EA-200

User's Guide

E

CASIO®

Important!
Please keep your manual and all information handy for future reference.

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Contents

— English —

Chapter 1

Chapter 2

■ Examples

Appendix A Command Tables

Appendix B Specifications

Handling Precautions

- The EA-200 is made up of precision components. Never try to take it apart.

- Avoid dropping the EA-200 and subjecting it to strong impact.

- Do not store the EA-200 or leave it in areas exposed to high temperatures, humidity, low temperatures, or large amounts of dust. Low temperatures can shorten battery life.

- Replace the main batteries once every two years regardless of how much the EA-200 is used during that period. Never leave dead batteries in the battery compartment. They can leak and damage the unit.

- Keep batteries out of the reach of small children. If swallowed, consult with a physician immediately.

- Avoid using volatile liquids such as thinner or benzine to clean the unit. Wipe it with a soft, dry cloth, or with a cloth that has been dipped in a solution of water and a neutral detergent, and wrung out.

- In no event will the manufacturer and its suppliers be liable to you or any other person for any damages, expenses, lost profits, lost savings or any other damages arising out of loss of data and/or formulas arising out of malfunction, repairs, or battery replacement. The user should prepare physical records of data to protect against such data loss.

- Never dispose of batteries, or other components by burning them.

- Replace batteries as soon as possible after the low battery indicator lamp (Batt) lights.

- Be sure that the power switch is set to OFF when replacing batteries.

- If the EA-200 is exposed to a strong electrostatic charge, its memory contents may be corrupted or the keys may stop working. In such a case, perform the Reset operation to clear memory contents and restore normal key operation.

- If you start to experience serious operational problems with the EA-200, use a thin, pointed object to carefully press the P button on the back of the EA-200. Note, however, that pressing the P button deletes all data currently in EA-200 memory. Proper operation does not resume after you press the P button, remove its batteries, and then replace them correctly in accordance with the instructions on page 0-3 of the User's Guide.

- Note that strong vibration or impact during program execution can cause execution to stop or can corrupt EA-200 memory contents.

- Using the EA-200 near a television or radio can cause interference with TV or radio reception.

- Before assuming malfunction of the EA-200, be sure to carefully reread this User's Guide and ensure that the problem is not due to insufficient battery power, programming or operational errors.

- Never allow foreign objects to get into connector holes. Doing so can result in malfunction.

- Always make sure to connect probes only to their correct terminals. Never force the plug of a probe into a wrong terminal connector.

- Be sure to turn the EA-200 off before connecting or disconnecting probes.

- Make sure that probes are connected securely before using them to take samples.

- Never insert a probe into an electric outlet. Never attempt to measure high voltages or household AC. Doing so creates the danger of electric shock.

- Never apply more than 15V to analog channels CH1 or CH2, more than 5V to analog channel CH3, or more than 5.5V to the SONIC, DIG IN, or DIG OUT channels. Doing so can damage the EA-200.

- The EA-200 is to be used for educational purpose only. It is not appropriate for industrial, research, medical, or commercial applications.

Unpacking

EA-200	Soft case	Data communication cable (SB-62)
Temperature probe	Optical probe	Voltage probe
Four AA-size alkaline batteries	AC adaptor	User's Guide (this manual)

Using the Soft Case

About the EA-200

The EA-200 is a digital device that makes it possible for you to sample data connected with everyday natural phenomena.

Data You Can Sample with the EA-200

Various different sensors can be used with the EA-200 to sample temperatures, light, voltage, distance, and other data. The EA-200 supports sampling of up to 120,000 points, and simultaneous sampling over five channels. Sampled data can be sent to a compatible Graphic Scientific Calculator, where it can be viewed and graphed.

Before Using the EA-200 for the First Time

Power Requirements

Your EA-200 requires four AA-size alkaline batteries for power. Battery life depends on the amount of time the EA-200 is left on, and the amount of current used by the connected probe(s). A low battery indicator lamp (Batt) lights to let you know when it is time to replace batteries. To extend battery life, it is a good idea to use the AC adaptor for power whenever sampling indoors.

When using the EA-200 in combination with the optional "Motion Sensor (EA-2)", be sure to power the EA-200 using its bundled AC adaptor (AD-A60024).

Though the EA-200 can normally operate on battery power, separate AC adaptor power is required while the optional "Motion Sensor (EA-2)" is being used.

Batteries are not loaded in the EA-200 when it is shipped from the factory. Because of this, use the following procedure to load batteries into the EA-200 before using it for the first time.

To load batteries

1. Remove the battery cover by pulling with your finger at the point marked ①. If there are batteries in the battery compartment, remove all four of them.

2. Load four new AA-size batteries. Make sure that the plus and minus ends of the batteries are facing in the directions shown by the markings inside the battery case. Replace the battery cover.

3. Slide the [ON/OFF] switch to turn on the EA-200. To turn off, slide the [ON/OFF] switch again.
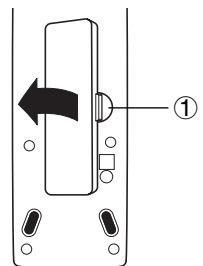
Auto Power Off (APO)

To extend battery life, power automatically turns off if you do not perform any operation for about 30 minutes. APO is disabled automatically whenever the EA-200 is standing by for sampling (ready state), or while sampling is in progress.

Extended Sampling Mode

The Extended Sampling Mode makes it possible to sample data over an extended period when operating under battery power. The following are the features of the Extended Sampling Mode.

• In the Extended Sampling Mode, sampling continues even though the power lamp is not lit.

• The Extended Sampling Mode is entered automatically whenever the sampling interval is five minutes or longer.

• To exit the Extended Sampling Mode, press the [START/STOP] key. Note that all other keys are disabled in the Extended Sampling Mode.

When to Replace Batteries

Replace batteries as soon as possible after the low battery indicator lamp (Batt) lights. The EA-200 may start to malfunction if you continue to use it while battery power is low.

• Be sure to replace the batteries at least once every two years, no matter how much you use the EA-200 during that time.

• The batteries that come with this EA-200 discharge slightly during shipment and storage. Because of this, they may require replacement sooner than the normal expected battery life.

• Before removing the batteries, make sure you make a separate copy of sample data by transferring it to a Graphic Scientific Calculator or some storage device. Cutting off all power to the EA-200 by removing its batteries while the AC adaptor is not connected causes all of the data in memory and all settings to be cleared.

• Whenever performing a sampling operation that requires more than a few minutes, we recommend that you power the EA-200 using the AC adaptor. This will help to ensure stable sampling operations.

AC Adaptor

Warning!

• Make sure the voltage of the power supply you are connecting to matches that of the rating marked on the EA-200. Do not overload extension cords and wall outlets. Failure to follow these precautions creates the danger of fire and electric shock.

• Never allow the power cord to become damaged, cracked, or broken. Never modify the power cord in any way, and never subject it to excessive twisting or pulling. Never place heavy objects on power cord and do not expose it to direct heat. A damaged power cord creates the danger of electric shock.

• Never touch the AC adaptor while your hands are wet. Doing so creates the danger of electric shock.

Caution!

• Always grasp the adaptor box and never pull on the power cord when unplugging the AC adaptor. Doing so runs the risk of damaging the cord and creating the danger of fire and electric shock.

• Be sure to always unplug the AC adaptor whenever leaving the EA-200 unattended for long periods.

• Use only the special AC adaptor that is specified for the EA-200.

• Use of any other type of AC adaptor creates the risk of serious problems with and damage to the EA-200 and/or AC adaptor. Never use another type of AC adaptor. Note that any damage due to use of the wrong type of adaptor is not covered by your warranty.

• Make sure you turn off the EA-200 before connecting the AC adaptor.

• The AC adaptor may become warm if you use it for a long time. This is normal and does not indicate malfunction.

To connect the AC adaptor to the EA-200

1. Slide the [ON/OFF] switch to turn off the EA-200.
2. Plug the AC adaptor into the port on the lower left of the EA-200.
3. Plug the other end of the AC adaptor into a wall outlet.
4. Slide the [ON/OFF] switch to turn on the EA-200.

Chapter 1

General Guide

Analog Channels × 3
(Analog output for CH3 only)

CH3 | CH2 | CH1

Digital input/output port ←→

SONIC Channel
EA-2*¹

Serial 232C (9-pin) port ←→
(for cross cable)

Calculator 3-pin
communication port
(SUB port) × 7

External microphone 2-pin port
(for condenser microphone) ←→

External speaker 2-pin port ←
Volume →

Calculator 3-pin
communication port
(MASTER port)

Ready Sampling Error Batt Power

Indicator lamps →

Built-in speaker

ON/OFF switch

P button (rear side)*²

SET UP

START/STOP

SET UP key

START/STOP key

AC adaptor port

Built-in microphone

Data communication
cable

*¹ When using the EA-200 in combination
with the optional "Motion Sensor (EA-2)",
be sure to power the EA-200 using its
bundled AC adaptor (AD-A60024).

Key Functions and Indicator Lamps

■ Key Functions

To do this:	Press this key:
Start a sampling operation from the ready state	[START/STOP]
Stop an ongoing sampling operation	[START/STOP]
Use Auto Setup (See "Auto Setup" on page 1-5.)	[SET UP]
Cancel the ready state	[SET UP]

■ Indicator Lamps

When this indicator lamp:	Does this:	It means this:
Power (Green)	Lights	Power is on.
Ready (Green)	Lights	EA-200 is standing by for data (ready state).
Sampling (Green)	Flashes	Sampling is in progress.
Error (Red)	Lights	An error occurred.
Batt (Red)	Lights	It is time to replace the batteries.

• While the "Ready" lamp is lit, press the [START/STOP] key to start sampling.

• To cancel the ready state, press the [SET UP] key.

• To interrupt a sampling operation, press the [START/STOP] key.

• For details about errors, see "Status Request" on page 1-5.

*² If you start to experience serious operational problems with the EA-200, use a thin, pointed object to carefully press the P button on the back of the EA-200. Note, however, that pressing the P button deletes all data currently in EA-200 memory. Proper operation does not resume after you press the P button, remove its batteries, and then replace them correctly in accordance with the instructions on page 0-3 of the User's Guide.

Supported Calculator Models

Connection to a supported scientific calculator is essential if you want to get the most out of your EA-200. A connected Graphic Scientific Calculator sends commands that control the EA-200 during transfer of sampled data and other operations. Transferred data can be graphed on the calculator. For details about commands, see "Using Commands" on page 1-3, and "Command Tables" on page α-1-1.

Supported Calculator Models

ALGEBRA FX Series	CFX-9850/fx-7400 Series
ALGEBRA FX 2.0 PLUS	CFX-9950GB PLUS
ALGEBRA FX 2.0	CFX-9850GB PLUS
FX 1.0 PLUS	CFX-9850Ga PLUS
FX 1.0	CFX-9850G PLUS
	CFX-9970G
	fx-9750G PLUS
	CFX-9950G
	CFX-9850G
	fx-7400G PLUS
	fx-7450G

Connecting the EA-200 to a Supported Calculator

Use the special data communication cable to connect the EA-200 to a supported Graphic Scientific Calculator model.

  (1) Turn off the EA-200 and the calculator.

  (2) Connect one end of the special data communication cable to the scientific calculator.

  (3) Connect the other end of the cable to the EA-200's MASTER port.

• Insert the plugs as far as they will go. If you experience problems when transferring data, check to make sure that both plugs are fully inserted.

• Be sure to read the user documentation that comes with the scientific calculator you are connecting.

Supported Probes

A probe is a sensor that connects to the EA-200 for sampling temperature, light, and other data.
The EA-200 comes with the three probes described below.

  • Voltage Probe .... Measures voltage in the range of –10V to +10V.
  CH3 measures in the range of –5V to +5V.

  • Optical Probe .... Measures luminance in the range of 100 to 999.

  • Temperature Probe .... Measures temperature in the range of –20°C to 130°C.

Connecting a Probe to a Channel

A probe connects to an input/output port called a "channel." The EA-200 has seven channels: three analog channels (CH1, CH2, CH3), one sonic channel (SONIC), one digital input/output channel (DIG I/O), a microphone channel, and a speaker channel. You can connect probes individually, or you can connect multiple probes for simultaneous sampling. You can use commands to configure the settings for the channel being used for sampling, to specify how sampled data should be handled, etc.

  CH1, CH2, CH3

  These channels are for the probes (voltage, temperature, optical) that come bundled with the EA-200.

  SONIC
  This channel is for connection of an optional "Motion Sensor (EA-2)".

  DIG I/O
  This port is for input and output of an 8-bit binary signal in the range of 0V to 5V.
  This could be used, for example, to light an LED.

  Built-in Microphone
  The microphone can be used to sample sound.

  Built-in Speaker
  The speaker can be used to output sound samples.

Using Commands

Basically, the EA-200 is controlled by commands from the connected calculator. This section explains how to send commands from the calculator to the EA-200.

To use a command, you store parameters as List data on the calculator, and then use the Send command to send the parameters to the EA-200.

EA-200 Operation

The following is an outline of the EA-200 command receive process.

① Slide the EA-200 [ON/OFF] switch to turn on power.

② EA-200 receives Command 0 sent from the calculator.
   • This initializes the EA-200 setup.

③ EA-200 receives Command 1 sent from the calculator.
   • This configures EA-200 channel settings.

④ EA-200 receives Command 3 sent from the calculator.
   • This configures EA-200 sampling conditions.
   • After sampling conditions are configured, the EA-200 enters the ready state.

⑤ Press the EA-200 [START/STOP] key.
   • This puts the EA-200 into sampling mode.
   • Sampling ends in accordance with the sampling conditions configured in step ④.

⑥ Sample data is sent from the EA-200 to the calculator in response to a Receive command.

Sending a Command

Example 1: To initialize the EA-200 setup

{0} → List 1↵   Stores {0} to List 1. 0 is the command number.

Send (List 1)↵   Sending List 1 executes Command 0.

Example 2: To configure channel settings

{1, 1, 2} → List 1↵   Stores {1,1,2} to List 1. The first 1 is the command number, the second 1 is the channel number, and the 2 indicates use of the voltage probe.

Send (List 1)↵   Sending List 1 executes Command 1.

Receive Data Command

As with command execution, all of the operations required to receive data from the EA-200 to the calculator are performed on the calculator.

You can transfer sampled data by executing the calculator's Receive command.

Data is transferred in the sequence shown below.

Record Time → CH1 → CH2 → CH3 → SONIC

Receive (List 1)↵   Stores transferred data into List 1 of the calculator.

Using the Voltage Probe, Temperature Probe, Optical Probe, and Motion Sensor (EA-2)

The following examples show how to use the temperature probe, voltage probe, optical probe, and "Motion Sensor (EA-2)". Perform the procedures in each example by creating programs on the calculator.

■ Taking 60 samples at one-second intervals over one minute

(1) Send Command 0 to initialize the EA-200 setup.

{0} → List 1↵   Stores {0} to List 1. 0 is the command number.

Send (List 1)↵   Sending List 1 executes Command 0.

(2) Send Command 1 to configure channel settings.

• Voltage Probe   (that is connected to CH1.)

{1, 1, 2} → List 1↵   The first 1 is the command number, the second 1 is the
Send (List 1)↵   channel number, and the 2 indicates use of the voltage
   probe.

• Temperature Probe   (that is connected to CH1.)

{1, 1, 7} → List 1↵   The first 1 is the command number, the second 1 is the
Send (List 1)↵   channel number, and the 7 indicates use of the temperature
   (Celsius) probe.

• Optical Probe   (that is connected to CH1.)

{1, 1, 9} → List 1↵   The first 1 is the command number, the second 1 is the
Send (List 1)↵   channel number, and the 9 indicates use of the optical probe.

• Optional "Motion Sensor (EA-2)"   (that is connected to SONIC channel.)

{1, 4, 2} → List 1↵   1 is the command number, 4 is the channel number
Send (List 1)↵   (SONIC), and 2 indicates use of the motion sensor (meters).

(3) Send Command 3 to configure measurement condition settings.

{3, 1, 60} → List 1↵   3 is the command number, 1 is the sampling interval, and 60
   is the number of samples.

Send (List 1)◢   You can change sampling conditions by using different
   sampling interval and number of samples values, if you want.

At this time, the Ready lamp lights on the EA-200.
Press the EA-200 [START/STOP] key to start sampling.
When sampling is complete, press the calculator's ⌷EXE⌷ key to restart the program.
◢ (Disp command) causes processing to stop until you press the ⌷EXE⌷ key.

(4) Sample data from the EA-200 is received by the calculator.

Receive (List 1)↵   Record Time data is received and stored in List 1.
Receive (List 2)↵   Sampling Data of CH1 is received and stored in List 2.

Using the Built-in Microphone

To take 255 samples at 50μs intervals

(1) Send Command 0 to initialize the EA-200 setup.

{0} → List 1↵   Stores {0} to List 1. 0 is the command number.
Send (List 1)↵   Sending List 1 executes Command 0.

(2) Send Command 1 to specify microphone as the channel.

{1, 10} → List 1↵   1 is the command number, and 10 indicates use of
Send (List 1)↵   the built-in microphone.

(3) Send Command 3 to configure measurement condition settings.

{3, 0.00005, 255} →   3 is the command number, 0.00005 is the sampling interval
List 1↵   (50μs), and 255 is the number of samples.

Send (List 1)◢   You can change sampling conditions by using different
   sampling interval and number of samples values, if you want.

At this time, the Ready lamp lights on the EA-200.
Press the EA-200 [START/STOP] key to start sampling.
When sampling is complete, press the calculator's ⌷EXE⌷ key to restart the program.
◢ (Disp command) causes processing to stop until you press the ⌷EXE⌷ key.

(4) Sample data from the EA-200 is received by the calculator.

Receive (List 1)↵   Record Time data is received and stored in List 1.
Receive (List 2)↵   Sampling Data of microphone is received and stored in List 2.

• When using the built-in microphone for sampling,
  position it so it is about two or three centimeters
  from the sound source.
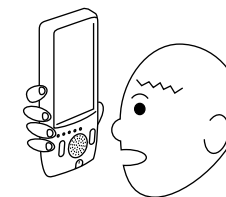
• If the graph shows that the sampled sound is exceeding the sampling range as
  shown below, either lower the volume of the sound source or move the microphone
  further away from the sound source.

Using the Built-in Speaker

To output sound recorded by the built-in microphone

(1) Send Command 0 to initialize the EA-200 setup.

{0} → List 1↵   Stores {0} to List 1. 0 is the command number.

Send (List 1)↵   Sending List 1 executes Command 0.

(2) Send Command 1 to specify microphone as the channel.

{1, 10} → List 1↵   1 is the command number, and 10 indicates use of
Send (List 1)↵   the built-in microphone.

(3) Send Command 3 to configure measurement condition settings.

{3, 0.00005, 120000}   3 is the command number, 0.00005 is the sampling interval
→ List 1↵   (50µs), and 120000 is the number of samples.

Send (List 1)◢   You can change sampling conditions by using different
          sampling interval and number of samples values, if you want.

At this time, the Ready lamp lights on the EA-200.
Press the EA-200 [START/STOP] key to start sampling.
When sampling is complete, press the calculator's [EXE] key to restart the program.
◢ (Disp command) causes processing to stop until you press the [EXE] key.

(4) Send Command 0 to initialize the EA-200 setup.

{0} → List 1↵   Stores {0} to List 1. 0 is the command number.

Send (List 1)↵   Sending List 1 executes Command 0.

(5) After sampling is complete, use Command 1 to configure speaker settings.

{1,12, 5,10} → List 1↵   1 is the command number, 12 specifies the speaker as the
Send (List 1)↵   channel, 5 is the number of loops, and 10 specifies output of
          values sampled by the microphone.

(6) Re-configure the sampling condition settings.

{3,0.00005,120000}   3 is the command number, 0.00005 is the sampling interval
→ List 1↵   (50µs), and 120000 is the number of samples.

Send (List 1)◢   You can change sampling conditions by using different
          sampling interval and number of samples values, if you want.

(7) Press [START/STOP] to output the sound recorded with the microphone.

Status Request

This function can be used to fetch the current status of the EA-200.

To use Status Request

{7} → List 1↵   Sends Command 7.

Send (List 1)↵

Receive (List 1)↵   Receives the status information and stores it in List 1.

Line 1	Line 2	Line 3	Line 4
Status	Error Code	Battery Condition	OS Version
0: Standby (No Sample Data in EA-200) 1: Ready 2: Sampling 3: Standby (Sample Data in EA-200)	= 0: Normal ≠ 0: Error Integer: Command number Decimal Part: Parameter position Example: 3.2 Second parameter of Command 3. Sampling interval value error	0 to 999 < 450: low battery	Version No.

Auto Setup

Auto Setup detects the Auto-ID of a probe, and configures applicable settings automatically. The three probes (voltage, temperature, optical) that come bundled with the EA-200 have Auto-IDs.[1]

To use Auto Setup

1. Connect a probe to a channel.

2. Slide the [ON/OFF] switch to turn on power.

 • This causes the Power lamp to light.

3. Press the [SET UP] key.

 • This causes the Ready lamp to light.

[1] The optional "Motion Sensor (EA-2)" does not have an Auto-ID.

4. Press the EA-200 [START/STOP] key to start sampling.

 • The Sampling lamp flashes as sampling is performed.

5. Press the [START/STOP] key again to stop sampling.

6. Connect the EA-200 to the calculator, and then use the Receive command to transfer the sampled data (see the "Receive Data Command" on page 1-3).

 • Data is transferred in the following sequence:
 Record Time → SONIC →CH1 → CH2 → CH3.

 • Any channel that is not being used is skipped automatically.

Group Link Function

A single EA-200 can be used to connect one "MASTER" calculator to up to seven other "SUB" calculators to distribute programs, data, etc.*1 Note, however, that you cannot have the following calculator models connected to the EA-200 at the same time.*2

 • ALGEBRA FX Series

 • CFX-9850/fx-7400 Series*3

To perform a Group Link operation

1. Use a Link Cable (SB-62) to connect the calculator that contains the data you want to send to the MASTER port of the EA-200.

2. Use a Link Cable (SB-62) to connect the calculators to which you want to send the data to the SUB ports of the EA-200).

3. Slide the [ON/OFF] switch of the EA-200 to turn it on.

4. On all of the SUB calculators, use the LINK application to enter the Receiving Mode.

5. On the MASTER calculator, use the LINK application to transmit the data.

6. The data transfer operation is over when the message "Complete" appears on the displays of the MASTER calculator and all of the SUB calculators.

*1 Backup data cannot be distributed.

*2 See the "Supported Calculator Models" on page 1-2 for more information about compatibility between various calculator models.

*3 fx-7400 Series calculators support Program and List data only.

Example Operation

The example below shows how a teacher can use the EA-200 Group Link function to distribute a sampling program and sampled data.

1. Students are divided into multiple groups, and each group has its own EA-200. The teacher uses his or her EA-200 to distribute a sampling program to each of the group leaders.
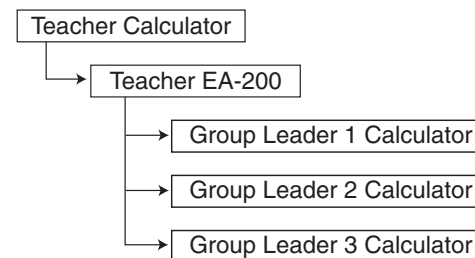
2. Each group uses the EA-200 to perform sampling using the program that was distributed to the group leader's calculator from the teacher's calculator. After sampling is complete, the EA-200 Group Link function is used to distribute the sampled data to the calculator of each group member.
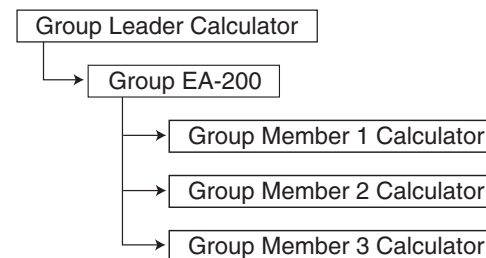
Important!

 • You can create your own sampling program while referring to the Program Library on page 2-16-1, or you can download a program at the CASIO Website: http://world.casio.com/edu_e/

Chapter 2

■ Examples

Uniformly Accelerated Motion

Period of Pendular Movement

Conservation of Momentum

Charles' Law

Polarization of Light

Natural Frequency and Sound

Column of Air Resonance and the Velocity of Sound

Construction of the Musical Scale

Direct Current and Transient Phenomena

AC Circuit

Dilute Solution Properties

Exothermic Reaction

Electromotive Force of a Battery

Sunlight and Solar Cells

Topographic Conditions and Climate

■ Program Library

Uniformly Accelerated Motion

This activity observes the movement of a cart down an incline and investigates uniformly acceleration motion caused by gravity.

Theory

A cart placed on an inclined ramp starts to move straight down the ramp. This movement is due to the force of gravity acting on the cart to pull it down the incline and pulling it against the ramp. The distribution of these two forces depends on the inclination of the ramp. The acceleration of the cart is determined by the magnitude of the force that moves the cart. Movement represented by an acceleration value that does not change over time is called "uniformly accelerated motion." The movement of the cart described above is uniformly accelerated motion. As shown below, the velocity of uniformly accelerated motion is proportional to time, and the distance traveled is proportional to the time squared. This means that if you observe the distance covered by the cart over a specific time, you can determine its acceleration.

$$F = ma = mg\ sin\theta$$
$$v = at$$
$$L = \frac{1}{2}at^2$$

F(N)   : Force Acting on Cart in Direction of the Ramp Surface
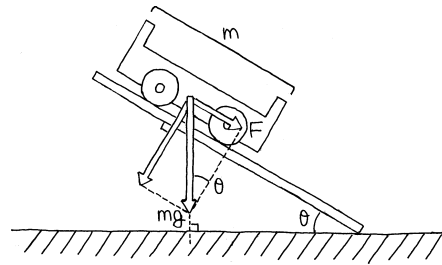a(m/s²) : Cart Acceleration
m(kg)   : Cart Mass
g(m/s²) : Gravitational Acceleration
θ(°)   : Ramp Angle of Inclination
v(m/s) : Cart Velocity
t(s)   : Cart Travel Time
L(m)   : Distance Traveled by Cart

Though actual gravitational acceleration depends on latitude and elevation, this activity can be conducted using the gravitational constant 9.8m/s².

Activity: Setup

### ■ Equipment

Cart   Ramp   Stand   Protractor
Distance Measurement Setup (EA-200, graphic scientific calculator, data communication cable, optional EA-2*¹)

■ Setting Up

● Affix the EA-2 to the arm of the stand.

● Measure the incline of the ramp with the protractor, and fix the ramp at an angle of 15 degrees.

① Stand
② Ramp
③ Desk
④ EA-2 (SONIC)
⑤ Protractor
⑥ Ramp Angle: 15 degrees
⑦ Distance from EA-2 to end of ramp: 150cm
⑧ Ramp Width: 30cm
⑨ EA-200
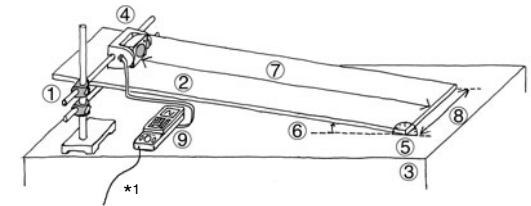
● Measure the mass of the cart, place it onto the ramp, and hold it in place with your hand.

① Desk
② Ramp
③ EA-2 (SONIC)
④ Cart Mass: m(kg)
⑤ Distance Between Cart and EA-2: 60cm
⑥ Protractor
⑦ Ramp Angle: 15 degrees
⑧ Hand
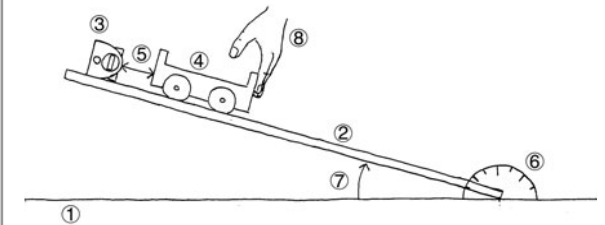
*¹ When using the EA-200 in combination with the optional "Motion Sensor (EA-2)", be sure to power the EA-200 using its bundled AC adaptor (AD-A60024).
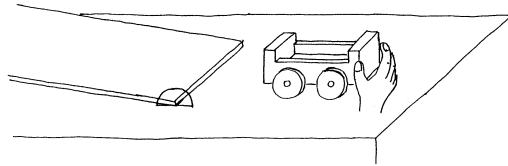
Activity: Operating the Equipment

■ Measuring Data

● Prepare the Distance Measurement Setup. Immediately after starting the measurement operation, let the cart go.
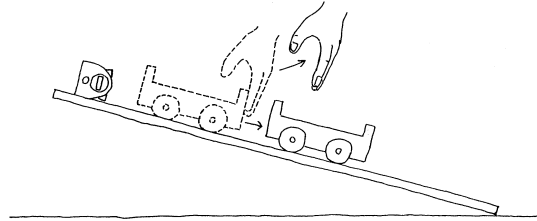

● When the cart reaches the desk, stop it.

● Graph the data on the calculator, observe its characteristics, and compare it with theoretical expectations.

● Change the angle of the ramp 10 degrees and then 20 degrees, and measure again.

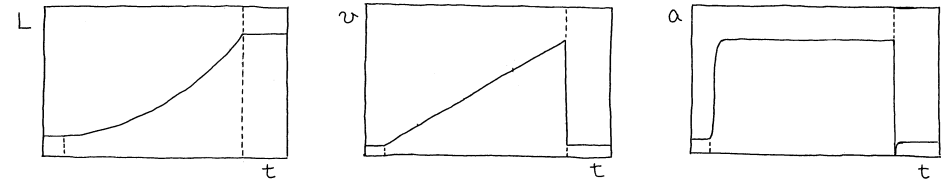● Observe how the graph changes as the ramp angle is changed.

① Protractor
② Ramp Angle: 15 degrees
③ Ramp Angle: 10 degrees
④ Ramp Angle: 20 degrees
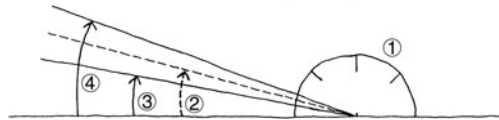
Measurement

■ Calculator Operation

● Find the applicable program in the Program Library (P.2-16-1), input it into your calculator, and then run it.

● Display graphs for the distance traveled, velocity, and acceleration of the cart.

L(m)   : Distance Traveled by Cart
v(m/s) : Cart Velocity
a(m/s^2) : Cart Acceleration
t(s)   : Cart Travel Time

Other Things To Do

● Study the relationships between the changes of distance traveled, velocity, and acceleration.

● Consider the reasons why the graphs change as the angle of the ramp is altered.

● Find out how the graph is affected when the mass of the cart is changed by placing a weight on it.

Period of Pendular Movement

In this activity, we create a simple pendulum and then visually check the periodicity of its movement, while determining its period.

Theory

A pendulum is a string whose one end is fixed and whose other end has a weight attached to it. As the weight swings, it keeps returning to the same position at the same velocity over time. Such motion is called "periodic motion," and the time it takes for the weight to return to a particular state is called its "period." A high-precision pendulum can continue to swing for a very long time with little change in its period over time. This is why such a pendulum is often used for timepieces.

A pendulum that moves across a single plane is called a simple pendulum. When the amplitude of the pendulum is sufficiently short in relation to its length, the period of a simple pendulum can be expressed as shown below.

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

ℓ(cm)　　: Pendulum Length
g(cm/s^2) : Gravitational Acceleration
m(g)　　 : Mass of Weight
T(s)　　 : Period
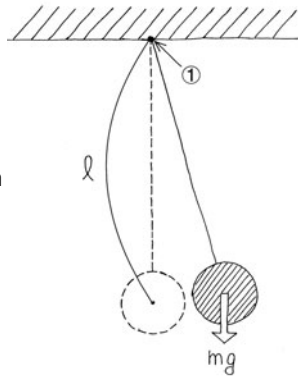
①　Fixed Point

All of this means that if gravitational acceleration is a fixed value that depends on the location where the activity is performed, then the period depends on the length of pendulum only.

With this activity, a pendulum is setup between a light source and an observer. The shadow created by the weight makes it possible to observe the periodicity of the pendular motion.

Though actual gravitational acceleration depends on latitude and elevation, this activity can be conducted using the gravitational constant. When gravitational acceleration is 980cm/s^2 and the length of the pendulum is 25cm, the oscillation period of the pendulum is about one second.

Activity: Setup

■ Equipment

String with little elasticity　　Weight　　　　Stand　　　　Height adjustment blocks (2)
Optical Measurement Setup (EA-200, graphic scientific calculator, data communication cable, optical probe)

■ Building a Pendulum

● Securing the fixed point of the pendulum so it cannot move, assemble the pendulum as shown in the illustration.

① Stand
② Pendulum Length: 30cm
③ Fixed Point
④ String
⑤ Weight: 100g
⑥ Weight Size: 3cm
⑦ Height: 2cm
⑧ Desk
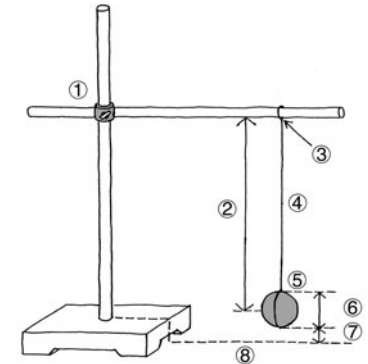
■ Setting Up

● Align the heights of the optical probe and flashlight so the flashlight is shining directly at the probe.

● Set up the pendulum so the weight blocks the light to the optical probe when it is at rest.
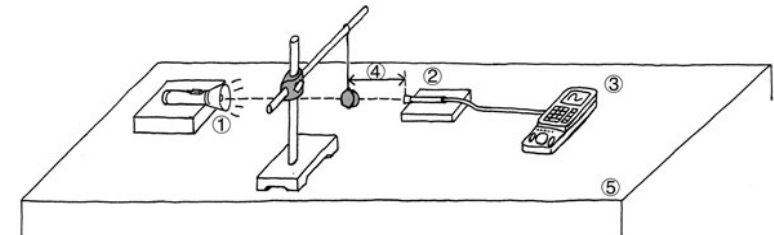
① Flashlight
② Optical Probe (Observer) (CH1)
③ EA-200
④ Distance Between Weight and Optical Probe: 10cm
⑤ Desk

Activity: Operating the Equipment

■ Measuring Data

• Prepare the Optical Measurement Setup.
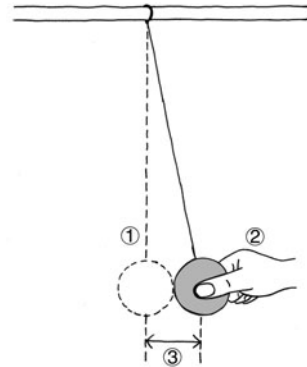
• Taking care not to allow the string to go slack, move the weight as shown in the illustration and then gently let it go.

• After the weight swings back and forward a few times, start the measurement operation on the EA-200.

① Weight Position of Equilibrium
② Hand
③ Amplitude: 3cm

• Move the optical probe from position A to position B or C, and then repeat the measurement operation.

① Weight Position of Equilibrium
② Flashlight
③ Weight Movement
④ Optical Probe
⑤ Distance Between A and B: 1cm
⑥ Distance Between A and C: 3cm
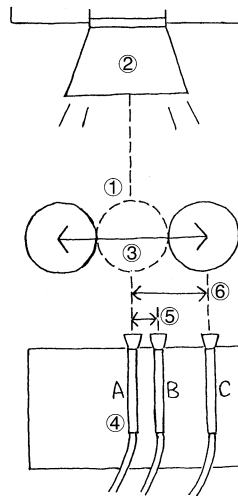
• Determine the period from the graph of measurement results, and compare this with the calculated value.

Measurement

■ Calculator Operation

• Perform the following operation to prepare for light measurement using the optical probe.
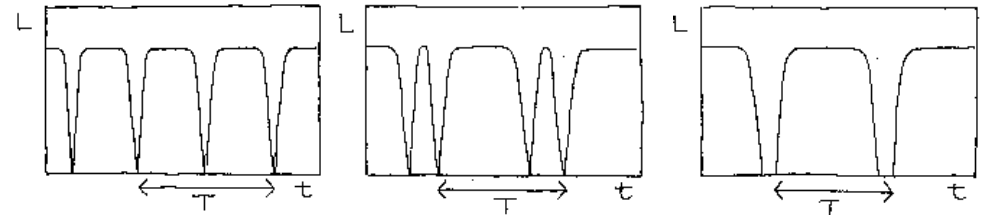
Using E-CON

[MENU] "E-CON" [EXE] [F1] (SETUP) [1] (Wizard) [EXE]
[F1] (CASIO) [3] (Light) 0.01 [EXE] 255 [EXE] [F1] (YES)

Using a Calculator Program

Find the applicable program in the Program Library (P.2-16-1), input it into your calculator, and then run it.)

• Determine the period from graphs of the measurement results obtained at each measurement position.

L : Light Intensity
t(s) : Time
T(s) : Period

☞ Other Things To Do ☜

• Find out how the period changes when you change the length of the pendulum.

• Find out how the period changes when you change the mass of the weight.

• Find out how the period changes when you change the size of the weight.

• Find out how the period changes when you change the amplitude.

• Find out what happens when you use an iron or magnetic weight with a magnetic sheet under the weight.

• Consider why the period changes under the conditions described above.

Conservation of Momentum

The purpose of this activity is to investigate the law of conservation of momentum through the collision of two carts.

Theory

Collisions can take on many different forms, and can involve automobiles, locomotives, shopping carts, or even two people. The force of the impact when the two objects collide depends not only on their velocities but also their respective masses (weight), and you can calculate the momentum of an object by multiplying its mass by its velocity.

Despite the variables involved, one principle always holds true – if external forces such as friction are ignored, the sum of the momenta of two objects prior to collision is the same as the sum of the momenta of the objects after collision. This is the principle known as the "conservation of momentum." This principle is an excellent tool for understanding the dynamics of collisions.

The following expresses conservation of momentum in the case of a stationary cart being struck by another cart, after which the two carts adhere to each other and continue in motion together.
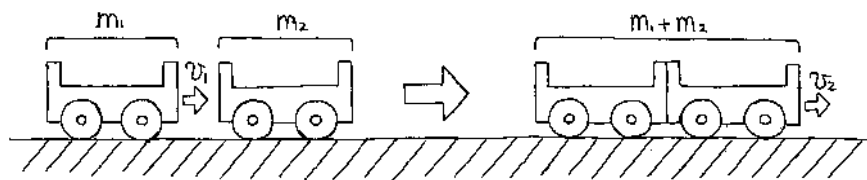
$$m_1 v_1 = (m_1 + m_2) v_2$$

m_1(kg) : Mass of Cart 1
m_2(kg) : Mass of Cart 2
v_1(m/s) : Velocity of Cart 1 Before Collision
v_2(m/s) : Velocity of Two Carts After Collision

This means that when the two carts are of identical mass, the combined velocity of the two carts after collision is one half that of the velocity of Cart 1 before the collision.

The above expression can be used to obtain the post-collision velocity of two carts (while they adhere to each other) of different masses.

Activity: Setup

■ Equipment

Two carts of identical mass	String	Pulley with a bracket to secure it
Velcro®	500g weight	Cushion

Distance Measurement Setup (EA-200, graphic scientific calculator, data communication cable, optional EA-2[*1])

■ Preparing the Carts

● Measure the masses of Cart 1 and Cart 2.

● Affix Velcro® to the impact surfaces of Cart 1 and Cart 2.

● Use tape to securely affix the string to the center of the front end (the same end where the Velcro® is affixed) of Cart 1.

① Back of Cart 1
② String
③ Velcro®
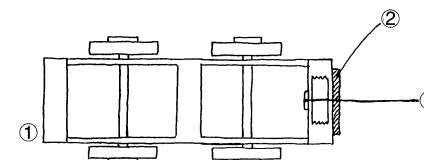
■ Setting Up

● Align the EA-2, Cart 1, Cart 2 and the pulley in a straight line.

● Run the string under Cart 2 and place it onto the pulley. Attach the weight to the end of the string.

● Support the weight with your hand so it does not pull Cart 1.

① Cart 1
② Cart 2
③ Pulley
④ 500g weight
⑤ String
⑥ Cushions
⑦ EA-2 (SONIC)
⑧ Allow 60cm between EA-2 and Cart 1.
⑨ Distance: 50cm
⑩ Height of weight from floor: 30cm
⑪ Desk
⑫ Floor
⑬ Velcro®
⑭ EA-200
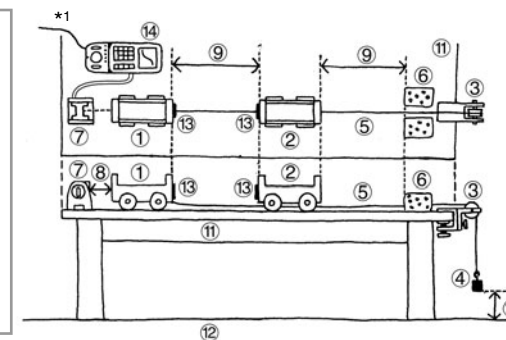
[*1] When using the EA-200 in combination with the optional "Motion Sensor (EA-2)", be sure to power the EA-200 using its bundled AC adaptor (AD-A60024).

Activity: Operating the Equipment

■ Measuring Data

● Prepare the Distance Measurement Setup. Immediately after starting the measurement operation, allow the weight to drop.

① Hand
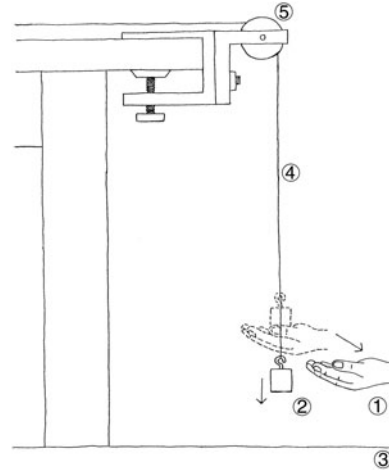② 500g weight
③ Floor
④ String
⑤ Pulley

● Be ready to catch the carts with your hands if the cushion does not stop them.

● Compare calculated theoretical velocity values with your measured velocity.

Measurement

■ Calculator Operation

● Find the applicable program in the Program Library (P.2-16-1), input it into your calculator, and then run it.

● Display graphs for the distance traveled, velocity, and acceleration of Cart 1.
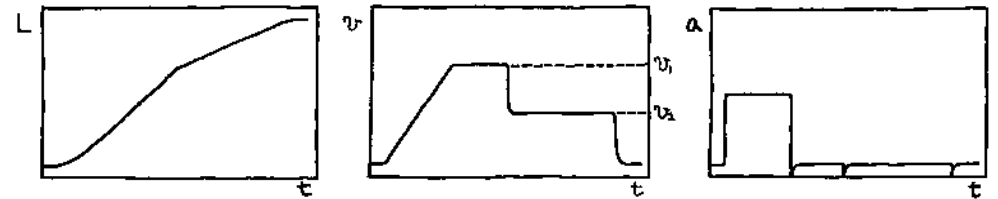
L(m)   : Cart 1 Distance Traveled
v(m/s)   : Cart 1 Velocity
a(m/s²) : Cart 1 Acceleration
t(s)   : Time

Other Things To Do

● Think about why Cart 1 Acceleration never registers a value of zero.

● Add weight to Cart 1 and Cart 2 to change their masses and find out how this affects velocity.

● Think about what would happen if we replaced the Velcro® with a spring.

Charles' Law

This activity is designed to confirm Charles' law through an actual experiment.

Theory

Increasing the temperature of a gas causes the molecules that make up the gas move faster. The pressure within the container that holds the gas is determined by the number of collisions between the molecules and the walls of the container, and by the velocity of the molecules when they collide with the walls. If pressure remains constant and temperature increases, the gas expands, which reduces the number of molecular impacts with the container walls and negates the increase in molecular velocity.

Charles' Law states that the thermal expansion of rarified gas of constant pressure is proportional to the increase in temperature, and is represented by the expression shown below. If the temperature when the volume of gas reaches zero is defined as absolute zero, absolute zero is −273°C.

$$V = \frac{V_0}{273}(T + 273)$$

V(m³) : Gas Volume
V_0(m³) : Gas Volume at 0°C
T(°C) : Gas Temperature

① Absolute Zero
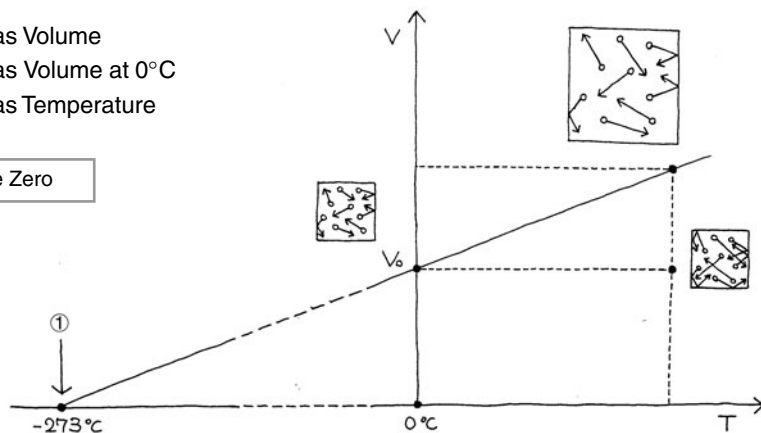
Activity: Setup

■ Equipment

Syringe (with scale markings)   Plastic Container   Rubber Tube
Rubber Gasket   Clip   Mixing Stick
Warm Water, Cold Water, Ice
Temperature Measurement Setup (EA-200, graphic scientific calculator, data communication cable, temperature probe)

■ Assembling the Equipment

● Cut a hole into the side of the plastic container, and affix the rubber gasket around the hole on the outside of the container.

● Slip the syringe with the rubber tube on its tip into the hole, and pack it with rubber to make it watertight.

● Affix the clip to the rubber tube to seal the air inside the syringe.

① Plastic Container
② Rubber Gasket
③ Rubber Tube
④ Syringe
⑤ Hole
⑥ Clip
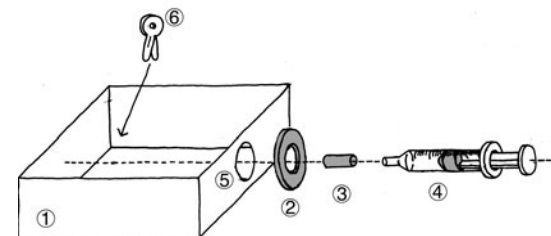
■ Setting Up

● Fill the plastic container with warm water and wait until the air in the syringe stabilizes.

① Plastic Container
② Warm Water: 60°C
③ Mixing Stick
④ Temperature Probe (CH1)
⑤ EA-200

Activity: Operating the Equipment

■ Measuring Data

• The water temperature is displayed on the calculator.

• Read the volume of the gas using the markings on the syringe and read temperature at that time, which is displayed on the calculator.

> ① Temperature Probe
> ② Mixing Stick
> ③ Syringe
> ④ Warm Water
> ⑤ Reading Position
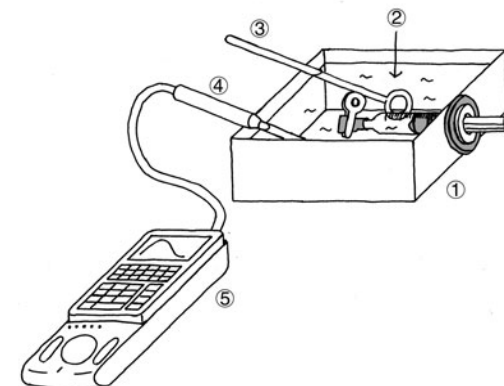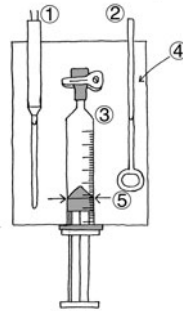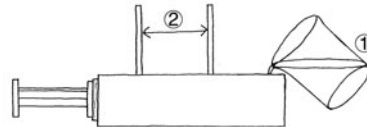
• Add a little of the cold water to the water in the container, and mix. After waiting a few minutes, take readings of the volume and temperature.

• Repeat this step until the temperature of the water in the container approaches the temperature of the cold water.

> ① Cold Water
> ② Mixing Stick

• Repeat the above steps, adding ice instead of cold water and taking readings.

> ① Ice
> ② Mixing Stick
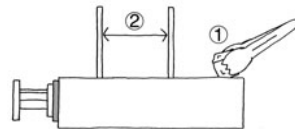
• Graph the readings, which produces a graph that is virtually linear.

• Substitute two of the values on the graph into the expression, and calculate the temperature where volume becomes zero.

$$V = \frac{V_1 - V_0}{T_1} T + V_0 \qquad T = - \frac{V_0 T_1}{V_1 - V_0}$$
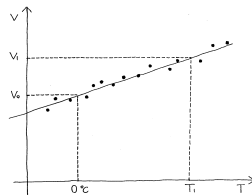
Should the plastic container become too full during the above steps, it is all right to remove some of the water. However, make sure that the syringe remains under the surface of the water.

Measurement

■ Calculator Operation

• Use the Temperature Measurement Setup to measure the temperature and then display it.

• Find the applicable program in the Program Library (P.2-16-1), input it into your calculator, and then run it.

∽ Other Things To Do ∽∽∽∽∽∽∽∽∽∽∽∽∽∽∽

• See if you can approximate a linear graph where a large number of measured values (plots) pass the point at –273°C (absolute zero).

• Consider why observed values are scattered around a straight line.

• Try repeating the above steps with the syringe filled with another type of gas (helium, oxygen, etc.).

Polarization of Light

This activity investigates the relationship between reflection, refraction, and polarization of light.

Theory

Light is electromagnetic radiation that has the properties of transverse waves. Sunlight includes transverse waves that oscillate in various directions.
A polarizer allows only light vibrating in a specific direction to pass, which means that sunlight coming out the other side is vibrating in that direction. This is called "polarization of light." Stacking together two polarizers with their polarization directions oriented perpendicular to each other "extinguishes" the light, which means that no light penetrates the second polarizer.
The expression below represents the change in the amplitude of light passing through the second polarizer. Since light quantity changes in proportion to the square of its amplitude, the light passing through the second polarizer is darker than the original light.

$$A' = A\cos\theta$$

A' : Amplitude of Light
    Polarized by Polarizer 2
A : Amplitude of Light
    Polarized by Polarizer 1
$\theta(°)$: Angle of Polarization
    Direction of Two Polarizers
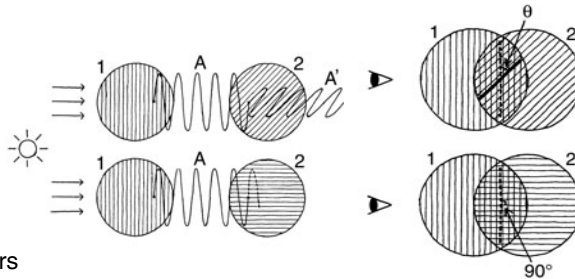
Most light is polarized when it is reflected or refracted by the boundary surface of material where electromagnetic fields meet the required boundary conditions.
Especially at an angle called "Brewster's angle," polarization is completely linear, and reflected light and refracted light polarization is orthogonal. The expression shown below defines the conditions that such an angle needs to satisfy.

$$\alpha + \beta = 90°$$

$\alpha(°)$: Angle of Incidence and
    Angle of Reflection
$\beta(°)$: Angle of Refraction

① Incident Light
② Reflected Light
③ Refracted Light
④ Boundary
    Surface
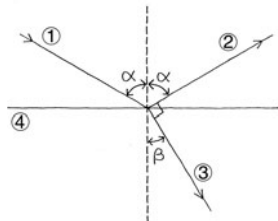
Activity: Setup

■ Equipment

Polarizers (2)	Thick Paper	Wood	Penlight
Glass	Screen	Protractor	

Optical Measurement Setup (EA-200, graphic scientific calculator, data communication cable, optical probe)

■ Preparing the Polarizers

● Cut holes in three sheets of thick paper, and use the protractor to measure and mark angles on one of them.

● Mark the polarizing direction on the polarizers, and cut out one as a circle.

● Affix the wood frame and blocks to the thick paper, sandwich the polarizer between the two sheets of paper as shown in the illustration.

① Wood Frame
② Wood Blocks
③ Thick Paper with Hole Cut Out
④ Arrow Indicating Polarizing Direction
⑤ Removable Polarizer
⑥ Circular Polarizer
⑦ Angle Markings
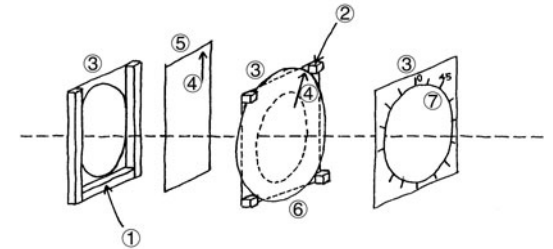
■ Preparing the Glass Stand

● Fix the screen one centimeter above the glass surface that will be struck by the incident light.

● Affix the protractor in accordance with the screen position.

① Glass
② Screen
③ Protractor
④ Distance Between Screen and Glass Surface: 1cm

Activity: Operating the Equipment

■ Measuring the Angle of Polarization and the Light Intensity

- Position the optical probe so it is pointing at the penlight and picking up the maximum light intensity.

- Prepare the Optical Measurement Setup and start the measurement. Rotate the polarizer 90 degrees at a constant speed, every 20 seconds.

① Penlight
② Polarizers
③ Optical Probe (CH1)
④ Hand
⑤ Polarizing Direction
⑥ Direction of Turn
⑦ EA-200

■ Measuring Brewster's Angle

- The light intensity is displayed on the calculator.

- From an angle determined using the protractor, shine the penlight beam onto the glass.

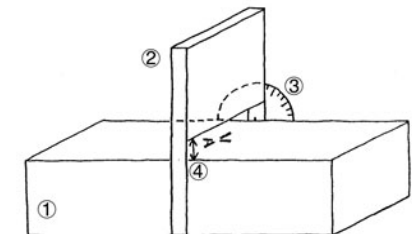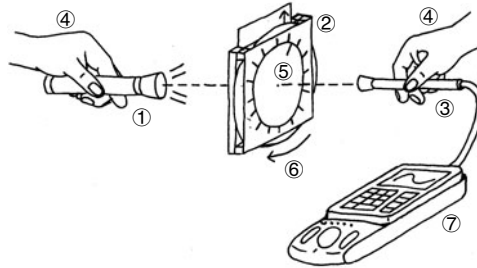- Position the optical probe so it is pointing at the light beam and picking up the maximum light intensity.

- Rotate the polarizer until the polarization direction is that where the light intensity is the greatest.

- Measure the polarizing direction of the reflected light.

- Measure the polarizing direction of the refracted light.

- Determine the angle of the penlight beam that satisfies the condition expression of Brewster's angle.

① Penlight
② Polarizer for Reflected Light Measurement
③ Optical Probe for Reflected Light Measurement
④ Polarizer for Refracted Light Measurement
⑤ Optical Probe for Refracted Light Measurement
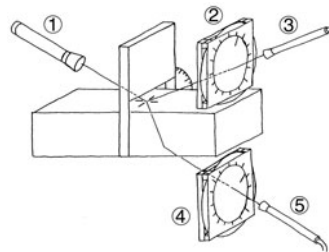
To obtain an accurate picture of changes in polarizer angle and light intensity, it is a good idea to graph light intensity at various angles.

Measurement

■ Calculator Operation

- Prepare for measurement of light intensity using the optical probe, which will let you determine the angle of polarization.

Using E-CON

[MENU] "E-CON" [EXE] [F1] (SETUP) [1] (Wizard) [EXE]
[F1] (CASIO) [3] (Light) 0.1 [EXE] 200 [EXE] [F1] (YES)

Using a Calculator Program

Find the applicable program in the Program Library (P.2-16-2), input it into your calculator, and then run it.

- This displays a graph that shows changes in light intensity as the polarizer is rotated.

L : Light Intensity
t(s): Time
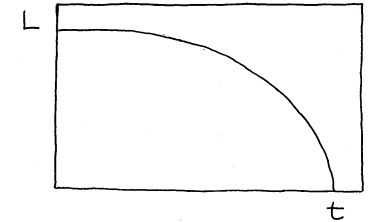
- Perform the following operation to measure Brewster's angle.

- Find the applicable program (Light Multi Meter) in the Program Library (P.2-16-2), input it into your calculator, and then run it to measure light intensity.

✎ Other Things To Do 〰〰〰〰〰〰〰〰〰〰〰〰〰〰

- Investigate changes in Brewster's angle using materials other than glass.

- The 3D effect is possible because of the slight difference between how an object is viewed by the left and right eyes. Consider how 3D imaging technology uses the characteristics of light polarization to achieve its effects.

Natural Frequency and Sound

This activity investigates sounds produced in accordance with the natural frequencies of objects we use in everyday life. It also studies the characteristics of frequencies.

Theory

Hitting, striking, plucking, or otherwise disturbing just about any object will cause it to vibrate. Dropping a pencil or ruler to the floor, or plucking a banjo string will cause it to vibrate. The sound produced when you blow over the top of a bottle is the air inside of it vibrating. The vibration of an object tends to occur at a particular frequency or a particular set of frequencies, which is the "natural frequency" of the object.

Though the strength of the strike, pluck, or other disturbance applied to an object affects the frequency of the sound produced, in most cases the sound produced is a louder version of the natural frequency. Generally, the sound produced by an object is the result of multiple natural frequency sound waves superimposed on each other.

The expression below provides the natural frequency of a string that is fixed at both ends. In this case, all of the natural frequencies are integer multiples of f_1, which is called the "fundamental frequency." The fundamental frequency is the lowest possible frequency at which an object can vibrate freely.

$$f_n = \frac{n}{2L} \sqrt{\frac{S}{\rho}}$$

f_n (Hz)   : String Natural Frequency (n = 1, 2, 3 ...)
L (m)   : String Length
S (N)   : String Tension
ρ (kg/m) : String Linear Density (per meter)
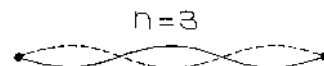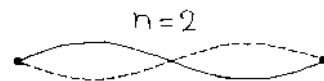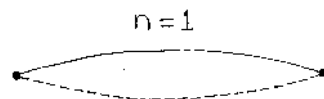
■ Equipment

Box   String   Bolts (2)   Triangular Wood Blocks (2)
Audio Measurement Setup (EA-200, graphic scientific calculator, data communication cable)

■ Building a Monochord

● Use tape to affix the bolts at either end of the box, and stretch the string taut between them.

● Insert a triangular wood block between the string and the box.

① Box
② Box Length: 50cm
③ Bolt
④ String
⑤ Block
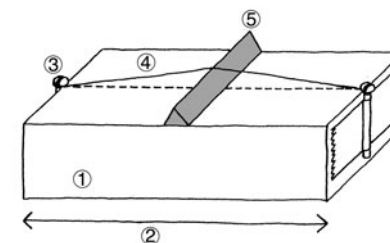
■ Setting Up

● Insert two wood blocks between the string and box, and set the monochord on a table or desk.

● Position the Audio Measurement Setup where it can pick up the sound from the monochord.

① Desk
② Monochord
③ EA-200

Activity: Operating the Equipment

■ Measuring the Sound Frequency

- Position the two wood blocks so there is about 40cm between them, and then lightly pluck the center of the string to produce a sound.
- Record the sound with the Audio Measurement Setup, perform FFT analysis, and view the frequency distribution.

① Monochord
② Desk
③ Distance Between Blocks: 40cm
④ Finger

- Position the two wood blocks so there is about 20cm between them, and then lightly pluck the center of the string to produce a sound.
- Record the sound on the Audio Measurement Setup, perform FFT analysis, and view the frequency distribution.

① Monochord
② Desk
③ Distance Between Blocks: 20cm
④ Finger
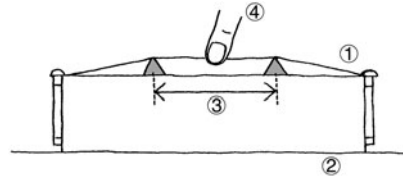
- Calculate values for f_{12}/f_{11}, f_{22}/f_{21}, f_{21}/f_{11}, and compare them.
- Next, note the relationship with each of the above values with the value 2.
- Try changing the distance between the blocks, the location where you pluck the string, and the strength of the pluck, and see how it affects the frequency.

Measurement

■ Calculator Operation

- Prepare the Audio Measurement Setup for recording.
- Find the applicable program in the Program Library (P.2-16-2), input it into your calculator, and then run it.
- Perform FFT analysis on the sound recorded when the blocks are 40cm apart, and study the frequency distribution.

① Waveform
② Frequency Distribution
③ f_{11}
④ f_{12}

S : Sound Volume
t(s) : Time
N(counts) : Number of Counts
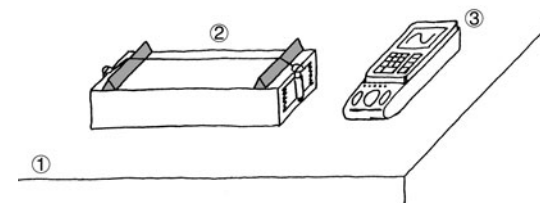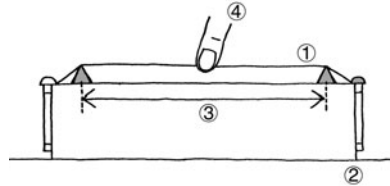f(Hz) : Frequency
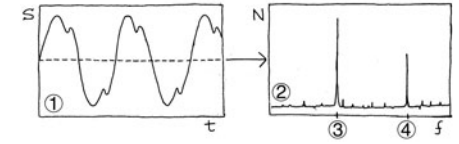
- Perform FFT analysis on the sound recorded when the blocks are 20cm apart, and study the frequency distribution.

① Waveform
② Frequency Distribution
③ f_{21}
④ f_{22}

S : Sound Volume
t(s) : Time
N(counts) : Number of Counts
f(Hz) : Frequency
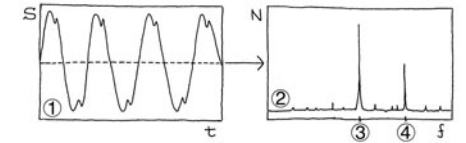
❧ Other Things To Do

- Consider the reason why f_{12}/f_{11}, f_{22}/f_{21}, and f_{21}/f_{11} are values in the vicinity of 2.
- Consider the reason why f_{12}/f_{11}, f_{22}/f_{21}, and f_{21}/f_{11} are not exactly 2.
- Find out how the natural frequency changes when you use a different type of string.
- Modify the monochord as shown in the illustration below, and adjust the weight so it changes the tension of the string. Study how the natural frequency is affected by changes in the tension of the string.

① Pulley
② Weight
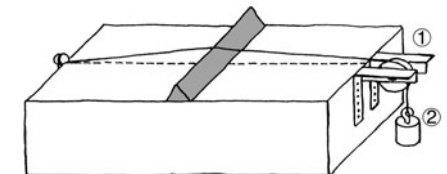
Column of Air Resonance and the Velocity of Sound

This activity uses the resonance of a column of air to measure the velocity of sound.

Theory

Resonance is what occurs when one object vibrating at the same natural frequency of a second object causes the second object to vibrate. If you have two tuning forks of the same natural frequency located near each other and strike one of the tuning forks so begins vibrating, the other tuning fork will also vibrate even if you do not strike it. This is due to resonance.

This activity uses a fixed-frequency sound source to produce resonance in a vertical resonance tube. The sound produced by the resonating column of air will sound louder than the sound produced by the sound source.

The expressions below show the relationships between the length of the column of air and wavelength, and the velocity of sound and wavelength. The relationship between the velocity of sound and wavelength is called the basic equation.

$$L_n = \frac{2n-1}{4}\ \lambda - \Delta L \quad v = f\lambda$$

L_n(m) : Air Column Length for Resonance
           Point n (n = 1, 2, 3...)

ΔL(m) : Air Column Open-end Correction

λ(m) : Wavelength of Sound

v(m/s) : Velocity of Sound

f(Hz) : Frequency of Sound Wave

① Resonance Point 1
② Resonance Point 2
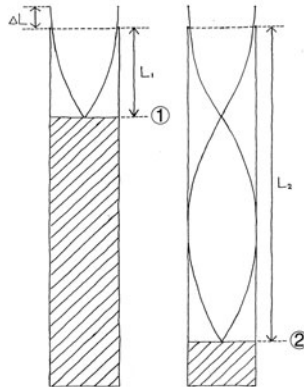
Actually, the air around the opening in the resonance tube also behaves like part of the air column. This is called "open-end correction." The effects of open-end correction can be eliminated by measuring the length of the air column at Resonance Point 1 and Resonance Point 2 and calculating the difference between the two. This can be used in combination with the wave basic equation to determine the velocity of sound, using the expression below.

$$v = 2f\,(L_2 - L_1)$$

■ Equipment

Glass Resonance Tube (Uniform Inside Diameter, With Scale Markings)

Rubber Tube   Reservoir   Stand

Low Frequency Generator (or Tuning Fork)

Audio Measurement Setup (EA-200, graphic scientific calculator, data communication cable)

Temperature Measurement Setup (EA-200, graphic scientific calculator, data communication cable, temperature probe)

■ Setting Up

- Set up the equipment as shown in the illustration, and fill with water, taking care it does not overflow.

- Raise and lower the reservoir and check to make sure that the level of the water changes.

① Glass Resonance Tube
② Tube Length: 1 meter
③ Stand
④ Reservoir
⑤ Rubber Tube
⑥ Low Frequency Generator: 800Hz
⑦ Speaker
⑧ EA-200
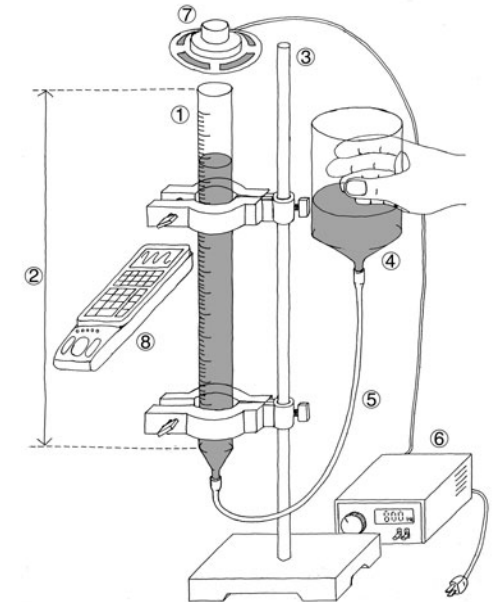
Activity: Operating the Equipment

■ Measuring the Resonance Points

- Record the sound on the Audio Measurement Setup, display the waveform, and observe the amplitude.

- Lower the water level, and find the point of maximum amplitude.

① Glass Resonance Tube	A: Water Level A
② Resonance Point 1	B: Water Level B
③ L_1	C: Water Level C
④ Sound Wave Amplitude	
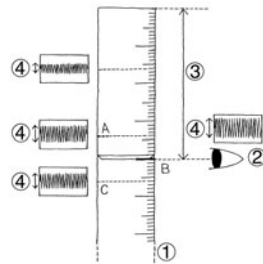
- Lower the water level more, and find the next point of maximum amplitude.

① Glass Resonance Tube	D: Water Level D
② Resonance Point 1	E: Water Level E
③ L_1	F: Water Level F
④ Resonance Point 2	
⑤ L_2	
⑥ Sound Wave Amplitude	
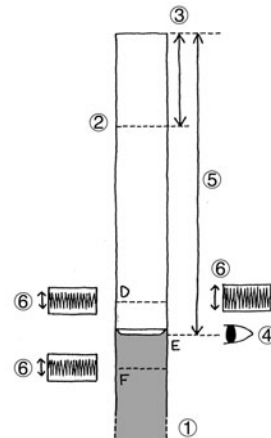
- Repeat the measurement three times and calculate the average of the results.

- Substitute the average values of L_1 and L_2 into the theoretical expression and calculate the velocity of sound.

■ Measuring the Temperature of the Air Column

- Use the Temperature Measurement Setup to measure the temperature and then display it.

- Substitute the measured temperature values into the expression and calculate the velocity of sound. Next, compare the results with the previously obtained value.

$$v = 331.5 + 0.61T$$

v(m/s) : Velocity of Sound

T(°C)   : Air Column Temperature

① Glass Resonance Tube
② Temperature Probe (CH1)
③ EA-200

Measurement

■ Calculator Operation

- Use the Audio Measurement Setup to record the sound and display the waveform.

- Find the applicable program in the Program Library (P.2-16-2), input it into your calculator, and then run it.

①	Waveform
②	Amplitude
S	:Sound Volume
t(s)	:Time
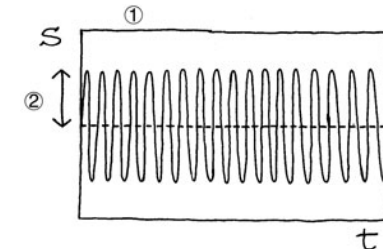
Waveform at Water Levels A, C, D, and F

- Confirm that amplitude is at its maximum for water levels B and E.
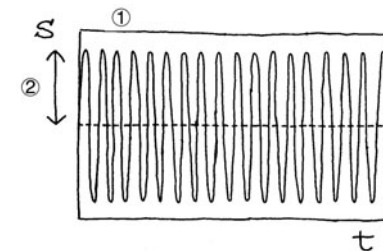
Waveform at Water Levels B and E

- Use the temperature probe to measure the temperature and then display it.

- Find the applicable program (Charles' Law) in the Program Library (P.2-16-1), input it into your calculator, and then run it.

✎ Other Things To Do

- Repeat the experiment using a different frequency, and compare the difference in resonance points and sound velocity.

- Use FFT analysis to determine the frequency at each water level, and compare the results with the sound source frequency.

- Substitute the observed velocity into the theoretical formula and calculate the open-end correction value.

- Investigate what you need to multiply the open-end correction value in order to obtain the inside diameter of the resonance tube.

- Perform the activity with a glass tube of a different diameter and find out how the open-end correction value is affected.

Construction of the Musical Scale

The purpose of this activity is to investigate the scale that is most commonly used for Western-style music, and to listen to some of the consonance it can produce.

Theory

The pitch of a note is determined by its frequency, and the human ear perceives notes as differences in frequency ratios, rather than differences in the relative amplitude of the frequency.

The ratios of the 12-note mean scale used for most Western-style music is governed by a number of restrictions. First, the frequency ratio of the same note from one octave to the next is 2:1 (higher note to lower note). Each octave is divided into 12 parts, with the same frequency ratio between each of the adjoining notes in the octave. The illustration below shows each of the notes in an octave, on a piano keyboard.

① 1 Octave (2:1 frequency ratio between notes)
② Tonic Note (Low Note)
③ Harmonic (High Note)
④ Adjacent Note (Note Frequency Ratio = $2^{(1/12)}$)
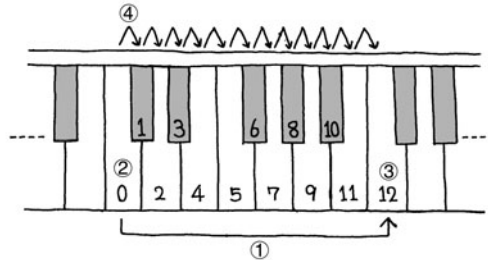
The frequencies of this 12-note scale can be expressed as shown below.

$$f_n = 2^{\frac{n}{12}} f_0$$

f_0(Hz) : Tonic Note Frequency
f_{12}(Hz): Harmonic Frequency
f_n(Hz) : Frequency of nth Note (n = 1, 2, 3, ...12)

① Frequency (Hz)
② Low Note
③ High Note
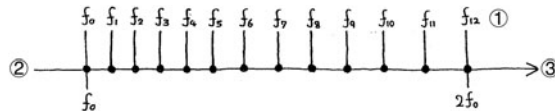
Generally, notes consist of sound waves of different frequencies and amplitudes. Producing two notes of different pitches at the same time sounds pleasing to the human ear, and such notes are said to be "consonant." Two notes whose frequency ratio is the ratio of two simple integers are very consonant.

Activity: Setup

■ Equipment
Piano (Sound Source)   Computer (MIDI Sound Source)
Audio Measurement Setup (EA-200, graphic scientific calculator, data communication cable)

■ Setting Up
• Take care so there is no unwanted noise in the area where you are conducting the activity.

① Piano
② Computer (MIDI Sound Source)
③ EA-200
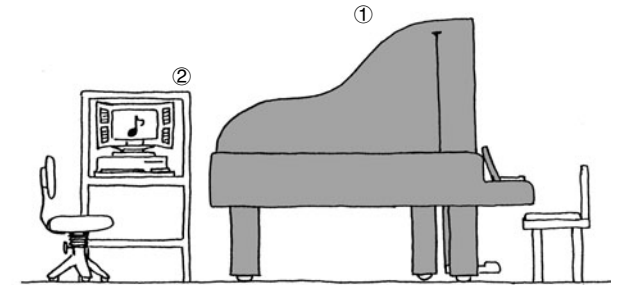
Activity: Operating the Equipment

■ Analyzing Do-Re-Mi

- Record the notes Do, Re, and Mi, and then record the peaks of their frequency distributions. These are called "frequency components."

- Study the relationship of the frequency components included in the single-note frequency distribution.

- Study the relationship of the highest peaks of different notes.

① Waveform
② Frequency Distribution
③ Peak
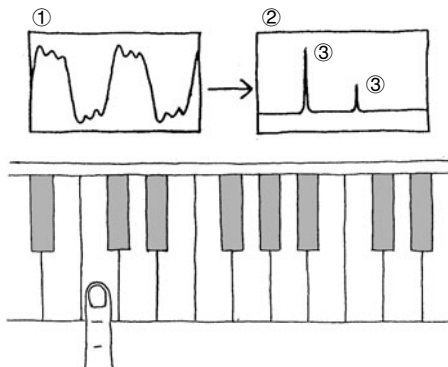
■ Octaves

- Record Do in two adjoining octaves, and make a note of its frequency components.

- On the EA-200, double the frequency of the lower Do to synthesize the higher Do, and then compare the result with the corresponding note played on the piano.

■ Consonant Notes

- The sound at a frequency ratio of 1:1 is the original sound, and the sound at 2:1 is called an "octave." Two notes such as these are said to possess "absolute consonance." Play the same note in two different octaves to see what absolute consonance sounds like.

- Sounds at the frequency ratios 3:2 and 4:3 possess "perfect consonance," sounds at 5:3 and 5:4 possess "medial consonance," and sounds at 6:5 and 8:5 possess "imperfect consonance" Predict the consonance of Do-Re-Mi from their frequencies, and then actually play the notes on the piano.

- Using the EA-200's frequency conversion function, create and produce consonant notes. Next, play the same notes on the piano for comparison.

■ Electronic Sound

- Use the EA-200 to record Do played using a piano timbre on the computer MIDI sound source, and check its frequency components. Next, compare this with the frequency component of Do played on the acoustic piano.

Measurement

■ Calculator Operation

- Record the sound on the EA-200, perform FFT analysis, and view the frequency.

- Find the applicable program in the Program Library (P.2-16-2), input it into your calculator, and then run it.

- Use the EA-200 frequency conversion function to create synthesized sounds.
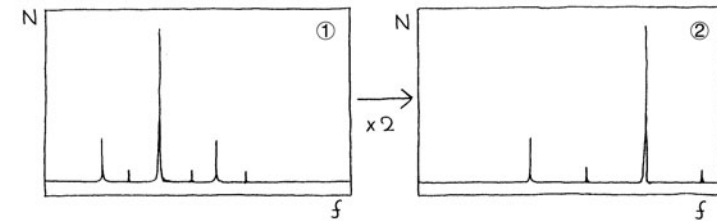
① Before Conversion
② After Conversion
f(Hz)　　 : Frequency
N(counts) : Number of Counts

- Find the applicable program (Natural Frequency and Sound) in the Program Library (P.2-16-2) , input it into your calculator, and then run it to use FFT graph (①, ②).

❧ Other Things To Do

- Consider why notes synthesized on the EA-200 are different from those produced by the piano.

- In many cases, physical properties become evident by studying frequency components. Consider why this is so.

- Consider what noise is by checking its frequency components.

Direct Current and Transient Phenomena

This activity investigates transient phenomena when direct current flows through a capacitor and coil.

Theory

Generally speaking, electrical current is the movement of free electrons within metal. When electrical current flows through a capacitor, electrons are accumulated, and the capacitor stores the charge. The accumulation of an electrical charge is called "charging," while the loss of the charge by the capacitor is called "discharging."

Connecting a resistor and capacitor serial circuit to a D.C. power supply causes current to flow to the capacitor, which charges until it reaches a steady state. Now if the power supply is removed and the circuit is closed, current flows to the capacitor again, which now discharges until it reaches a steady state. Current flows to the capacitor in the opposite direction that it flowed during charging. The change in capacitor voltage during the transient phase until the capacitor reaches a steady state, while charging and discharging is represented by the expression shown below.

$$V_C = V - V_R = V\left(1 - e^{-\frac{t}{RC}}\right)$$

$$V_C = V_R = Ve^{-\frac{t}{RC}}$$

① Charge Circuit
② Discharge Circuit

V_R(V): Voltage Across the Resistor
V_C(V): Voltage Across the Capacitor
V(V) : Power Supply Voltage
R(Ω) : Resistance
C(F) : Capacitance
t(s) : Time
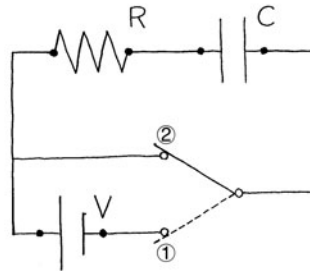
When the current flowing through a coil changes over time, the coil induces voltage, like an electrical generator. This is called "self-induced electromotive force," which acts to oppose the change in current. When a D.C. power supply is connected in a resistor and coil series circuit, the effect of the coil's self-induced electromotive force can be observed until current reaches a fixed value. Similarly, self-induced electromotive force can also be observed by cutting off the power supply to a circuit through which steady current is flowing.

The change in coil voltage during these transient phases is represented by the expressions below.

$$V_L = V_R - V = -Ve^{-\frac{R}{L}t}$$

$$V_L = V_R = Ve^{-\frac{R}{L}t}$$

① Circuit With Power Supply
② Circuit Without Power Supply

V_R(V): Voltage Across the Resistor
V_L(V): Voltage Across the Coil
V(V) : Power Supply Voltage
R(Ω) : Resistance
L(H) : Self-inductance
t(s) : Time
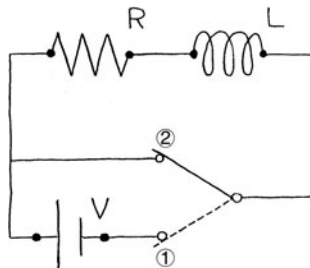
■ Equipment

Battery (D.C. Power Supply)   Resistor   Capacitor   Coil   Switch
Voltage Measurement Setup (EA-200, graphic scientific calculator, data communication cable, voltage probe)

■ Building the RC Series Circuit

• The product of the resistance value and the capacitor's capacitance should be around 1.

① 3V D.C. Power Supply
② Switch
③ 10kΩ Resistor
④ 100μ F Capacitor
⑤ Voltage Probe (CH1)
⑥ EA-200
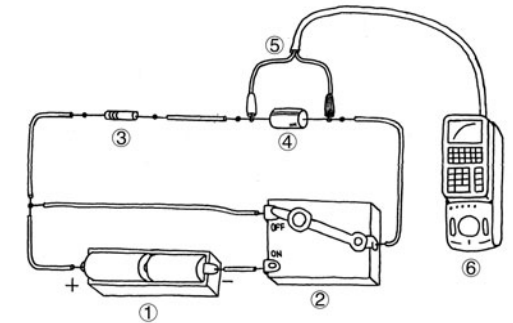
■ Building the RL Series Circuit

• The quotient when the resistance value is divided by the self-inductance of the coil should be around 1.

① 3V D.C. Power Supply
② Switch
③ 0.1Ω Resistor
④ 100mH Coil
⑤ Voltage Probe (CH1)
⑥ EA-200
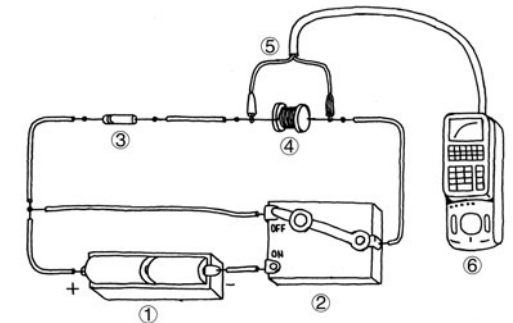
Activity: Operating the Equipment

■ Measuring Data

• Prepare the Voltage Measurement Setup. At the same time you start the measurement operation, move the switch to "ON" to connect the power supply.

• Wait until the circuit achieves a steady state.

① Switch
② Power Supply Connected
③ Power Supply Cut
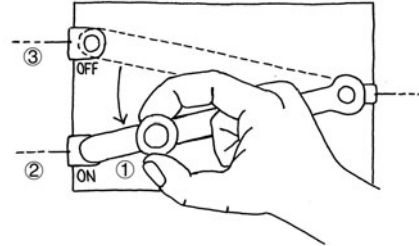
• Prepare the Voltage Measurement Setup. At the same time you start the measurement operation, move the switch to "OFF" to disconnect the power supply.

• Wait until the circuit achieves a steady state.

① Switch
② Power Supply Connected
③ Power Supply Cut
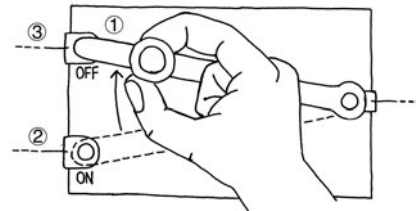
• Perform the above operation for the RC series circuit and the RL series circuit.

• Read and check the RC and R/L values from the graph.

Measurement

■ Calculator Operation

• Perform the following operation to prepare for voltage measurement using the voltage probe.

Using E-CON

[MENU] "E-CON" [EXE] [F1](SETUP) [1](Wizard) [EXE]
[F1](CASIO) [1](Volt) 0.02 [EXE] 255 [EXE] [F1](YES)

Using a Calculator Program

Find the applicable program in the Program Library (P.2-16-3), input it into your calculator, and then run it.

• Graph results for when the power supply is connected and for when it is disconnected.
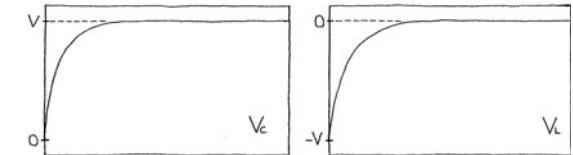
Voltage Change when Power Is Connected
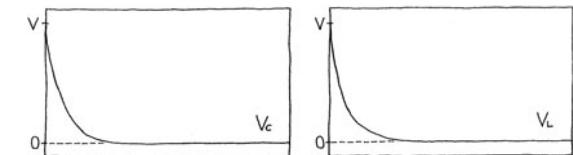
Voltage Change when Power Is Disconnected

～ Other Things To Do ～

• It appears as if combining the curve during capacitor charging and the curve during capacitor discharging will produce a straight line with no change over time. This, however, is not necessarily so. Consider the reason for this.

• In the case of the coil voltage curves as well, it appears as combining them as expressions should produce a straight line. However, this also does not happen. Consider the reason for this.

• Change the resistor, capacitor, and coil and find out how the voltage is affected.

• While the capacitor is charged, cut off the power supply and observe changes in capacitor voltage with the circuit left open. Compare what you observe with the change in voltage when the circuit is closed.

AC Circuit

This activity investigates the characteristics of a resistor, capacitor, coil (RCL) series circuit, which is connected to an AC power supply.

Theory

The electrical power sent from power generating stations to homes is alternating current (AC), not direct current (DC). Though direct current does not alternate with time, alternating current alternates according to a regular cycle, and this cyclical change can be expressed as a trigonometric function. When the voltage and frequency of a AC power supply are defined, the current flowing through the circuit has the same frequency as but a different phase from the power supply voltage. The phase difference and the magnitude of current depends on the component parts of the circuit. The voltage and current when a AC power supply is connected to a series circuit composed of a resistor, capacitor, and coil (RCL series circuit) can be expressed by the expressions shown below.

$$V = V_0 \cos\omega t \quad I = I_0 \cos(\omega t - \phi) \quad \omega = 2\pi f$$

$$I_0 = \frac{V_0}{\sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}} \quad \tan\phi = \frac{1}{R}\left(L\omega - \frac{1}{C\omega}\right)$$
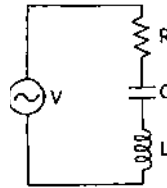
V(V) : AC Power Supply Voltage	R(Ω) : Resistance Value
V_0(V) : Amplitude of AC Power Supply Voltage	C(F) : Capacitor Capacitance
I(A) : AC Current	L(H) : Coil Self-inductance
I_0(A) : Amplitude of AC Current	ϕ(rad) : Current Phase Difference
ω(rad/s): Angular Frequency	t(s) : Time
f(Hz) : AC Frequency	

This activity investigates the voltage across the components of a series circuit. When a current that alternates with time is applied, the voltage across a capacitor and a coil is out of phase with the power supply voltage by -π/2 and π/2 respectively. The resistor does not have this characteristic, and so there is no phase lag. All of this means the peaks and valleys of the waveforms of the voltage across the components will be in different locations. The voltage across each of the components is expressed as follows.

$$V_R = I_0 R \quad V_C = \frac{I_0}{C\omega} \quad V_L = I_0 L\omega$$

V_R(V) : Voltage Across the Resistor
V_C(V) : Voltage Across the Capacitor
V_L(V) : Voltage Across the Coil

We also know that the maximum current value is achieved using a capacitor-coil combination that satisfies the conditions shown below. A frequency like this is called a "resonant frequency."

$$\omega^2 = \frac{1}{LC}$$

Activity: Setup

■ Equipment
AC Power Supply (Switched)   Resistor   Capacitor   Coil
Voltage Measurement Setup (EA-200, graphic scientific calculator, data communication cable, voltage probe (3))

■ Building the RCL Series Circuit
● Build a circuit for a 3V, 50Hz power supply.

① 3V, 50Hz AC Power Supply
② 10Ω Resistor
③ 100μ F Capacitor
④ 10mH Coil
⑤ Voltage Probe
⑥ CH1
⑦ CH2
⑧ CH3
⑨ EA-200
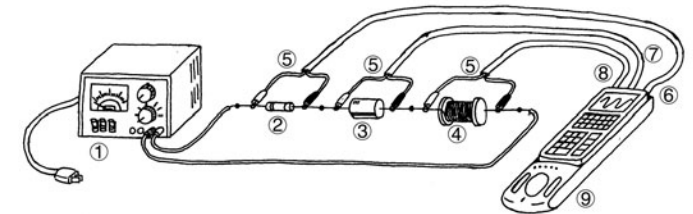
Activity: Operating the Equipment

■ Measuring Data

- Check the values of the AC power supply, resistor, coil, and capacitor, and then switch on the power supply.

- Prepare the Voltage Measurement Setup and measure voltage.

- Display and compare the change of voltage across each component.

Make sure that the individual voltage value across the resistor, capacitor, and coil does not exceed 5V. Consequently, you should make sure that the power supply voltage for the combination shown here does not exceed 3V.

Measurement

■ Calculator Operation

- Perform the following operation to prepare for voltage measurement using the voltage probe.

Using E-CON

MENU "E-CON" EXE F1 (SETUP) 2 (Advan)

1 (Channel) F1 (CH1) ⊙ F1 (CASIO) 1 (Volt) ⊙ F1 (LIST) 2 EXE

⊙ F2 (CH2) ⊙ F1 (CASIO) 1 (Volt) ⊙ F1 (LIST) 3 EXE

⊙ F3 (CH3) ⊙ F1 (CASIO) 1 (Volt) ⊙ F1 (LIST) 4 EXE EXE

2 (Sample) F1 (NO) ⊙ F1 (TIMER) 0.001 EXE ⊙ F1 (NUM) 255 EXE EXE F1 (START)

Using a Calculator Program

Find the applicable program in the Program Library (P.2-16-3), input it into your calculator, and then run it.

- Display V_R, V_C, and V_L.

  V_R(V) : Voltage Across the Resistor (CH1)
  V_C(V) : Voltage Across the Capacitor (CH2)
  V_L(V) : Voltage Across the Coil (CH3)
  t(s) : Time
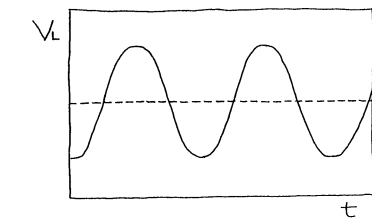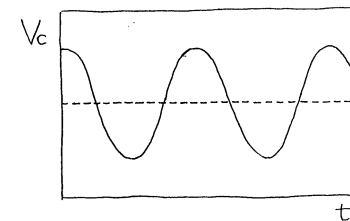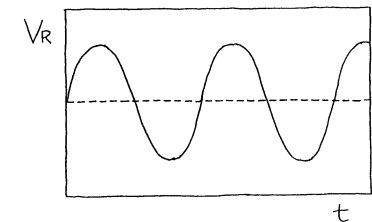
Other Things To Do

- Consider what type of combination would be required to keep voltage across all parts below 5V.

- Consider combinations that satisfy conditions for resonance.

- Consider what component combinations would satisfy the conditions of this activity (5V or less across each component, resonance circuit) for other AC frequencies.

- Perform FFT analysis and compare the frequency of each component.

Dilute Solution Properties

This activity investigates boiling point elevation and freezing point depression of a dilute solution.

Theory

Dissolving a small amount of a substance (solute) in a theoretically pure liquid (solvent) to create a dilute solution causes the boiling point of the dilute solution to become greater than and the freezing point to become less than that of the solvent. This is because the proportion of solvent molecules is reduced by the amount of solute molecules mixed in, which lowers the vapor pressure of the solvent and elevates the boiling point. At the same time, it also reduces the proportion of solvent molecules that congeal, which suppresses the freezing point. These changes are determined by the amount of solute molecules, and the type of solute does not matter, as long as it is non-volatile. Consequently, both boiling point elevation and freezing point depression are proportional to the solute molality, as shown in the expressions below.

$$\Delta T_1 = K_1 m$$
$$\Delta T_2 = K_2 m$$

$\Delta T_1(°C)$: Boiling Point Elevation of Solution
$\Delta T_2(°C)$: Freezing Point Depression of Solution
$K_1(°C\ kg/mol)$: Molal Boiling Point Elevation Constant
$K_2(°C\ kg/mol)$: Molal Freezing Point Depression Constant
$m(mol/kg)$: Molality

① Solvent
② Solution
③ Boiling Point Elevation
④ Freezing Point Depression
$T(°C)$: Temperature
$P(atm)$: Vapor Pressure
$t(s)$: Time
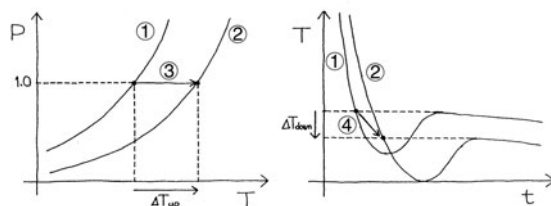
Here, the proportion coefficient is determined by the solvent type. It is a constant that is not affected by the solute type. For example, the molal boiling point elevation constant for benzene is 2.53°C kg/mol, and the boiling point is 80.1°C. The molal freezing point depression constant is 5.12°C kg/mol, and the freezing point is 5.53°C.

When the solvent is pure water, the molal boiling point elevation constant is 0.515°C kg/mol, and the boiling point is 100°C. The molal freezing point depression constant is 1.853°C kg/mol, and the freezing point is 0°C.

Activity: Setup

■ Equipment

Stand	Heater	Reflux Condenser	Desiccant
Auto Stirrer	Beaker	Round Bottom Flask (2)	Mixing Stick
Ice Water	Benzene	Naphthalene	

Temperature Measurement Setup (EA-200, graphic scientific calculator, data communication cable, temperature probe)

■ Setting Up the Boiling Point Elevation Equipment

● Pour the benzene solution into the flask, and secure it in place as shown in the illustration.

① Stand
② Heater
③ Round Bottom Flask
④ Reflux Condenser
⑤ Desiccant
⑥ Naphthalene-Benzene Solution
⑦ Temperature Probe (CH1)
⑧ EA-200
⑨ Water Flow Direction
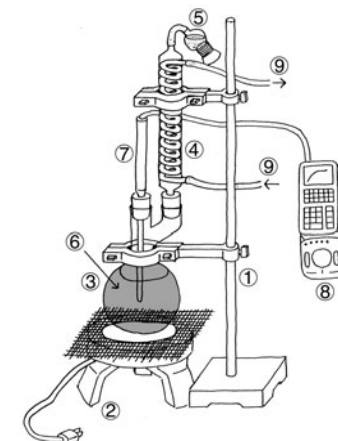
■ Setting Up the Freezing Point Depression Equipment

● Pour the benzene solution into the flask, and secure it in place as shown in the illustration.

① Stand
② Auto Stirrer
③ Beaker
④ Round Bottom Flask
⑤ Mixing Stick
⑥ Ice Water
⑦ Temperature Probe (CH1)
⑧ EA-200

20020601
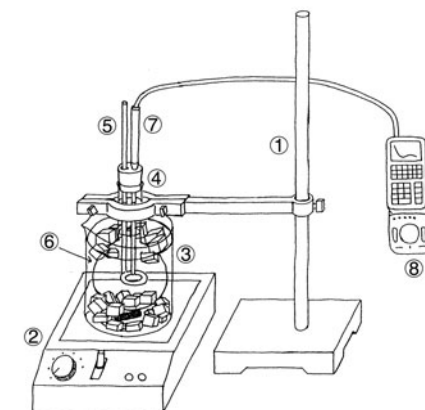
Activity: Operating the Equipment

■ Measuring Data

- Measure the mass of the beaker used for creating the solution.
- Slowly pour the benzene into the beaker so it flows down the inside surface of the beaker.
- Measure the mass of the small amount of naphthalene being used.
- Dissolve the small amount of naphthalene to create a dilute benzene solution, and then measure the mass of the solution.
- Calculate the molality of the naphthalene.
- Divide the dilute benzene solution between two flasks, pouring the solution slowly along the inside surfaces of the flasks.
- Secure one of the flasks in the boiling point elevation system, and the other one in the freezing point depression system.

① Benzene
② Naphthalene
③ Beaker
④ Round Bottom Flask
⑤ Naphthalene-Benzene Solution
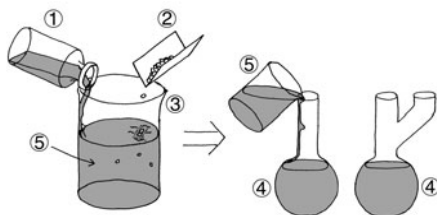
- As shown in the illustration, force water through the reflux condenser.

① Reflux Condenser
② Tap
③ Water Flow Direction
④ Open the tap.
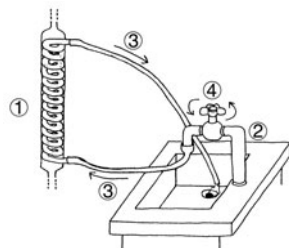
- For boiling point elevation, turn on the heater and use the Temperature Measurement Setup to measure the temperature.
- For freezing point depression, turn on the auto stirrer and use the Temperature Measurement Setup to measure the temperature.
- Use the measured changes in temperature to determine boiling point elevation and freezing point depression.
- Compare the measured results with the results calculated from naphthalene molality.

For freezing point depression, use the mixing stick to stir the flask contents.

Measurement

■ Calculator Operation

- Perform the following operation to prepare for temperature measurement using the Temperature Measurement Setup.

Using E-CON

[MENU] "E-CON" [EXE] [F1](SETUP) [1] (Wizard) [EXE]
[F1](CASIO) [2] (TEMP) [1] (°C) 5 [EXE] 240 [EXE] [F1] (YES)

Using a Calculator Program

Find the applicable program in the Program Library (P.2-16-3), input it into your calculator, and then run it.

- Display a graph of temperature change starting from the point that the solution is first heated.

  T(°C) : Temperature
  t(s)   : Time
  T_1(°C) : Solution Boiling Point
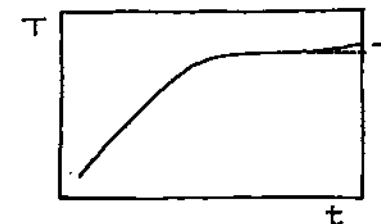
- Display a graph of temperature change starting from the point that the solution is first cooled.

  T(°C) : Temperature
  t(s)   : Time
  T_2(°C) : Solution Freezing Point
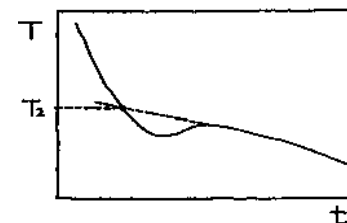
✎ Other Things To Do

- Consider how the molecular weight of naphthalene can be determined using the measurement results.
- Consider why the cooling curve of freezing point depression is not clear.
- Create another dilute solution using a different solute, and determine the boiling point elevation and the freezing point depression.
- Create another dilute solution using a different solvent, and determine the boiling point elevation and the freezing point depression.

Exothermic Reaction

This activity uses the neutralization of hydrochloric acid and sodium hydroxide to study heat that is given off or absorbed by chemical reactions.

Theory

A chemical reaction causes a change in the properties of matter, and always gives off or absorbs heat. The sum of the heat of reaction when a chemical reaction takes place depends solely on the condition of the matter at the time of the reaction, and is totally independent of the reaction pathway and the number of steps between the initial state and the final state. This is called Hess's law.

The following illustrates the chemical reaction when sodium chloride (aq) is generated from sodium hydroxide (s) and hydrochloric acid (aq).

$$NaOH(s) + aq = NaOH(aq) + 44.5kJ$$
$$NaOH(aq) + HCl(aq) = NaCl(aq) + H_2O + 56.4kJ$$
$$NaOH(s) + HCl(aq) = NaCl(aq) + H_2O + 100.9kJ$$
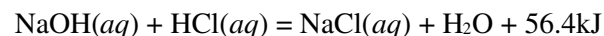
① Reaction Path 1
② Reaction Path 2
③ Energy
④ Solvent (Water)
s : solid
aq : aqua
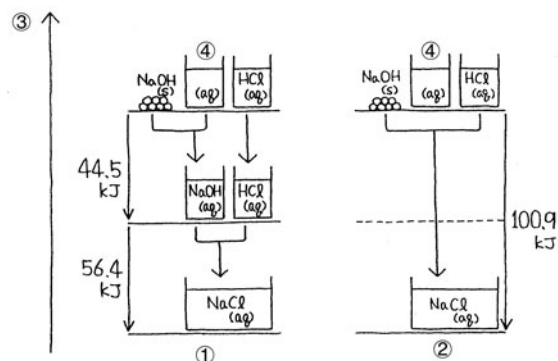
Here, Reaction Path 1 includes the heat of dissolution when sodium hydroxide (s) is dissolved in distilled water, and the heat of neutralization of sodium hydroxide (aq) and hydrochloric acid (aq).

Reaction Path 2, on the other hand, consists of the heat of neutralization of sodium hydroxide (s) and hydrochloric acid (aq).

All of this means that the total heat is the same, regardless of whether or not the pathway includes a process for dissolving the sodium hydroxide (s), as in Reaction Path 1.

Activity: Setup

■ Equipment

| Stand | Auto Stirrer | Beaker (3) |
| Hydrochloric Acid (Solution) | Sodium Hydroxide (Solid) | Distilled Water |

Temperature Measurement Setup (EA-200, graphic scientific calculator, data communication cable, temperature probe)

■ Setting Up

- Measure the mass of the hydrochloric acid (aq) and distilled water to be used in the activity.
- Measure the amount of sodium hydroxide (s) required so the number of its moles is equal to that of the hydrochloric acid (aq).
- Fix the probe in place at a point between the center of the beaker and the wall of the beaker, in a location where it does not strike the stirrer's magnet, at a depth so it is sufficiently immersed in the solution.

① Stand
② Auto Stirrer
③ Beaker
④ Temperature Probe (CH1)
⑤ Solution
⑥ EA-200
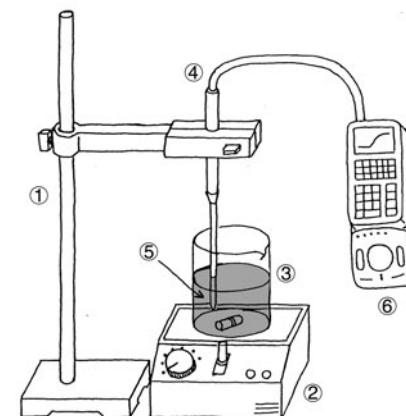
Activity: Operating the Equipment

■ Reaction Path 1 Measurement

- Turn on the auto stirrer and start a measurement operation with the calculator.
- Little-by-little, add sodium hydroxide (*s*) to the distilled water, and observe how the temperature changes.
- After all the sodium hydroxide (*s*) is dissolved and the temperature rise stabilizes, determine the heat of dissolution.

① Beaker	④ Distilled Water
② Temperature Probe	⑤ Temperature rise due to heat of dissolution
③ Sodium Hydroxide (*s*)	
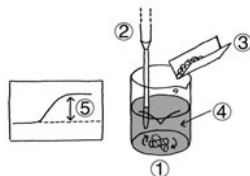
- Turn on the auto stirrer and start a measurement operation with the calculator.
- Little-by-little, add the hydrochloric acid (*aq*) to the sodium hydroxide (*aq*), and observe how the temperature changes.
- After all the hydrochloric acid (*aq*) is added and the temperature rise stabilizes, determine the heat of neutralization.
- Calculate the sum of heat by adding the heat of neutralization to the heat of dissolution.

① Beaker	④ Sodium Hydroxide (*aq*)
② Temperature Probe	⑤ Temperature rise due to heat of neutralization
③ Hydrochloric Acid (*aq*)	
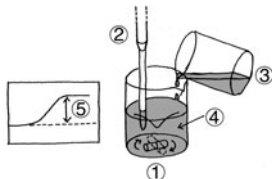
■ Reaction Path 2 Measurement

- Turn on the auto stirrer and start a measurement operation with the calculator.
- Little-by-little, add sodium hydroxide (*s*) to the hydrochloric acid (*aq*), and observe how the temperature changes.
- After all the sodium hydroxide (*s*) is dissolved and the temperature rise stabilizes, determine the heat of neutralization.
- Calculate the heat, and compare it with the total heat you calculated for Reaction Path 1.

① Beaker	④ Hydrochloric Acid (*aq*)
② Temperature Probe	⑤ Temperature rise due to heat of neutralization
③ Sodium Hydroxide (*s*)	
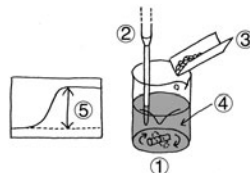
When converting the temperature rise to joule heat, be sure to take the difference in the volume of water into consideration. The specific heat of distilled water is 4.2J/g°C.

Measurement

■ Calculator Operation

- Use the Temperature Measurement Setup to measure the temperature and then display it.
- Find the applicable program in the Program Library (P.2-16-3), input it into your calculator, and then run it.

∽ Other Things To Do ∽∽∽∽∽∽∽∽∽∽∽∽∽∽∽∽∽∽∽

- Determine whether this activity verifies Hess's Law. If it does not, consider the reason why.
- Compare the theoretical chemical reaction expression and the measurement results. If they do not match, consider the reason why.
- Find out if Hess's Law holds true for other chemical reactions.

Electromotive Force of a Battery

This activity investigates the changes in the electromotive force of a voltaic battery over time.

Theory

A voltaic battery is made of a zinc (Zn) plate and a copper (Cu) plate immersed in a dilute solution of sulfuric acid (H_2SO_4). Employing the difference in the ionization tendencies between the two metals, the zinc plate is the negative electrode (cathode), while the copper plate is the positive electrode (anode).

Ionization tendency is the tendency of metal to release electrons, which become positively charged ions. As shown below, zinc and copper are on opposite sides of the hydrogen molecule.

K Ca Na Mg Al Zn Fe Ni Sn Pb (H_2) Cu Hg Ag Pt Au

Exposing zinc, which has a relatively strong ionization tendency, to the hydrogen ions in a dilute sulfuric acid solution, causes the zinc to dissolve and release electrons, creating a minus charge. When the battery is connected to a circuit, the released electrons flow through the circuit to become electric current, and collect on the copper plate, which has a relatively weak ionization tendency and is not dissolving. The electrons on the surface of the copper plate are consumed when they attach to hydrogen ions in the dilute sulfuric acid solution and give off hydrogen gas. As the electrons on the copper plate are consumed, the zinc plate releases more electrons, which allows the flow of current to continue. The reaction that occurs at the two electrodes at this time is represented by the chemical expression shown below.

$$Zn \rightarrow Zn^{2+} + 2e^- \text{ (Negative Electrode Reaction)}$$
$$2H^+ + 2e^- \rightarrow H_2 \text{ (Positive Electrode Reaction)}$$
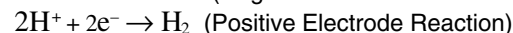
① Dilute Sulfuric Acid Solution
② Flashlight Bulb
③ Negative Electrode (Zinc Plate)
④ Positive Electrode (Copper Plate)
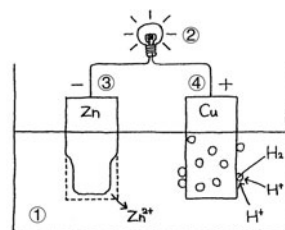
It should be noted here that should too much hydrogen gas foam build up on the copper plate surface, a phenomenon called "polarization" can cause the hydrogen gas to start to return to hydrogen ions. Allowing polarization to continue will lead to deterioration of the electromotive force of the battery. If this happens, hydrogen peroxide can be added to the area around the copper plate, which reacts with the hydrogen gas and reduces the amount of foam present. This, in turn, restores the electromotive force of the battery. Repeating this measure when required will theoretically allow the battery to operate properly until the zinc plate is completely dissolved. In actual practice, a voltaic battery will reach the end of its useful life before then.

Activity: Setup

■ Equipment

Stand
Voltaic Battery (Zinc Plate, Copper Plate, Dilute Sulfuric Acid Solution, Cistern)
Flashlight Bulb   Hydrogen Peroxide   Pipette with a bulb
Voltage Measurement Setup (EA-200, graphic scientific calculator, data communication cable, voltage probe)

■ Setting Up

• Taking care that the two electrodes do not become shorted, setup the equipment as shown in the illustration.

① Stand
② Cistern
③ Dilute Sulfuric Acid Solution
④ Zinc Plate
⑤ Copper Plate
⑥ Negative Electrode
⑦ Positive Electrode
⑧ Flashlight Bulb
⑨ Voltage Probe (CH1)
⑩ EA-200
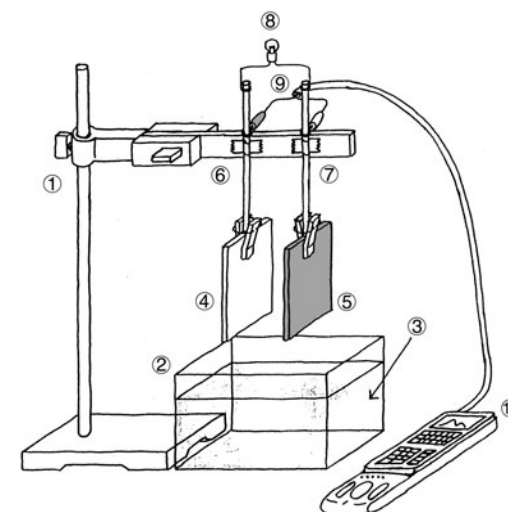
Activity: Operating the Equipment

■ Measuring Data

• The voltage is displayed on the calculator.

• Lower the arm of the stand so the metal plates are submersed in the dilute sulfuric acid solution, without coming into contact with the cistern.

| ① Stand Arm |
| ② Cistern |
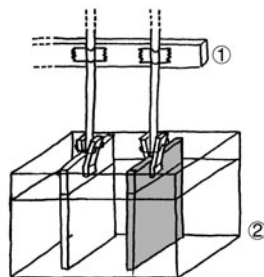
• If the variation in voltage becomes small, use the pipette with a bulb to inject a small amount of hydrogen peroxide into the dilute sulfuric acid around the copper plate.

| ① Stand Arm |
| ② Cistern |
| ③ Copper Plate |
| ④ Pipette with a bulb |
| ⑤ Hydrogen Peroxide |
| ⑥ Hydrogen Foam |
| ⑦ Hand |
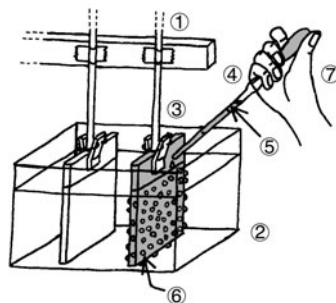
• Repeat this process as you monitor the life of the battery.

| ① Hydrogen Peroxide Added Here |
| V(V): Voltage |
| t(s)　: Time |
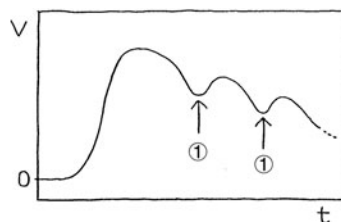
Measurement

■ Calculator Operation

• The voltage is measured and displayed using the Voltage Measurement Setup.

• Find the applicable program in the Program Library (P.2-16-4), input it into your calculator, and then run it.

⌘ Other Things To Do ⌘⌘⌘⌘⌘⌘⌘⌘⌘⌘⌘⌘⌘⌘⌘⌘

• Compare the initial voltaic battery electromotive force with the theoretical value of 1.1V.

• Try changing the surface area of the two electrodes that is in contact with the dilute sulfuric acid solution, and note any changes in the electromotive force.

• Find out what you can about the Daniel Cell, which is one type of battery that is not prone to loss of voltage due to hydrogen build-up on the positive electrode.

• Perform long-term measurement of a commercially available manganese battery (5V maximum) and determine its useful life.

Sunlight and Solar Cells

This activity studies how change in the amount of sunlight available per day affects the electromotive force of a solar cell, with a view to understanding the characteristics of power generation by a solar cell.

Theory

Solar cells have been receiving a great deal of attention in recent years as one source of renewable, environmentally-friendly energy. One problem with solar cells, however, is the fact that the amount of power that can be generated is unstable, because the quantity of sunlight hitting the solar cell panel surface is affected by weather and other factors. In order to maximize power generation efficiency, it is necessary to design a system that is able to change the orientation of the solar cell panel to suit changes in the angle of the sun due to the rotation and revolution of the Earth, and seasonal changes. The diagram below shows the optimum orientation of a solar cell panel in relation to the sun.

① Sun
② Morning
③ Afternoon
④ Evening
⑤ Solar Cell Panel Surface
⑥ Magnetic Compass
$\theta(°)$: Angle of Inclination
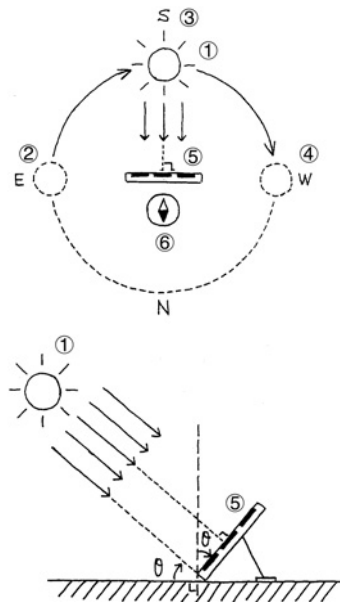
In spite of the above, most solar cell panels are pointed in a fixed direction, because it costs too much to be continually changing their orientation. With this activity, we will investigate the correlation between the amount of sunlight per day picked up by a fixed solar cell panel and the electromotive force of a solar cell.

Activity: Setup

■ Equipment

Solar Cell Panel (Operating Voltage: 5V max.)   Magnetic Compass
Rain Cover   Wood Block
Voltage Measurement Setup (EA-200, graphic scientific calculator, data communication cable, voltage probe)
Optical Measurement Setup (EA-200, graphic scientific calculator, data communication cable, optical probe)

■ Preliminary Setup

● Standing in a location that is exposed to sunlight, hold the equipment in your hands and point the solar cell panel and optical probe towards the sun.

① Solar Cell Panel
② Voltage Probe (CH1)
③ Optical Probe (CH2)
④ EA-200
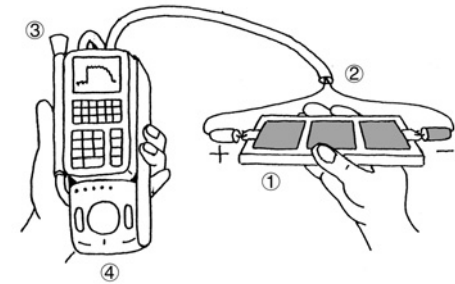
■ Setting Up

● Fix the optical probe and solar cell panel so they are pointing in the direction and at the angle you determined during the preliminary measurement.

① Sun
② Solar Cell Panel
③ Voltage Probe
④ Optical Probe
⑤ Angle adjustment block
⑥ Transparent Rain Cover
⑦ CH1
⑧ CH2
⑨ EA-200
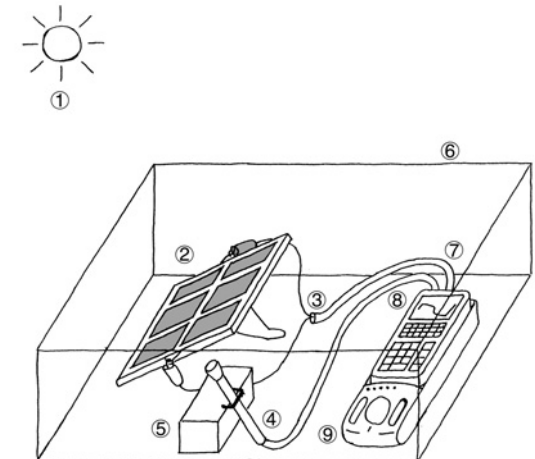
Activity: Operating the Equipment

■ Performing Preliminary Measurements

• Display the light intensity (or voltage) measurement result on the calculator.

• Keeping the angle of the solar cell panel and optical probe fixed, turn around until you find the direction where the displayed value is at its maximum.

① Sun
② Person Holding Equipment
③ Magnetic Compass
④ Direction of Turn
⑤ Direction Producing Maximum Value
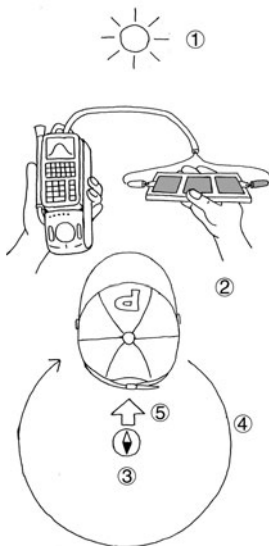
• Fix the solar cell panel and the optical probe so they are pointed in the direction you determined above.

• Display the light intensity (or voltage) measurement result on the calculator.

• Starting with the solar cell panel facing the ground, slowly angle it upwards, until you find the angle that produces the maximum measured value.

① Sun
② Ground
③ Zenith
④ Solar Cell Panel Surface
⑤ Direction of Turn
⑥ Angle Producing the Maximum Value
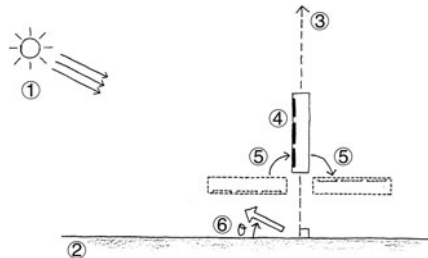
■ Performing Main Measurements

• Fix the optical probe and solar cell panel so they are pointing in the direction and at the angle you determined in the preliminary step, above.

• Set up the EA-200 for long-term measurement, start measurement, and then set the rain cover in place.

• After measurements are complete, study the correlation between light intensity and voltage.
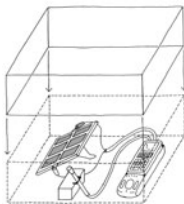
The best time to perform the preliminary steps is noon. If it is hot or if there is the possibility that the EA-200 might become too hot, place a shade over the EA-200 to block the sun.

Measurement

■ Calculator Operation

• Use the optical probe (or voltage probe) to measure light intensity (or voltage) and display the results on the calculator.

• Perform the following operation to set up the optical probe and voltage probe for long-term measurement.

Using E-CON

[MENU] "E-CON" [EXE] [F1](SETUP) [2] (Advan)

[1] (Channel) [F1](CH1) ⊙ [F1](CASIO) [1] (Volt) ⊙ [F1](LIST) 2 [EXE]

⊙ [F2](CH2) ⊙ [F1](CASIO) [3] (Light) ⊙ [F1](LIST) 3 [EXE] [EXE]

[2] (Sample) [F1](NO) ⊙ [F1](TIMER) 360 [EXE] ⊙ [F1](NUM) 241 [EXE] [EXE] [F1](START)

Using a Calculator Program

Find the applicable program in the Program Library (P.2-16-4), input it into your calculator, and then run it.

L : Light Intensity
V(V): Voltage
t(s) : Time
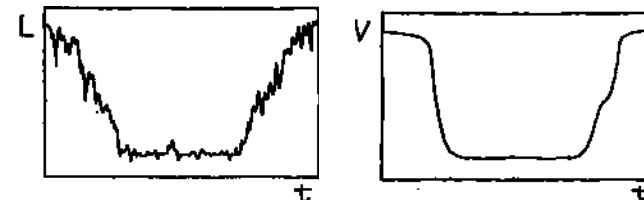
☞ Other Things To Do

• Consider why there is such a large change in measured values over a 24-hour period.

• Consider why there are many changes in the graph over a comparatively short period of time.

• See if the angle of inclination of the solar cell panel and the light intensity satisfy the expression shown below.

$$L = L_{max} \cos(\theta - \theta_{max})$$

L : Light Intensity
L_{max} : Maximum Light Intensity Value
$\theta (°)$: Solar Cell Panel Angle of Inclination
$\theta_{max}(°)$: Angle of Inclination Determined by Preliminary Step

• Predict what changes can be expected throughout the year, and take long-term (24-hour) measurements during different seasons to see what happens.

Topographic Conditions and Climate

The difference in the specific heat of landmasses and seawater causes differences between the climate of coastal areas and inland areas, even when they are located at the same latitude.

This simple activity investigates these differences.

Theory

Specific heat expresses how the temperature of a unit mass of a substance changes when a quantity of heat is applied. The greater the specific heat of a substance is, the smaller is its change in temperature. The expression for this change in temperature is shown below. The table shows the specific heat values for a number of common substances.

$$\Delta T = \frac{\Delta Q}{mc}$$

ΔT(°C) : Change in Temperature of Substance
ΔQ(J) : Heat Quantity Applied to Substance
m(g) : Mass of Substance
c(J/g°C) : Specific Heat of Substance
T(°C) : Measured Temperature

Substance	c(J/g°C)	T(°C)
Water	4.2	15
Ice	2.1	0
Seawater	3.9	20
Rock	0.8	20
Wood	1.2	20

The above indicates that seawater is difficult both to heat and cool, while landmasses are easy to heat and cool. The result is that there tends to be less fluctuation between heat and cold in marine climates, and greater fluctuation further inland. It should be noted, however, that there are many different variations in actual climates, due to ocean currents, air currents, topography, wind patterns, and other factors. This activity investigates changes in the temperature of common everyday substances as they absorb heat from sunlight. It also compares the tendency to change temperature with measured values.

Activity: Setup

■ Equipment

500ml Clear Plastic Bottles (3)　　Dry Earth (or Sand)　　Seawater (or Water)
Styrofoam Boards　　Rain Cover
Temperature Measurement Setup (EA-200, graphic scientific calculator, data communication cable, temperature probe (3))

■ Preparing the Plastic Bottle

● Remove the label from the plastic bottle, wash it out, and let it dry.

● Pierce the center of each of the Styrofoam boards with a temperature probe, attach the board/probe assembly to a bottle cap, and then seal the bottle.
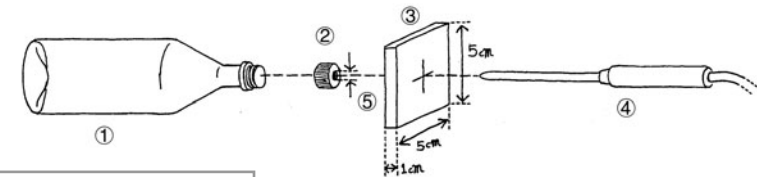
① Plastic Bottle
② Bottle Cap
③ Styrofoam Board 5cm × 5cm × 1cm
④ Temperature Probe
⑤ Hole Diameter: 6mm

■ Setting Up

● Weigh the empty bottle and the other two bottles to determine the mass of the substance inside each.

● Locate the bottles in an area that is constantly exposed to sunlight.

① Styrofoam Board
② Air
③ Seawater
④ Earth
⑤ Temperature Probe
⑥ Rain Cover
⑦ EA-200
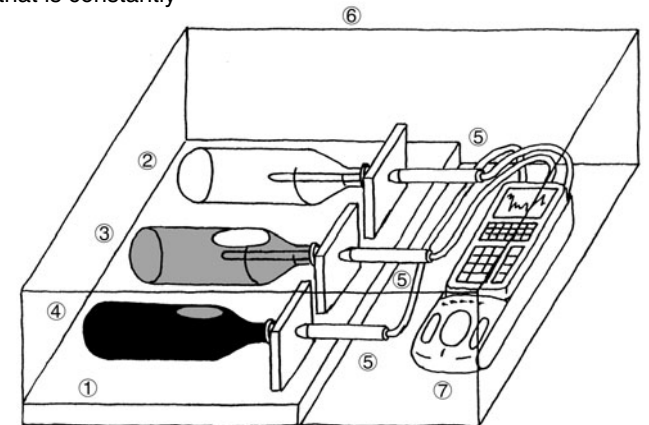
Activity: Operating the Equipment

■ Measuring Data

● Prepare the Temperature Measurement Setup and start temperature measurement.

● Cover the system with the rain cover.

● Remembering that the mass of each of the substances is different, observe the measured change in temperature and its relationship with the specific heat.
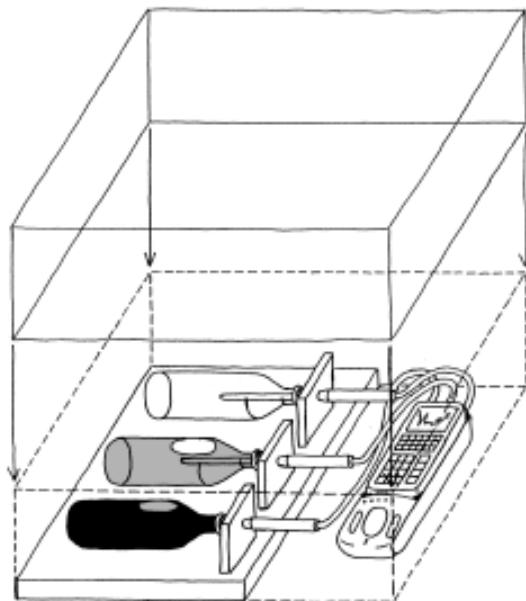
If there is the possibility that the EA-200 might become too hot, place a shade over the EA-200 to block the sun. Note that you should put a little water into the air bottle and a little air into the seawater bottle. Doing so reduces the effect of thermal expansion inside each bottle.

Measurement

■ Calculator Operation

● Perform the following operation to prepare for temperature measurement using the temperature probe.

Using E-CON

MENU "E-CON" EXE F1(SETUP) 2 (Advan)

1 (Channel) F1(CH1) ⬇ F1(CASIO) 2 (TEMP) 1 (°C) ⬇ F1(LIST) 2 EXE

⬇ F2(CH2) ⬇ F1(CASIO) 2 (TEMP) 1 (°C) ⬇ F1(LIST) 3 EXE

⬇ F3(CH3) ⬇ F1(CASIO) 2 (TEMP) 1 (°C) ⬇ F1(LIST) 4 EXE EXE

2 (Sample) F1(NO) ⬇ F1(TIMER) 360 EXE ⬇ F1(NUM) 241 EXE EXE F1(START)

Using a Calculator Program

Find the applicable program in the Program Library (P.2-16-4), input it into your calculator, and then run it.

● Display the temperature measurements.

① Air
② Seawater
③ Earth
T(°C) : Temperature
t (s) : Time
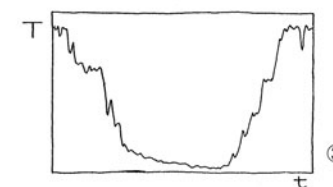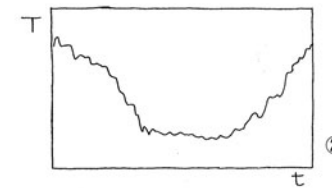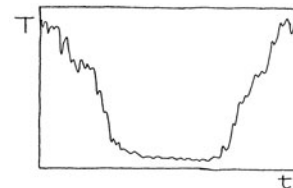
❧ Other Things To Do

● Use the measurement results to estimate differences in air temperature between a dry inland area and a coastal area.

● Use the specific heat values provided in the table for seawater and stone to calculate the quantity of heat absorbed by the seawater and earth in the bottles, and compare them. Consider why this value is different for each of the bottles.

● Try replacing the substances inside the bottles with other substances.

● Consider why it is impossible to determine the specific heat value from temperature changes, and to determine the ratio of specific heat between two substances.

● Attach one optical probe to the EA-200, and investigate the relationship between light intensity and change in temperature.

Program Library

You can download the programs used in the activities at the CASIO Website: http://world.casio.com/edu_e/

Uniformly Accelerated Motion

Conservation of Momentum

```
{0}→List 6↵
Send(List 6)↵
{1,4,1,2}→List 6↵
Send(List 6)↵
{3,0.02,50,1,1}→List 6↵
Send(List 6)↵
"SAMPLING START?"↵
" PRESS [START]"↵
"WHEN SAMPLING IS DONE"↵
" PRESS [EXE]"◢
Receive(List 1)↵
Receive(List 2)↵
Receive(List 3)↵
Receive(List 4)↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
List 2,1,Dot↵
Cls↵
"DISTANCE"↵
DrawStat◢
S-Gph1 DrawOn,xyLine,List 1,
List 3,1,Dot↵
Cls↵
"VELOCITY"↵
DrawStat◢
S-Gph1 DrawOn,xyLine,List 1,
List 4,1,Dot↵
Cls↵
"ACCELERATION"↵
DrawStat◢
"END"
```

Period of Pendular Movement

```
{0}→List 6↵
Send(List 6)↵
{1,1,9}→List 6↵
Send(List 6)↵
{3,0.01,255,1,1}→List 6↵
Send(List 6)↵
"SAMPLING START?"↵
" PRESS [START]"↵
"WHEN SAMPLING IS DONE"↵
" PRESS [EXE]"◢
Receive(List 1)↵
Receive(List 2)↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
List 2,1,Dot↵
Cls↵
"LIGHT"↵
DrawStat◢
"END"
```

Charles' Law

```
{0}→List 6↵
Send(List 6)↵
{1,1,7}→List 6↵
Send(List 6)↵
{3,2,-1}→List 6↵
"SAMPLING START?"↵
" PRESS [EXE]"◢
Send(List 6)↵
ClrText↵
For 1→X To 1800↵
Receive(A)↵
Locate 1,1,"TEMP C"↵
Locate 1,2,A↵
Next↵
"END"
```

* This program cannot be run on an fx-7400 Series calculator.

Polarization of Light

```
[0]→List 6↵
Send(List 6)↵
[1,1,9]→List 6↵
Send(List 6)↵
[3,0.1,200,1,1]→List 6↵
Send(List 6)↵
"SAMPLING START?"↵
" PRESS [START]"↵
"WHEN SAMPLING IS DONE"↵
" PRESS [EXE]"◢
Receive(List 1)↵
Receive(List 2)↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
List 2,1,Dot↵
Cls↵
"LIGHT"↵
DrawStat◢
"END"
```

Light Multi Meter

```
[0]→List 6↵
Send(List 6)↵
[1,1,9]→List 6↵
Send(List 6)↵
[3,2,-1]→List 6↵
"SAMPLING START?"↵
" PRESS [EXE]"◢
Send(List 6)↵
ClrText↵
For 1→X To 1800↵
Receive(A)↵
Locate 1,1,"LIGHT"↵
Locate 1,2,A↵
Next↵
"END"
```

*This program cannot be run on
 an fx-7400 Series calculator.

Natural Ferquency and Sound
Column of Air Resonance and the Velocity of Sound

```
[0]→List 6↵
Send(List 6)↵
[1,10,1,10,10]→List 6↵
Send(List 6)↵
[3,5E-5,1024,1,1]→List 6↵
Send(List 6)↵
"SAMPLING START?"↵
" PRESS [START]"↵
"WHEN SAMPLING IS DONE"↵
" PRESS [EXE]"◢
Receive(List 1)↵
Receive(List 2)↵
Seq(X÷5E-5÷1024,X,0,99,1)→
List 3↵
[5,10,10,1,100]→List 6↵
Send(List 6)↵
Receive(List 5)↵
[5,10,11,1,100]→List 6↵
Send(List 6)↵
Receive(List 6)↵
√(List 5²+List 6²)→List 4↵
0→List 4[1]↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
List 2,1,Dot↵
Cls↵
"SOUND WAVE"↵
DrawStat◢
S-Gph1 DrawOn,xyLine,List 3,
List 4,1,Dot↵
Cls↵
"FFT"↵
DrawStat◢
"END"
```

Construction of the Musical Scale

```
[0]→List 6↵
Send(List 6)↵
[1,10,1]→List 6↵
Send(List 6)↵
[3,4E-5,120000,0,1]→List 6↵
Send(List 6)↵
"SAMPLING START?"↵
" PRESS [START]"↵
"WHEN SAMPLING IS DONE"↵
" PRESS [EXE]"◢
"OUTPUT?"↵
" PRESS [EXE]"◢
[0]→List 6↵
Send(List 6)↵
[1,12,5,10]→List 6↵
Send(List 6)↵
[3,4E-5,120000,0,0]→List 6↵
Send(List 6)↵
"OUTPUT(×2)?"↵
" PRESS [EXE]"◢
[0]→List 6↵
Send(List 6)↵
[1,12,5,10]→List 6↵
Send(List 6)↵
[3,2E-5,120000,0,0]→List 6↵
Send(List 6)↵
"END"↵
```

Direct Current and Transient Phenomena

```
[0]→List 6↵
Send(List 6)↵
[1,1,2]→List 6↵
Send(List 6)↵
[3,0.02,255,1,1]→List 6↵
Send(List 6)↵
"SAMPLING START?"↵
" PRESS [START]"↵
"WHEN SAMPLING IS DONE"↵
" PRESS [EXE]"◢
Receive(List 1)↵
Receive(List 2)↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
List 2,1,Dot↵
Cls↵
"VOLTAGE"↵
DrawStat◢
"END"
```

AC Circuit

```
[0]→List 6↵
Send(List 6)↵
[1,1,2]→List 6↵
Send(List 6)↵
[1,2,2]→List 6↵
Send(List 6)↵
[1,3,2]→List 6↵
Send(List 6)↵
[3,0.001,255,1,1]→List 6↵
Send(List 6)↵
"SAMPLING START?"↵
" PRESS [START]"↵
"WHEN SAMPLING IS DONE"↵
" PRESS [EXE]"◢
Receive(List 1)↵
Receive(List 2)↵
Receive(List 3)↵
Receive(List 4)↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
List 2,1,Dot↵
Cls↵
"CH1"↵
DrawStat◢
S-Gph1 DrawOn,xyLine,List 1,
List 3,1,Dot↵
Cls↵
"CH2"↵
DrawStat◢
S-Gph1 DrawOn,xyLine,List 1,
List 4,1,Dot↵
Cls↵
"CH3"↵
DrawStat◢
"END"
```

Dilute Solution Properties
Exothermic Reaction

```
"Y-MAX(°C)"?→A↵
"Y-MIN(°C)"?→B↵
[0]→List 6↵
Send(List 6)↵
[1,1,7]→List 6↵
Send(List 6)↵
[3,5,-1]→List 6↵
Seq(0,X,1,240,1)→List 2↵
"SAMPLING START?"↵
" PRESS [EXE]"◢
Send(List 6)↵
ClrText↵
Cls↵
ViewWindow 0,1200,,B,A↵
Receive(Z)↵
For 1→X To 239↵
Z→List 2[X]↵
Receive(Y)↵
F-Line 5(X-1),Z,5X,Y↵
Y→Z↵
Next↵
Y→List 2[X+1]↵
Seq(5X,X,0,239,1)→List 1↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
List 2,1,Dot↵
Cls↵
DrawStat◢
"END"
```

Electromotive Force of a Battery

```
"Y-MAX(V)"?→A↵
"Y-MIN(V)"?→B↵
[0]→List 6↵
Send(List 6)↵
[1,1,2]→List 6↵
Send(List 6)↵
[3,5,-1]→List 6↵
Seq(0,X,1,240,1)→List 2↵
"SAMPLING START?"↵
" PRESS [EXE]"◢
Send(List 6)↵
ClrText↵
Cls↵
ViewWindow 0,1200,,B,A↵
Receive(Z)↵
For 1→X To 239↵
Z→List 2[X]↵
Receive(Y)↵
F-Line 5(X-1),Z,5X,Y↵
Y→Z↵
Next↵
Y→List 2[X+1]↵
Seq(5X,X,0,239,1)→List 1↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
List 2,1,Dot↵
Cls↵
DrawStat◢
"END"
```

Sunlight and Solar Cells

```
[0]→List 6↵
Send(List 6)↵
[1,1,2]→List 6↵
Send(List 6)↵
[1,2,9]→List 6↵
Send(List 6)↵
[3,360,241,1,1]→List 6↵
Send(List 6)↵
"SAMPLING START?"↵
" PRESS [START]"↵
```

*Run the following program after
 sampling is complete.

```
"VOLTAGE"↵
Receive(List 1)↵
Receive(List 2)↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
,List 2,1,Dot↵
Cls↵
DrawStat◢
"LIGHT"↵
Receive(List 3)↵
S-Gph1 DrawOn,xyLine,List 1,
List 3,1,Dot↵
Cls↵
DrawStat◢
"END"
```

Topographic Conditions and Climate

```
[0]→List 6↵
Send(List 6)↵
[1,1,7]→List 6↵
Send(List 6)↵
[1,2,7]→List 6↵
Send(List 6)↵
[1,3,7]→List 6↵
Send(List 6)↵
[3,360,241,1,1]→List 6↵
Send(List 6)↵
"SAMPLING START?"↵
" PRESS [START]"↵
```

*Run the following program after
 sampling is complete.

```
"CH1"↵
Receive(List 1)↵
Receive(List 2)↵
S-WindAuto↵
S-Gph2 DrawOff↵
S-Gph3 DrawOff↵
S-Gph1 DrawOn,xyLine,List 1,
List 2,1,Dot↵
Cls↵
DrawStat◢
"CH2"↵
Receive(List 3)↵
S-Gph1 DrawOn,xyLine,List 1,
List 3,1,Dot↵
Cls↵
DrawStat◢
"CH3"↵
Receive(List 4)↵
S-Gph1 DrawOn,xyLine,List 1,
List 4,1,Dot↵
Cls↵
DrawStat◢
"END"
```

Appendix A Command Tables

Command 1 - Channel Setup

*: parameter value marked with asterisk are initial defaults.   { 1, Channel, Operation, Post-Processing, FFT Samples }

Channel		Operation		Post-Processing		FFT Samples	
0	Clear all channels	—		—		—	
*1	Channel 1	0	Clear the selected channel.	0	None		
2	Channel 2	*1	Auto-ID	*1	d/dt	—	
3	Channel 3	2	Voltage (± 10V) (for Voltage probe)	2	d/dt, d^2/dt^2		
		4	Resistance	10	FFT-Real	1 to 14	Samples used
		5	Period	11	FFT-Real, Imaginary	(*6)	2^n (2-16384)
		6	Frequency				
		7	Temperature (Celsius)				
		8	Temperature (Fahrenheit)				
		9	Light				
		10	Voltage (0-5V)				
		11	Absolute Time				
4	SONIC Channel	0	Clear the SONIC channel.	0	None		
		*1	Meters	*1	d/dt		
		2	Meters	2	d/dt, d^2/dt^2		
		3	Feet			—	
		5	Period				
		6	Frequency				
		11	Absolute Time				
5	DIG IN Port	0	Clear the digital input channel.	—		—	
		*1	Active				
6	DIG OUT Port	**Data String Output Loops**		**Data string**			
		0	Clear the digital input channel.	0 to 255	Output data element value	—	
		1 to 32 (*1)	Number of output data elements				
10	Microphone	0	Clear the Microphone.	*0	None		
		*1	Active	10	FFT-Real	1 to 14	Samples used
				11	FFT-Real, Imaginary	(*6)	2^n (2-16384)
11	Analog Out CH 3 1pin ±3Vout	**Data String Output Loops**		**Data Output Selection**		**Data string**	
		0	Clear the analog out or speaker.	*0	Data string	± 1.5	Output data element value
12	Speaker	1 to 65535 (*1)	Number of output data elements	1	Channel 1		
				2	Channel 2		
				3	Channel 3		
				10	Microphone		

• Channel = 1, 2, 3 or 4, Operation = 5, 6, 11

{ 1, Channel, Operation, Pin No, Trigger Threshold, Trigger Edge }

Pin No		Trigger Threshold		Trigger Edge (Operation = 5, 6)	
*2	1pin Vin (± 10V)	± 10	Set input voltage threshold value −10 to +10.	*0	Rising edge to rising edge
				1	Falling edge to falling edge
				2	Rising edge to falling edge
				3	Falling edge to rising edge
10	6pin Vin-low (0-5V)	0 to 5		**Trigger Edge (Operation = 11)**	
				*0	Rising edge
				1	Falling edge
				2	Rising and falling edge

• Record Time for Operations 5, 6, and 11 must be 2, 1, and 1 respectively.
• Trigger Source for Channels 1, 2, 3, and 4 must be 2, 3, 4, and 12 respectively.
• Clock Source must be 10.

Command 3 - Sample and Trigger Setup

{ 3, Sample Interval, Number of Samples, Record Time, Trigger Source, Trigger Threshold, Trigger Edge, Clock Source }

Sample Interval		Number of Samples		Record Time	
0.00002 to 16000 (*0.1)	Number of seconds	1 to 120000 (*100)	Number of samples	0	Off
				*1	Absolute time recording
				2	Relative time recording

Trigger Souce		Trigger Threshold	Trigger Edge		Clock Source	
1	[START/STOP] key	──		──	*0	Timer (Sample interval)
2 or 5	CH 1	Sampled Values • Corrected values when Command 4	0	Falling edge	10	Same as Trigger Source
3 or 6	CH 2		*1	Rising edge		
4 or 7	CH 3		2	Rising and falling edge		
8	DIG IN Clock	──				
9	DIG IN 8bit data	0-255 (D7-D0) (*1)		──		
10	Microphone	Sampled Values ±1.5V	0	Fallig edge		
			*1	Rising edge		
			2	Rising and falling edge		
11	SONIC	Distance • Unit depends on Command 1. (*0.05)	0	Falling edge		
			1	Rising edge		
			*2	Difference with previous value is below		──
			3	Difference with previous value is above		
20	Count down	**Count Number (sec)**		──		
		1 to 10 (*10)				
−1	Command 8	──		──		

Command 4 – Conversion Equation Setup

{ 4, Equation Number, Equation Type, Number Format, Constants }

Equation Number		Equation Type			Number Format		Constants
* 0	Clear All equations.	* 0	Clear equation selected by the equation number parameter.				—— ——
1	Equation 1 (Channel 1)	1	Polynomial	$K0 + K1X + K2X^2 +...+ KnX^n$ *1	* 0	Standard	$K0(,K1,...,K9)$ *3,4
2	Equation 2 (Channel 2)	2	Mixed polynomial	$KmX^{-m} + ...+ K{-1}X^{-1} + K0 + K1X +...+ KnX^n$ *2	10	Integer part (Decimal part cut off.)	$K{-4}(,..., K{-1}, K0, K1, ..., K5)$ *3,4
3	Equation 3 (Channel 3)	3	Power	$K0 \cdot X^{(K1)} + K2$			
		4	Modified power	$K0 \cdot K1^X + K2$			
		5	Logarithmic	$K0 + K1 \ln(X)$			
		6	Modified logarithmic	$K0 + K1 \ln(1 / X)$			
		7	Exponential	$K0e^{(K1X)} + K2$			$K0(, K1, K2, K3)$ *3,4
		8	Modified Exponential	$K0e^{(K1/X)} + K2$			
		9	Geometric	$K0X^{(K1X)} + K2$			
		10	Modified geometric	$K0X^{(K1/X)} + K2$			
		11	Reciprocal logarithmic	$1 / \{K0 + K1 \ln(K2X)\} + K3$			
		12	Steinhart-Hart	$1 / \{K0 + K1(\ln 1000X) + K2(\ln 1000X)^3\} + K3$			
4	Equation 4 (SONIC channel)	* 0	Clear equation 4		**Unit**		**Temperature**
		1	Temperature used by distance conversion expression		* 0	°C(Celsius)	Temperature
					1	°F (Fahrenheit)	(*20)
					2	°C (Celsius)	
					3	K (kelvin)	
					4	°R (Rankin)	

*1 Polynomial: Input constants in sequence, from $n = 0$ to 9. *2 Mixed polynomial: Input constants in sequence from $m = 4$ to 1, and $n = 0$ to 5.
*3 Input of zero for constants can be skipped if all remaining constants are not used. *4 Input 0 for constants that are not used.
• When the conversion result of the "conversion equation" selected by Command 4 causes an overflow, the EA-200 sends a result of zero (0) to the calculator.

Command 5 - Data Range Setup

{ 5, Channel Select, Data Select, (FFT Samples,) Data Begin, Data End, Step, K }

Channel Select		Data Select		Data Begin	Data End	Step	K	FFT Samples
* 0	Current send channel	* 0	Raw data	1 to 120000	1 to 120000	Data Range Steps	(*255)	1 to 14 : Samples used
1	Channel 1	1	d/dt	(*1)	* 0 : Last sample	−1: Data range number / K		(*6) $2^n(2–16384)$
2	Channel 2	2	d^2/dt^2			(*1)		
3	Channel 3	10	FFT-Real					
4	SONIC channel	11	FFT-Imaginary					
5	DIG IN channel							
6	Recorded time data							
10	Microphone							

Command 6 - System Setup

{ 6, Command, Auto Power Off Time }

Command		APO Time(sec)	
0 or 2	Abort Sampling (*0)	—	
3	Turns sound off		
4	Turns sound on		
10	APO (Auto Power Off)	* 0	1800
		1	10
		2	360

Command 8 - Sampling Start

{ 8 }

Command 11 - Buzzer and LED Operation Commands

{ 11, Output Select, Length, Period }

Output Select		Length (sec)	Period (sec)
* 0	Buzzer	Operating Time (sec)	Period (sec)
2	Ready LED		
3	Sampling LED		—
4	Error LED		
5	Batt LED		

• An error occurs when fraction data is sent.
• Send commands to the EA-200 in accordance with the command table contents.
• An error occurs when a parameter that does not exist in the command table is sent.
• The EA-200 uses six digits for internal calculations.

Command 10 - Sensor Warmup

{ 10, Warmup Time (sec) }

Warmup Time (sec)	
0.1 to 360	Warmup time (sec) (*0.1)
0	Auto
−1	None
−2	Normal warmup

Command 12 - Data Send Sequence

{ 12, Send Sequence }

Send Sequence	
* 0	Non-real Time Format
1	Real Time Format

Appendix B Specifications

Model: .... CASIO EA-200

Power Supply: .... Four AA-size alkaline batteries (LR6 (AM3)) or
AC adaptor (AD-A60024)

Power Consumption: 1.5W

Battery Life: .... LR6 (AM3): Approximately 50 hours (when is left with
power on) / Approximately one year (when is left with
power off)
Battery life is also affected by the type of probes that
are connected, sampling program setup, etc.

Auto Power Off: .... Approximately 30 minutes after last key operation. See
page 0-4 for information on conditions under which
Auto Power Off is disabled.

Operating Temperature: .... 0°C to 40°C (EA-200)
The tip of the temperature probe can be used in
temperatures ranging from –20°C to 130°C.

Dimensions: .... 84.0(W) $\times$ 246.0(D) $\times$ 32.0(H) mm
$3^{5/16}$″ (W) $\times$ $9^{11/16}$″ (D) $\times$ $1^{1/4}$″ (H)

Weight: .... 350g (12.3 oz) including batteries

Standard Accessories: ...... Optical Probe (CDAP-01); Temperature Probe (CDAP-
02); Voltage Probe (CDAP-03); four AA-size alkaline
batteries (LR6 (AM3)); AC adaptor (AD-A60024); Data
Communication Cable (SB-62); Soft Case; User's
Guide

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