ScienceCube

C18A/C18B/C18C
Smart Temperature
User Guide

May 11 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. 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 temperature in °C or °F. Rugged stainless steel probe with students' grip handle.
Probe	Sensing element is located inside the probe's tip. The diameter of the stainless steel probe is slightly (than ≤) 3.96mm. Probe length: 130mm (C18B), 180mm (C18C)
Usage	Use only in water or mildly acidic solutions.

Specifications

Item	Description
Input range	Max. measurement*: -40°C to 125°C -40°F to 257°F
Resolution	±0.0625°C/12bit ±0.25°C/10bit ±0.5°C/9bit
Uncertainty (Accuracy)	Typical: ±0.25°C (in -40°C to 125°C) Max: ±1.0°C
Reading time	Typical: 30ms(9bit, 33Hz Sampling rate) 65ms(10bit, 15Hz Sampling rate) 250ms(12bit, 4Hz Sampling rate)
Sampling rate	Power-up default sampling rate is 4Hz Max. 33samples/second

*Maximum measurement range is specified for operation with short-term exposure limit without physically damaged. The limit means also the time for up to maximum minutes without danger to health, work efficiency and safety.

Additional equipment or application

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

CAUTION:

1. DO NOT use to measure the temperature of candle flame, cooking oil. You use only as either a water temperature sensor or a liquid temperature sensor with everyday materials.
2. DO NOT use this sensor in a strong acid and a strong base, a chemical reaction in a certain condition may indeed cause permanent and more damage.
3. DO NOT place sensor handle or cable in liquids, flame or on a hot plate. DO NOT place the sensor in a freezer, oven or near fire.
4. To protect against electrical shock, DO NOT plug the probe into the electric outlet or conductive solutions.

Setup and Usage

1. Launch MentorStart software and connect the sensor to the sensor port in your Mentor device. MentorStart will automatically detect the sensor. Place the Temperature sensor in liquids or air.
2. Wait minimum 10 seconds for the measurement digits display to stabilize. You may wait more seconds for stable readings when you want to record the accurate temperature of the liquids.

Fig.1 An easy experiment with everyday materials like water, soda and water cup. In this activity, you can plot the temperature graph of the liquids with cooling time.

Guide to Science Experiments

Table.1 Easy Science Experiments with everyday household materials using Smart Temperature

Students' activity (Science Experiments)
Water evaporation
Evaporative cooling and humidity
Endothermic or exothermic reactions
Boiling or freezing point of water
Supercooling of water
Inquiry to Dew point temperature

1. Investigate endothermic or exothermic reactions using such as baking soda, citric acid, and water.
2. Measure the boiling temperature of the water in the normal condition or the freezing point depression of the water by adding salt.
3. Use this sensor to measure and describe how everyday materials can be changed in a heating or cooling process, for example, you can measure a coffee cooling temperature in air or a supercooling of water.

NOTE: If you plan to use the Smart Temperature probe in strong acids, base or other different types of solutions, check the chemical compatibility of the solution you are using with stainless steel.

Creating a temperature and time graph for cooling

For example, you can use Newton's law of cooling to determine the cooling-off time of water or coffee in your room. The cooling time can be calculated as the followings :

Cooling Time, t=(1/K)*ln[(initial T(°C) – ambient T(°C)) / (final T(°C) – ambient T(°C))]

where K is cooling constant.

This model says the rate of a heat loses or gains. In order to solve the cooling constant using your experimental data, you can go directly to the analyze menu after the measurement of cooling down. Use the exponential fitting model, y=a*exp(b*x) or y=a*exp(b*x)+c to solve the cooling constant represented by experimental equation containing time and temperature quantities:

$$T(t)=a*\exp(Kt)$$

For now you are considering only cooling constant K and in order to solve the K constant, let's attention to b*x=K*t from the fitting equation y=a*exp(b*x).

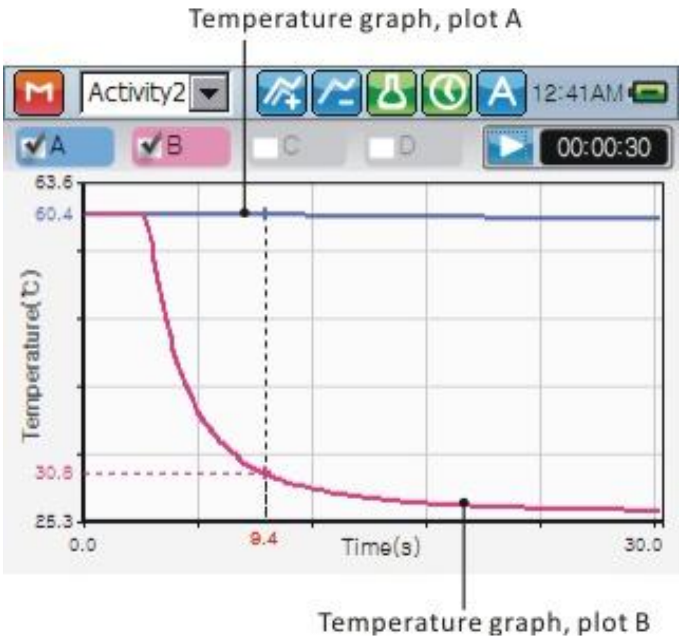

Fig.2 Air cooling experiment using two temperature probes in stable room temperature condition.

If you grab a cup of coffee, hot water or coffee with sugar, you can estimate the cooling time, and so you can take a mathematical formula. Also you can explore thermal reactions with everyday materials, for example: when you put a teaspoon of salt into a cub of water or a bit of baking soda into some vinegar, you can measure whether its temperature change or not.

Fig.4 Measure the temperature of a cooling water and coffee and inquire how hot coffee get cool enough. In this experiment you can gather simultaneously from two temperature sensors, and while the data are being collected, you can construct a mathematical model of the experiment and determine whether the exponential model fits the data as like the formula shown below.

$$\Delta T(t) = \Delta T(t0)\exp(-Kt)$$
$$\Delta T(t) = T(t)\_coffee - T(t)\_air$$

If you are using Microsoft Excel, you can solve the mathematical model[1] from which you analyze the data. When you construct a model of the data you can solve it using Excel Solver as the followings.

	A	B	C	D	E	F
1	t	T (Lab)	M (Model)	(T-M)^2		
2	0.5		=+$F$3*EXP(- $F$4*A2)+$F$5	=+POWER (B2-C2,2)		=+SUM(D2..D50)
3	1.0				T0	
4	1.5				K	
5	2.0				C	
6	2.5					

[1] See Hyunsoo Kim, Computational Dynamics with curriculum guide, 2008.

The figure shown below is an exploring and inquiring temperature difference with the freezing point depression. The mathematical model of this activity is

$$\Delta T_{freezing} = (K_{freezing}) \times (m_b)$$

where K_freezing is the constant for solvent, m_b is the molality of the solution. In this activity, students can inquire how an ice cube covered in salt melts quicker than ice cubes without salt.

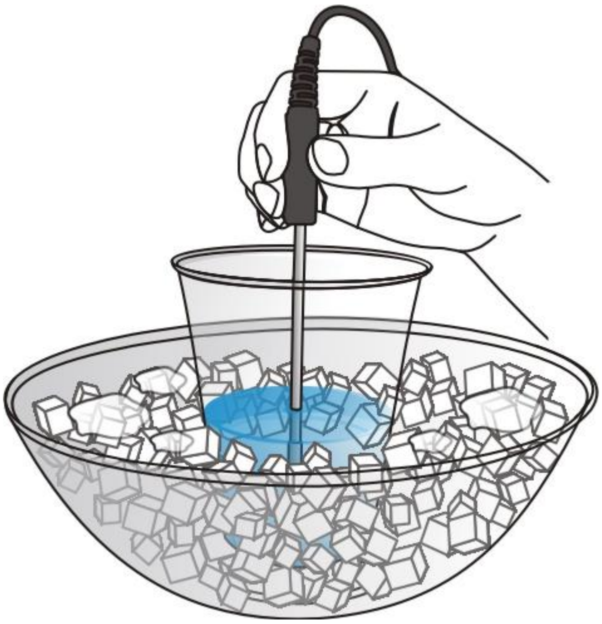

Fig.5 Easy experiment using ice cubes and salt for a measurement of freezing point depression[2].

Fitting and analyzing the cooling curve

When you are fitting the cooling curve of water or air, you can get the coefficients of analysis data graph for the experiment. The coefficients can be used to calculate above experimental formula.

[2] Go to the web site, http://en.wikipedia.org and search the keyword, freezing point depression. You can view more information for the freezing point.

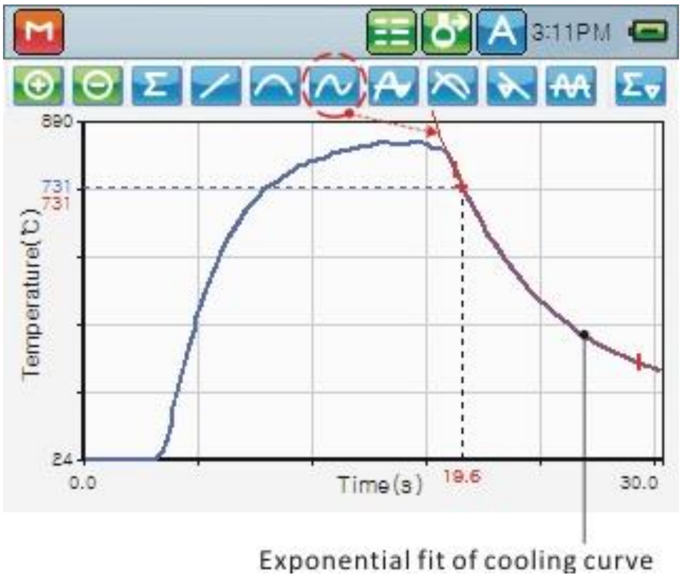

Fig.6 Exponential curve fitting of cooling air. Students can report the best fit graph and analysis data using exporting project files to web page. In this experiment, evaporation cools air. Best fit is the graph of dependent values of the fitted model.

Table.2 Example of the analysis results for the best fitted model.

	Results of curve fitting : y=A*exp(B*x)+C
t0	19.2
t’	29.6
dt	0.2
Number of data	48
A	598.509888
B	-0.186512
C	175.893372
R-squared	0.999951
RMSE(Fit standard error)	1.138471

When you are fitting the curve using the fitted model, MentorStart calculate and report the R-square (or R-squared) and RMSE value describe how well a fitted model matches the original data set. R-squared is a normalized parameter to measure the goodness of fit. The closer to 1 the R-squared, the better the fit.

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