IBM

Personal Science Laboratory

User's Guide

IBM

IBM Personal Science Laboratory

G544-3298-00

User's Guide

PSL Explorer Version 0.9

The following statement applies to this IBM product. The statement for other IBM products intended for use with this product will appear in their accompanying manuals.

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Warning: This equipment generates, uses, and can radiate radio frequency energy and if not installed and used in accordance with the instructions manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class A computing device pursuant to Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user at his own expense will be required to take whatever measures may be required to correct the interference.

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Setup Instructions

For set up instructions, see "Setting Up a PSL" on page 15.

About This Book

This book describes IBM Personal Science Laboratory, whose hardware is a microcomputer-based laboratory with range, flexibility, quality, accuracy, and simplicity to serve from the elementary grades through university levels, and beyond. The supporting software, PSL Explorer, is a easy-to-use, menu-driven interface for the user.

All users of PSL need the first four chapters, which describe:

- Microcomputer-based laboratories
- PSL
- How to set up PSL
- How to install the supporting software.

If you are using PSL Explorer to control PSL, then the next two chapters are for you:

- PSL Explorer, the software that helps you control PSL
- How to use PSL in the classroom, with two sample explorations

Related Publications

For technical information, such as programming interfaces or circuit designing details, the following publication can be ordered:

S544-3299 IBM Personal Science Laboratory Technical Reference

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1. About Microcomputer-Based Laboratories

The microcomputer-based laboratory (MBL) has proved to be a strikingly effective tool for science education from the middle grades through college. With software that relieves students from some of the "bookkeeping" of data collection and display, an MBL allows students to concentrate on the science of an experiment. For example, software can graph the data in real time, and then can perform changes of scale or mathematical transformations (such as differentiation) which may be difficult for the student to perform, yet is valuable for them to see. It gives students tools for exploration and analysis so that they can do real science: asking and answering their own questions while building on their experience and intuition as they work with actual events.

The IBM Personal Science Laboratory™ (PSL™) is such an MBL. PSL was developed to encourage quality experimentation by using the resource of a microcomputer for both exploration and analysis. The result of experimenting in such an environment is a better understanding about the phenomena being studied. IBM has drawn on the extensive experience of Technical Education Research Centers (TERC) with microcomputer-based laboratories to ensure that PSL serves in many levels of experimentation. The same experience is applied to the development of the sample experiments included in this manual.

PSL fills an important need in science learning by enabling students to explore a subject in ways that would impractical, were it not for the simulation, graphics, and data-collecting powers of the computer.

The software supplied with PSL allows students to manipulate variables, analyze data in both graphic and mathematical modes, and see immediate results from their experimental innovations. This quick feedback and the flexibility in response to student queries have made science accessible to many students who might otherwise be put off by computer use, mathematical tools, or the science facts themselves. In fact, it has proved to be quite inviting to those with poor preparation for the science course.

PSL introduces students to a wide range of science, yet does not require great fluency or expertise in the "language" of scientific investigation. Instead, the knowledge of science and of scientific methodology can grow together.

Recently, studies have examined the effect of microcomputer-based laboratories on students' learning, at high school and college levels.[1] The results show a remarkable jump in the understanding of science by students of many levels and backgrounds. PSL is a powerful tool for helping students make sense of their study and of their experiences. The result is a tangible, lasting improvement in learning science facts and in physical intuition.

PSL also changes the teacher's role in the lab. The students are engaged in scientific investigation; the teacher's input helps break impasses, rephrase

[1] Brasell, Heather. *Effect of real-time lab graphing.* Presented at American Educational Research Association, 1987.

Thornton, Ronald K. *Implications from research on the design and use of real-time laboratory measurement tools for physics learning.* Presented at Joint Session of American Association of Physics Teachers and American Physics Society, January 1988.

questions, and change perspectives in the service of an inquiry that is free and yet productive for the learners of science.

2. The IBM Personal Science Laboratory

The IBM Personal Science Laboratory (PSL) is a flexible, and powerful microcomputer-based laboratory (MBL). PSL consists of hardware and software, working together to provide the optimal science learning experience.

The Names of PSL Components

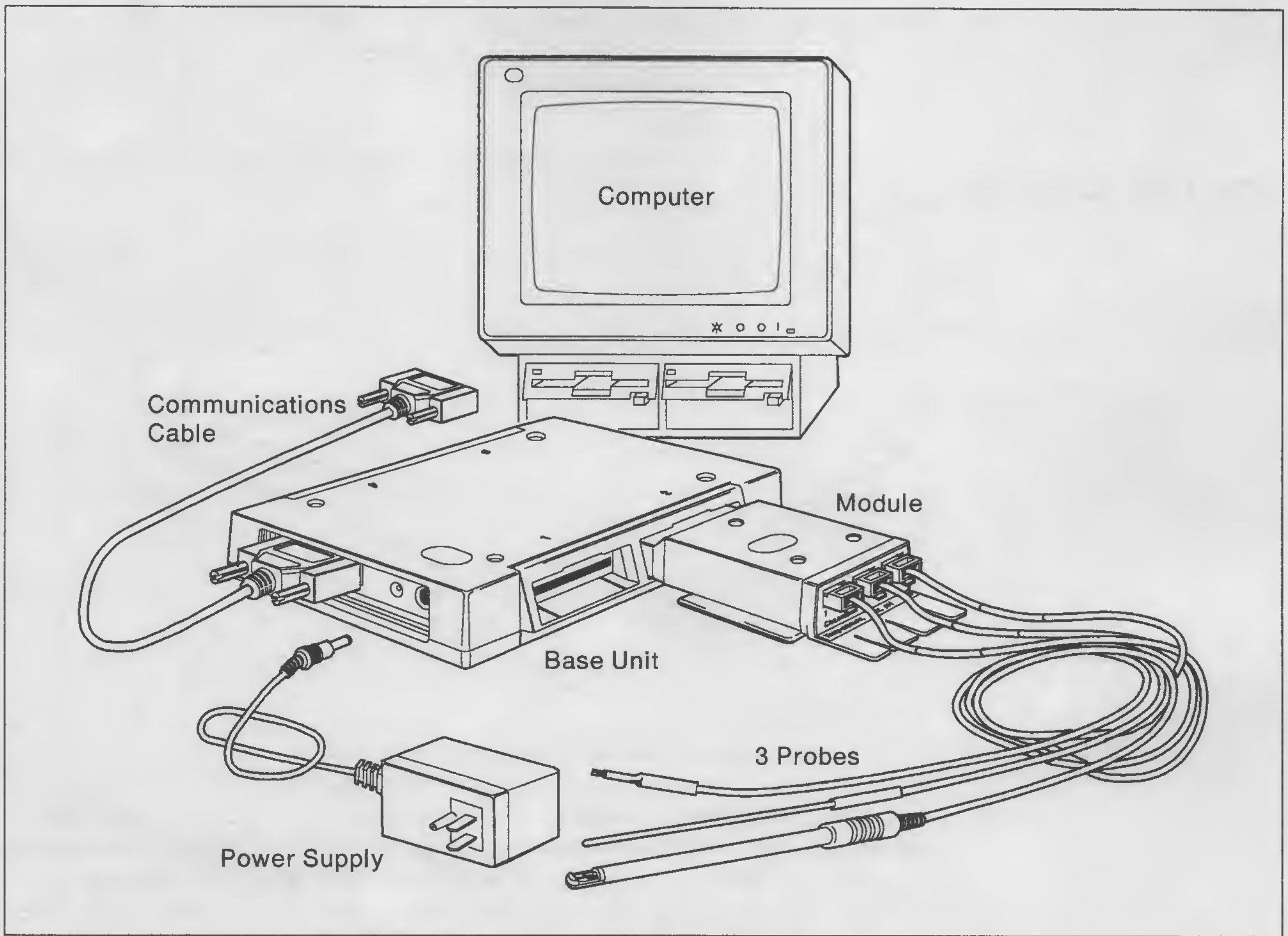


Figure 1. IBM Personal Science Laboratory

The Hardware Components

The hardware for PSL consists of a *base unit* with *modules* and *probes*, plus the power supply and communications cable.

Probe Contains the sensing device.

Module Provides electronics specific to each type of probe. (To extend a PSL's capability, only another module or probe is required.)

Base unit Is the control center of a IBM Personal Science Laboratory, performing commands from the computer, collecting data from the probes, and sending that data back to the computer over the communications cable.

A single PSL base unit can accommodate up to four modules at once — of different types, if desired. Moreover, some computers have multiple communications ports and can attach as many as four PSL base units at once.

The Software Components

The software supplied with PSL consists of the *PSL Explorer* and the *PSL Device Driver*.

PSL Explorer Provides a friendly interface for the user, using menus to control PSL. (As new modules and probes are added to PSL, PSL Explorer will be updated to support them.)

PSL Device Driver Incorporates support for PSL into the operating system of the computer, allowing an application program to control PSL with standard commands.

The PSL Base Unit

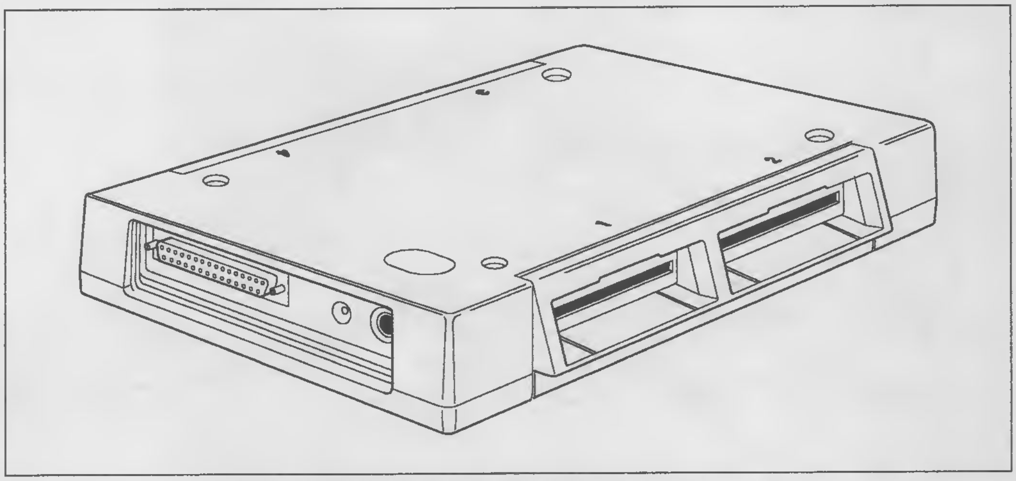


Figure 2. The base unit for the IBM Personal Science Laboratory

The hub of PSL's hardware is the base unit. Actually a small microcomputer itself, one base unit controls multiple probes at once. At one end are the communications connecter and the power jack. The communications cable attaches here, allowing communication with the computer. Power comes from the low-voltage power supply that is provided with PSL. A small light next to the power socket indicates when the unit is on.

Four module ports are provided: two on both sides of the base unit. All module ports are functionally identical; any module can be inserted into any port.

The remaining openings at the opposite end from the power socket are reserved for future use by IBM.

Modules and Probes

Modules contain electronics specific to the probes that they support, and plug into the ports on either side of the base unit. One base unit accommodates four modules. The probes in turn plug into modules.

PSL currently supports three types of modules:

Temperature, Light, and pH (TLp)
Accepts up to three temperature, light, or pH probes (only one of these can be pH)

Motion-and-Mechanics Module
Accepts one distance probe

Prototype Module
Provides a blank circuit board for a user-built module. (This module is not described in this book; for details, refer to *IBM Personal Science Laboratory Technical Reference*.)

Temperature, Light, and pH (TLp) Module

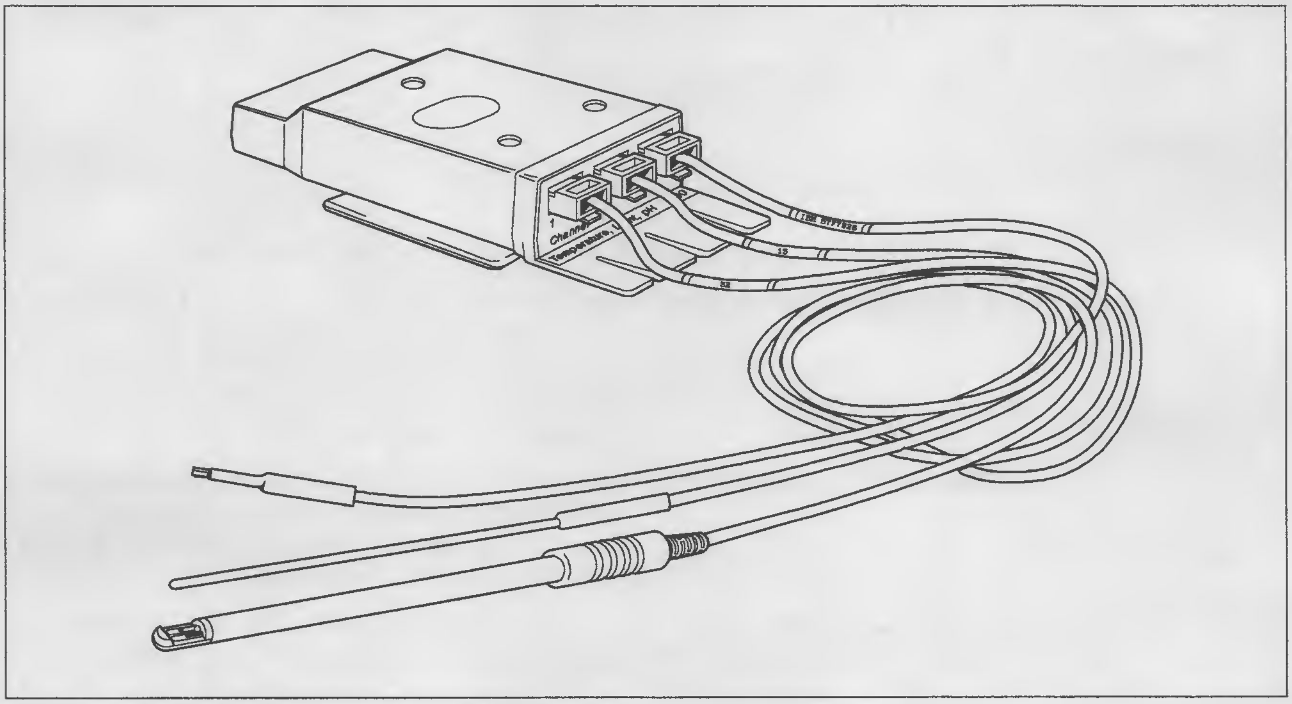


Figure 3. A TLp module with three temperature probes

The blue TLp module supports three different types of probes: temperature, light, and pH. The TLp module has three telephone-style jacks and can accommodate up to three probes at any time:

- Up to three temperature probes
- Up to three light probes
- A single pH probe
- Any combination from the above for a total of three probes.

The base of the module is a bobbin for storing the cables of its probes, and modules stack together for storage.

Temperature Probes

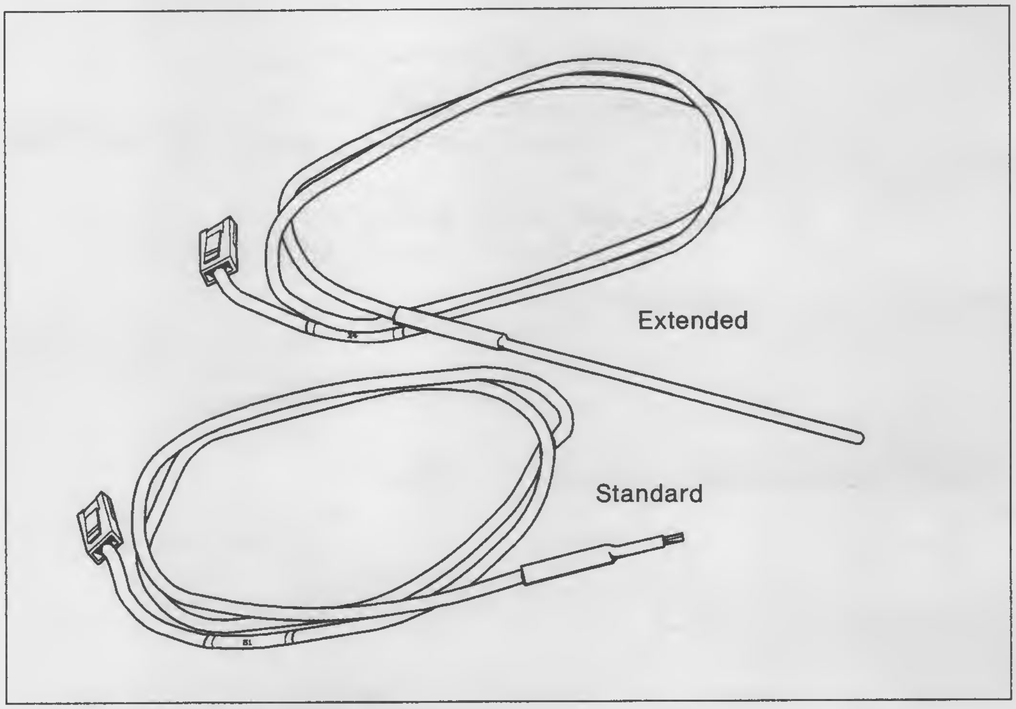


Figure 4. Temperature Probes

Two types of temperature probes are available: *Standard* and *Extended*.

Standard Temperature Probe Ranges from -40°C to 105°C., and is a small metallic protrusion at the end of its connecting cable, which provides fast response because of the low thermal mass. (Also, it is waterproof and can be safely lowered into water to any depth.)

Extended Temperature Probe Ranges from -55°C to 150°C., and is encased in a stainless-steel tube for easier handling and chemical resistance. Its cable is built to withstand these extremes of temperature.

Both types of probes carry a calibration number on a label attached to the cable near the connecting plug. PSL Explorer requests this number during setup to effect calibration for an experiment.

If required, an shielded extension for the connecting cable can be used without disturbing the calibration; these probes are not sensitive to the length of the cable (up to 100 m).

Technical Specifications

Standard Temp.	Range	-40°C to +105°C
	Linearity	±1°C
	Time Constant	0.14 sec
	Resolution	.05°C
	Sampling rate	50/sec
Extended Temp.	Range	-55°C to +150°C
	Linearity	±.8°C for -55°C to +150°C
		±.5°C for -25°C to +105°C
	Time Constant	1.2 sec
	Resolution	.05°C
	Sampling Rate	48/sec

Note: See "Technical Specifications" on page 77 for more information about the technical specifications of the temperature probes.

Light Probe

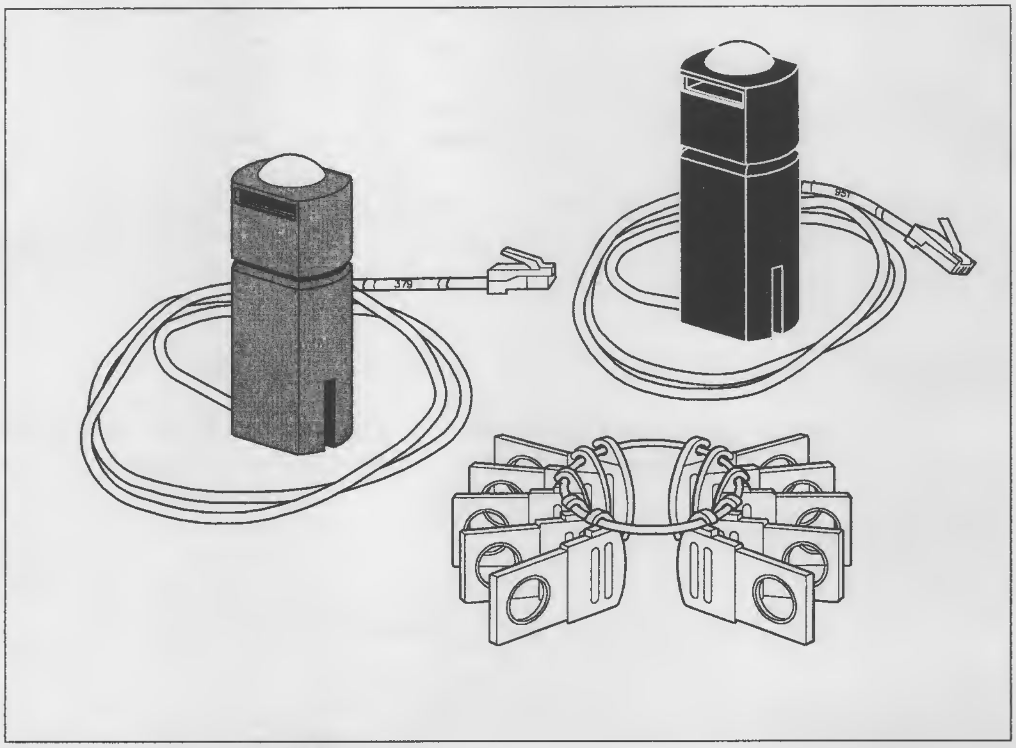


Figure 5. Light probes with filter holders

Two types of light probes are provided: *Photometric* and *Radiometric*.

Photometric Probe — Responds to visible light as does the human eye (that is, experiments with this probe are physiologically based). The unit of measurement for the Photometric Probe is the lux (lm/m^2).

Radiometric Probe — Measures the absolute intensity of light (that is, experiments with this probe are physically based). The unit of measurement for the Radiometric Probe is $\mu Watt/cm^2$.

Figure 6 on page 9 illustrates the response curves for these two probes. The Photometric probe is more sensitive at certain wavelengths (colors) of light. The Radiometric probe, however, is relatively uniform in its response to varying wavelengths of light. It also responds to a broader spectrum of light than does the Photometric probe, "seeing" slightly into the infrared. (The visible spectrum is approximately 400nm to 700nm, and the radiometric probe responds to wavelengths up to about 1000nm.)

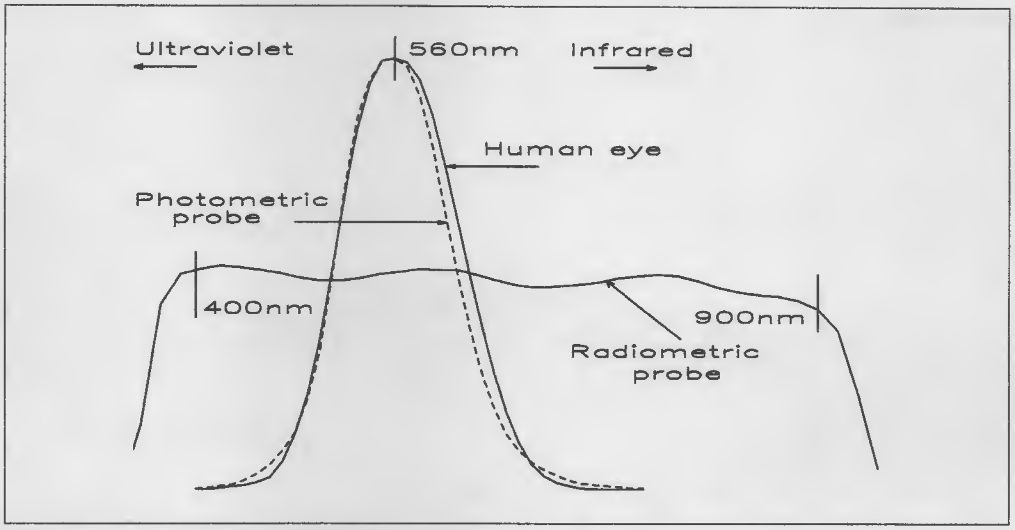


Figure 6. Light-Probe Response

Both types of light probes are supplied with filter holders, which can be used with your choice of filter material for measurement of specific light frequencies or colors.

A threaded receptacle in the light probe's housing matches a standard camera tripod, and flat surfaces allow clamping. Both light probes are waterproof to allow underwater measurements.

Both types of probes carry a calibration number on a label attached to the cable near the connecting plug.

Technical Specifications

Radiometric Light	Spectral Range	400nm to 950nm
	Sensitivity	$0.1\mu W/cm^2$ to $10{,}000\mu W/cm^2$
	Sampling rate	25/sec to 200/sec
Photometric Light	Spectral Range	400nm to 700nm
	Sensitivity	.5 lux to 100,000 lux
	Sampling rate	25/sec to 200/sec

pH Probe

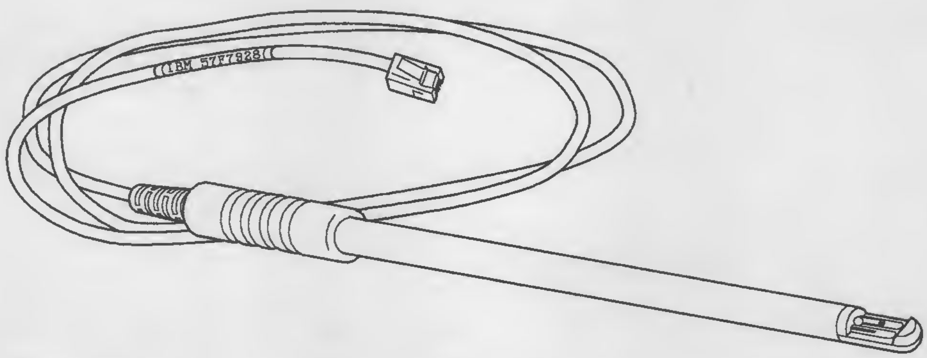


Figure 7. pH Probe

The pH Probe is solid-state and, unlike glass-bulb technology, is not easily damaged, nor does it require storage in a buffered solution. Rather, for maximum life, it should be stored dry, with a protective cap (supplied with the probe) in place to protect the reference junction.

The pH Probe is used by inserting it into the liquid being tested far enough to cover the depression at the tip, and it will fit into a standard test tube. However, it can also measure the pH of a single droplet of liquid by holding the probe horizontally and placing the drop directly on the sensing element.

The pH Probe contains a built-in thermistor that is used by the supporting software for automatic temperature compensation. There is no need to use a separate thermometer and manually adjust the readings for the temperature of the test material. In addition, the probe's thermistor can be used as a temperature sensing device independently from the pH sensor.

Technical Specifications

pH	Range	0 pH to 12 pH
	Accuracy	±0.2 pH (one-point calibration)
		±0.1 pH (two-point calibration)
	Resolution	0.01 pH
	Time constant	0.7 sec
Thermistor	Range	0°C to 60°C
	Accuracy	±0.5°C
	Resolution	.25°C
	Sampling rate	50/sec

Note: pH accuracy is rated over a range of $\pm$10°C from the temperature at which it is calibrated.

See "Hints and Tips" on page 75 for proper use of the pH probe.

Motion-and-Mechanics Module

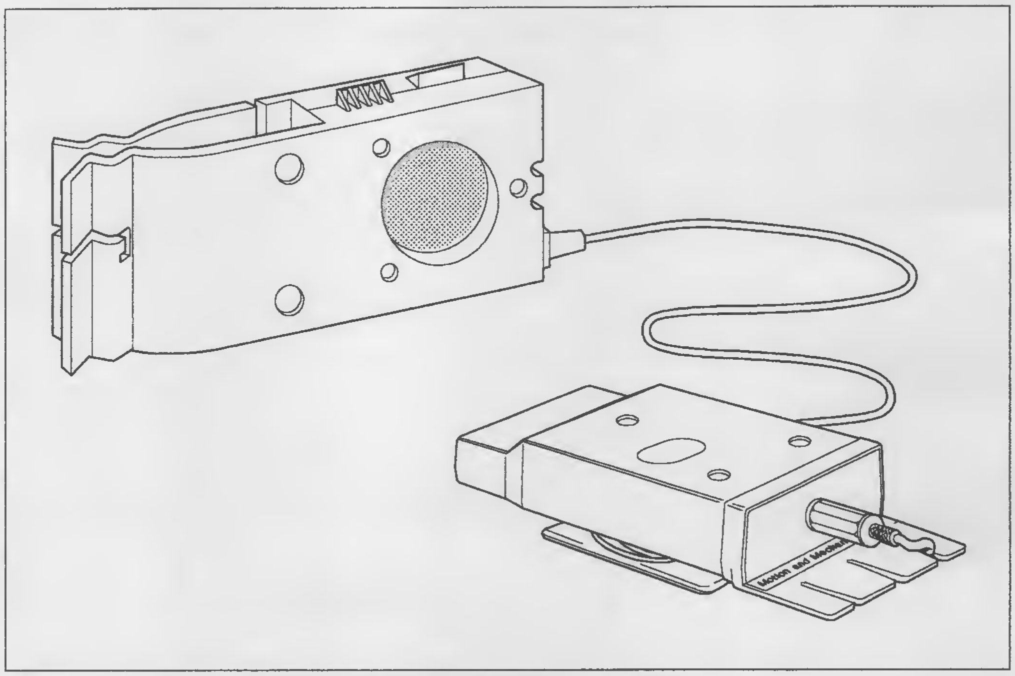


Figure 8. Motion-and-Mechanics Module with Distance Probe

The yellow Motion-and-Mechanics Module supports the Distance Probe and is used for experiments requiring measurements of distance. Taken over time (even one second), these measurements provide data about motion. Only one Distance Probe can be used by a Motion-and-Mechanics Module, but up to four of these modules can be attached to a single base unit, and up to four base units can be attached to one computer.

The base of the module is a bobbin for storing the cable of Distance Probe, and modules stack together for storage.

Distance Probe

The Distance Probe operates by emitting small bursts of ultra-high-frequency sound that bounce off the target and produce echoes that are detected by the probe. The time from emission to detection is directly proportional to the distance of the target from the probe.

The housing of the Distance Probe provides many ways to use the probe. It clips to all standard laboratory ring stands and also to a thin panel, such as a clipboard or the cover of a three-ring binder.

Small suction cups can be exposed to grip any smooth surface. The two slots at the cable end of the probe accept the cable to help aim the probe. By pressing the cable into the slots, a loop is formed to tilt the probe when using suction cups.

Hook-and-loop tape on the back can be mated to the appropriate strip attached to any surface you wish. The probe can also be fastened by screws through three holes in the body of the probe.

The probe can be hung on a string by the notch in the ring-stand clips. By looping the string around the notch, the probe can be tilted to aim it down the string. The probe's aim can also be adjusted by pressing the cable into one of the two end slots, looping the cable over the string, and securing the cable into the other end slot. By adjusting the loop's length, the probe can be aimed. The screw holes can be used for sighting.

One side of the probe has ribs exactly perpendicular to the sensor plane, so that it can be accurately placed on a table and sense along the table's surface.

Two ribbed flanges are on the other side of the probe. These flanges are exactly on the plane of the sensor and can be used to verify distances from the sensor.

A threaded receptacle accepts a standard camera tripod.

Technical Specifications

Distance	Range	0.4m to 10m
	Accuracy	±7.0mm
	Resolution	0.4mm
	Sampling rate	350/sec (dependent on distance)

The PSL Explorer

PSL's supporting software is called the PSL Explorer. You use the PSL Explorer by following a set of menus to set up and then perform an experiment. The data from the experiment can be displayed graphically while it is collected, and it can be optionally stored for later review. With menus, the data can be analyzed to understand the relationships between parameters of the experiment.

Use of the PSL Explorer is explained in detail in "Using the PSL Explorer with PSL" on page 25.

The PSL Device Driver

The PSL Device Driver is the software that makes PSL operate with your computer. The driver manages the communications between the computer and the base unit, sends commands to the base unit, sorts out the data that is received from the probes via the base unit, and diagnoses any problems that might develop with PSL.

Normally, you will not be aware of the PSL Device Driver during daily use of PSL. It is, however, an important part of PSL and must be installed along with the PSL Explorer. For directions on installing the PSL Device Driver, see "Installing the Software" on page 19.

The PSL Device Driver provides a stable programming base for development of your own PSL programs. The PSL Explorer features ease of use and is adequate for the vast majority of PSL applications. However, the PSL hardware is capable of more versatility and complexity than can be supported by PSL Explorer. You might want to exploit more of the power inherent in the PSL hardware, and you need specialized programs to do so. The driver provides the interface for those programs. If you wish to write your own software for PSL, consult *IBM Personal Science Laboratory Technical Reference*, which provides the detailed technical information that you need for that task.

3. Setting Up a PSL

No special skills or tools are required to set up PSL to perform an experiment. Components plug together or attach to cables in a myriad of configurations without the need for opening covers or exposing any circuitry. This chapter illustrates the simple procedures.

What You Need

Computer Requirements

Any IBM personal computer with a serial communications (RS232C) port can act as the computer for PSL. PSL has been tested with the following machines:

IBM PC[2]
IBM PC/XT[2]
IBM PC/XT 286[2]
IBM PC/AT[2]
IBM PC/Convertible[3]
IBM PS/2 model 25
IBM PS/2 model 30
IBM PS/2 model 30/286
IBM PS/2 model 50
IBM PS/2 model 60
IBM PS/2 model 70
IBM PS/2 model 80

PSL Explorer supports all standard graphics displays in monochrome and EGA and VGA displays in color. PSL Explorer requires at least 384k of memory for operation.

> **Important**
>
> Do not confuse communications ports with PSL ports. Communications ports are found on the rear panel of your computer and accept the communications cable from the base unit. PSL ports are found on the base unit and accept modules.

Operating System Requirements

DOS 3.0 or above is required for operating PSL.

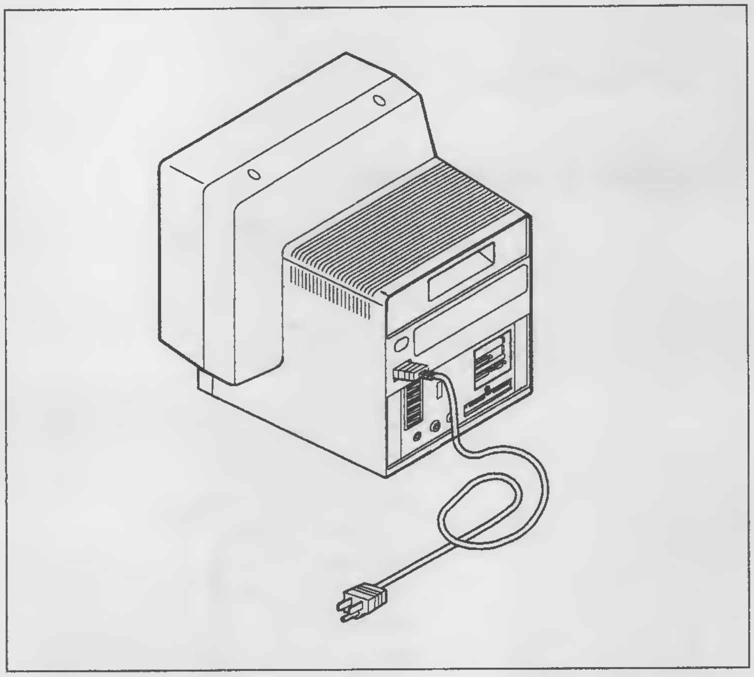
2 An IBM PC requires an adapter card such as the asynchronous communications adapter or a serial/parallel card.

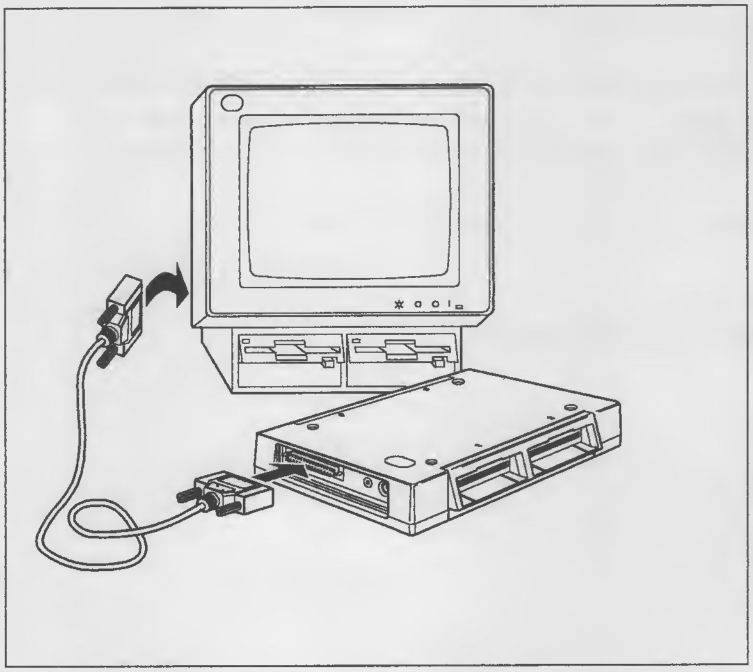
3 An IBM Convertible requires the IBM Convertible Serial/Parallel Adapter or its equivalent.

Attaching PSL to a PC or PS/2

Installing the PSL hardware consists of nothing more than plugging the units together. Four easy steps are shown by the following figures.

1 Turn off the computer and remove the power cord from the wall. PSL is designed in such a way that attaching and detaching under power should not cause damage, but be safe and remove all power before making any changes in configuration.





2 Plug the male end of the communications cable into the base unit.

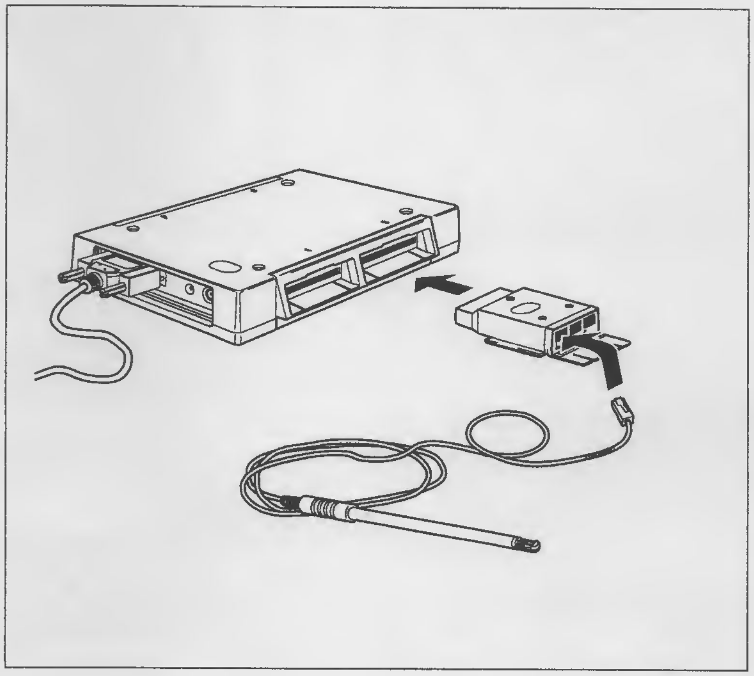
Plug the female end of the communications cable into the serial port of your computer.

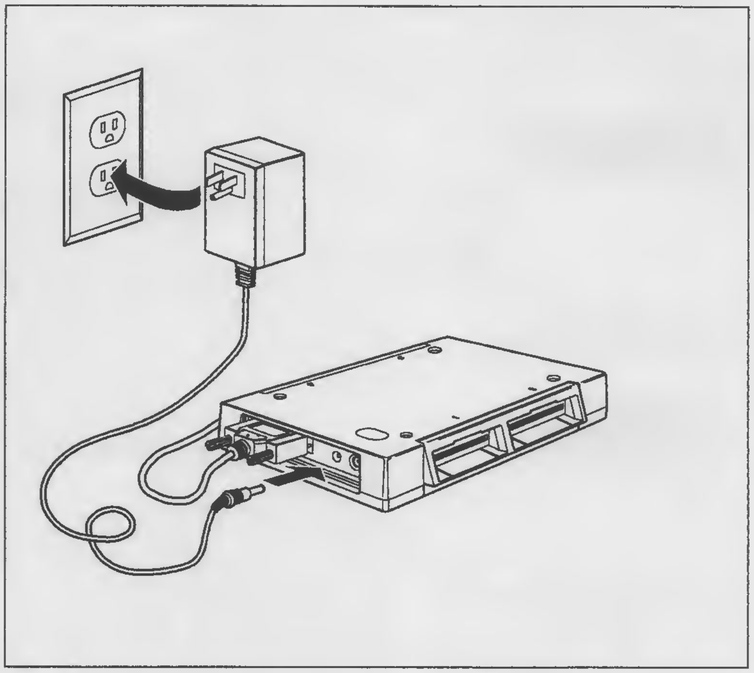
If you are using a PS/2, the serial port is built-in to the computer. If you have an IBM PC, you need to have an adapter card such as the asynchronous communications adapter or a serial/parallel card in your computer.

3 Insert the module required for your chosen experiment into one of the base unit's ports.

Push it in until you feel a faint click. Push firmly; it is a tight fit.

Plug the probes into their respective modules. Each probe is designed to plug into a specific module.





4 Insert the small plug of PSL's power supply into the power jack in the base unit.

Plug the power supply into a 3-prong, grounded wall socket.

Plug the computer back in and turn it on.

CAUTION:
This product is equipped with a UL-listed wall-mounted power supply for safety. Use it with a properly grounded 110-volt AC receptacle to avoid electrical shock.

4. Installing the Software

The software need be installed only once. The procedure depends on whether you have a computer with only diskette drives or a fixed drive.

Using Diskette Drives

Installation consists of making a copy of the PSL diskette. Keep the original PSL diskette in a safe place and away from the copy. Use the copy for day-to-day operation. The copy contains all necessary files for stand-alone operation.

You need your DOS diskette and blank diskettes, one if you are using 3½-inch diskette drives, or two if you are using 5¼-inch diskette drives.

Single-Drive Systems

If you have a single drive system:

1. Start DOS in the usual manner.

   DOS is ready when A> is displayed.

2. Type `DISKCOPY a: b:` and press &enterkey..

   After a moment, a message asks you to insert the source diskette in the drive. (The source diskette is your original PSL Explorer diskette.)

3. Remove the DOS diskette and insert the source diskette in the drive. Press any key.

   After a moment, a message asks you to insert the target diskette in the drive. (The target diskette is the blank diskette you want to make into an operating copy.)

4. Remove the source diskette from the drive and insert a blank diskette in the drive. Press any key.

   When making a copy, you have to switch the diskettes. Messages on the screen prompt you when to switch diskettes. Follow the messages on the screen until the message `Copy another diskette (Y/N)?` appears.

5. If you are copying a 3½-inch diskette, type `N`. If you are copying a 5¼-inch diskette, type `Y`, and repeat the previous two steps for the second diskette.

6. When you see the message: `Copy another diskette (Y/N)?` and you have no more diskettes to copy, type `N`.

   A message similar to the following below is displayed:

   ```
   Insert disk with \COMMAND.COM in drive A
   and strike any key when ready
   ```

7. Remove the target diskette from the drive, insert the DOS diskette in the drive, and press any key.

Note: Label each diskette copy as you complete the procedure.

Dual-Drive Systems

If you have a dual-drive system:

1. Start DOS in the usual manner.

   DOS is ready when > is displayed.

2. Type `DISKCOPY a: b:` and press &enterkey..

   After a moment, a message asks you to insert the source diskette in drive A and to insert the target diskette in drive B. (The source diskette is your original PSL Explorer diskette and the target diskette is the blank diskette you want to make into an operating copy.)

3. Remove the DOS diskette from drive A and insert the source diskette in drive A.

4. Insert a blank diskette in drive B and press any key.

   After a moment or two, a message asks: `Copy another diskette (Y/N)?` appears.

5. If you are copying a 3½-inch diskette, type `N`. If you are copying a 5¼-inch diskette, type `Y`, and repeat this procedure for the second diskette.

6. When you see the message: `Copy another diskette (Y/N)?` and you have no more diskettes to copy, type `N`.

   A message similar to the following below is displayed:

   ```
   Insert disk with \COMMAND.COM in drive A
   and strike any key when ready
   ```

7. Remove the source diskette from drive A, insert the DOS diskette in drive A, and press any key.

Note: Label each diskette copy as you complete the procedure.

Using a Fixed Disk

The PSL Explorer can be stored on and operated from a fixed disk. Once the program is installed on a fixed disk, the diskettes are no longer needed to start and use the program. To install PSL Explorer on your fixed disk:

1. Turn on the computer and start DOS in the usual manner.

2. Insert the PSL Explorer diskette into drive A. (If you are using an 5¼-inch drive, insert PSL Explorer diskette 1 into drive A.)

3. If the current drive is not drive A, then switch to drive A by typing `a:` and pressing &enterkey..

4. When you see the DOS prompt (`A>`), type `install` and press &enterkey..

5. After a moment, you will be asked if you wish the PSL Explorer to start automatically when the computer is turned on.

   If you answer yes, the following lines are appended to your AUTOEXEC.BAT file

   ```
   cd \PSL
   PSL
   ```

   which cause PSL Explorer to begin automatically after your computer has started.

   If you answer no, you must manually start the PSL Explorer each time you start the computer, by typing these lines.

6. If you are using an 5¼-inch drive, you will be prompted for the second diskette. Follow the instructions on the screen.
7. When you see the message `Installation is complete.`, remove the original PSL Explorer diskette from drive A and store it in a safe place.

Special Installation Considerations

The procedures on the previous pages are adequate for most installations. However, you may need to consider the information in this section if you:

- have tailored your AUTOEXEC.BAT for special situations
- use communications ports for other applications besides PSL
- require unusually large data buffers for PSL
- use a diskette-only system with multiple communications ports.

AUTOEXEC.BAT

During the installation procedure for fixed disk, you are asked if you want PSL to be started automatically. If you answer yes, the following lines are appended to the AUTOEXEC.BAT file found in your root directory (or one is created if none is found).

```
cd \PSL
PSL
```

Diskette-only systems always automatically call PSL. If you require manual invocation, you must edit the AUTOEXEC.BAT file found on the PSL Explorer diskette. Edit your copy only and save the original as a backup.

CONFIG.SYS in Fixed-Disk Systems

The installation procedure appends the following line to the CONFIG.SYS file found in your root directory (or one is created if none is found):

```
device = c:\psl\psldevl.sys /N:abcd
```

where *abcd* are the communications port numbers that exist in your computer. (Only ports 1, 2, 3, or 4 can be used by PSL.) A buffer is allocated for each; therefore, if you intend to use fewer ports than your computer has available, you can reclaim valuable memory by tailoring this parameter.

For example, if you require ports 1 and 3 for PSL, then the following statement is appropriate in CONFIG.SYS:

```
device = c:\psl\psldevl.sys /N:13
```

Buffer size for each port defaults to 2048 bytes, but may also be specified by the size parameter (/S:nnnnn). Size must be at least 256 bytes, and cannot be more than 65,536 bytes. A small buffer increases the risk of loss of data when the volume of data is high, whereas large buffers unnecessarily tie up valuable memory.

For example, the following CONFIG.SYS entry allocates a buffer of 16,384 bytes for activity through communications port 1:

```
device = c:\psl\psldevl.sys /N:1 /S:16384
```

Important

Do not confuse communications ports with PSL ports. Communications ports are found on the rear panel of your computer and accept the communications cable from the base unit. PSL ports are found on the base unit and accept modules.

CONFIG.SYS in Diskette-Drive Systems

The PSL startup diskette contains CONFIG.SYS, as follows:

```
device = psldevl.sys /N:1
```

which assumes communications port 1 in your computer. If this is not appropriate, then change CONFIG.SYS as required as described in "CONFIG.SYS in Fixed-Disk Systems" on page 22.

File Naming Conventions

PSL Explorer reserves two file name extensions for its data files:

.PSS A *setup* file that contains a pre-defined experiment. All options such as probes, labels, axis parameters, and duration have been selected and the experiment is ready to be run.

.PSL A *data* file that contains an experiment, both setup parameters and collected data, produced when a completed experiment is saved. You can retrieve this file and analyze the data at any time.

5. Using the PSL Explorer with PSL

This chapter describes how to use the PSL Explorer program. It begins by describing how to start PSL Explorer, and then describes how to make selections from the five menus that make up PSL Explorer and lists the options available on each of the menus. This chapter also describes the function keys and other keyboard keys used to operate the program.

Note: This chapter assumes that you have installed PSL. If you have not installed PSL, see "Installing the Software" on page 19 for instructions concerning how to install the PSL Explorer program.

Starting PSL Explorer

PSL Explorer starts automatically when you turn your computer on or re-boot unless:

1. You have exited PSL Explorer and wish to restart
2. You are using a fixed-disk system and elected for manual start during the installation of PSL Explorer
3. You have modified AUTOEXEC.BAT on your diskette system to inhibit starting PSL Explorer automatically.

To manually start PSL Explorer on a diskette system, type:

```
a:
psl
```

To manually start PSL Explorer on a fixed-disk system, type:

```
c:
cd \psl
psl
```

Important

When starting or re-booting a diskette system, the PSL Explorer Startup Diskette must be ready in drive A.

PSL Explorer and the PSL Probes

PSL Modules can be plugged into any port in the base unit and PSL Explorer can identify which is which. Because only one Distance Probe can be plugged into a Motion-and-Mechanics Module, there is no confusion in identifying where distance probes are located.

However, the TLp Module supports temperature, light, and pH probes, and PSL Explorer cannot distinguish between them. Therefore, this version of PSL Explorer uses a predetermined algorithm to locate probes. You need to understand how PSL Explorer names the probes to use some of the menus described in this chapter.

Probes are named alphabetically, moving counter-clockwise from the power jack as you look down on the base unit. Probe jacks are used consecutively; that is, none are skipped over.

When only one probe is used in an experiment, that probe is named "sensor A" and is plugged into the first available jack for its type.

When multiple probes are used in an experiment, temperature probes (if any) are plugged into the first available jacks of the TLp modules. These probes are named temperature sensor A, temperature sensor B, and so on.

Light probes (if any) follow the temperature probes consecutively, plugged into the next available jacks of the TLp modules. These probes are named light sensor A, light sensor B, and so on. If multiple light probes are used with no temperature probes, they plug into the first available jacks of the TLp modules.

pH probes, however, follow different rules. If pH is the only probe being used, it can be plugged into any jack of the first TLp module. If multiple pH probes are being used, each must be plugged into a separate TLp module. The first pH is named pH sensor A, the second pH probe is named pH sensor B, and so on.

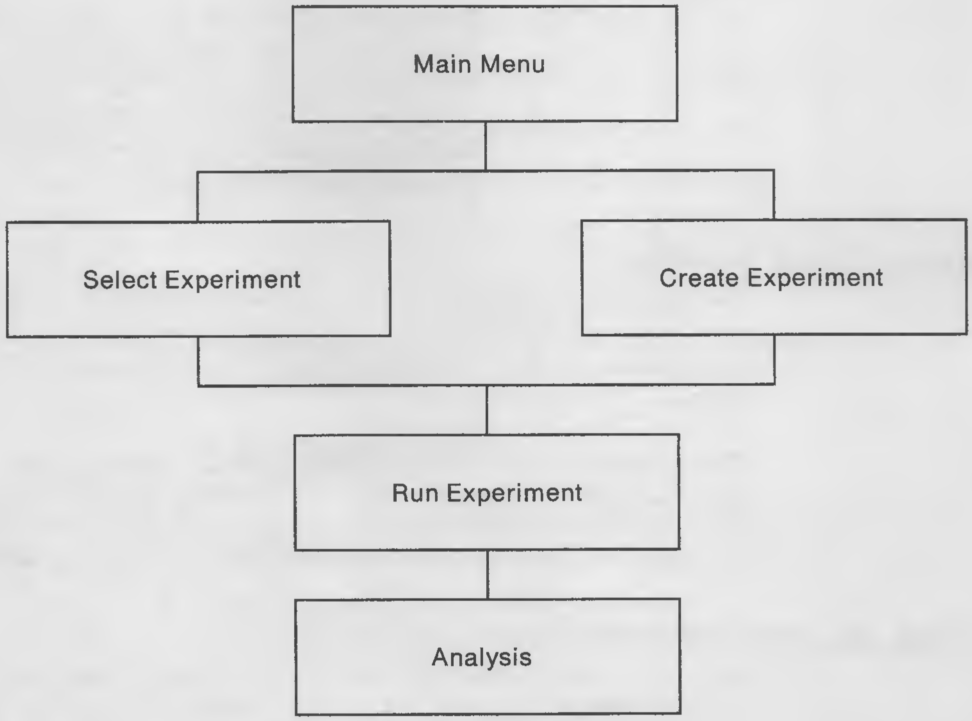
Combining pH with temperature and light forces PSL Explorer to assign the pH probes to channel 3 of each TLp modules. Temperature and light probes are assigned to channels 1 and 2 of each TLp module, all temperature probes (if any) first followed by all light probes (if any).

The Easy Way

PSL Explorer tells you where it expects to find the probes with the View Option of "Run Experiment Menu" on page 42. Simply plug the modules into any port of the base unit but do not plug in probes until the Run Experiment Menu is displayed. Then select ***Run Experiment*** followed by ***View***. PSL Explorer displays the relationship between probe names and physical modules and channels for you. Plug in the probes to match PSL Explorer's display.

The PSL Explorer Menus

PSL Explorer is comprised of the following five menus that you use to select, run, and analyze an experiment:



Main Menu
This menu appears when PSL Explorer is started. Use this menu to select one of several programmed experiments that come with PSL Explorer, begin an experiment of your own, or access an experiment stored on disk. This menu is described in "The PSL Explorer Main Menu" on page 31.

Select Experiment Menu
This menu appears when you choose Select Experiment from the Main Menu. Use this menu to select one of several experiments included with PSL Explorer. Because these experiments come with preset parameters, choosing one of them is the quickest and easiest way of performing an experiment with PSL. This menu is described in "Select Experiment Option" on page 31.

Create Experiment Menu
This menu appears when you choose Create Experiment from the Main Menu. Use this menu to select and define an experiment of your own by choosing the type and number of probes used in the experiment. This menu is described in "Create Experiment Menu" on page 34.

Run Experiment Menu
This menu appears after you have chosen an experiment from the Select Experiment Menu, chosen the Accept option (**F8**) on the Create Experiment Menu, or accessed a stored experiment with the Disk option.

Use this menu to reset the parameters for an experiment, run an experiment, calibrate probe, or select a communications port for PSL. This menu is described in "Run Experiment Menu" on page 42.

Analysis Menu

This menu is displayed when an experiment is completed. Use this menu to perform a graphical analysis of the experiment's results, to reset the parameters for the experiment, to perform calculations with the results, or to display the results in tabular form. This menu is described in "Analysis Menu" on page 49.

Making a Menu Selection

Menu options are listed across the top of the screen. You select an option by using the cursor movement keys to move a highlight bar from one menu option to another. When the menu option you want to use is highlighted, press **Enter** to select the option.

Often, when you select a menu option, a window appears. You select a suboption from a window in the same manner as selecting an option from a menu. Use the cursor movement keys to highlight the option you wish to use, then press **Enter**. You answer a prompt by entering information and pressing **Enter**.

The PSL Explorer Keyboard Keys

You control the PSL Explorer program with your computer's keyboard, mostly by using the cursor and function keys, but occasionally by typing letters or words to answer on-screen prompts. The following is a list of the keyboard keys you use to operate the PSL Explorer program.

cursor keys

Press these keys, labeled with arrows pointing up, down, left, and right, to move the cursor or highlight bar to an option that you want to select.

The cursor keys also scroll the window through a large data set, when more data exists than can be displayed at once. Continuing to press the down arrow key when the highlight bar is already at the bottom of the window forces the window to display the next line in that data. Similarly, scrolling to the top or sides of a window have the corresponding effect. When no more data exists in the direction of the scroll, nothing happens.

Pressing these keys in Graph mode moves the cursor from data point to data point in your graph.

Enter

Press this key to select an option after you have highlighted it with the cursor keys. Pressing the **Enter** key tells the computer that you are ready to continue.

Esc

Press this key when you do not wish to continue with an operation, i.e., return to the previous menu. This key can be used any time that it is shown on the screen.

End

Press this key to move the cursor or highlight bar to the end of a list of menu options or suboptions, or to move the cursor to the end of a graph.

Home — Press this key to move the cursor or highlight bar to the beginning of a list of menu options or suboptions, or to move the cursor to the beginning of a graph.

Ins=Save — Press this key to save data to a file on disk storage under the Disk Option, described in "Disk Option" on page 32. You are prompted for a file name.

Del=Delete — Press this key to erase a PSL data file from disk storage, under the Disk Option.

F1=Help — Press this key to display information about a menu or option.

F2=Switch — Press this key to select the top or bottom graph when two graphs are displayed. The selected graph is framed in a box.

F3=Split — Press this key to choose a single graph or a split screen with two graphs.

F4=Scale — Press this key to change the scale of a graph so that the data that was collected during an experiment fills the available area of the screen.

F5=Print — Press this key to print the graph or graphs displayed on the screen. This key is active when the Analysis Menu is displayed, and is described in "F5=Print" on page 54.

F6=Drive — Press this key to change to another disk drive, under the Disk Option. You are prompted for the drive letter.

F7=MkDir — Press this key to make a new directory, under the Disk Option. You are prompted for the name and path of the new directory.

F8=Rerun/Accept — Press this key to accept setup parameters for an experiment and go to the Run Experiment Menu, described in "Run Experiment Menu" on page 42.

After you have performed an experiment, you can run the experiment again by pressing **F8**. This action clears all data but leaves the current setup intact. Pressing this key displays the following window:

```
Discard experiment data?
          No
          Yes
```

This prompt is provided to help prevent the accidental loss of data generated by an experiment.

Select **Yes** and press **Enter** to clear all current data. Select ***No*** and press **Enter** if you want to save this data before re-running the experiment.

F9=Restart — Press this key to begin a new experiment by returning to the Main Menu. This action clears both data and setup. Pressing **F9** displays the following window:

```
Discard experiment data?
          No
          Yes
```

This prompt is provided to help prevent the accidental loss of data generated by an experiment.

Select ***Yes*** and press **Enter** to return to the Main Menu without saving the data collected by the current experiment. Select ***No*** and press **Enter** if you want to save the results of the current experiment before beginning a new experiment.

F10 = Quit

Press this key to exit from the PSL Explorer program and return to DOS. Pressing **F10** displays the following window:

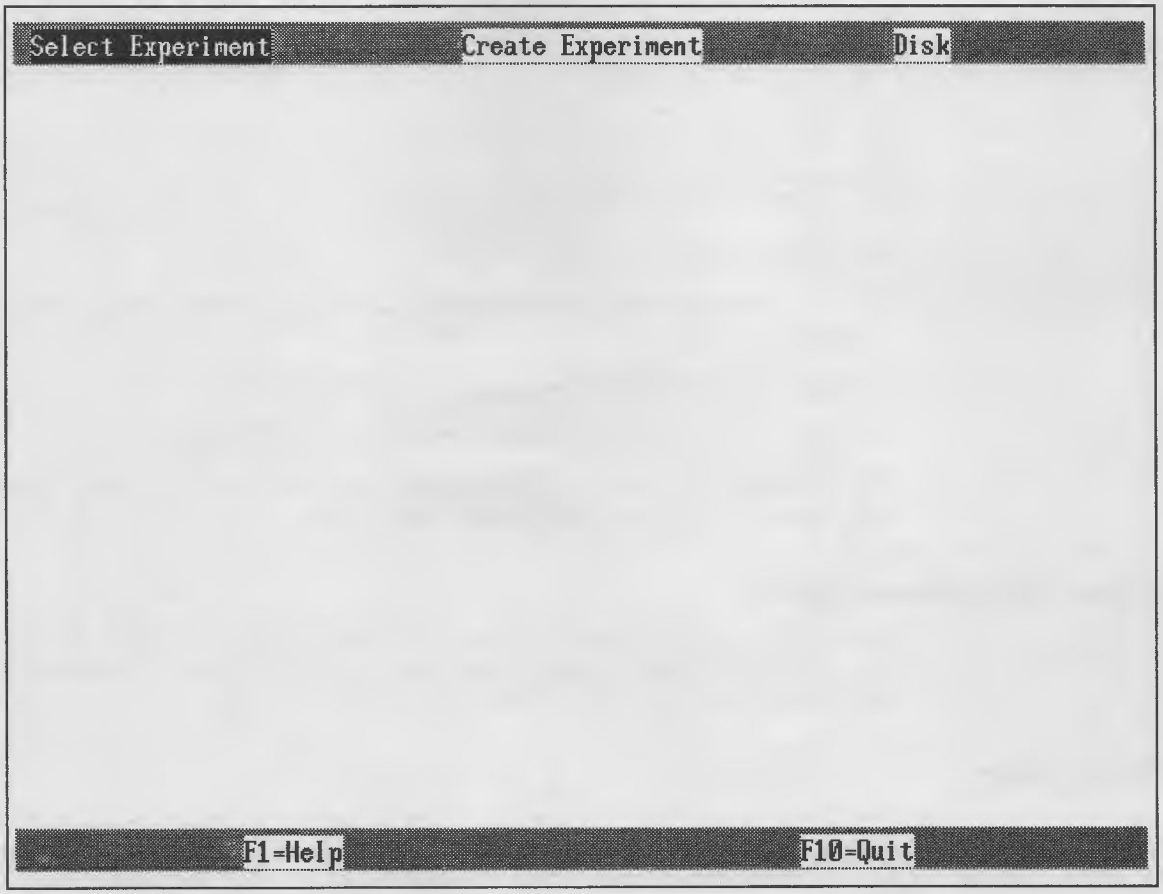
```
Exit from PSL Explorer?
          No
          Yes
```

This prompt is provided to help prevent the accidental loss of data generated by an experiment.

Select ***Yes*** and press **Enter** to leave the PSL Explorer program without saving the data collected by the current experiment. Select ***No*** and press **Enter** if you want to save the results of the current experiment before leaving the PSL Explorer program.

The PSL Explorer Main Menu

The Main Menu is displayed when you start the PSL Explorer program. An example of the Main Menu is shown below.



This menu provides three options that are listed across the top of the screen:

- Select Experiment
- Create Experiment
- Disk

The function keys that may be used with this menu are listed at the bottom of the screen.

You select an option from this screen by:

1. Using the cursor keys to move the highlight bar to the option you want to select.
2. Pressing **Enter** when the desired option is highlighted.

Select Experiment Option

Selecting the Select Experiment option displays the Select Experiment Menu that provides access to pre-programmed experiments stored on your computer's disk. Several of these pre-programmed experiment are supplied with PSL Explorer, and you can add others of your own design. These experiments are the quickest and easiest way of conducting an experiment. Parameters for these experiments are preset and you need only to have the appropriate probe(s) attached to the PSL base unit and, of course, readied any external materials required by the experiment.

An example of the Select Experiments Menu is shown below.

```
One Temperature vs. Time
8 Second Motion Exp
Monitor 3 Temps Overnight
Light Pend. - Two Views
Standard Titration
Neutralization-pH & Temp.
Spring and Mass Motion
```

You select an option from this menu by:

1. Using the cursor keys to move the highlight bar to the experiment you want to select.
2. Pressing **Enter** when the desired option is highlighted.
3. Press **Esc** to return to the main menu without making a selection.

After you select an option from this screen, the Run Experiment Menu is displayed, described in "Run Experiment Menu" on page 42.

Create Experiment Option

Selecting the Create Experiment option displays the Create Experiment Menu. Select this option if you want to design your own experiment. This menu is described in detail in "Create Experiment Menu" on page 34.

Disk Option

Selecting the Disk option allows you to retrieve an experiment stored on disk, or to save an experiment to a disk. A saved experiment can consist of only setup parameters, or also contain data. The following window and suboptions are displayed when you select this option:

```
Select file type
----------------
Data...
Setup...
```

A suboption is selected by using the cursor keys to move the highlight bar to the option you want to use and then pressing the **Enter** The following describes each of these suboptions.

1. Select file type.

   Data allows access to the PSL saved experiments, which contain both the data and the parameters of each experiment. After reading a saved experiment, the Analyze Menu is displayed. You might then analyze the saved data or, by pressing **F8** (Rerun), clear the data and use the saved parameter setup for another collection of data. The Analysis Menu is described in "Analysis Menu" on page 49.

   Setup allows access to the PSL setup files, which contain the parameters for pre-programmed experiment. After reading a setup file, the Run Experiment Menu is displayed, described in "Run Experiment Menu" on page 42.

2. After selecting file type, a window is displayed that lists all available files of that type, as illustrated below. This example shows file type ***setup***.

```
C:\PSL
.\             Subdirectory
..\            Subdirectory
ONETEMP.PSS    One Temperature vs. Time
MOT8SEC.PSS    8 Second Motion Exp
3TEMP.PSS      Monitor 3 Temps Overnight
LGHTPEND.PSS   Light Pend. - Two Views
SPRING1.PSS    Spring and Mass System
```

Note: Data extension ***PSL*** is used for data files, and ***PSS*** is used for setup files.

3. Use the up and down cursor keys (arrows) to scroll through all available files. Not all files may be visible in the window at one time. The window scrolls across the entire list of files as the highlight bar is forced into the bottom or top of the window with the up and down cursor keys.

4. Select a file or change directory. The current directory is shown in the title window and available PSL data files that are listed within the window.

5. To change directories, highlight the characters ..\ and press **Enter**. A second window is displayed that lists available directories for selection.

Important

To read a file, it must be in the current directory. Similarly, when data is written to a file, that file is written into the current directory. You must ensure that the directory shown in the title of the suboption window is correct before reading or writing.

6. To make a new directory, press **F7**. Enter the new directory's path and name into the window that appears and press **Enter**.

7. Highlight a file's name and press **Enter** to select that file. The data and setup parameters are read from disk and the Run Experiment Menu is displayed, described in "Run Experiment Menu" on page 42.

8. To erase a PSL file from disk storage, highlight the name of the file to be erased, and press **Del**.

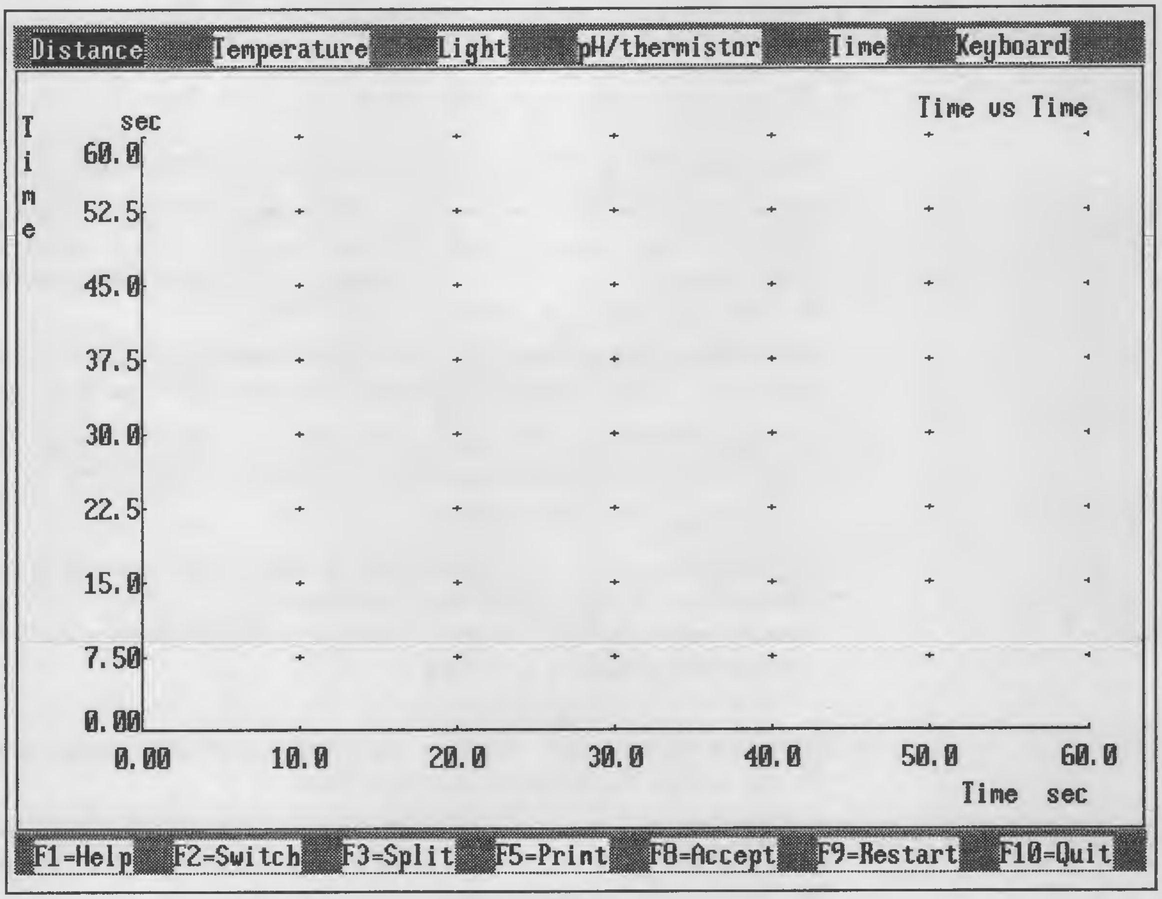
9. To save the current data and parameters of an experiment, press **Ins** and type the name for the new file in the window that appears. Then press **Enter**.

   Note: The **Ins** has no meaning from the Main Menu. It can only be used from the Create Experiment Menu, the Run Experiment Menu, or the Analysis Menu. These menus are described in "Create Experiment Menu" on page 34, "Run Experiment Menu" on page 42, and "Analysis Menu" on page 49, respectively.

10. To change to another disk drive, press **F6**. Type the letter for the desired drive in the window that appears and press **Enter**.

Create Experiment Menu

You use the Create Experiment Menu to design your own experiment. You access this menu by selecting the Create Experiment option from the Main Menu, described in "The PSL Explorer Main Menu" on page 31. The Create Experiment Menu is shown below.



The options on this menu allow you to set the parameters for an experiment. This includes specifying which probes are used, how the probes are configured, the duration of the experiment, and how the results of the experiment are to be displayed.

You refine these parameters with the Reset Parameters option, described in "Reset Parameters Option" on page 43. The Reset Parameters option allows you to change the:

- variable assigned to each axis
- duration of the experiment
- label of the experiment
- range of each axis
- number of significant digits that are displayed
- type of plot (points or lines)

Time is assumed to be one of the values to be collected and plotted, so you must select at least one other source for data for the options provided by this menu.

You select an option from this screen by:

1. Using the cursor keys to move the highlight bar to the option you want to select.
2. Pressing **Enter** when the desired option is highlighted.

Important

The information and procedures in the following sections describe how to set up the PSL Explorer program, PSL base unit, and probes for an experiment of your own design. Not included, however, is information regarding any physical apparatus or additional materials required to conduct the experiment.

Distance Option

You use this option to design an experiment that uses the Motion-and-Mechanics Module with the Distance Probe. Complete the following steps to set-up the experiment:

1. Select the Distance option from the Create Experiment Menu, described in "Create Experiment Menu" on page 34. When you select this option, the following window and suboptions are displayed:

```
Select experiment type
----------------------
Distance...
Motion
```

2. To design a distance experiment, select the Distance suboption and press **Enter**.

   Note: If you select the Motion suboption, the Run Experiment Menu is displayed. The major parameters are all set up, and additional refinements can be made with the Reset Parameters option. The Run Experiment Menu is described in "Run Experiment Menu" on page 42.

   The following window is displayed:

```
Select probe name
-----------------
Dist A...
Dist B...
Dist C...
```

3. Select the Distance Probe to use (naming counter-clockwise wise from the power jack) and press **Enter**.

   The following window is displayed:

```
Select an axis
--------------
X-axis
Y-axis
Memory
```

4. Select the axis on which you want the distance data points plotted and press **Enter**.

   If you select "memory," the data is stored in the computer's internal memory and not displayed on the graph. Data in memory can be displayed at will in the Analysis Menu, described in "Analysis Menu" on page 49.

   Note: If you use a split screen with two graphs, "X-axis" and "Y-axis" refers to the window framed by a box. Pressing **F2** switches between the top and bottom windows, which allows you to plot the distance data on any of the four axes displayed on the screen.

5. When you are certain that the experiment is set up as you want it, press **F8** to display the following window:

```
Accept experiment configuration?
--------------------------------
              No
              Yes
```

   Select ***No*** to continue selecting parameters, and ***Yes*** to display the Run Experiment Menu, described in "Run Experiment Menu" on page 42.

Temperature Option

You use this option to design an experiment that uses one or more temperature probes. Complete the following steps to set-up the experiment:

1. Select the Temperature option from the Create Experiment Menu, described in "Create Experiment Menu" on page 34. When you select this option, the following window is displayed:

```
Select probe name
-----------------
Temp A...
Temp B...
Temp C...
```

2. Select the temperature probe to be used (naming counter-clockwise from the power jack) and press **Enter**. The following window is displayed:

```
Select an axis
--------------
X-axis
Y-axis
Memory
```

3. Select the axis on which you want this temperature data plotted and press **Enter**.

   If you select "memory," the data is stored in the computer's internal memory and not displayed on the graph. Data in memory can be displayed at will in the Analysis Menu, described in "Analysis Menu" on page 49.

   Note: If you use a split screen with two graphs, "X-axis" and "Y-axis" refers to the window framed by a box. Pressing **F2** switches between the top and bottom windows, which allows you to plot the temperature data on any of the four axes displayed on the screen.

4. When you are certain that the experiment is set up as you want it, press **F8** to display the following window:

```
Accept experiment configuration?
--------------------------------
No
Yes
```

   Select ***No*** to continue selecting parameters, and ***Yes*** to display the Run Experiment Menu, described in "Run Experiment Menu" on page 42.

Light Option

You use this option to design an experiment that uses the light probe. Complete the following steps to set-up the experiment:

1. Select the Light option from the Create Experiment Menu, described in "Create Experiment Menu" on page 34. The following window and suboptions are displayed:

   ```
   Select probe name
   -----------------
   Light A...
   Light B...
   Light C...
   ```

2. Select the light probe to be used (naming counter-clockwise from the power jack) and press **Enter**. The following window is displayed:

   ```
   Select type
   -----------------
   Photometric...
   Radiometric...
   ```

3. Select the type of probe you are using during the experiment and press **Enter**. The following window is displayed:

   ```
   Select response
   -----------------
   Dim range...
   Bright range...
   ```

   Dim range is used in experiments with relatively dim light (approximately 0 to 5,000 lux), whereas Bright range is used in relatively bright light (approximately 0 to 100,000 lux).

4. Select a light range appropriate to your experiment and press **Enter**. The following window is displayed:

   ```
   Select smoothing
   -----------------
   Off...
   On...
   ```

   Fluorescent lighting flickers at 100 or 120 Hertz, a rate high enough to be unnoticed by the human eye. For some experiments, however, this flicker can interfere with the desired data. Smoothing eliminates this flicker. However, selecting the smooth option also slows the sampling rate to approximately two per second.

5. Choose whether or not to smooth your data by selecting ***On*** or ***Off*** and pressing **Enter**. The following window is displayed:

   ```
   Select an axis
   -----------------
   X-axis
   Y-axis
   Memory
   ```

6. Select the axis on which you want the light data plotted and press **Enter**.

If you select "memory," the data is stored in the computer's internal memory and not displayed on the graph. Data in memory can be displayed at will in the Analysis Menu, described in "Analysis Menu" on page 49.

Note: If you use a split screen with two graphs, "X-axis" and "Y-axis" refers to the window framed by a box. Pressing **F2** switches between the top and bottom windows, which allows you to plot the light data on any of the four axes displayed on the screen.

7. When you are certain that the experiment is set up as you want it, press **F8** to display the following window:

Accept experiment configuration?
No Yes

Select ***No*** to continue selecting parameters, and ***Yes*** to display the Run Experiment Menu, described in "Run Experiment Menu" on page 42.

pH/thermistor Option

You use this option to design an experiment that uses one or more pH probes. Complete the following steps to set-up the experiment:

1. Select the pH/thermistor option from the Create Experiment Menu, described in "Create Experiment Menu" on page 34. When you select this option, the following window and suboptions are displayed:

Select pH or Thermistor
pH... Thermistor...

2. Select pH or Thermistor and press **Enter**

pH

If you select the pH suboption, the following window is displayed:

Select probe name
pH A... pH B... pH C...

1. Select the pH probe to be used (counting counter-clockwise from the power jcak) and press **Enter**. The following window is displayed:

Select calibration method
1 point... 2 point...

2. Select the degree of calibration that you require. ***1-point*** is simpler and provides pH accuracy of $\pm$0.2, whereas ***2-point*** provides pH accuracy of $\pm$0.1. Calibration occurs in the Run Experiment Menu, described in "Run Experiment Menu" on page 42. The following window is displayed:

```
Select an axis
X-axis
Y-axis
Memory
```

3. Select the axis on which you want this pH data plotted and press **Enter**.

   If you select "memory," the data is stored in the computer's internal memory and not displayed on the graph. Data in memory can be displayed at will in the Analysis Menu, described in "Analysis Menu" on page 49.

   Note: If you use a split screen with two graphs, "X-axis" and "Y-axis" refers to the window framed by a box. Pressing **F2** switches between the top and bottom windows, which allows you to plot the pH data on any of the four axes displayed on the screen.

4. When you are certain that the experiment is set up as you want it, press **F8** to display the following window:

```
Accept experiment configuration?
              No
              Yes
```

   Select ***No*** to continue selecting parameters, and ***Yes*** to display the Run Experiment Menu, described in "Run Experiment Menu" on page 42.

Thermistor

The pH probe contains a built-in thermistor that is normally used by PSL Explorer to compensate pH readings for the temperature of the liquid. Ttemperature data can be separately collected and displayed, however, only when the pH probe is also in use.

If you select the thermistor suboption, the following window is displayed:

```
Select probe name
Therm A...
Therm B...
Therm C...
```

1. Select the pH/Thermistor probe to be used (counting counterclockwise from the power jack) and press **Enter**. The following window is displayed:

```
Select an axis
X-axis
Y-axis
Memory
```

2. Select the axis on which you want this thermistor data plotted and press **Enter**.

   If you select "memory," the data is stored in the computer's internal memory and not displayed on the graph. Data in memory can be displayed at will in the Analysis Menu, described in "Analysis Menu" on page 49.

   Note: If you use a split screen with two graphs, "X-axis" and "Y-axis" refers to the window framed by a box. Pressing **F2** switches between the top and bottom windows, which allows you to plot the thermistor data on any of the four axes displayed on the screen.

3. When you are certain that the experiment is set up as you want it, press **F8** to display the following window:

```
Accept experiment configuration?
              No
              Yes
```

Select ***No*** to continue selecting parameters, and ***Yes*** to display the Run Experiment Menu, described in "Run Experiment Menu" on page 42.

Time Option

You use this option to specify the axis on which you want time data to be plotted during an experiment. Complete the following steps to specify where time data is to be plotted:

1. Select the Time option from the Create Experiment Menu, described in "Create Experiment Menu" on page 34. The following window is displayed:

```
Select an axis
X-axis
Y-axis
```

2. Select the axis on which you want time data plotted and press **Enter**.

   Note: If you use a split screen with two graphs, "X-axis" and "Y-axis" refers to the window framed by a box. Pressing **F2** switches between the top and bottom windows, which allows you to plot time on any of the four axes displayed on the screen.

3. When you are certain that the experiment is set up as you want it, press **F8** to display the following window:

```
Accept experiment configuration?
              No
              Yes
```

Select ***No*** to continue selecting parameters, and ***Yes*** to display the Run Experiment Menu, described in "Run Experiment Menu" on page 42.

Keyboard Option

You use this option to manually input simulated data, or to control when a data point is collected with the keyboard. (Typically, such an experiment is not timed.) Complete the following steps to enable this option:

1. Select the Keyboard option from the Create Experiment Menu, described on "Create Experiment Menu" on page 34. The following window and suboptions are displayed:

```
Select sampling method
Keyboard Input...
Keyboard Trigger...
```

2. Select how you want data points to be collected and press **Enter**.

Keyboard Input

Keyboard input allows you to enter simulated data for an experiment.

If you select this suboption, the following window is displayed:

Select probe name
KB A...
KB B...
KB C...
KB D...

1. Up to four inputs can be defined from your keyboard. This allows you to enter a complete, four-valued experiment for graphic display and analysis. Each keyboard input is represented by a data box. Other probes (if any) are sampled continuously; their data is displayed in data boxes as well. The display is updated every half-second.

   Keyboard inputs are named "KB A," "KB B," and so on. A data point is complete and recorded when the input with the highest name has been entered ("B" is higher than "A").

   Select the keyboard input number you want to use during the experiment and press **Enter**. The following window is displayed:

Enter axis values	
Axis label	Time
Axis units	Sec

2. If the label and units are appropriate for your experiment you need not change the default values. If the values are not appropriate, type a new label, unit of measure, or both.

3. When the values are correct, move the highlight bar to the "Enter axis values" prompt and press **Enter**. The following window is displayed:

Select an axis
X-axis
Y-axis

4. Select the axis on which you want this data plotted and press **Enter**.

   Note: If you use a split screen with two graphs, "X-axis" and "Y-axis" refers to the window framed by a box. Pressing **F2** switches between the top and bottom windows, which allows you to plot this keyboard data on any of the four axes displayed on the screen.

Keyboard Trigger

If you select this suboption, the following window is displayed:

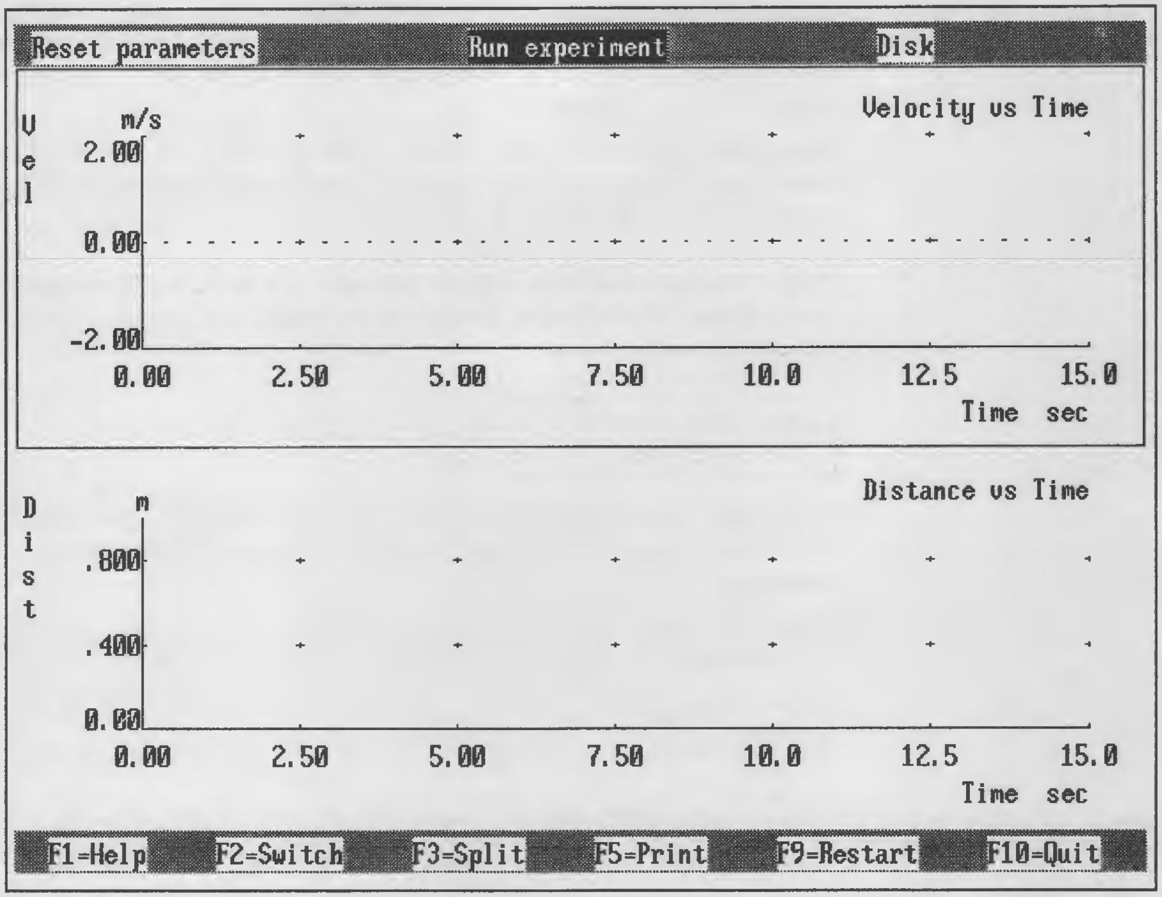
Keyboard triggering
On
Off

Selecting keyboard triggering ***on*** provides for an experiment that has no dependence on time. Data for each probe is collected when **Enter** is pressed.

Run Experiment Menu

You use this menu to run an experiment you have selected from the Select Experiment Menu, an experiment that you designed with the Create Experiment Menu, or after an experiment has retrieved by using the Disk Option. These menus are described in "Select Experiment Option" on page 31, "Create Experiment Menu" on page 34, and "Disk Option" on page 32, respectively. You can also reset the parameters for an experiment and then run the experiment again by pressing **F9**

An example of the Run Experiment Menu is shown below. The available function keys are listed across the bottom of the menu.



You select an option from this screen by:

1. Using the cursor keys to move the highlight bar to the option you want to select.
2. Pressing **Enter** when the desired option is highlighted.

The following describes each of the options and suboptions available on this menu.

Disk Option

The disk option is described in "Disk Option" on page 32.

Reset Parameters Option

You use this option to reset or refine the parameters for an experiment that you have selected from the Select Experiment Menu or designed with the Create Experiment Menu. These menus are described in "Select Experiment Option" on page 31, and "Create Experiment Menu" on page 34, respectively.

Note: If you are using a split screen and displaying two graphs, the options affect the graph that is framed by a box. Press **F2** to switch from one to the other and select the graph you wish to modify.

When you select this option the following window and suboptions are displayed:

```
Select parameter
-----------------------
Axis variables...
Duration...
Labels...
Ranges of axes...
Significant digits...
Type of plot...
```

Axis Variables...

Use this suboption to change the values displayed on the x-axis and y-axis of the graph. The choices displayed in this window depend on the current parameters of the experiment. The following window is an example of what is displayed:

```
Select variable
---------------
Time...
Dist...
Vel...
Accl...
```

Select the value you wish to assign. The following window is displayed:

```
Select an axis
--------------
Top: x-axis
Top: y-axis
Bot: x-axis
Bot: y-axis
```

Select the axis to receive this assignment.

Duration...

Use this suboption to change the duration of the experiment. The following window is displayed:

Enter new duration	15.0

Enter the new duration in seconds and press **Enter**.

Labels....

Use this suboption to change the title of the graph. The following window is displayed:

Enter graph title	Velocity vs Time

Enter the new title and press **Enter**. Changing the title does not change the labels for the x-axis or y-axis of the graph.

Ranges of axes...

Use this suboption to change the current ranges of values used to graph the results of an experiment. The following window is an example of what is displayed:

Enter=accept Esc=restore	
Bottom: x-min(Time in sec)	.0960
Bottom: x-max(Time in sec)	7.9680
Bottom: y-min(Dist in m)	.44730
Bottom: y-max(Dist in m)	.63777

Move the highlight to the axis you wish to change by using the cursor keys and enter the new value. After you have entered all the changes that you wish to make, press **Enter** to put those values into effect. Press **Esc** if you wish to cancel the changes and restore the original values.

Significant digits...

Use this suboption to control the number of significant digits that are used to display data numerically. The following window is displayed:

Enter=accept Esc=restore	
X-axis significant digits	3
Y-axis significant digits	3

Enter a new digit and press **Enter**. Changing the number of significant digits does not affect the accuracy of a data point.

Type of plot...

Use this suboption to select how you want the results of an experiment displayed. The following window is displayed:

Select plot type
Line
Points

If you choose ***Lines***, the data points are connected by a continuous line. If you choose ***Points***, only the points on the graph for which data is collected is displayed.

Run Experiment Option

You use this option to start an experiment, calibrate a probe, preview the experiment, or specify the communications port to which the PSL base unit is connected.

When you select this option the following window and suboptions are displayed:

Select action
Start
Calibrate...
Preview...
Set COM...
View...

Start

Use this suboption to start an experiment that you have selected or designed.

Calibrate...

Use this suboption to calibrate the probe(s) used for an experiment. When you select this suboption the following window is displayed:

```
Select probe
--------------
Temperature...
Light...
pH...
```

Use the cursor keys to highlight the type of probe you want to calibrate, then press **Enter**.

Temperature

The following window is displayed for temperature probes:

Enter=accept Esc=restore	
Sensor A calibration	500
Sensor B calibration	500
Sensor C calibration	500

Move the highlight bar to the temperature probe that you are calibrating and type the calibration number for that probe. (The calibration number is the three-digit number found on the label attached to the wire just above the plastic connector on each probe.)

Note: PSL Explorer names the temperature probes as described in "PSL Explorer and the PSL Probes" on page 26.

After typing the calibration information for each probe you are calibrating, use the cursor keys to move the highlight bar to the "Press Enter to accept values" prompt and press **Enter**.

Light

The following window is displayed for light probes:

Enter=accept Esc=restore	
Sensor A calibration	500
Sensor B calibration	500
Sensor C calibration	500

Move the highlight to the light probe that you are calibrating and type the calibration number for that probe. (The calibration number is the three-digit number found on the label attached to the wire just above the plastic connector on each probe.)

Note: PSL Explorer names the light probes as described in "PSL Explorer and the PSL Probes" on page 26.

After typing the calibration information for each probe you are calibrating, use the cursor keys to move the highlight bar to the "Press Enter to accept values" prompt and press **Enter**.

pH

Before you begin, you need distilled or deionized water and pH reference solutions, which are available from chemical laboratory supply companies.[4]

For an accuracy of ±0.2 pH, one-point calibration with one reference solution is sufficient, 7 pH is a good choice.

For an accuracy of ±0.1 pH, two-point calibration with two reference solutions is required; for example, 4 pH and 7 pH or 7 pH and 10 pH work well.

You need enough reference solution to cover the depression in the tip of the pH probe.

The choice of one-point or two-point calibration is made when pH is selected for input. This is described on 38.

Immerse the tip of the pH probe in distilled or deionized water for 10 minutes after removing it from storage. Rinse it in distilled or deionized water after each reference solution.

The following window is displayed for pH probes:

Enter=accept Esc=restore	
Sensor A calibration	5000
Sensor B calibration	5000
Sensor C calibration	5000

Move the highlight bar to the pH probe that you are calibrating and type the calibration number for that probe. This number is for the thermistor in the pH probe, and provides automatic temperature compensation by PSL Explorer. (The calibration number is the four-digit number found on the label attached to the wire just above the plastic connector on each probe.)

Note: PSL Explorer names the pH/Thermistor probes as described in "PSL Explorer and the PSL Probes" on page 26.

The following window is displayed for each pH probe:

Start calibration for pH sensor A
No Yes

Select ***Yes*** to begin the calibration procedure.

The following window is displayed:

Immerse sensor 2 in solution 1
Press enter to continue

Place the tip of the pH probe into the reference solution and press **Enter**. The following window is displayed:

Enter pH of solution (@T=27.1C)	7.0

4 A sample packet of E-Z CAL™ is shipped with the pH probe. Additional packets may be purchased from Chemfet Corporation, Bothell, WA. E-Z CAL is a trademark of Chemfet Corporation.

Enter the value of the reference solution into the window and press **Enter**.

Note: This window displays the current reading of the thermistor for your reference. An example is shown here, "T=27.1C," but may be different in your case.

If you are using two-point calibration, these two windows are repeated for the second reference solution.

Thermistor

The following window is displayed for the thermistor in the pH probe:

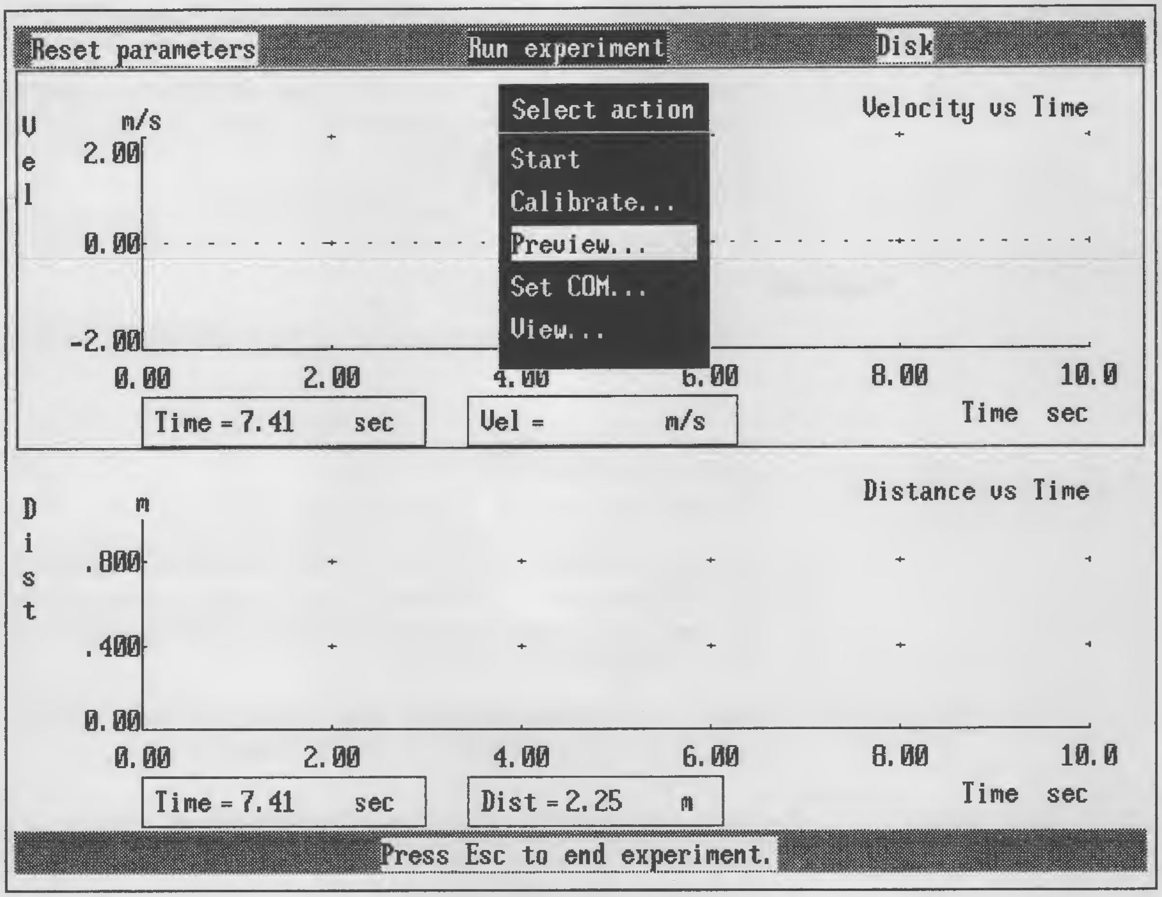
Enter=accept Esc=restore	
Sensor A calibration	5000
Sensor B calibration	5000
Sensor C calibration	5000

Move the highlight bar to the pH probe that you are calibrating and type the calibration number for that probe. (The calibration number is the four-digit number found on the label attached to the wire just above the plastic connector on each probe.)

Note: PSL Explorer names the pH/Thermistor probes as described in "PSL Explorer and the PSL Probes" on page 26.

Preview...

Use this suboption to ensure that all probes are functioning as expected before starting the experiment, to see that the ranges are appropriate, or to simply get a reading without graphing it. When you select this suboption the following window is displayed:



Each probe's data is displayed in boxes along the bottom of the graph until you press **Esc**, which returns you to the Run Experiment Menu, described in "Run Experiment Menu" on page 42.

Set COM...

Use this suboption to specify the communications port to which the PSL base unit is attached. When you select this suboption the following window is displayed:

Select COM
COM1:
COM2:
COM3:
COM4:

Use the cursor keys to move the highlight bar to the correct port for your computer and base unit, then press **Enter**.

View...

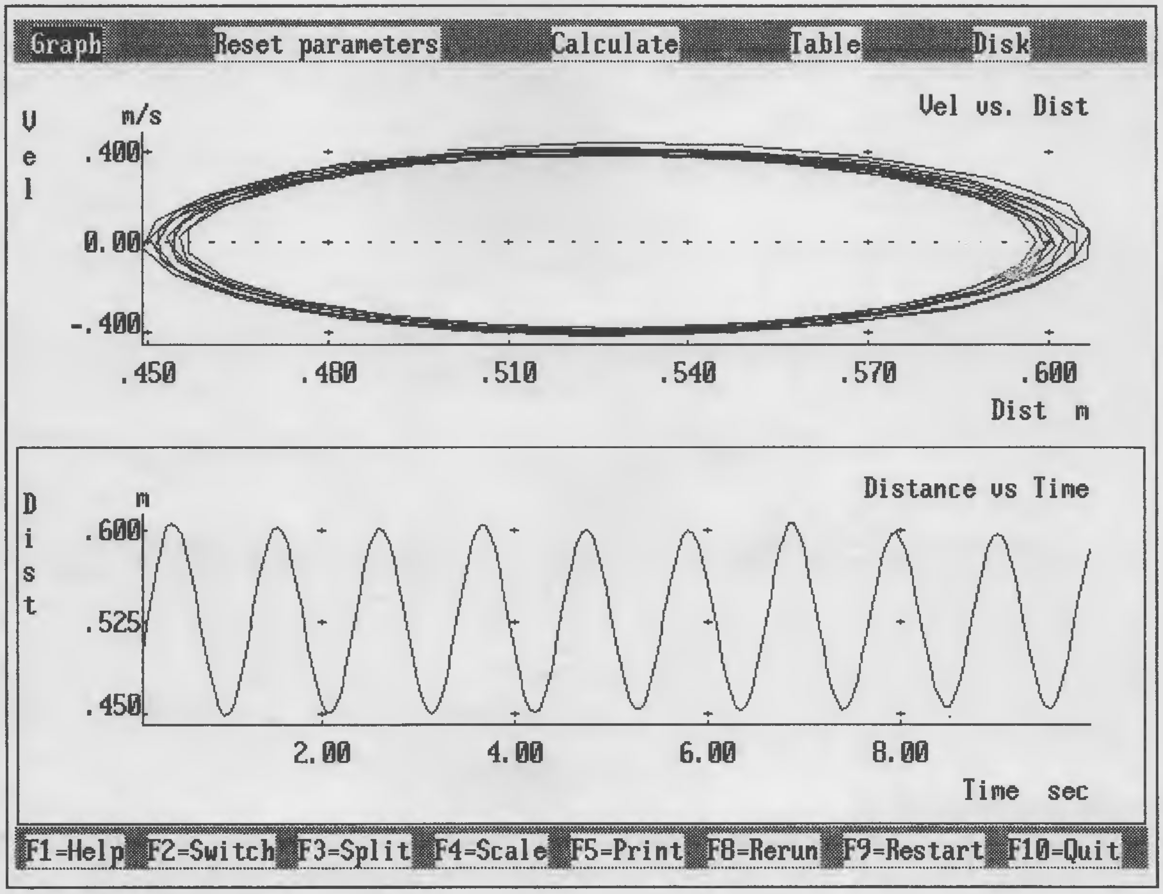
Use this suboption to view the parameters for an experiment; i.e., which probes are configured and the port and channel where PSL Explorer expects them.

Probe	Description	Port	Channel
Light A	Photo - Dim	2	1
Dist A	Distance	1	1

> **Important**
>
> You can plug modules into any port of the base unit and PSL Explorer will find them. The probes, however, must be placed as PSL Explorer lists them in this window.

Analysis Menu

You use the Analysis Menu and its options to analyze and manipulate the data collected during an experiment. This menu appears automatically at the completion of an experiment. Before you analyze your data, you should save it because it is possible to modify or erase that data during analysis. A saved copy of the data allows you to restore it. An example of the Analysis Menu is shown below.



You select an option from this screen by using the cursor keys to move the highlight bar to the option you want to select and pressing **Enter** when the desired option is highlighted.

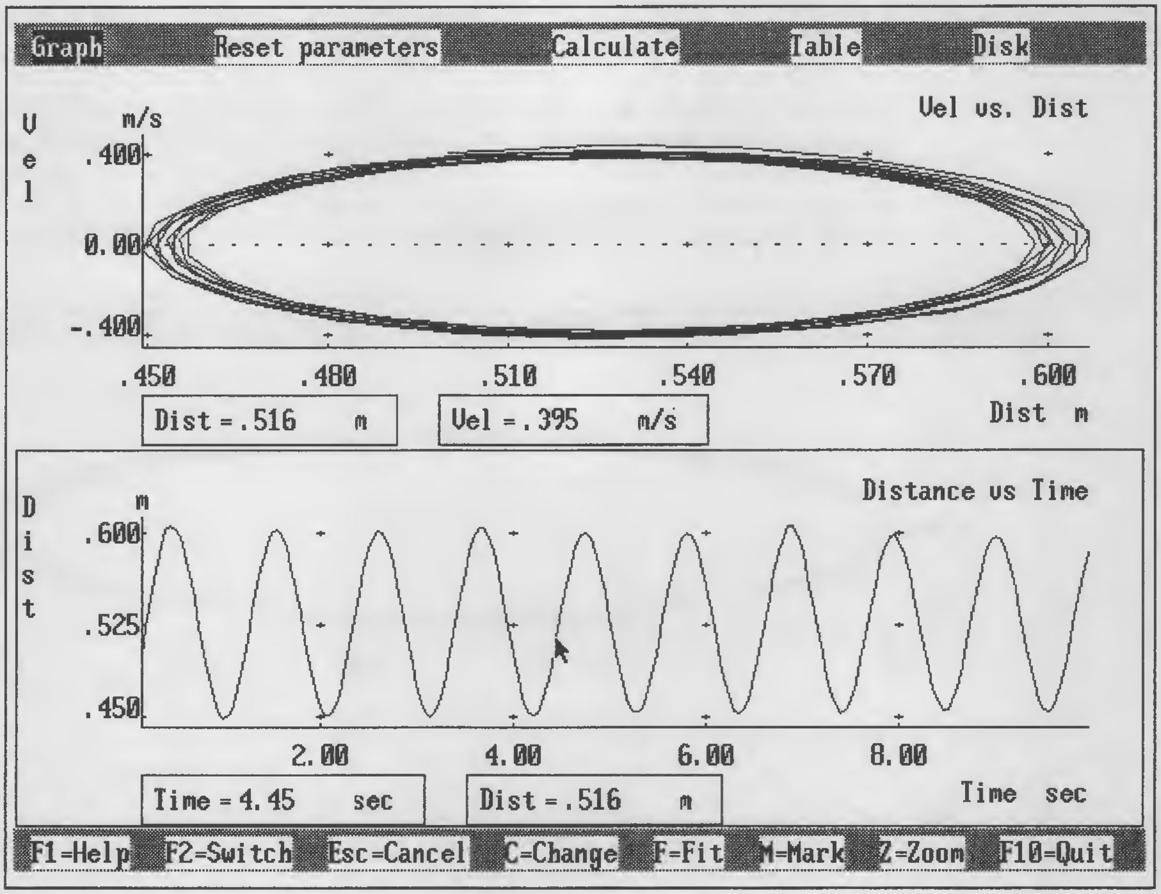
Disk Option

The disk option is described "Disk Option" on page 32.

Graph Option

You use this option to manipulate and perform statistical analysis of the data collected during an experiment.

When you select the Graph option, the following screen is displayed:



The following section discusses the options listed on the Graph screen. You select an option from the bottom of the menu are selected by pressing the indicated letter key.

Graph Screen Options

When the Graph screen is displayed, an arrow-shaped cursor appears on the graph. This cursor is moved by pressing the cursor arrows on your keyboard. The left and right arrows move the cursor along the graph to the left and right, respectively. The up arrow centers the cursor on the graph.

Fast cursor movement occurs by pressing &ctrlkey along with the arrow keys. Pressing **Home** moves the cursor to the beginning of the graph, and pressing **End** moves the cursor to the end of the graph.

Esc

Pressing **Esc** returns you to the Analysis Menu.

Change

Press **C** to edit the data. The following window is displayed:

```
Select operation
D=delete point
L=linearize
X=change x
Y=change y
```

Select an operation and press **Enter**, or press **Esc** to cancel this window.

> **Important**
>
> These operations change the data and the graph is then redrawn from the changed data. If you want to preserve the original data, you must save it as described in "Disk Option" on page 32.

Delete

Select this operation to delete a data point. Before you can use this operation, you must first move the cursor to the point you wish to delete.

Linearize

Select this operation to connect the two end points of the marked area of the graph with a straight line. When you select this option, the following window is displayed:

```
Select linearize operation
Leave data unchanged
Replace data by points on line
```

You must select one of these option and press **Enter** to continue. Before you can use this suboption, you must first mark an area of the graph.

Change x

Select this operation to change the x value of a data point. Enter the new value, and press **Enter**. Before you can use this operation, you must first move the cursor to the point you wish to change.

Change y

Select this operation to change the y value of a data point. Enter the new value, and press **Enter**. Before you can use this operation, you must first move the cursor to the point you wish to change.

Fit

Press ***F*** to perform a least-squares fit and draw the best straight line for the marked area of the graph. When you select this option the following window is displayed:

```
Select fit operation
Draw approximating line
Erase all approximating lines
```

Before you can use this suboption, you must first mark an area of the graph.

Mark

Press ***M*** to "mark" an area of the graph with which you want to perform additional operations. This suboption is used to prepare for the Change, Zoom, Linearize, and Fit suboptions. Move the cursor to the beginning of the area on the graph that you want to select and press ***M***. Then move the cursor to the end of the area of the graph that you want to mark and press ***M*** again. The area of the graph is now marked and you can perform additional operations with the marked area.

To "unmark," simply press ***M*** again.

Zoom

Press **Z** to display only the marked area of the graph. This option enlarges the marked area of the graph so that the marked area is as large as the previous graph. Press **Z** again to "unzoom" the marked area and restore the previous graph.

Reset Parameters Option

The Reset Parameters Option is discussed in full in "Reset Parameters Option" on page 43.

Calculate Option

You use this option to perform mathematical manipulations of the data collected during an experiment to explore the nature of the data and relationships between parameters. You can, for example, add, subtract, multiply, or divide the collected data by a constant, perform logarithmic operations, differentiation, and integration. These manipulations are performed along one axis at a time.

Important

Calculations change the data and the graph is then redrawn from the changed data. If you want to preserve the original data, you must save it as described in "Disk Option" on page 32.

When you select this operation the following window is displayed:

```
Select axis
-----------
X-axis...
Y-axis...
```

Select an axis and press **Enter**.

X-axis

When you select this axis the following window is displayed:

```
Select an operation
-----------------------
Add a constant...
Subtract a constant...
Multiply by a constant...
Divide by a constant...
Log (base 10)
```

Select one of the operations by highlighting it pressing **Enter**. For Add, Subtract, Multiply, or Divide the following window is displayed:

```
Enter value of constant | 0.00
```

Type the constant the you wish to use. Minus values are allowed.

The following provides a brief explanation of each of the operations listed above.

Add a constant

This operation adds a constant to the x value of each data point in the graph. This has the effect of shifting the entire graph to the right.

Subtract a constant

This operation subtracts a constant from the x value of each data point in the graph. This has the effect of shifting the entire graph to the left.

Multiply by a constant

This operation multiplies the x value of each data point by a constant. For example, multiplying by -1 reverses the graph from right-to-left (reflects the data around the y-axis).

Divide by a constant

This operation divides the x value of each data point by a constant. For example, for a graph in which all x values are non-negative, dividing by the largest x value in the data re-scales the data to lie between 0 and 1 along the x-axis.

Log (base 10)

This operation computes the common logarithm of the x value of each data point in the graph. You might use this operation to determine if your data is logarithmic along the y-axis when you know that the x values are linear (for example, time). Taking the log of all x values produces a straight line if the test is true.

Y-axis

When you select this axis the following window is displayed:

```
Select an operation
-----------------------------
Add a constant...
Subtract a constant...
Multiply by a constant...
Divide by a constant...
Log (base 10)
Antilog (10th power)
Differentiate
Integrate
```

Select one of the operations by highlighting it and pressing **Enter**. For Add, Subtract, Multiply, or Divide the following window is displayed:

```
| Enter value of constant | 0.00 |
```

Type the constant the you wish to use. Minus values are allowed.

The following provides a brief explanation of each of the operations listed above.

Add a constant

This operation adds a constant to the y value of each data point in the graph. This has the effect of shifting the entire graph upward.

Subtract a constant

This operation subtracts a constant from the y value of each data point in the graph. This has the effect of shifting the entire graph downward.

Multiply by a constant

This operation multiplies the y value of each data point by a constant. For example, multiplying by -1 turns the graph upside down (reflects the data around the x-axis).

Divide by a constant

This operation divides the y value of each data point by a constant. For example, for a graph in which all y values are non-negative, dividing by the largest y value in the data re-scales the data to lie between 0 and 1 along the y-axis.

Log (base 10)

This operation computes the common logarithm of the y value of each data point in the graph.

Antilog (10th power)

This operation computes the anti-log of the y value of each data point in the graph. You might use this operation to determine if your data is logarithmic along the y-axis when you know that the x values are linear (for example, time). Taking the anti-log of all y values produces a straight line if the test is true.

Differentiate

This operation computes the derivative of (differentiates) each data point in the graph. Differentiation is the rate of change of y with respect to x in your data. For example, differentiating distance with respect to time produces velocity.

Integrate

This operation integrates the x value of each data point in the graph. Integration is the opposite of differentiation; it accumulates (sums) the change in y with respect to x. For example, integrating velocity with respect to time produces distance.

F5 = Print

When you press **F5**, the following window is displayed:

```
Select print operation
-----------------------
Print graph
Change printer parameters
```

Select one of the operations by highlighting it and pressing **Enter**.

Print graph

This option causes the graph that is currently displayed to be printed on your computer's printer.

Change printer parameters

This option allows you to specify printer parameters. When this option is selected, the following window is displayed:

```
Reset printer parameters:
-------------------------
Printer output file/device
Orientation
Printer scaling factors
```

Printer output file/device

When this option is selected, the following window is displayed:

Send printed output to	LPT1:

To change to a different printer, type its DOS name and press **Enter**.

Orientation

When this option is selected, the following window is displayed:

Which way?
PORTRAIT LANDSCAPE

Portrait refers to up-and-down orientation, with the narrow dimension at the top. ***Landscape*** refers to side-to-side orientation, with the narrow dimension at the side.

Printer scaling factors

When this option is selected, the following window is displayed:

Enter=accept Esc=restore	
Horizontal scale	1000
Vertical scale	1000

Typing over these scaling numbers changes the size of the printed graph. A larger number increases the corresponding dimension, and smaller number decreases it. For example, entering 500 beside "Vertical scale" produces a graph compressed to half-height without affecting the width.

Table Option

This option is used to display in tabular form the data collected during an experiment. The following is an example of the Table screen:

Graph Reset parameters Calculate Table Disk

Distance vs Time

Time sec	Dist m
.150	.500
.200	.524
.250	.548
.300	.570
.350	.591
.400	.604
.450	.607
.500	.604
.550	.598
.600	.585
.650	.568
.700	.547
.750	.524
.800	.502

F1=Help Esc D=Delete X=change X Y=change Y F10=Quit

The left column of the table contains the values along the x-axis of the corresponding graph, and the right column contains the y values. The following section discusses the options listed on the Table screen. You select an option from the bottom of the menu by pressing the indicated letter key.

Table Screen Options

Esc

Pressing **Esc** returns you to the Analysis Menu.

Delete

Deletes the highlighted row of data in the table. Be sure that you first highlight the row of data you want to delete *before* choosing this option.

change X

Allows you to change the value of the left column of the highlighted data point. (This option is not valid if the x-axis represents time.)

change Y

Allows you to change the value of the right column of the highlighted data point.

6. Sample Explorations

Two sample explorations are included in this chapter: one using the temperature probe and one using the distance probe. Both are intended as samples of actual classroom materials, complete with "fill-in-the-blanks" questions for the students and a teacher's section.

Note: Teachers have the right to make copies of these sample explorations for students' use.

Each exploration begins with a brief overview of the phenomena under study and then asks the students to think about the experiment about to be performed. The students are asked to predict what the outcome will be and to commit that prediction to paper. An activity section guides the students through the experiment itself, after which they are asked to compare the results to their prediction and to explain these results. Finally, several extensions are suggested for further study.

The teacher's notes give more insight into the experiment or its analysis, together with the expected answers to the questions asked of the students.

Heat and Temperature: How Objects Lose Heat

Before You Start

To Find Out

During this exploration, you will learn how warm objects behave as they cool.

Materials

This exploration requires the following items:

- PSL with TLp Module, Standard Temperature Probe, and PSL Explorer
- Aluminum foil
- Hair Dryer
- Tweezers.

Introduction

A hot object tends to cool when you stop heating it. A cold object taken out of the freezer tends to become warm if it sits at room temperature. These statements seem obvious. But why are they so?

In this exploration, you will be using PSL with a temperature probe to discover facts about the way objects cool.

About the Temperature Probe

This exploration requires one Standard Temperature Probe. The temperature probe is a very sensitive, quickly responding device that enables you to measure temperature over a wide range. By connecting the probe to the computer, you can record temperature changes as time passes.

Before the advent of the computer, such measurements were laborious and required careful attentiveness to both a thermometer and a clock.

Keep in mind that the probe, while ruggedly constructed, is a delicate measuring tool. It should not be treated as a toy.

Graphs

In this lab, the results are shown as graphs of temperature versus time. PSL Explorer measures temperature in degrees Celsius.

Think about It

Observe

If you put an empty pie tin in a hot oven, the tin will absorb heat, and its temperature will rise. If you then take the pie tin out of the oven, it will begin to cool.

How cool will it get?

____

Will it cool to room temperature?

____

Will it cool to below room temperature?

____

Where does the heat go?

____

____

Predict

This is an experiment to study how aluminum foil cools.

Take a small piece of aluminum foil (about 5cm. x 5cm.) and fold it into a stiff packet (two or three folds should be fine.) Hold it by an edge with some tweezers. Touch the foil with your finger. Is it warm to the touch? ____________

While holding the aluminum foil with the tweezers, place it in front of a hair dryer. Turn the hair dryer on at the highest heat setting, and hold the aluminum foil in front of the hair dryer for 30 seconds. Now gently touch the foil with your finger. Has the foil temperature changed? ____________

Now turn the hair dryer off and continue to hold the foil with the tweezers. After 15 seconds, gently touch the foil with your finger. What do you notice about the temperature of the foil?

____

Now heat the foil again for 30 seconds. Then turn off the hair dryer and time for two minutes. At the *end of the first minute* answer the following question:

Does the aluminum foil feel like it is

a. above room temperature?
b. at room temperature?
c. below room temperature?
____ (a, b, or c?)

At the *end of the second minute* answer the following questions:

Does the aluminum foil feel like it is

a. above room temperature?
b. at room temperature?
c. below room temperature?
____ (a, b, or c?)

3 Did the aluminum foil have a greater change in temperature in the *first minute* or in the *second minute*? ______________________________________

After you have answered the questions, choose which graph in Figure 9 you think represents the temperature of the aluminum foil as it cools vs. time.

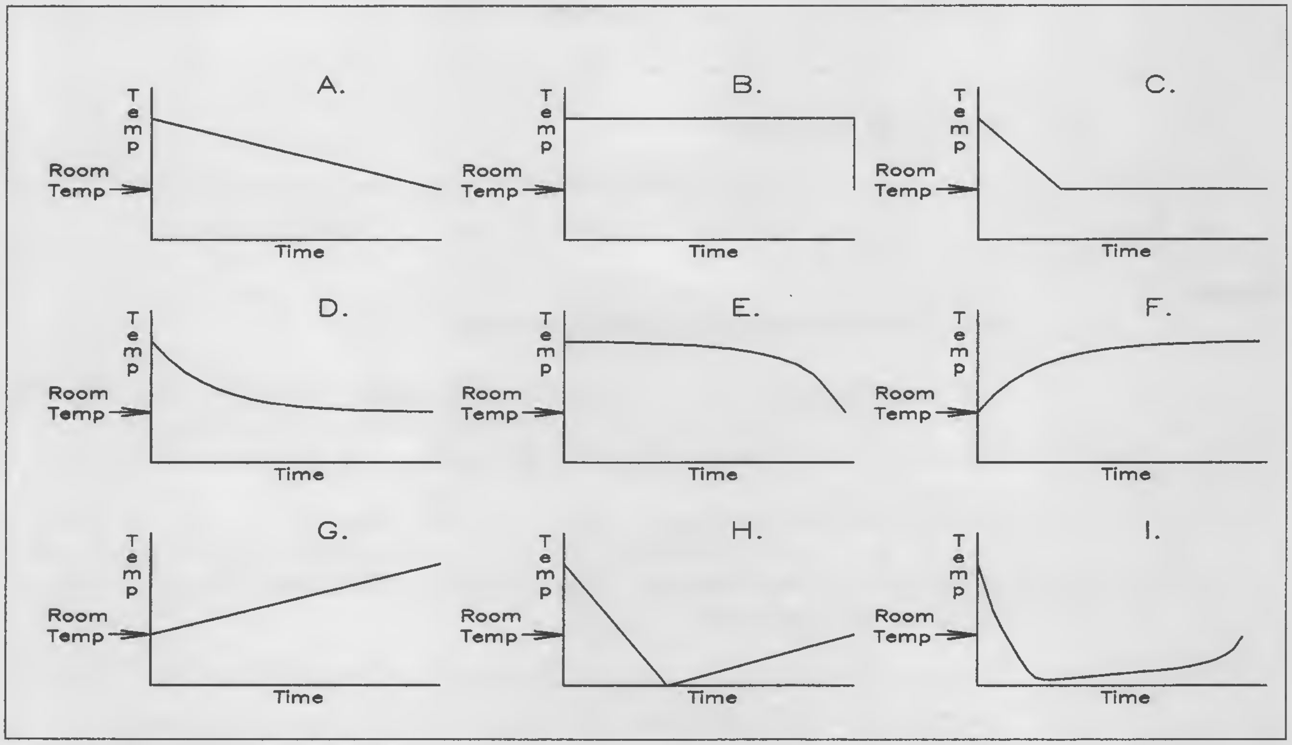


Figure 9. Possible Cooling Curves?

Write the letter of the graph you chose here. _____ This is your prediction.

Now, explain why you chose this graph.

____

____

____

Activities

This experiment illustrates simple cooling.

Explore the Temperature Probe

1. Plug the Standard Temperature Probe into channel 1 of the TLp module and the module into any port of the base unit.

2. Start the PSL Explorer program.

3. On the Main Menu, move the highlight bar to ***Select experiment*** and press **Enter**.

4. Select ***One Temperature vs Time*** and press **Enter**.

5. Select ***Duration...***, enter 120., and press **Enter**.

6. Select the ***Calibrate...*** option, and press **Enter**.

7. Select ***Sensor A calibration*** and type in the calibration constant that appears on the probe cable near the connector end.

8. Select ***Run experiment*** and press **Enter**.

9. Select ***Preview...*** and press **Enter**.

10. Measure the temperature of the air as follows: hold the probe by the cable. Don't touch the end of the probe with your fingers, because this will cause the probe to heat up to your body temperature.

    The probe will record a steady temperature, which is the room temperature.

11. After about 10 seconds, read the air temperature in degrees Celsius from the data box displayed along the bottom of the screen.

    After watching the temperature for several seconds, estimate the temperature of the room air.

    Air Temperature =_______°C.

12. Switch to graphing the data by pressing **Esc** to get out of Preview mode.

13. Select ***Start*** and press **Enter**.

14. Use the first 10 seconds to measure the room temperature. This will be your "Reference Temperature.."

15. Hold the tip of the probe between your fingers. Observe the change on the screen and see if your fingers are warmer or colder than room temperature. Then hold the probe so that your fingers do not touch the tip, and observe the change on the screen.

16. Press **F8** again. The screen will display: "Discard experiment data?" Use the down arrow key to choose ***Yes*** and then press **Enter**. Now you can restart the experiment by selecting ***Run experiment*** and pressing **Enter**.

17 Select ***Start*** and press **Enter**. Use the first 10 seconds to measure the air temperature.

18 Put the probe in front of the hair dryer on high heat setting. When the temperature is steady, stop the computer by pressing **Esc**.

19 Now you can find out the air temperature in degrees Celsius by selecting ***Graph*** and pressing **Enter**. The screen will show an arrow at the beginning of the graph. Below the graph, the screen shows the ***Time*** of the measurement and the ***Temperature*** in degrees Celsius.

20 By moving the position of the arrow, you can look at the value of temperature for each You can move the arrow by using the Arrow keys, located on the lower right-hand part of the keypad.

Try moving the arrow by using the left and right arrow keys. Notice how the Time changes. Does the Temperature change? ______________

Look at several data points in the steady portion of the graph, and estimate the temperature of the air coming from the hair dryer.

Temperature of hot air from hair dryer = _______°C.

21 Reset the program by using **F8** and selecting YES when the computer displays "Discard experiment data?." Select ***Run experiment.*** and press **Enter**. Select ***Start***. *Do not press* **Enter** *yet.*

22 Put the tip of the temperature probe inside the packet of aluminum foil. Hold the packet in front of the hair dryer, which is set on high heat, for 30 seconds. Hold the packet and probe by the wire without touching the packet.

23 Record the experiment. Turn off the hair dryer. Continue to hold the probe wire, and do not let the packet touch anything. Begin recording data by pressing **Enter**. The screen will show the temperature of the packet over time. The computer will take data for 120 sec.

24 Record your results in Figure 10 on page 63. Sketch the graph seen on the computer on the axes in the figure. This sketch should be an idealized version of the graph seen on the screen, by using ***Graph*** mode. which means you can smooth out any tiny bumps seen on the screen.

If you have a printer attached to your computer, you can print a copy of the graph by pressing **F5**.

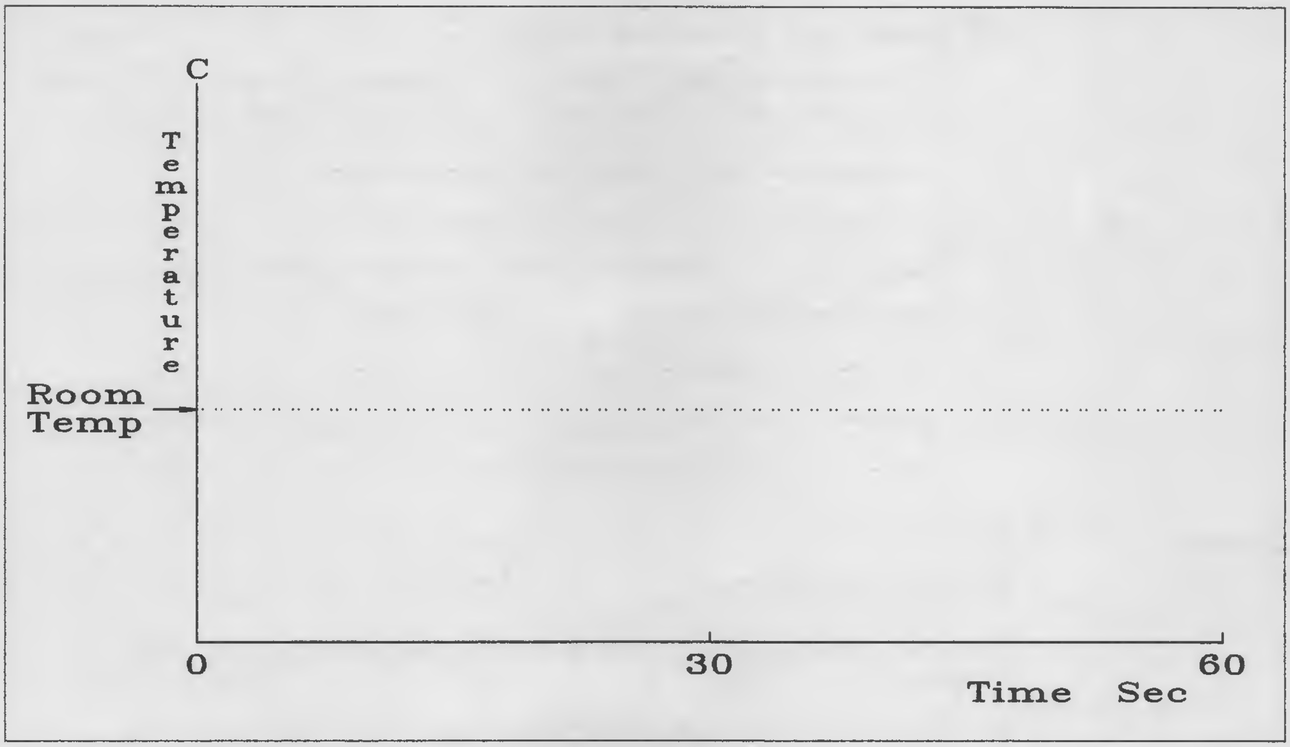


Figure 10. Aluminum Foil's Cooling Curve

25 Analyze your results. Get into Graph mode by pressing **Enter**. The screen will show an arrow at the first recorded point and the time and temperature of that point. Record the starting temperature below.

Starting Temperature T_0 _______°C

Now use the arrow keys at the lower right-hand side of the keypad, and move the arrow to the right until you reach a point which is at approximately 60 seconds. You may not be able to get to exactly 60.0 seconds, because the computer may not have taken a measurement at exactly this time. Record the temperature at this point, which is roughly half-way through the experiment.

$time_1$ = _______ sec. T_1 = _______ °C

Now advance the arrow to the end, either by pressing the right arrow key, or by finding and pressing **End** in the right hand portion of the keypad. Record the time and temperature at the end of the experiment.

$time_2$ = _______ sec. T_2 = _______ °C

Calculate the temperature lost in the first minute of cooling:

Temperature lost in first minute:

$T_1 - T_0$ = _______°C

Calculate the temperature lost in the second minute of cooling:

Temperature lost in second minute:

$T_2 - T_1$ = _______°C

26 Compare your results and predictions.

a. Compare the graph you copied from the computer screen with the graph you chose as your prediction on page 60. How are they different?

____

____

____

b. What have you learned from this experiment?

____

____

____

Explain

You have plotted the temperature of a solid as it cools.

From your graph sketched from the computer screen, answer the following questions:

1. Will it continue to cool to a temperature below room temperature?

   ____

2. Where does the heat in the aluminum foil go? Explain your answer.

   ____

   ____

   ____

3. Did the aluminum foil have a greater change in temperature in the first minute or in the second minute? To find out, look at your data analysis (step 11).

   ____

   Does this agree with your answer on page 60?

   ____

Extend

1. Measure the behavior of water as it cools. Heat a small beaker of water. Place the probe in the water and record the water temperature as it cools. (You may wish to change the duration to 300 seconds or even longer.) How does the curve compare with the cooling curve of the probe when it was cooling, measured above?
2. Measure the cooling curve of mineral oil. Compare it with that of water.

Teacher's Notes

The PSL Explorer software displays temperature in degrees Celsius. You might wish to spend some time with the class reviewing the conversion from Celsius to Fahrenheit, so that the students have a more intuitive feel for the temperature range they are measuring.

After temperature data has been collected, the graph can be changed to display degrees Fahrenheit by using the Analysis Menu (described in "Analysis Menu" on page 49) as follows:

1. Select the ***Calculate*** option.
2. Multiply the temperature axis by 1.8.
3. Add 32 to the same axis.

The cooling curve for the probe, as for all substances that don't change phase (that is, don't change from liquid to solid or gas to liquid upon cooling down), looks roughly like this:

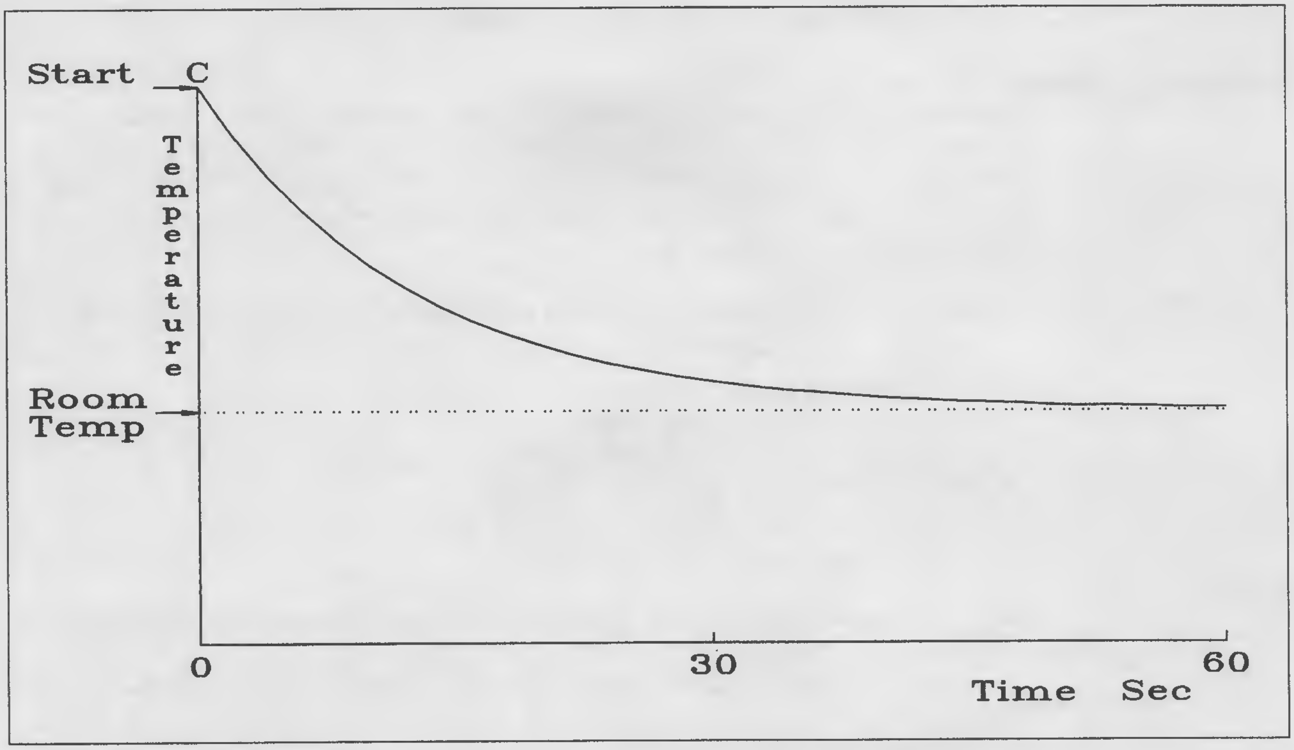


Figure 11. Typical cooling curve

The temperature of the probe will not go below room temperature unless:

- It comes in contact with a substance that is colder than room temperature.
- It still has water on it, which cools the probe by evaporation.

Motion: The Pendulum

Before You Start

To Find Out

During this exploration, you will study:

- The motion of a simple pendulum
- The relationship between distance and velocity graphs for the simple harmonic motion of a pendulum
- ★[5] The acceleration of a pendulum in simple harmonic motion.

Materials

This exploration requires the following items:

- PSL, with the Motion and Mechanics Module, the Distance Probe, and PSL Explorer
- String
- 50 g. mass holder and set of slotted masses

The Distance Probe

The Distance Probe measures distance by emitting ultrasonic pulses and timing the echoes. The farther away the target object, the longer the time before an echo returns from it. The best data are obtained when the ultrasound generates a clear echo. To do this, you need a fairly large, hard object squarely in front of the detector, but not too close.

Please keep in mind the following points in relation to the motion detector: The detector will not work properly if

- The object drifts off to one side
- You try to use too small an object
- The object absorbs sound, like a sweater or a sponge
- You try to record something too far away
- The object is closer than 40 cm (about 18 inches).

Graphs

In this lab, the results are shown as graphs of distance, velocity, and acceleration.

The distance graph is a record of the distance between the end of the pendulum and the detector. As the pendulum swings, this distance changes, getting larger, then smaller, and repeating its motion.

The velocity graph is a record of the velocity of the end of the pendulum as it changes with time. The velocity can be positive or negative, depending upon whether the pendulum is swinging away from the detector or toward the detector.

★ The acceleration graph is a record of the change in velocity, and it can be positive or negative, depending on whether the pendulum is speeding up or slowing down.

---

5 Material marked with ★ is for advanced study or requires quantitative skills.

Think about It

Observe

Set up the pendulum by placing the slotted mass holder on the end of a string. Tie the other end of the string to a ring stand. Start the pendulum in motion by swinging the mass holder so that it is at a *small angle* from the vertical and allow the pendulum to swing back and forth. The detector should be roughly 0.75m from the pendulum. The diagram below is one possible way to set up the apparatus.

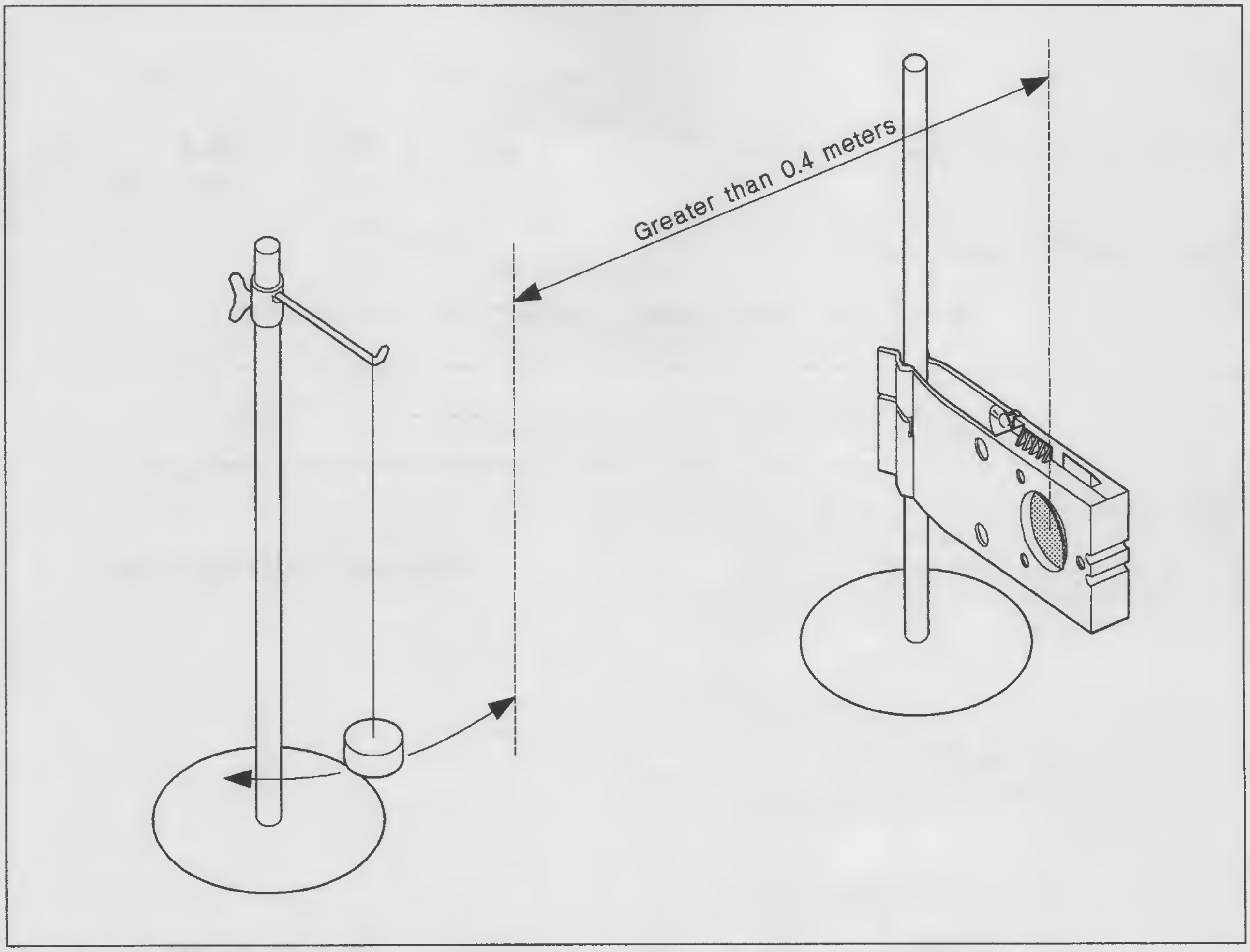


Figure 12. Distance Probe Measuring a Pendulum

Predict

Try to predict the shapes of the graphs you will be seeing in the experiment. Does the pendulum repeat its motion? Does the pendulum get faster, then slower, then faster again? When the distance of the pendulum from the detector is largest, is the velocity largest or smallest? When is the velocity positive, negative, or zero? Think about these questions; then draw your graphs.

Use colored pen, or label these graphs as "My Prediction."

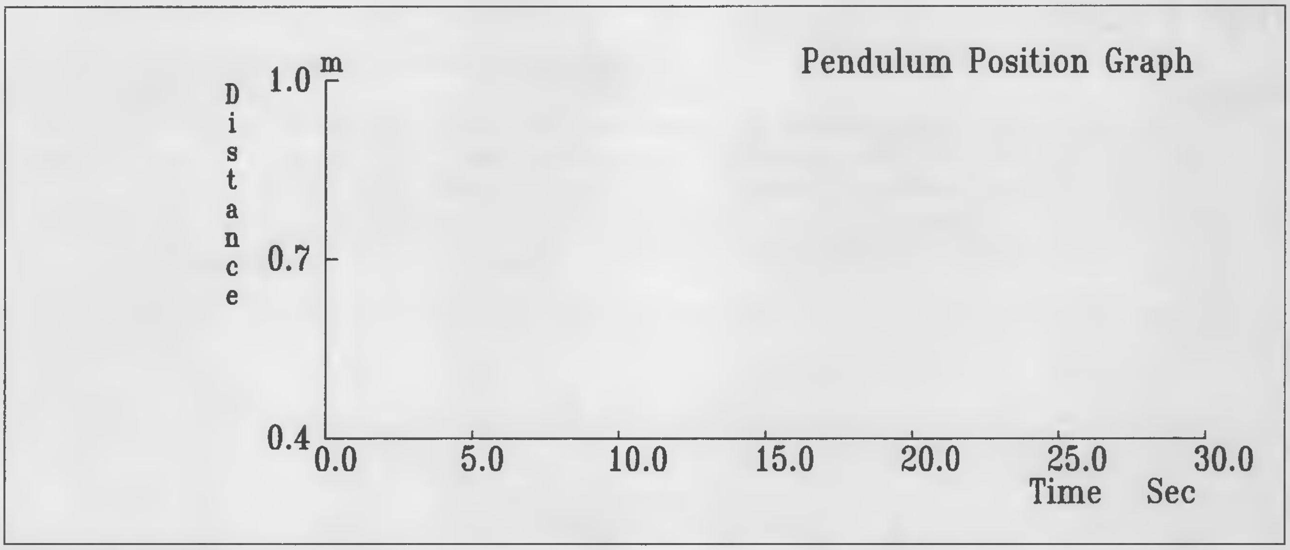


Figure 13. Pendulum Position Graph

Explain your predicted graph by describing its important features.

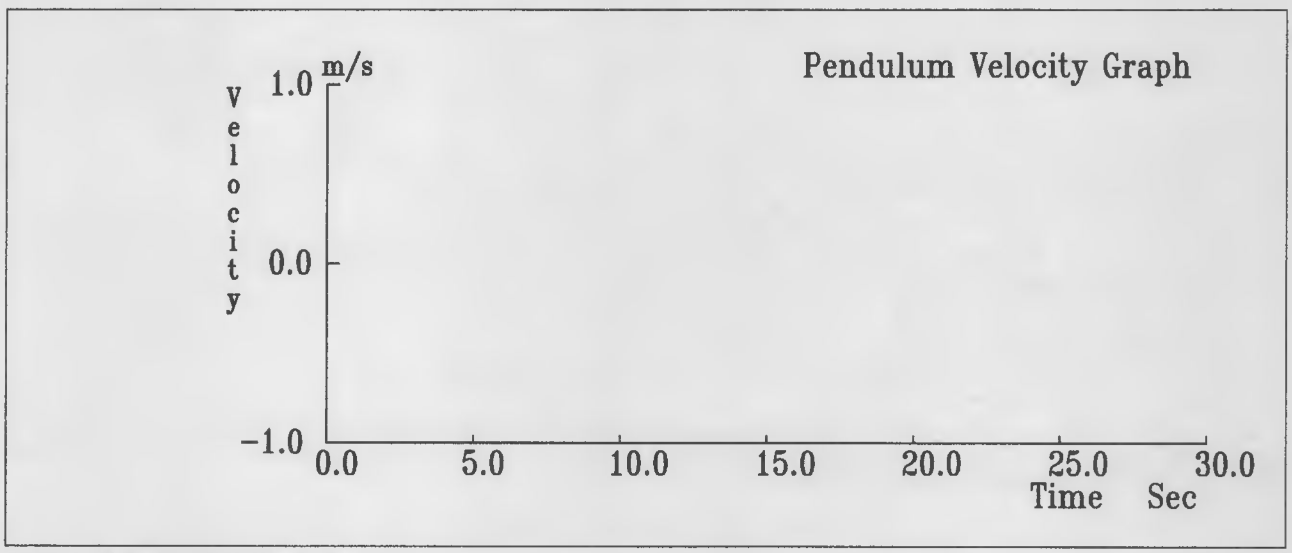


Figure 14. Pendulum Velocity Graph

Explain your predicted graph by describing its important features.

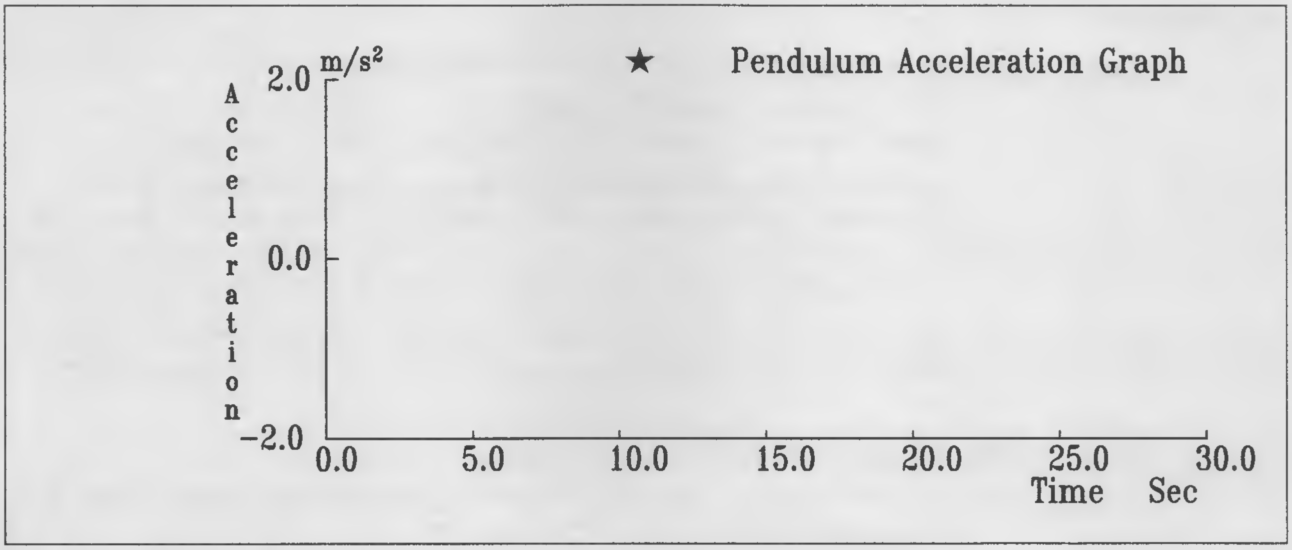


Figure 15. ★Pendulum Acceleration Graph

★ Explain your predicted graph by describing its important features.

Activities

This experiment measures the motion of a pendulum.

1. Mount the detector so that it is detecting horizontal motion, by clamping it on a vertical ring stand, or by attaching it to a wall with the suction cups.

   Make sure that the pendulum does not get any closer than 40 cm. (about 18 inches) away from the detector. Make sure that the mass is at the same height from the table as the middle of the detector. If not, your data will not be smooth, as the detector will "see" other objects besides the pendulum.

   You will know if your motion detector is properly lined up if the data is smooth and repeats itself on the screen, much as the motion of the pendulum repeats itself.

2. Start PSL Explorer.

3. Set up the software. Select **Harmonic motion** from the **Select Experiment** menu. This gets the software ready for the experiment.

4. Select **Run experiment** and press **Enter**. The computer screen displays **Start**. Make sure the cup on the pendulum can be seen by the detector by having the detector situated directly in front of the pendulum.

5. Start the pendulum moving by displacing the mass from its resting position by a small amount (less than 30° from the vertical), and then press **Enter**. When the run is finished, the computer will show two graphs: distance vs. time and velocity vs. time.

6. Repeat steps 4 and 5 until you are satisfied with the graphs seen on the screen. The graphs should be smooth lines.

   To repeat a measurement, press **F8**. The screen will ask if data should be overwritten. Choose **Yes**. This will cause the data you've just recorded to be thrown away, and will make room for the new data to be recorded.

7. Sketch the position and velocity graphs obtained with the computer onto the graphs on page 68. Use another color pen or clearly label these results as "Computer Recorded Data." These graphs should be idealized versions of the graphs on the screen.

   ★ Sketch the acceleration graph on page 69.

   If there is a printer attached to your computer, you can print the graph by pressing **F5**.

8. Compare your results and predictions. Look at the two lines on each graph, representing your predictions and results.

   How were your results different from your predictions?

   ____

   ____

   ____

9. Answer the following questions by estimation:

   a. Does the distance graph always return to the same maximum height? Answer *yes* or *no*. _________

      (You can use a ruler to measure the height of several maxima if you wish, but don't try to be too exact. Estimating "by eye" is fine.)

b. Does it always take the same amount of time for the graph to repeat itself? Answer *yes* or *no*. _________

(Here again, you can measure with a ruler whether or not each cycle takes up the same distance along the x-axis, which is the time axis. You can also use your eye if you wish.)

10. ★Verify your answers to question 9. Select **Graph** mode and press **Enter**. Make sure the screen at the bottom has a box around it. If not press **F2**. Then, using the arrow keys on the lower right-hand side of the keypad, move the marker arrow on the screen over to the first maximum. Write the values for distance and time:

    $Distance_1$ _____________ ***m.*** ***$Time_1$*** _____________ ***sec.***

    Now move to the next maximum, and record below the distance and time.

    $Distance_3$ _____________ ***m.*** ***$Time_2$*** _____________ ***sec.***

    Now move to the next maximum, and record below the distance and time.

    $Distance_3$ _____________ ***m.*** ***$Time_3$*** _____________ ***sec.***

    Compare ***$Distance_1$, $Distance_2$, $Distance_3$***.

    a. Are they all approximately the same? _________ If the numbers are within 1 cm, we will assume the differences are due to experimental measurement error..

       Now calculate the following:

       $Time_3 - Time_2 = \Delta t_1 =$ _____________

       $Time_2 - Time_1 = \Delta t_2 =$ _____________

    b. Compare Δt_1 and Δt_2. Are they approximate the same? _________ If the two values are within 0.2 sec., assume the differences are due to measurement error.

Explain

Your graphs of the motion of the pendulum as recorded by the computer are ***periodic***, which means that they have a repetitive nature. These graphs reflect the repetitive nature of the motion. Both the distance and velocity graphs are repetitive.

1. Is the same amount of time taken for the distance graph to repeat itself every cycle? _________
2. Is the same amount of time taken for the velocity graph to repeat itself every cycle? _________
3. Is the period of oscillation for the velocity curve the same as for the distance curve? _________
4. ★ Is the period of oscillation for the acceleration curve the same as for the distance curve? _________

Extend

1. Explore how changing the mass of the pendulum affects the period.

   Double the mass by adding a 50 g. mass to the pendulum. Measure the period of the pendulum, using **Graph** mode. Measure the time for 10 oscillations to be completed, and divide the time by 10 to get the period.

   Now compare the period for a mass of 50 g with the period for a mass of 100 g.

   How does increasing the mass affect the period of the pendulum?

2. Explore how changing the length of the pendulum affects the period.

   Halve the length of the pendulum and measure its period.

   Now double the original length and measure the period. (You may have to hang the pendulum from the table if it is too long.)

   How does changing the length affect the period of a pendulum?

3. ★The theoretical expression for the period of a pendulum is

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

   where g is the acceleration due to gravity: $g = 9.80 m/sec^2$, and L is the length of the string.

   Looking at your results for question 2 above; do they agree with the formula? If not, can you think of a reason?

Teacher's Notes

When properly lined up, the graphs will look like sine waves. If they do not, check to see that:

- The middle of the mass is aligned with the middle of the detector. If the detector catches an edge of the mass hanger, the graph will have a "hiccup" in it; i.e., there will be a periodic blip appearing superimposed on the sine wave.
- The detector is aimed horizontally. If problems persist, sometimes slanting the detector a bit downwards helps to reduce spurious reflections.
- The maximum amplitude of the pendulum is no more than 30° from the vertical. For oscillations greater than this amplitude, the motion begins to deviate from that of simple harmonic motion. For large amplitudes, the graphs will not look sinusoidal.
- All pendulums executing simple harmonic motion will produce a sine graph for the amplitude vs. time. The amplitude of the oscillation depends upon the initial starting amplitude. Also, the period depends upon the length of the pendulum, which will vary from setup to setup. Hence, not all students will have exactly the same sine curve, but all curves will have the same general shape.
- The period of a pendulum does not depend upon its mass, as shown by the formula

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

  where g is the acceleration due to gravity: $g = 9.80 m/sec^2$, and L is the length of the string.

  However, a large mass on the end of a string may cause the string to stretch, which will change the period of the pendulum.

Appendix A. Hints and Tips

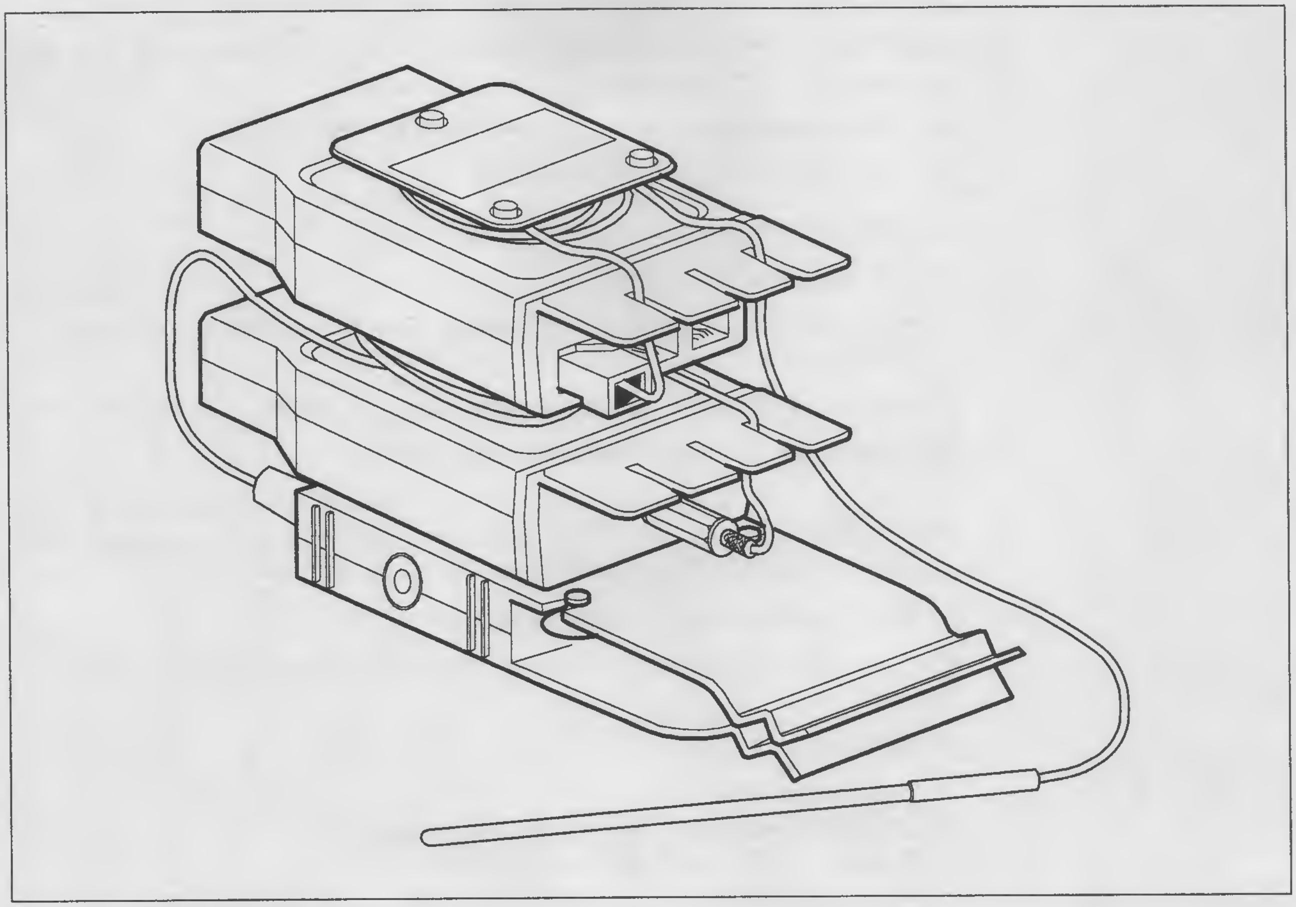


Figure 16. Storing Probes

Modules

Modules snap together like children's plastic blocks for easy storage and carrying convenience. Probe cables wind around the bobbin under the module for easy storage. Notches relieve cable strain when used as shown.

Base Units

The base units also snap together for easy storage and carrying convenience.

pH Probe

Follow these tips when using the pH probe:

1. Store the pH probe dry, with the sensing tip covered by the supplied cap. Leaving the pH probe in liquid will shorten its useful life.
2. Cover the tip of the pH probe with the protective cap when not in use. The cap prolongs the life of this probe.
3. Always rinse the pH probe with distilled or deionized water:
   - after each calibration with buffer solution
   - after each test
   - before storing the probe
   - when removing the probe from storage. Soak the probe for ten minutes before using.
4. After rinsing, blot (not wipe) the sensor surface with a clean, lint-free material.
5. **Do not wipe the sensor surface of the pH probe.**
6. If erratic or unstable results are observed, gently swab the surface of the sensor with a cotton-tipped applicator saturated with methanol (methyl alcohol). After swabbing, rinse the probe in distilled or deionized water.
7. Only use the pH probe with aqueous samples.
8. In strong alkaline solutions, remove the pH probe immediately after taking a reading.
9. **Do Not Use in:**
   - hydrofluoric acid
   - organic solvents such as methanol or benzene
   - fluoride solutions with a pH less than 4.0.

Appendix B. Technical Specifications

Distance	Range	0.4m to 10m
	Accuracy	±7.0mm
	Resolution	0.4mm
	Sampling rate	350/sec (dependent on distance)
Standard Temp. (note 2, 3)	Range	-40°C to +105°C
	Linearity	±1°C
	Time Constant	0.14 sec
	Resolution	.05°C
	Sampling rate	50/sec
Extended Temp. (note 2,3)	Range	-55°C to +150°C
	Linearity	±.8°C for -55°C to +150°C ±.5°C for -25°C to +105°C
	Time Constant	1.2 sec
	Resolution	.05°C
	Sampling Rate	48/sec
Radiometric Light	Spectral Range	400nm to 950nm
	Sensitivity	0.1μW/cm^2 to 10,000μW/cm^2
	Sampling rate	25/sec to 200/sec
Photometric Light	Spectral Range	400nm to 700nm
	Sensitivity	.5 lux to 100,000 lux
	Sampling rate	25/sec to 200/sec
pH (note 4)	Range	0 pH to 12 pH
	Accuracy	0.2 pH (one-point calibration) 0.1 pH (two-point calibration)
	Resolution	0.01 pH
	Time constant	0.7 sec
Thermistor	Range	0°C to 60°C
	Accuracy	±0.5°C
	Resolution	.25°C
	Sampling rate	50/sec

Notes:

1. Sampling rate is user controlled. Cited rates are the nominal maximums that are possible.
2. Temperature accuracy is non-linear over the total range of the the probe. Figure 17 on page 78 outlines the worst case error in degrees Celsius for both the Standard and the Extended Temperature Probes.

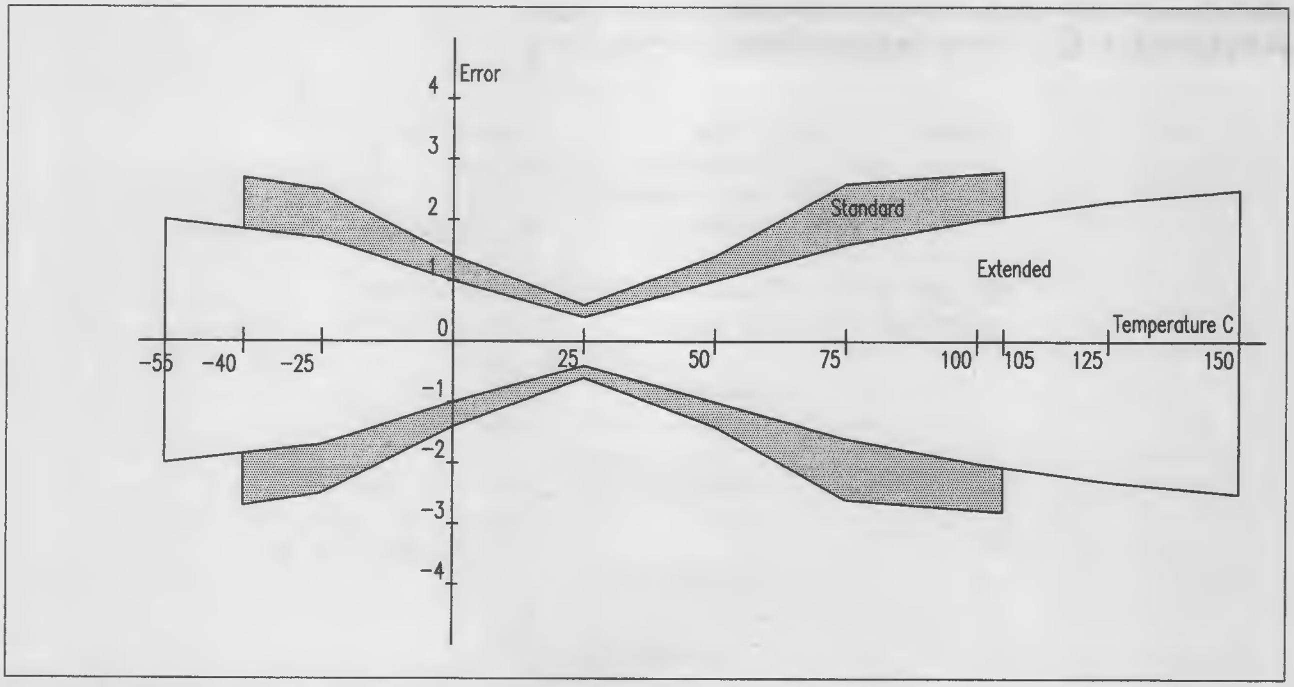


Figure 17. Worst-case error of temperature probes over their range

3. Temperature time constant (T) is defined as the time required for the probe to register 63% of the actual temperature in water flowing at 1 m/sec.

4. pH calibration is valid for ±10°C from the temperature at which it is calibrated.

Appendix C. Part Numbers

57F7921	TLp Pak
57F7922	Motion and Mechanics Pak
57F7923	Base Unit with Power Supply
57F7924	Prototype Module
57F7925	TLp Module
57F7926	Standard Temperature Probes (pkg of 2)
57F7927	Extended Temperature Probes (pkg of 2)
57F7928	Ph Probe
57F7929	Photometric Probe w/ filter holders
57F7930	Radiometric Probe w/ filter holders
57F7931	Power Supply
57F7932	RS232C attachment cable
57F7933	Standard Prototype cards (pkg of 5)
57F7934	Long Prototype cards (pkg of 3)
57F7935	Distance Probe
57F7936	User's Guide publication w/ diskette (3½-inch)
57F7937	Technical Reference publication

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