a roller coaster or bungee jump and drop.

NOTE: As the sensor measure three accelerations in orthogonal coordinate system, the measurements values can be expressed easily for pointing the axes of interest towards the center of the Earth, rotating degrees and noting output values. If there is no acceleration present, the sensor will measure zero g in X and Y axis whereas the Z axis will measure 1.00g because the nominal acceleration g0 is applied to the sensor due to gravity at the Earth's surface at sea level. The value of g0 can be defined by using the mass and radius of Earth:

$$g_0 = GM/(R^2) \approx 9.81 m/s^2 \ (1g)$$

Transform the 3-axis acceleration between coordinate systems

In the practice of physics, you can use the coordinate systems to describe the vector properties of the position, velocity or acceleration. You can view the acceleration values in the Cartesian coordinates, the cylindrical coordinates or the spherical coordinates. For example, the peak value of the triaxial acceleration sensor with respect to x-axis should represent a positive value of acceleration when subjected to a force acting in positive direction.

$$x, y, z \ \text{(Cartesian)}$$

$$\rho=(x^2+y^2)^{(1/2)}, \phi=\arctan(y/x), z \ \text{(cylindrical)}$$

$$r= (x^2+y^2+z^2)^{(1/2)}, \theta=\arccos(z/r), \phi=\arctan(y/x) \ \text{(spherical)}$$

where **r** is the length of the position vector.

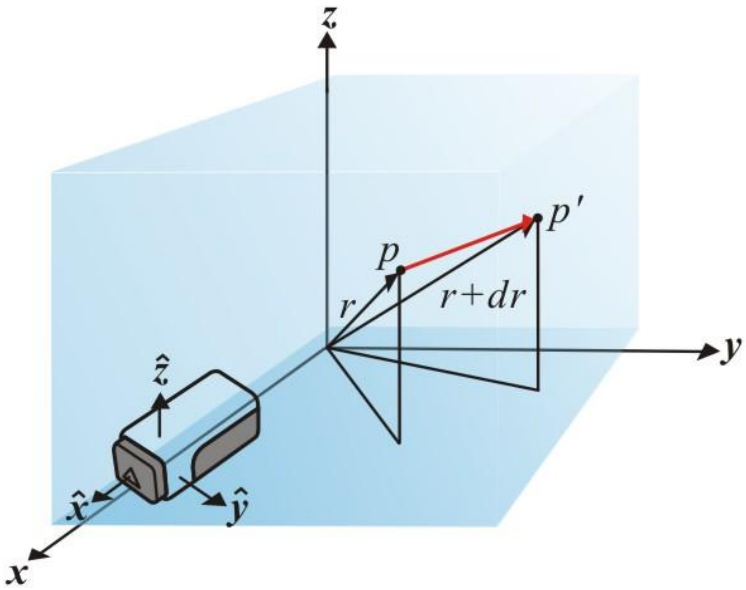

Fig.1 Cartesian Coordinates: You can use the scalar quantity of the resultant vector r as the sum of 3 vectors to view and analyze a motion of objects by using Newton's second law.

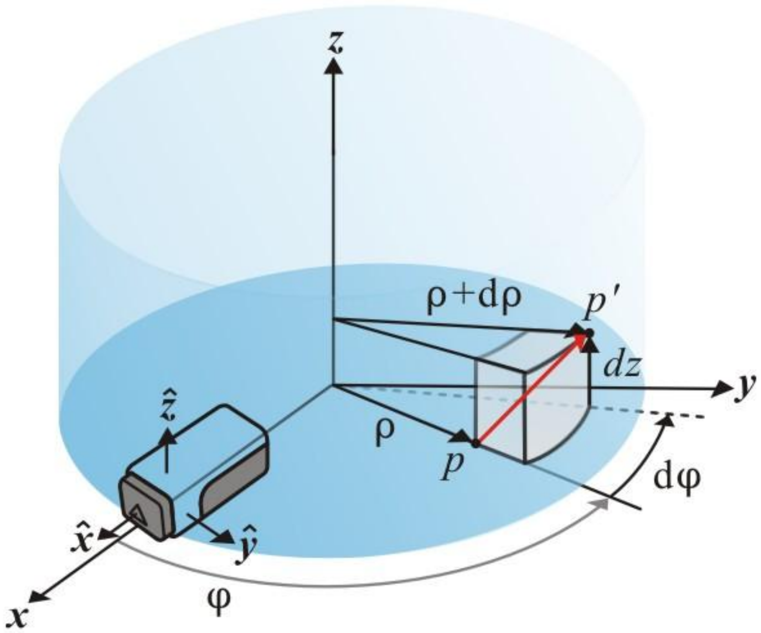

Fig.2 Cylindrical Coordinates: This orthogonal coordinates system can be commonly used in physics laboratory such as a rotational motion that its perpendicular distance ρ from z-axis and the rotational angle ϕ are mutually perpendicular.

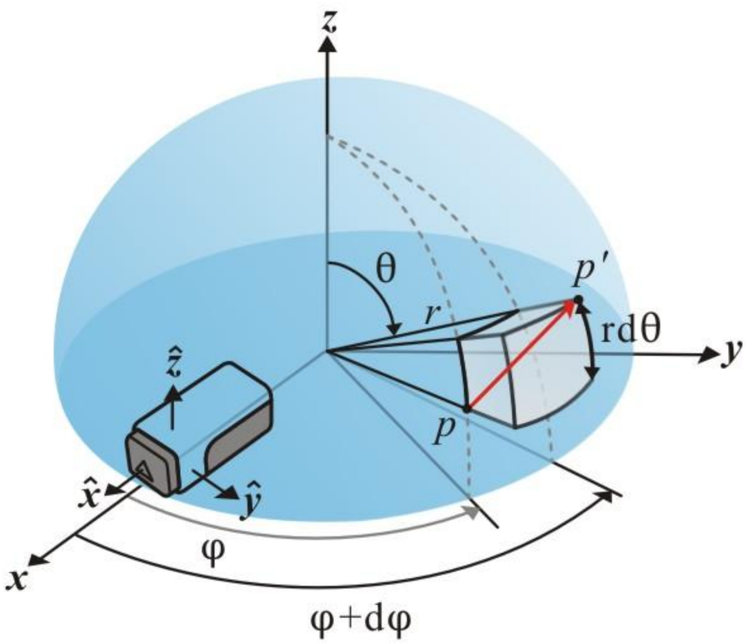

Fig.3 Spherical Coordinates: In MentorStart program, the magnitude **r, θ, ϕ** are measured from the spherical coordinates. The scalar component of r can be used to view and analyze a motion of object.

Measure the acceleration and resistance due to force of gravity

Students can measure the acceleration and resistance using dynamics cart in a horizontal plane. It is easy and simple to collect the acceleration data due to force of gravity as shown in the figure below.

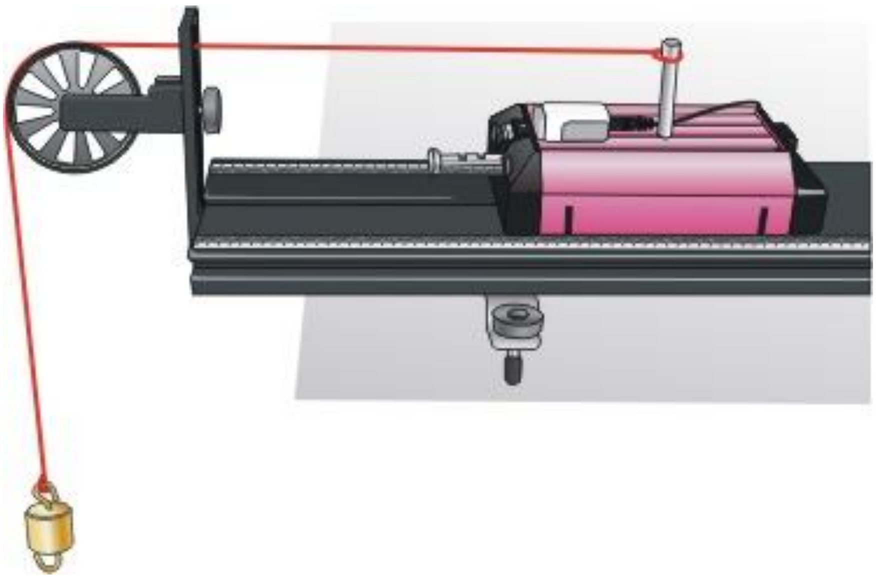

Fig.4 Uniformly accelerated motion of dynamics cart. When you release a small mass from the rest, it will accelerate the cart to speed up.

When a mass suspended from a light string at the end is ascending in the dynamic cart system with constant acceleration **a**, the cart moves in the horizontal plane. In terms of Cartesian coordinates, you can measure the scalar length of the acceleration vector **a.** After measurement of the x-acceleration, you can calculate the coefficient of dynamic friction between the cart and plane using the equations[6],

$$\mu=(mg-(M+m+I/r^2)*a)/Mg$$

where the rotational moment of pulley $I=1/2*Mr^2$. For example, when you set the mass of **M** to 0.0061kg and the radius of the pulley **r** to 0.032m, the moment can be calculated such as $I=1/2 \times 0.0061 \times 0.032^2 = 3.09 \times 10^{-6}$ **kgm^2**. In this investigation, you can expect and measure the acceleration of the cart using Newton's equation of motion and examine how it is different with a hanging mass. To test your predictions, you can drive the acceleration from the constraint equation of the cart[7] such as $a=(m-\mu M)g/(M+m+I/r^2)$.

After performing this activity (**Fig.4**), you can study the acceleration graph for a cart as shown below.

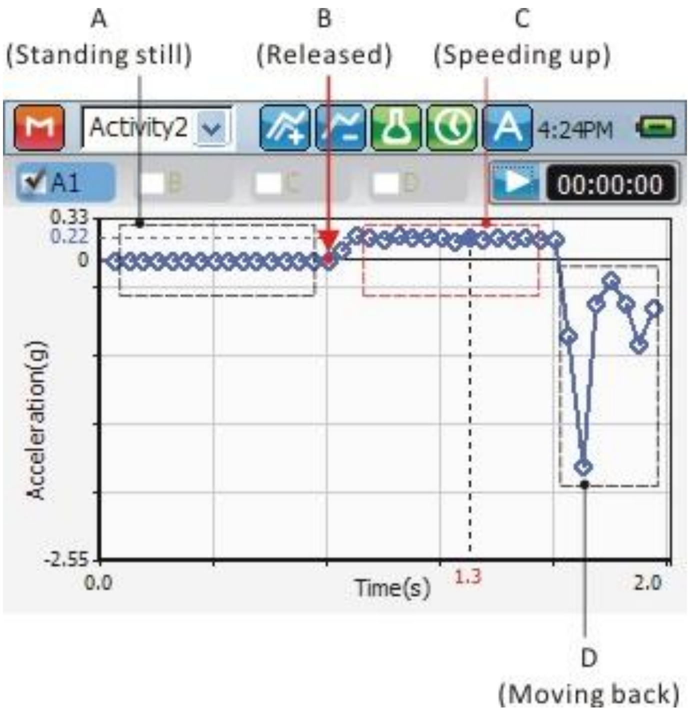

Fig.5 An acceleration-time graph of a cart whose motion produced the plot of constant acceleration.

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[6] See, Hyunsoo Kim, Computational Dynamics, 2008.

[7] Equation of cart run can be described as the following. my"+Mx"+μMg+Ix"/r^2-mg=0. See, Hyunsoo Kim, Computational Dynamics, 2008.

The plot label **A** in the chart show the zero reading and **B** show that the cart is moving away from the origin speeding up at a steady rate. **C s**how the reversing direction and moving back toward the origin.

In **Table.2**, the results of these activities show how the acceleration of the cart is different according to a hanging mass where **acc_g** is the averaged value of the acceleration in g, **a** is the calculated value in m/s^2, **±δa**[8] is the experimental uncertainty of **a**, **acc_eq** means the calculated value (theoretical value) from the equation of motion with no frictional force.

Table.2 Measurement of the acceleration with a different mass (Fig.4)

m (kg)	M (kg)	acc _g (g)	a (m/s^2)	±δa	acc_eq (m/s^2)	μ
0.05	0.525	0.074	0.726	0.01	0.852	0.014
0.10	0.525	0.144	1.408	0.01	1.568	0.019
0.15	0.525	0.207	2.027	0.02	2.178	0.019

Measure the time dependent acceleration

In advanced physics laboratory, students can investigate the acceleration of an object which is time dependent.

Fig.6 A linear fit for the time dependent acceleration graph of a cart whose acceleration is proportional to time.

[8] See, Hyunsoo Kim, Computational Dynamics, 2008.

The acceleration proportional to time can be expressed as a linear equation in time, as an example, **Fig.6** show the time dependent acceleration graph and the linear fit of the plot label **C** show the equation of acceleration such as **a=-0.109838t + 0.240687**, where the standard errors of slope and intercept are 0.007316 and 0.010791.

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If you have any questions about a guide to physics experiment using the sensor, please contact author at sooall@snu.kr