The Pocket Professional™

Physics

Owner's Manual

SPARCOM®

Edition 1
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Printing History

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Physics Pac Changes

The following changes were made to the Physics Pac for version 2.5:

✔ Browser: Cursor movement and scrolling speed have been increased.

✔ Constant Library: Constants have been updated to conform to latest accepted values.

HP 48GX USERS ONLY: You should install the application card in Port 1 for two reasons:

1. Application cards installed in Port 1 will execute ~ 20% faster than those installed in Port 2.

2. Application cards installed in Port 2 may experience long pauses (~ 5-10 seconds or more) intermittently during operation. This is not a software defect. It is caused by the new memory architecture of the extended HP 48GX Port 2, which is different from the HP 48SX Port 2. Such pauses will not occur if the application card is operated from Port 1 of the HP 48GX or if it is operated from either port of the HP 48SX.

Physics Pac Manual Changes

These changes apply to the Physics Pac Manual, Edition 1, April 1992.

Changes for the HP 48GX

General: To display all libraries on the HP 48GX, press [→] [LIBRARY] instead of [←] [LIBRARY].

General: On the HP 48GX, the [ATTN] key has been replaced by CANCEL.

General: To perform a screen dump on the HP 48GX, press [ON]–[I/O] instead of [ON]–[MTH].

General: To display an item too wide for the display on the HP 48GX, press [→] [CMD] instead of [→] [VISIT].

Page 34: Loading a Value from the Stack: To access the Interactive Stack from an input screen on the HP 48GX, press [←] [EDIT] [↑STK] instead of [▲]. Afterwards, press [→] [MENU] to restore the previous menu, if desired.

Pages 41, 42: Graphics Environment: On the HP 48GX, the Graphics Environment menus have been re-arranged.

Page 54: User-Defined Integrals: Item 4: On the HP 48GX, press [PRG] [TYPE] [→TAG] instead of [PRG] [OBJ] [→TAG] to tag an object.

Changes for Version 2.5

Page 15: The search mode is now case-insensitive.

Page 19: Constant Library: The Constant Library now includes 43 constants.

Page 19: Using the Constant Library: Picture should contain "π" instead of "pi" and "Napier" instead of "Napiere."

Page 29: Variables Screen: 1st picture should indicate radians as the default unit for θ instead of °.

Page 31: Turning Units On: Picture should indicate 0_r as the value of θ instead of 0_°.

Page 31: Entering Values: Change sentence from "Type 45 as your input:" to "Type 45 and press the 2nd softkey as your input:"

Page 31: Entering Values: 1st picture should indicate 45_° as the entry on the command line instead of 45. Also, the menu keys should read [R] [°] [GRAD] instead of [°] [R] [GRAD].

Page 31: Entering Values: Delete the phrase, "(default units of ° will be assumed)".

Page 39: Turning Units Off: Picture should indicate 1.0109 as the value of θ instead of 57.9210.

Page 40: Plotting an Equation: 2nd picture should indicate (r) as the units for θ instead of (°).

Page 40: Entering Ranges: Example: Change sentences from "Vary θ from 30° to 60°. To do this, type 30 SPC 60 as your input:" to "Vary θ from π/6 radians (30°) to π/3 radians (60°). To do this, type .5236 SPC 1.0472 as your input:"

Page 40: Entering Ranges: 1st picture should indicate (r) as the units for θ instead of (°), and the command line should contain the values .5236 and 1.0472.

Page 49: Viewing an Integral: Picture should not include L and U because the integral is indefinite.

Page 63: SI Prefixes: Picture should indicate prefixes as 1E18, 1E15, ...

Page 72: Expanding a Function: 1st picture menu keys should read DEG RAD GRAD XYZ R<Z R<< instead of PARTS PROB HYP MATR VECTR BASE.

Page 77: Dot Products: 2nd picture menu keys should read ←SKIP SKIP→ ←DEL DEL→ INS ↑STK instead of PARTS PROB HYP MATR VECTR BASE.

Page 79: Del Operator (∇): Picture has several errors.

Page 80: Gradient: Example: Change sentence from, "Then press the fifth softkey R<Z ..." to "Then press the second softkey RAD and the fifth softkey R<Z ...".

Page 125: Orbits (Circular): Equation 2 should be $v^2 = \frac{G \cdot m1}{a}$.

Page 127: Projectile Motion: XI, XF, YI, and YF variable descriptions are swapped.

Appendix C: The default angle unit has been changed from ° to r.

Contents

Chapter 1

Getting Started

Sparcom's Pocket Professional™ software is the first of its kind, developed to provide speed, efficiency and portability to students and professionals in the technical fields. When you slide the Pocket Professional™ Physics Pac into your HP 48SX, your calculator is instantly transformed into an electronic "textbook," ready to efficiently solve your physics problems. The Physics Pac is organized into eight separate modules: Constant Library, Equation Library, Integral Tables, Polynomial Solver, Reference Data, Reference Formulas, Special Functions, and Vector Analysis... all available in an efficient, menu-driven format.

This chapter covers:

- ❑ Installing and Removing a ROM Card
- ❑ Moving Around the Screen
- ❑ Using the Main Menu
- ❑ Changing the Font Size
- ❑ Viewing Items Too Wide for the Display
- ❑ Using the Search Mode
- ❑ Text Editing
- ❑ Alpha Lock
- ❑ How to Load Data from the Stack
- ❑ System Flags
- ❑ User Flags
- ❑ Memory Requirements
- ❑ The 'SPARCOM' Directory

Installing and Removing a ROM Card

The HP 48SX has two ports for installing plug-in ROM cards. You can install your Physics Pac in either port.

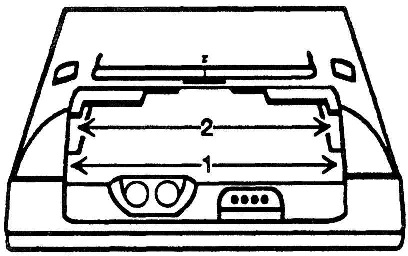
> **WARNING: Turn off the HP 48SX while installing or removing a ROM card! Otherwise, your HP 48SX memory may be erased.**

Installing a ROM Card

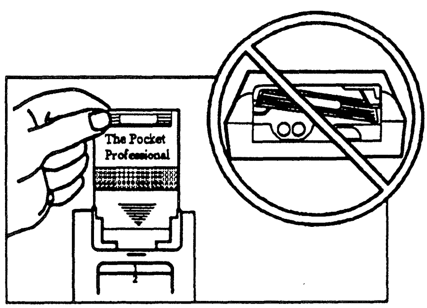
To install a ROM card, follow these steps:

❶ Turn the HP 48SX off. Do not press [ON] until you have completed the installation procedure.

❷ Remove the port cover. Press against the grip lines and push forward. Lift the cover to expose the two plug-in ports, as shown below:



❸ Select either empty port for the Advanced Pocket Professional™ card, and position the card just outside the slot. Point the triangular arrow on the card toward the HP 48SX port opening, as shown below:



❹ Slide the card firmly into the slot. After you first feel resistance, push the card about 1/4 inch further, until it is fully seated.

❺ Replace the port cover.

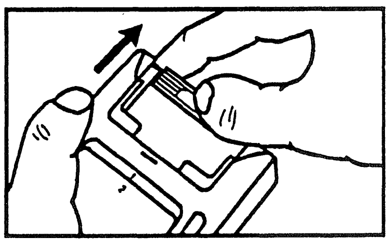
Removing a ROM Card

To remove a ROM card, follow these steps:

❶ Turn the HP 48SX off. Do not press [ON] until you have completed the removal procedure.

❷ Remove the port cover. Press against the grip lines and push forward. Lift the cover to expose the two plug-in ports, as shown above.

❸ Press against the card's grip and slide the card out of the port, as shown below:

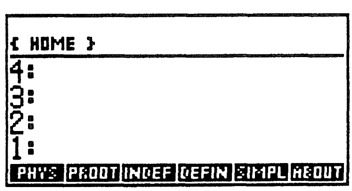


❹ Replace the port cover.

Starting the Physics Pac

After you turn on your HP 48SX by pressing [ON], there are three ways to start the Physics Pac:

- Press [←] [LIBRARY] to display all libraries available to the HP 48SX. Find and press PHYS to enter the Physics Pac library directory. The screen displays new menukeys (softkeys) along the bottom, as shown:



  Press PHYS (the first softkey) to start the application. To display a screen containing the revision number and product information about the Physics Pac, press ABOUT (the sixth softkey). (For more information about the remaining softkeys, refer to Chapter 10, "Programmable Commands.")

- Type [α][α] PHYS [ENTER] to start the application.

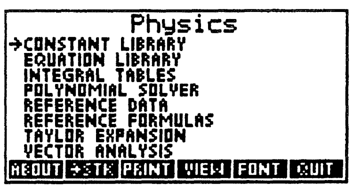
- Add the command PHYS to the CST (custom) menu. (For more information, refer to Chapter 15 of the HP 48SX Owner's Manual, "Customizing the Calculator.") After the command has been added to CST, press [CST] PHYS to start the application.

Moving Around the Screen

Use the [▲] and [▼] keys to move the pointer up and down in a menu screen. Press [◄][▼] to move the pointer to the bottom of the screen, or to page down one screen at a time if the pointer is already at the bottom of the screen. Press [◄][▲] to move the pointer to the top of the screen, or to page up one screen at a time. Press [►][▼] to move the pointer to the very end of the menu or press [►][▲] to move the pointer to the very beginning of the menu.

Using the Main Menu

After you start the application, the Main menu appears:



The Main menu lists the eight modules of the Physics Pac. A module is selected by moving the pointer to the desired item and pressing [ENTER].

Items in the Main Menu

Each item in the Main menu is briefly described below and is discussed in detail in the various chapters of this manual.

Item	Description	See...
Constant Library	Includes 45 universal constants.	Chapter 2
Equation Library	Over 250 equations in 11 categories.	Chapter 3
Integral Tables	Nearly 100 integrals in 5 sections.	Chapter 4

Polynomial Solver	A polynomial root-finder accepting real or complex coefficients.	Chapter 5
Reference Data	Includes Greek alphabet, SI prefixes, and solar system data tables.	Chapter 6
Reference Formulas	Moments of inertia, centroids, and standard trigonometric/hyperbolics.	Chapter 7
Taylor Expansion	Taylor expansion function.	Chapter 8
Vector Analysis	Reference formulas/functions for dot, cross, del, div, curl, grad, Laplacian.	Chapter 9

Summary of Operations

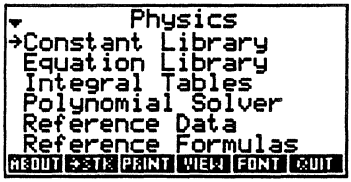
Screen	Softkeys
Main	ABOUT →STK PRINT VIEW FONT QUIT

Key	Action
ABOUT	Displays a screen containing the revision number and product information about the Physics Pac. Pressing any key erases the screen and returns to the previous menu or to the HP 48SX stack.
FONT	Toggles between the small and large fonts.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
QUIT	Quits the Physics Pac to the HP 48SX stack.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Moves down one level in the menu structure, entering the module selected by the pointer.
ON–MTH	Dumps the current screen to an IR printer.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Changing the Font Size

The default font for the Physics Pac displays information in condensed, uppercase letters only. Pressing FONT will toggle the information to a larger font, which is case-sensitive:



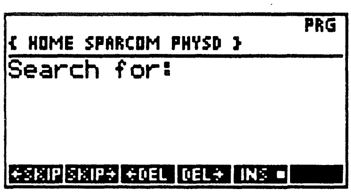
The font size will remain the same until FONT is pressed again.

Viewing Items Too Wide for the Display

If the text of a menu item is too wide to fit within the display, an ellipsis (...) appears at the end of the line. On some screens, the VIEW softkey will be present—press VIEW to display the entire text of an item, up to one entire screen size. Once the full text has been displayed, press ENTER or ATTN to return to the menu. At all screens, including those screens where VIEW is not present, pressing ⬏ VISIT will perform the same function. If an item does fit entirely on the screen, VIEW or ⬏ VISIT will beep and do nothing.

Using the Search Mode

When menu lists are long, it is faster to locate an item using the search mode. To initiate a search, press α to display the following screen:



The HP 48SX is now locked in alpha-entry mode, as indicated by the alpha annunciator at the top of the screen (not shown). Alpha entry mode activates the white capital letters printed to the lower right of many keys. (For more information, refer below to "Alpha Lock" and to Chapter 2 of the HP 48SX Owner's Manual, "The Keyboard and Display.")

To perform a search, enter the first letter or letters of the desired string and press ENTER. The search function is case-sensitive, and will scan through all information in the current menu. To enter a lowercase letter in the alpha entry mode, precede the letter with [←]. To abort the search, press ATTN.

Text Editing

The softkeys present at the search screen and at many data input screens are command line editing keys. They allow you to edit the search string or input data. Their functions are summarized below. (For more information, refer to Chapter 3 of the HP 48SX Owner's Manual, "The Stack and Command Line.")

Summary of Operations

Screen	Softkeys
Text Editing	←SKIP SKIP→ ←DEL DEL→ INS ↑STK

Key	Action
←DEL	Deletes all characters in the current word prior to the cursor.
DEL→	Deletes all characters between the cursor's current position and the first character of the next word.
INS	Toggles between insert and type-over modes.
←SKIP	Moves the cursor to the beginning of the current word.
SKIP→	Moves the cursor to the beginning of the next word.
↑STK	Activates the Interactive Stack, allowing arguments to be copied from the stack to the command line for editing by pressing ECHO.
ATTN	Clears the command line if there is text present, or aborts text entry if the command line is already blank.
ENTER	Accepts the current command line as the entry and returns to the previous menu or list.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Alpha Lock

System flag –60 controls whether or not Alpha Lock mode is set. The default setting for flag –60 is clear, which means that pressing [α] places the HP 48SX in alpha-entry mode for only one character, and you must press [α][α] to lock alpha-entry mode. If flag –60 is set, however, then pressing [α] only once locks alpha-entry mode. The examples in this manual assume that flag –60 is clear, so that each [α] keystroke turns on alpha-entry mode only for the following character. (For more information, refer to Chapter 2 of the HP 48SX Owner's Manual, "The Keyboard and Display.")

How to Load Data from the Stack

At all data input prompts, it is possible to copy values from the HP 48SX stack to the command line, even though the Physics Pac is executing. This is achieved through a limited version of the Interactive Stack. To activate the Interactive Stack at a data input prompt, press [▲], or if that does not work, press [←][EDIT] to display the EDIT menu and then press →STK. At this point, unless the stack is empty, the screen will display the contents of the stack. Move the pointer up and down the stack by pressing [▲] and [▼], and when you reach the desired value, press ECHO to copy it to the command line for editing. To exit the Interactive Stack and return to the command line, press [ENTER] or [ATTN]. After returning to the command line, you can edit the value with the editing softkeys described above. (For more information, refer to Chapter 3 of the HP 48SX Owner's Manual, "The Stack and Command Line.")

System Flags

Executing the Physics Pac will not change the flag settings or stack depth on your HP 48SX, unless you push →STK at some point to leave results on the stack. For your convenience, most flag settings are preserved during operation of the Physics Pac, including the alpha-lock setting. However, for the software to operate properly, some system flags are temporarily modified during execution:

- Binary word size is set to 64
- Clock display is turned off
- Radix mark is set to "." (period)
- Last Arguments are not saved
- User Mode is turned off

When you press ATTN or QUIT to exit the Physics Pac to the HP 48SX stack, all system and user flags are restored to their previous settings for your convenience.

> **WARNING: Pressing ATTN multiple times in rapid succession may abort the Physics Pac without resetting the state of your HP 48SX. Do not do this! The Pac is designed to be tolerant of a few ATTN presses, but it cannot properly restore your stack and flag settings if you push ATTN too many times in a row.**

User Flags

The display font size is controlled by the setting of user flag 57. If flag 57 is clear, the smaller display font will be used; if flag 57 is set, the larger display font will be used. Changes in the display font during operation of the Physics Pac are preserved after you quit to the HP 48SX stack.

The state of units (on or off) is controlled by the setting of user flag 61. If flag 61 is clear, units are on; if flag 61 is set, units are off. Changes in the units status during operation of the Physics Pac are preserved after you quit to the HP 48SX stack.

Memory Requirements

A minimum of about 1.7K free memory is required for the Physics Pac to operate, but more free memory is required to interactively use functions and solve equations. The precise free memory requirements vary according to the complexity of the function arguments or the number of equations you solve.

If the Physics Pac appears to be functioning incorrectly—e.g., if you attempt to create a plot or solve an equation and nothing happens—it is likely that there is not enough free memory in your HP-48SX to complete the operation. Possible solutions to the problem of too little free memory are:

- ❑ Simplify the problem you are solving by using a smaller subset of equations or variables, or by entering simpler symbolic arguments to the function.

- ❑ Quit the Physics Pac and delete unwanted variables from the VAR menu. (For more information, refer to Chapter 6 of the HP 48SX Owner's Manual, "Variables and the VAR Menu.")

- ❑ Add additional free memory to your HP 48SX by merging a 32K or 128K RAM card. (For more information, refer to Chapter 5 of the HP 48SX Owner's Manual, "Calculator Memory.")

The 'SPARCOM' Directory

Most Sparcom Pocket Professional™ Pacs create a directory 'SPARCOM' in the HOME directory of your HP 48SX. Inside the 'SPARCOM' directory, each particular Pac creates a specific subdirectory—for the Physics Pac, the name of that subdirectory is 'PHYSD'. All variables and equations for the Physics Pac are stored inside 'PHYSD', so as not to conflict with your global variables in other directories. If you are extremely low on free memory and do not need to keep any of the Physics Pac variables in your HP 48SX, you can purge the 'PHYSD' directory, using the command PGDIR. The next time you execute the Physics Pac, the 'PHYSD' directory will automatically be re-created. (For more information, refer to Chapter 7 of the HP 48SX Owner's Manual, "Directories.")

Chapter 2

Constant Library

The Constant Library lists 45 universal constants for quick reference. Constant values can be displayed on the screen, copied to the stack, or printed on an IR printer, either one at a time or all at once.

This chapter covers:

- ❑ Using the Constant Library
- ❑ Viewing a Constant

Using the Constant Library

To get to the Constant Library, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press PHYS to enter the Physics Pac library directory.

❸ Press the first softkey, PHYS, to start the Physics Pac.

❹ At the Main menu, make sure the pointer is at "Constant Library" and press [ENTER]:

```
▾  Constant Library
→pi  circle ratio         ...
 e   Napiere constant     ...
 γ   Euler constant       ...
 ø   golden ratio         ...
 α   fine structure       ...
 c   speed of light       ...
MAIN →STK PRINT UNITS FONT UP
```

Viewing a Constant

Browse through the list to find the desired constant, or use the search mode. (For more information, refer to "Using the Search Mode" in Chapter 1.) When you have found the desired constant, press [ENTER] to display the constant description and value on a full screen, [→STK] to copy the value to the stack, or [PRINT] to print the value on an IR printer.

Example: Look up the value of the Stefan-Boltzmann constant. Type [α] [→] S [ENTER] to search for the letter σ. Then press [ENTER] to view the value:

```
   Constant Library
σ   Stefan-Boltzmann
      5.67032E-8

PRESS [ENTER] TO RETURN TO LIST...
```

When you have finished viewing the value, press [ENTER] or [ATTN] to return to the Constant Library. When you have finished browsing the Constant Library, press [UP] or [MAIN] to return to the Main menu, or [ATTN] to quit the Physics Pac.

Summary of Operations

Screen	Softkeys
Constant Library	[MAIN] [→STK] [PRINT] [UNITS] [FONT] [UP]

Key	Action
[FONT]	Toggles between the small and large fonts.
[MAIN]	Returns to the Main menu.
[PRINT]	Prompts for [ONE] or [ALL] to select items, and then sends those items to an IR printer.
[→STK]	Prompts for [ONE] or [ALL] to select items, and then copies those items to the stack. The items are placed in a list if [ALL] was chosen.
[UNITS]	Pressing this key toggles units, stripping units from or appending units to all values.
[UP]	Moves up one level in the menu structure, returning to the Main menu.

ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Displays the screen title, the constant label, and the constant value, all expanded to one screen.
ON–MTH	Dumps the current screen to an IR printer.
↱ VISIT	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Chapter 3

Equation Library

This chapter introduces you to the power and flexibility of the Equation Library with several examples. The contents of the Equation Library (over 250 equations in 11 categories) are described in detail in Appendix C, "Equation Library Reference."

This chapter covers:

- ❑ Using the Equation Library
- ❑ Categories Screen
- ❑ Topics Screen
- ❑ Equations Screen
- ❑ Variables Screen
- ❑ Solver Screen
- ❑ Plotting Equations
- ❑ Managing Units and Solving
- ❑ What Does Multiple Equation Solver Mean?
- ❑ Using a Guess to Speed Computing Time
- ❑ "Bad Guess(es)" Message

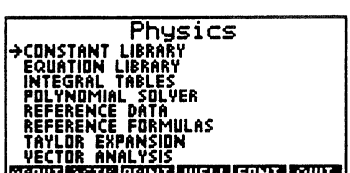
Using the Equation Library

To get to the Equation Library, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **PHYS** to enter the Physics Pac library directory.

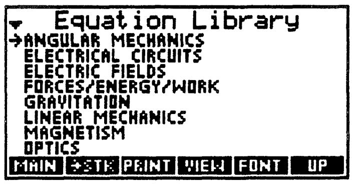
❸ Press the first softkey, **PHYS**, to start the Physics Pac:



Categories Screen

The categories screen lists the categories in the Equation Library. Each category includes a number of topics.

Example: Calculate the horizontal range of a cannon aimed 45° above the horizontal that emits cannonballs with velocities of 250_ft/s. The first step in solving this problem is to enter the Equation Library. To do this, make sure the pointer is at "Equation Library" and press ENTER. The categories screen appears:



This screen shows the eleven categories of equations in the Physics Pac.

Summary of Operations

Screen	Softkeys
Categories Screen	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure, returning to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Physics Pac to the HP 48SX stack.

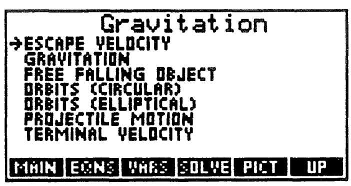
ENTER	Displays the topics screen for the category selected by the pointer.
ON–MTH	Dumps the current screen to an IR printer.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Topics Screen

The topics screen lists the topics for the current category. Each topic includes an equation or set of equations, a list of variables and descriptions, a set of default units for the equation variables, and (usually) a picture illustrating the topic.

Example (cont.): Select the category of Gravitation. To do this, make sure the pointer is at "Gravitation" and press ENTER. The topics screen for Gravitation appears:



This screen shows the seven topics of equations in the Gravitation category. A topic is selected by moving the pointer to the desired topic and pressing ENTER

Summary of Operations

Screen	Softkeys
Topics Screen	MAIN EQNS VARS SOLVE PICT UP MAIN →STK PRINT SOLVE FONT UP

Key	Action
EQNS	Displays the equations screen for the topic selected by the pointer.
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.

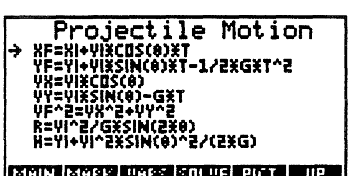
PICT	Displays the picture for the topic selected by the pointer, if one exists.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
SOLVE	Displays the solver screen for the topic selected by the pointer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure, returning to the categories screen.
VARS	Displays the variable screen for the topic selected by the pointer, including descriptions and default units.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Displays the equations screen for the topic selected by the pointer.
⮫ VISIT	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ON–MTH	Dumps the current screen to an IR printer.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Equations Screen

The equations screen displays the equation or set of equations for the current topic.

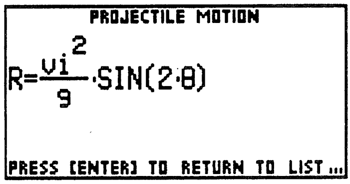
Example (cont.): Select the topic of Projectile Motion. To do this, make sure the pointer is at "Projectile Motion" and press ENTER or EQNS. The equations screen appears:



This screen shows the seven equations that describe projectile motion.

Marking an Equation

Example (cont.): Select the equation necessary to solve the problem. Since the problem asks only for the range, it makes sense to solve only the sixth equation. To view that equation in EquationWriter format, move the pointer to the sixth equation and press ENTER:



When you have finished viewing the equation, press ENTER or ATTN to return to the equations screen. Press MARK to mark the sixth equation. Observe that after marking the equation, the pointer is automatically incremented one location for convenience:

All further operations will involve only the marked subset of equations (in this case, the sixth equation).

Solving Multiple Equations

Just as a single equation can be selected by marking it, so can multiple equations be marked. The most common method of solving is to simply solve *all* of the equations by marking none (or all) of them and pressing SOLVE. The advantage of solving all of the equations at once is that you do not need to know which equations are necessary to solve a problem. The disadvantage of solving all of the equations at once is that many more variables will be solved for than those which interest you, unless you make use of the wanted feature. (For more information about the wanted feature, refer below to "Solver Screen.")

Summary of Operations

Screen	Softkeys					
Equations Screen	MAIN	MARK	VARS	SOLVE	PICT	UP
	MAIN	→STK	PRINT	SOLVE	FONT	UP
	MAIN	EQWR	PLOT	SOLVE	FONT	UP

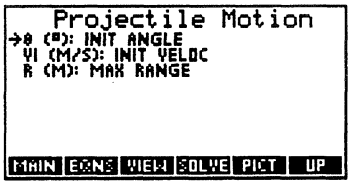
Key	Action
EQWR	Displays equation selected by pointer in the EquationWriter.
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
MARK	Toggles the equation selected by the pointer between marked and unmarked status, adding or removing a triangular tag. Only variables in the marked set of equations will appear in the solver and variable screens.
PICT	Displays the picture for the current topic, if one exists.
PLOT	Plots the equation selected by the pointer, prompting for x-axis and y-axis values. Plotting is only allowed for equations of the form $y = f(a,b,\ldots)$, and all but one of the variables on the right-hand side of the equation must be held constant (i.e., known).
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
SOLVE	Displays the solver screen for the current topic.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure, returning to the topics screen.
VARS	Displays the variable screen for the current topic, including descriptions and default units.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Displays equation selected by pointer in the EquationWriter.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Variables Screen

The variables screen displays the variables for the current topic. Only variables used by the marked set of equations are displayed. (All variables are shown if no equations are marked.)

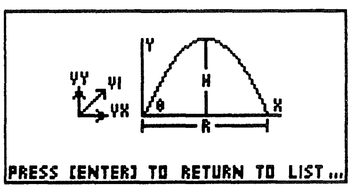
Example (cont.): Before solving the marked equation, bring up the variable screen to verify that the range is a variable in the equation. To do this, press VARS. The variables screen appears:



This screen shows the names, descriptions, and default units for all of the variables used by the marked equations (in this case, the sixth equation).

Viewing the Picture

Example (cont.): View the Projectile Motion picture. To do this, press PICT:



Note the location of R, the range. When you have finished viewing the picture, press ENTER or ATTN to return to the variables screen.

You can view the picture for the current topic from the topics, equations, variables, or solver screen. However, not all topics have associated pictures.

Summary of Operations

Screen	Softkeys					
Variables Screen	MAIN MAIN	EQNS →STK	VIEW PRINT	SOLVE SOLVE	PICT FONT	UP UP

Key	Action
EQNS	Displays the equations screen for the current topic.
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PICT	Displays the picture for the current topic, if one exists.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
SOLVE	Displays the solver screen for the current topic.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure, returning to the categories screen.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Displays the topic, the variable name (with default units), and the full description, for the variable selected by the pointer, all expanded to one screen.
ON–MTH	Dumps the current screen to an IR printer.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Solver Screen

The solver screen displays the values of equation variables for the current topic, and allows you to change variable values, convert values, purge variables, and solve for unknown variables.

Example (cont.): Solve the equation. To do this, press SOLVE. The solver screen is displayed:

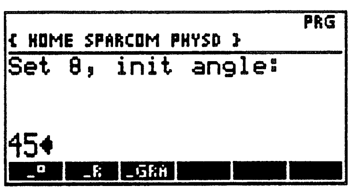
This screen shows the names and values of all the variables used by the marked equation(s).

Turning Units On

Example (cont.): By default, no units are present, so turn them on. To do this, press ⬅ PREV UNITS. The solver screen will reappear, with the default units shown next to the variable values:

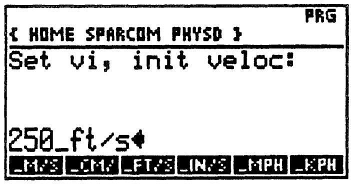
Entering Values

Example (cont.): Set the value of θ to 45_°. Make sure the pointer is at "θ" and press ENTER. Type 45 as your input:



Press ENTER to accept the value (default units of ° will be assumed) and return to the solver screen:

The triangular tag next to θ indicates that the value is user-defined, or known. Observe that after entering a value, the pointer is automatically incremented one location for convenience, so that more than one value can easily be entered. Since the pointer is now pointing to VI, press ENTER to enter 250_ft/s for VI. Type 250 and press the 3rd softkey as your input:



Press ENTER to accept the value and return to the solver screen:

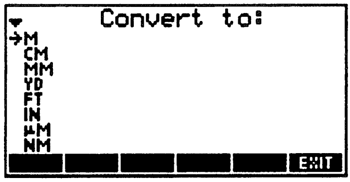
Solving for Unknowns

Example (cont.): Press CALC to solve for R, the range. You will see a message describing the equation being solved. Then, the calculated value will be displayed, and the solver screen will reappear:

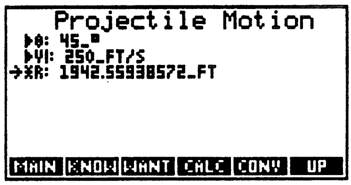
The asterisk tag next to R indicates that its value was just found in the last calculation.

Converting a Value

Example (cont.): The value for R was returned in the default SI units of meters. Convert the value to feet. To do this, make sure the pointer is at "R" and press NXT CONV:



This is a list of all the dimensionally consistent units to which you can convert the value of R. Move the pointer down to FT and press ENTER. The value will be converted and the solver screen will reappear:



This is the answer to the first example problem.

Copying a Result to the Stack

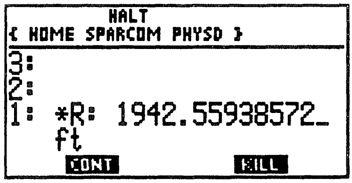
Example (cont.): Copy the final result to the stack. To do this, make sure the pointer is at "R" and press NXT NXT →STK:

Press ONE to copy only the value of R to the stack, tagged with the variable name. (Pressing ALL would copy all variable values to the stack in a list.) When you quit the Physics Pac later, the value(s) will be present on the stack.

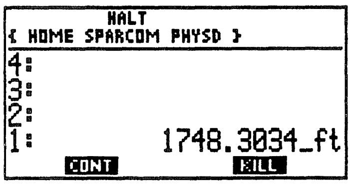
Using the Stack for Calculations

Example (cont.): Calculate the angle required to send the cannonball only 90% as far, given the same initial velocity. The first step in solving this related problem is to calculate 90% of the last result. Because this calculation cannot be done inside the Physics Pac, it will be done with the help of the HP 48SX stack.

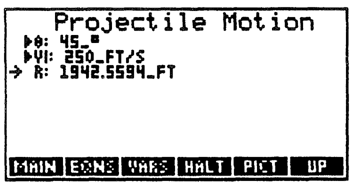
Press ← PREV HALT to temporarily suspend execution of the Physics Pac and exit to the stack:



Note the result previously copied to the stack. Type 0.9 [×] to calculate 90% of that value. (The tag will automatically be removed.) While you are at the stack, you can also perform other operations, such as changing the display notation. Change it to FIX 4 by typing 4 [SPC] [α] [α] FIX [ENTER]:



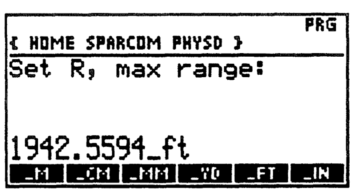
Press CONT or [←] [CONT] to return to the Physics Pac:



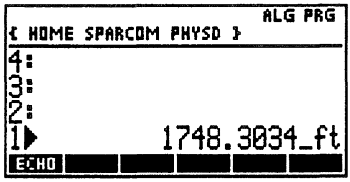
Note that the display precision has changed, as desired.

Loading a Value from the Stack

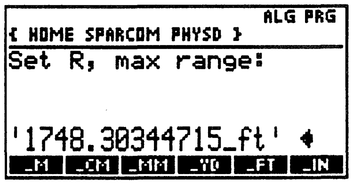
Example (cont.): Load the 90% distance from the stack. To do this, make sure the pointer is at "R" and press [ENTER]. The previous value appears:



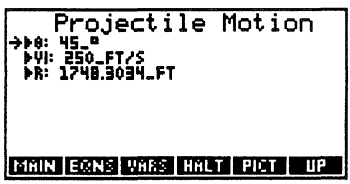
Press [ATTN] to clear the command line. Press [▲] to activate the Interactive Stack:



Press ECHO to copy the value in stack level 1 onto the command line. Then press ENTER or ATTN to exit the Interactive Stack and return to the command line:

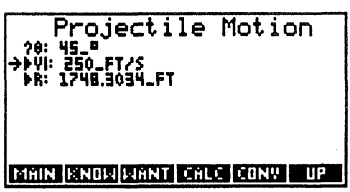


Press ENTER to accept the value and return to the solver screen:



Using the Wanted Feature

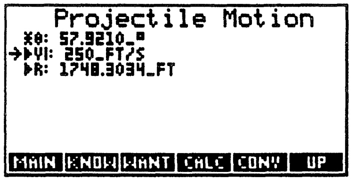
Example (cont.): Mark θ as wanted. To do this, make sure the pointer is at "θ" and press ⬅ PREV WANT:



The question tag next to θ indicates that the value is user-desired, or wanted.

Solving for Unknowns

Example (cont.): Press CALC to solve for θ, the angle. You will see a message describing the equation being solved. Then, the calculated value will be displayed, and the solver screen will reappear:



The asterisk tag next to θ indicates that its value was just found in the last calculation.

This is the answer to the related problem.

Known Variables

Pressing KNOW toggles a variable between known (user-specified) and unknown. When a value is entered into a variable, it is automatically marked as known.

Wanted Variables

Pressing WANT toggles a variable between wanted (user-desired) and unwanted. If no variables are marked as wanted, pressing CALC will cause the solver to systematically search through all the equations, solving for all possible variables. However, if one or more variables are marked as wanted, then the solver will terminate immediately upon finding values for all of the wanted variables. (For more information, refer below to "What Does Multiple Equation Solver Mean?")

Clearing Variables

Pressing CLEAR resets values of all current variables to zero, but does not change the global copies in the 'PHYSD' directory.

Purging Variables

Pressing PURG purges the global copies in the 'PHYSD' directory of the current variables, but does not change the values currently stored inside the Physics Pac.

Summary of Operations

Screen	Softkeys					
Solver Screen	MAIN	KNOW	WANT	CALC	CONV	UP
	MAIN	EQNS	VARS	HALT	PICT	UP
	MAIN	→STK	PRINT	CALC	FONT	UP
	MAIN	CLEAR	PURG	CALC	UNITS	UP

Key	Action
CALC	Stores variables values and systematically iterates through the set of marked equations in an attempt to find values for all wanted variables. Also, stores the known and found values into global variables in the 'PHYSD' directory.
CLEAR	Resets values of all current variables to zero, but does not change the global copies, which are only affected by CALC and PURG operations.
CONV	Converts a variable to different units, if units are on.
EQNS	Displays the equations screen for the current topic.
FONT	Toggles between the small and large fonts.
HALT	Halts the Physics Pac so that operations can be performed on the HP 48SX stack. Pressing CONT or ⬅ CONT returns to the Physics Pac, while pressing KILL terminates the Physics Pac.
KNOW	Toggles the variable selected by the pointer between known and unknown status, adding or removing a triangular tag.
MAIN	Returns to the Main menu.
PICT	Displays the picture for the current topic, if one exists.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
PURG	Purges the global copies (in the 'PHYSD' directory) of the current set of variables, but does not change the values currently stored inside the Physics Pac.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UNIT	Indicates that units are currently turned on. Pressing this key turns off units, automatically converting all variable values to SI units and then stripping the units.
UNITS	Indicates that units are currently turned off. Pressing this key turns on units, automatically appending standard SI units to the values.
UP	Moves up one level in the menu structure, returning to the topics screen.
VARS	Displays the variable screen for the current topic, including descriptions and default units.

WANT	Toggles the variable selected by the pointer between wanted and unwanted status, adding or removing a question tag.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Prompts for a value for the variable selected by the pointer.
ON – MTH	Dumps the current screen to an IR printer.
⮫ VISIT	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Plotting Equations

Each equation in the Equation Library can be plotted in one of two ways:

❶ *Without* the help of the Physics Pac. This procedure is recommended only if you are familiar with variable manipulation and the Plot application of your HP 48SX. (For more information, refer to Chapter 18 of the HP 48SX Owner's Manual, "Basic Plotting and Function Analysis.")

① Copy the desired equation to the stack and quit the Physics Pac.

② Store the equation on the stack into 'EQ' and plot it with the HP 48SX Plot application.

③ Use the HP 48SX Graphics environment to analyze the resulting plot.

❷ *With* the help of the Physics Pac. This procedure provides an easy way to plot equations, as well as a simple method for overlaying multiple plots of an equation.

① (Optional) At the equations screen, mark the desired equation.

② At the solver screen, enter values for (or mark as known) all but the independent and dependent variables in the desired equation. (The advantage of performing step ① is that only the variables in the desired equation will appear at the solver screen.)

③ At the equations screen, move the pointer to the desired equation and press PLOT. (Important: The equation that will be plotted is the one selected by the pointer, regardless of which equations are marked.)

④ Enter the X range for the plot, and either auto-scale or enter the Y range.

⑤ Use the HP 48SX Graphics environment to analyze the resulting plot.

⑥ (Optional) Return to the solver screen and change the values of one or more known variables in the desired equation. Then plot the equation again, without clearing PICT, to create an overlay.

Preparing to Plot

Example (cont.): Plot the variation of cannonball range, R, as a function of the cannon angle, θ. For this problem, θ is the independent variable and R is the dependent variable. For the plot to work correctly, R must be unmarked as known. To do this, make sure the pointer is at "R" and press KNOW to unmark R as known:

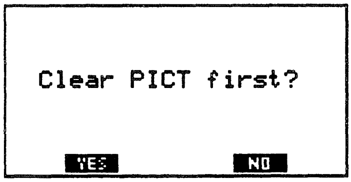
Note that the triangular tag next to R has disappeared. The fact that θ is marked as found does not matter.

Turning Units Off

Example (cont.): Plotting an equation proceeds faster if units are turned off. To do this, press ⬅ PREV UNITS. The solver screen will reappear, with the values converted to default SI units (For more information, refer below to "Managing Units and Solving."):

Plotting an Equation

Example (cont.): Plot the equation. To do this, press NXT NXT EQNS to display the equations screen. Make sure the pointer is at the sixth equation and press NXT NXT PLOT. This prompt appears:



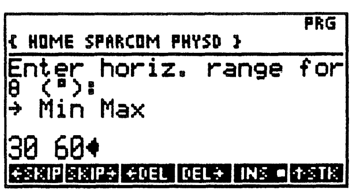
Pressing **NO** would leave PICT intact so that the current plot would be overlaid on previous plots. For this example, press **YES**, to erase PICT and create a new plot. The following prompt appears:

Entering Ranges

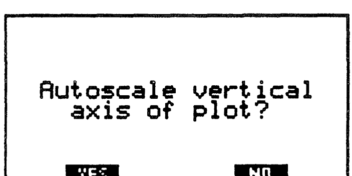
You must specify the range for the X axis, the axis of the independent variable. You must enter both a minimum and maximum value.

> **<u>NOTE</u>: Ranges cannot be entered as unit objects. If units are off, the values you enter are assumed to be in SI units, whereas if units are on, the values are assumed to be in the units of the independent variable, as indicated in the prompt.**

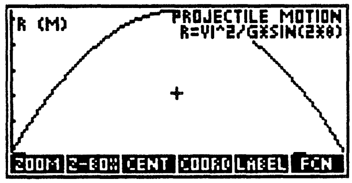
Example (cont.): Vary θ from 30° to 60°. To do this, type 30 [SPC] 60 as your input:



Press [ENTER] to accept those values and continue. The following prompt appears:



Pressing **NO** would allow you to enter a minimum and maximum value for the Y axis, the axis of the dependent variable. For this example, press **YES**, to autoscale the Y axis. The plot appears:



The equation has been plotted and the HP 48SX Graphics environment invoked. If you wish, you can now analyze the plot. (For more information, refer below to "Graphics Environment.") When you have finished, press [ATTN] to return to the equations screen.

Creating an Overlay Plot

Example (cont.): If you wish, you could now return to the solver screen, change the value of the initial velocity, VI, and plot the equation again without clearing PICT, to see how the curve varies for a different initial velocity.

This concludes the example. You may quit the Physics Pac by pressing [ATTN].

Graphics Environment

The HP 48SX Graphics environment provides extremely useful functions for graphically analyzing functions. Explaining in detail the functionality of the Graphics environment is beyond the scope of this manual, but the behavior of selected, useful softkeys at the Graphics environment and the Function menu is explained below. (For more information, refer to Chapter 18 of the HP 48SX Owner's Manual, "Basic Plotting and Function Analysis.")

WARNING: The SLOPE and F' functions only work correctly when a plot is made with units turned off, because the HP 48SX cannot take derivatives of expressions whose variables contain unit objects.

Summary of Operations

Screen	Softkeys					
Graphics Environment	ZOOM	Z-BOX	CENT	COORD	LABEL	FCN
	DOT+	DOT-	LINE	TLINE	BOX	FIRCL
	MARK	REPL	SUB	DEL	+ -	KEYS
Function Menu	ROOT	ISECT	SLOPE	AREA	EXTR	EXIT
	F(X)	F'	NXEQ			

Key	Action
AREA	Displays the area under the function defined by the X axis value of the mark and cursor.
COORD	Displays the coordinates of the cursor position.
F(X)	Displays the function value at the X axis value of the cursor, and moves the cursor to that point on the function.
F'	Plots the first derivative the current function.
FCN	Displays the Function menu for further analysis.
MARK	Places a mark (X) at the cursor location.
ROOT	Moves the cursor to the nearest root and displays the coordinate of the root.
SLOPE	Displays the slope of the function at the X axis value of the cursor, and moves the cursor to the point on the function at which the slope was calculated.
SUB	Copies the rectangle bounded by the mark and the cursor location to the stack as a graphics object (GROB).
▲ ▼ ◄ ►	Moves the cursor in the indicated direction. When prefixed with ↱, moves the cursor to the edge of the screen in the indicated direction.
ATTN	Exits the plot and returns to the equations screen.
↰ REVIEW	Temporarily displays the plot status menu, including the axis ranges, until REVIEW is released.
STO	Copies PICT to the stack as a graphics object (GROB).
ON – MTH	Dumps the current screen to an IR printer.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Managing Units and Plotting

The plotter can work either with units or without units. In general, plotting works much faster when units are off, but you may want to work with units in order to have plot axes in the desired units. There are several important points to the behavior of the unit manager as it relates to the plotter that you should understand:

❶ When units are on, X and Y axis range values are entered in the units of the independent and dependent variables, as set at the solver screen. For example, to enter 0_cm to 3_cm as the X axis range, set the units of the independent variable to cm at the solver screen, toggle the variable back to unknown by pressing KNOW, and later enter 0 SPC 3 at the X axis range prompt.

❷ When units are off, X and Y axis range values are entered in the default SI units of the independent and dependent variables. For example, to enter 0_cm to 3_cm as the X axis range, type 0 SPC .03 at the prompt, since the default units for the independent variable will be meters.

❸ Plotting with units may take up to 10 times as long as plotting without units. Therefore, in cases where only the qualitative shape of the plot is important, you should plot without units to get results more quickly. In cases where the Graphics environment will be utilized to analyze a plot, it may be necessary to plot with units, so that the coordinates are in the desired units. (The coordinates will always be in default SI units for plots done with units off, and this may be inconvenient in some cases.)

❹ When plotting with units, the SLOPE and F' functions may not work correctly, because the HP 48SX cannot take derivatives of expressions whose variables contain unit objects.

❺ When plotting with units, unsimplified units may occasionally appear on the Y axis variable. For example, if you were to plot the equation used in the example throughout this chapter, but with units turned on, you would notice that the Y axis maximum value was at $6373.2263\_\text{ft}^2/\text{m}$, rather than the simplified value of 592.0921_m. This is a side-effect of the fact that VI has units of ft, while the constant g has units of m/s^2. This problem can be circumvented by plotting with units off.

Managing Units and Solving

The solver can work either with units or without units. In general, solving works much faster when units are off, but you may want to work with units in order to view answers in the desired units. There are several important points to the behavior of the unit manager as it relates to the solver that you should understand:

❶ When units are on, values can be entered in any unit, as chosen from the menu presented at the entry screen. The default SI unit is always the first softkey, and entering a value without appending a unit will cause the default SI unit to be appended.

❷ When units are off, all values are considered to be SI units, so that equations can be solved without yielding inaccurate results. If a value is entered with a unit from the entry screen, the value is automatically converted to the default SI units, and then the unit is stripped. Thus, if units are off, and 2_cm is entered for a variable, you will see .02 at the solver screen, because the value has been automatically converted to meters.

❸ When units are on, the units of a desired or wanted variable can be specified in advance. Simply enter a value in the desired units into the variable. Then press KNOW to toggle the variable back to an unknown state, or press WANT to mark the variable as wanted. Then press CALC to solve for the variable; the answer will be returned in the specified units. The alternative to this process is to press CONV to convert the found value to the desired units after the solving operation has been completed.

❹ When CALC is pressed, all the values in the variables are stored in global copies of the variables, inside the 'PHYSD' directory. Therefore, after many uses of the Physics Pac, you may begin to notice that variables already seem to contain values when you solve equations. This is normal—the Physics Pac is automatically loading in the existing values from the global variables for convenience, as long as the units are dimensionally consistent with the units required for the variable.

Since solving with units takes a noticeably longer time, the following procedure is recommended to yield the quickest results. Start with units off, and enter all known values in the correct units by making use of the automatic conversion feature. All of the values will be converted to consistent unitless SI values. Then, solve for the desired variable(s). After the solver has completed, turn units on, to append SI units to all variables. Then, select the desired variable(s), and press CONV to convert them to the final units. This procedure gives the best of both worlds: no units for fast solving, but units for convenient results.

What Does Multiple Equation Solver Mean?

The Sparcom multiple equation solver is a *systematic* solver, not a *simultaneous* one. For example, it can solve this set of equations, provided it is given a user-specified value of either x or y:

$$x + y + z = 5$$
$$x + y = 3$$

However, it cannot solve this set of equations, when neither x or y is known in advance:

$$x + y = 2$$
$$x - y = 0$$

The solver iterates through a set of equations, searching for an equation with only one unknown variable. When an equation satisfying this requirement is found, it utilizes the HP 48SX root-finder (programmable command ROOT) to solve for the unknown variable. After the value is found, that variable is marked as found, and the solver continues to search. The solver does not terminate its search until one of four conditions occurs:

❶ All equations are solved, and all variables found.

❷ All wanted variables are found.

❸ No more equations can be solved, because all remaining unsolved equations have more than one unknown variable.

❹ A solving error occurs, such as Divide By Zero or Bad Guess(es).

All variables for which values are found in a solving operation are marked with an asterisk tag at the solver screen. If a variable is not marked with an asterisk, then it was either not marked as wanted, or a value for it was not found because of too many unknowns.

Using a Guess to Speed Computing Time

Pressing CALC activates the HP 48SX root-finder to calculate the solution(s). The root-finder requires an initial value on which to base its search. You can provide a guess for the HP 48SX to use; if you do not do so, the solver will supply a guess of 1. The root-finder then generates pairs of intermediate values and interpolates between them to find the solution. The time required to find the root depends on how close the initial guess is to the actual solution.

You can speed up computing time by providing a guess close to the expected solution. At the solver screen, enter your guess into the variable. Upon returning to the solver screen, the variable will be marked as known; press KNOW to toggle the variable back to unknown. Then press CALC, and the HP 48SX will use the stored value for the variable as its initial starting point. (For more information, refer to Chapter 17 of the HP 48SX Owner's Manual, "The HP Solve Application.")

"Bad Guess(es)" Message

If the HP 48SX displays the "Bad Guess(es)" message at some point after you press the CALC softkey, it indicates an error has been made in setting up the problem. Go back through the setup process and check for error in specifying data, such as a variable value which causes a zero in the denominator of a fraction. (For more information, refer to Chapter 17 of the HP 48SX Owner's Manual, "The HP Solve Application.")

Chapter 4

Integral Tables

The Integral Tables include nearly 100 integrals organized in six sections for quick reference: user-defined, rational, irrational, trigonometric/hyperbolic, exponential/logarithmic, and definite. You can add as many integrals as you wish to the user-defined section.

This chapter covers:

- ❑ Using the Integral Tables
- ❑ Choosing a Section
- ❑ Solving an Integral
- ❑ User-Defined Integrals

Using the Integral Tables

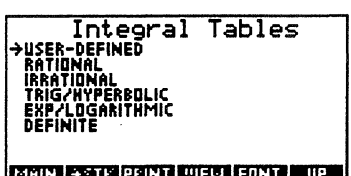
To get to the Integral Tables, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press PHYS to enter the Physics Pac library directory.

❸ Press the first softkey, PHYS, to start the Physics Pac.

❹ At the Main menu, make sure the pointer is at "Integral Tables" and press [ENTER]:



Items in Integral Tables

Each item in Integral Tables is briefly described below and is discussed in detail in the various sections of this chapter.

Item	Description
User-Defined	User-defined indefinite and definite integrals.
Rational	Indefinite integrals involving rational arguments.
Irrational	Indefinite integrals involving irrational arguments.
Trig/Hyperbolic	Indefinite integrals involving trig/hyp arguments.
Exp/Logarithmic	Indefinite integrals involving exp/log arguments.
Definite	Definite integrals.

Summary of Operations

Screen	Softkeys					
Integral Tables	MAIN	→STK	PRINT	VIEW	FONT	UP

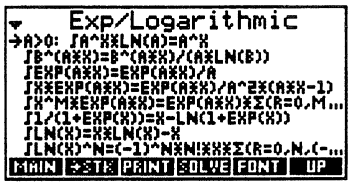
Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack.
UP	Moves up one level in the menu structure, returning to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Moves down one level in the menu structure, entering the selected integral section.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Choosing a Section

Each of the six sections of integrals contains a group of related integrals. Each integral can be displayed in EquationWriter or text format, copied to the stack, or solved, indefinitely or definitely. You can also search for a specific integral using the search mode. (For more information, refer to Chapter 1, "Using the Search Mode.") The user-defined integral section behaves identically to all other sections, once you have entered your own integrals.

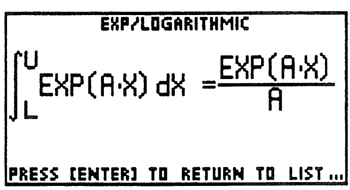
Example: Investigate the section of integrals with forms containing exponentials. To do this, make sure the pointer is at "Exp/Logarithmic" and press [ENTER]:



This particular section contains thirteen integrals.

Viewing an Integral

Example (cont.): View the third integral in this section in EquationWriter format. To do this, make sure the pointer is at the third equation and press [ENTER]. After a brief delay, the integral will be displayed in EquationWriter format:



When you have finished viewing the integral, press [ENTER] or [ATTN] to return to the list. Many integrals are too large for the screen, and will be displayed with the cursor keys activated for scrolling purposes.

WARNING: While the HP 48SX is building the EquationWriter format version of an integral, key presses by the user will cause strange behavior, resulting in no display of the equation. Therefore, do not press any keys until the integral has been drawn, erased, and re-drawn with the accompanying messages. If you change your mind during a long integral build, press [ATTN] to abort the build process and return to the integral screen.

Summary of Operations

Screen	Softkeys
Integral Section	MAIN -STK PRINT SOLVE FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
SOLVE	Solves the integral selected by the pointer.
-STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure, returning to the Main menu.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Displays the integral selected by the pointer in the EquationWriter.
ON–MTH	Dumps the current screen to an IR printer.
⮫ VISIT	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Solving an Integral

The integral solving process is one of substitution and algebraic simplification.

Example (cont.): To solve the third integral, make sure the pointer is at it and press SOLVE.

Selecting Indefinite or Definite

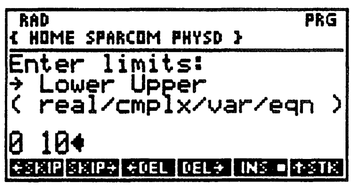
The first step in solving an integral is choosing the type of integration to perform. You can do either definite or indefinite integrations. If you choose to perform an indefinite integration, then a constant of integration will be added to the final result.

Example (cont.): Perform a definite integration by pressing DEFIN.

Entering Limits of Integration

If you choose to perform a definite integration, you will be prompted to enter limits of integration. Limits can either be real numbers, names (variables), or algebraic expressions. This means you can integrate from 0 to 1, or from A to B, or even from $\sin(t)$ to $\cos(t+u)$, provided that none of the variables used in the limits are identical to the variable of integration, always X.

Example (cont.): Integrate from 0 to 10. Type 0 [SPC] 10:



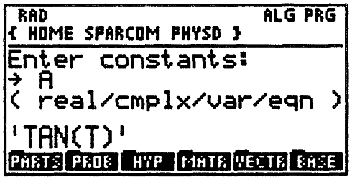
Press [ENTER] to accept those limits of integration.

> **NOTE: Be sure to enclose *algebraic* limits within tic marks (').**

Entering Values of Constants

When solving an integral (either indefinitely or definitely), you must specify values for all the unknown constants in the integral. This does *not* include the variable of integration, for which you do not enter a value. These constants must be constant with respect to the variable of integration, X. Like the limits of integration, the constants can either be real numbers, names (variables), or algebraic expressions.

Example (cont.): Set the value of A to $\tan(\mathrm{T})$, where T is a constant. Type ['] [TAN] [α] T:



Press ENTER to accept that constant value.

> **NOTE: If you wish to enter a name (variable) as a limit or a constant, the tic marks surrounding the name are optional. For example, T can be entered as 'T' or T.**

Viewing the Result

After the limits and constants have been specified, the integration will be performed and the desired result displayed:

The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press UP to return to the integral section list, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Simplifying the Result

To simplify the result of an integration, follow these steps:

1. Press →STK and then ONE to copy the result to the stack.
2. Press ATTN to quit the Physics Pac.
3. Press ⬅ LIBRARY to display all libraries available to your HP 48SX.
4. Find and press PHYS to enter the Physics Pac library directory.
5. Press the fifth softkey, SIMPL, to simplify the expression.

(For more information, refer to "Miscellaneous Commands" in Chapter 10.)

Summary of Operations

Screen	Softkeys
Result Screen	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure, returning to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Displays the result in the EquationWriter.
ON–MTH	Dumps the current screen to an IR printer.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

User-Defined Integrals

To add an integral to the user-defined section of the Integral Tables, follow these steps:

❶ Go to the HP 48SX stack.

Example: Press ATTN to quit the Physics Pac.

❷ Enter or recall the integral you wish to store to level 1 of the stack. The syntax of the integral must satisfy the following conditions:

① The integral must be an algebraic expression. It can therefore be entered by way of the HP 48SX EquationWriter and left on the stack.

(For more information, refer to Chapter 16 of the HP 48SX Owner's Manual, "The EquationWriter Application.") The algebraic expression must include an equal sign with an integral on the left and an arbitrary expression on the right, which is the solution of the integral.

> **NOTE: The Physics Pac does not *solve* arbitrary integrals—it merely stores them for reference and provides substitution and evaluation help (refer above to "Solving an Integral"). When entering a new user-defined integral, you must derive or look up the solution to the integral and specify it as a part of the algebraic expression.**

② The variable of integration should be an uppercase X. If the variable of integration of the integral on level 1 is *not* X, INDEF or DEFIN will automatically convert the variable of integration to X during the store process, but problems will result if X appears elsewhere in the original integral.

③ The HP 48SX will always require you to enter limits of integration for a valid algebraic integral, but these limits will be ignored if you choose to store the integral in an indefinite form (see below).

④ If you want the integral to appear with a constraint label (such as $a \neq 1$), then you should enter the integral as an algebraic, enter the constraint label as a string, and then press [PRG] OBJ →TAG to tag the integral with the string.

Example (cont.): To enter the indefinite integral $\int \cos(x)dx = \sin(x)$, press [←] [EQUATION] [→] [∫] 0 [►] 0 [►] [COS] [α] X [►] [►] [α] X [←] [=] [SIN] [α] X [ENTER]. Note that the HP-48SX requires limits, but since the integral will be stored indefinitely, they will be ignored. To place a constraint label on this integral, type [→] [""] [α] [α] TEST [ENTER] [PRG] OBJ →TAG. After these operations, a tagged integral will be in level 1.

❸ To store the integral in an indefinite form (thus ignoring the limits of integration), press INDEF, or to store in a definite form (thus preserving the limits of integration), press DEFIN.

Example (cont.): Press [←] [LIBRARY] PHYS INDEF to store the integral indefinitely. It will now be accessible from the Integral Tables.

(For more information, refer to "User-Defined Integral Commands" in Chapter 10.)

Chapter 5

Polynomial Solver

The Polynomial Solver handles arbitrary orders of polynomials with real or complex coefficients.

This chapter covers:

- ❑ Using the Polynomial Solver
- ❑ Solving a Polynomial

Using the Polynomial Solver

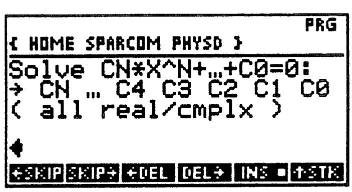
To get to the Polynomial Solver, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press PHYS to enter the Physics Pac library directory.

❸ Press the first softkey, PHYS, to start the Physics Pac.

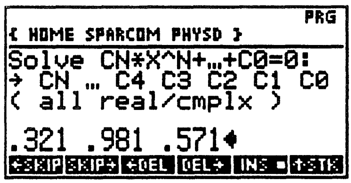
❹ At the Main menu, make sure the pointer is at "Polynomial Solver" and press [ENTER]:



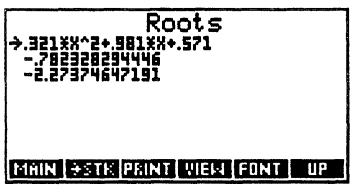
Solving a Polynomial

The Polynomial Solver takes as input a series of real or complex coefficients of a polynomial expression, and returns all roots—both real and complex—of that polynomial.

Example: Calculate the roots of $0.321x^2 + 0.981x + 0.571$. Type in .321 [SPC] .981 [SPC] .571 as your input:



Press [ENTER] to calculate the roots, and they will appear:



The first item is the polynomial that was solved, and the remaining items are the roots of that polynomial. The polynomial can be viewed in the EquationWriter by selecting it with the pointer and pressing [ENTER], and all of the items can be copied to the stack or printed on an IR printer. When you have finished viewing the results, press UP or MAIN to return to the Main menu, or [ATTN] to quit the Physics Pac.

Summary of Operations

Screen	Softkeys
Result Screen	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.

→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure, returning to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Either views the polynomial in the EquationWriter or displays the root selected by the pointer expanded to a full screen.
ON–MTH	Dumps the current screen to an IR printer.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Chapter 6

Reference Data

Reference Data includes tables of the Greek alphabet, standard SI prefixes, and common solar system data for quick reference.

This chapter covers:

- ❑ Using Reference Data
- ❑ Greek Alphabet
- ❑ Solar System Data
- ❑ SI Prefixes

Using Reference Data

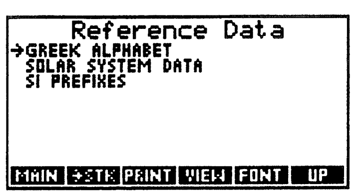
To get to Reference Data, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press PHYS to enter the Physics Pac library directory.

❸ Press the first softkey, PHYS, to start the Physics Pac.

❹ At the Main menu, make sure the pointer is at "Reference Data" and press [ENTER]:



Items in Reference Data

Each item in Reference Data is briefly described below and is discussed in detail in the various sections of this chapter.

Item	Description
Greek Alphabet	Uppercase and lowercase Greek letters.
Solar System Data	Commonly used solar system properties.
SI Prefixes	Commonly used SI prefixes.

Summary of Operations

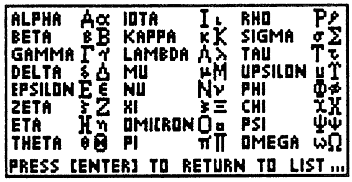
Screen	Softkeys
Reference Data	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure, returning to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
[ATTN]	Quits the Physics Pac to the HP 48SX stack.
[ENTER]	Displays the screen title, the item label, and the value, all expanded to one screen.
[ON]–[MTH]	Dumps the current screen to an IR printer.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Greek Alphabet

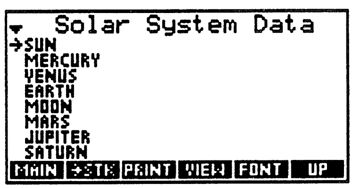
Upon choosing Greek Alphabet from Reference Data , the following screen appears:



This screen is a picture displaying representations of all of the uppercase and lowercase Greek letters. Many of these characters are available from the HP 48SX keyboard, but not all of them. To get a printed copy of this screen, press [ON]–[MTH]. Press [ENTER] or [ATTN] to return to Reference Data.

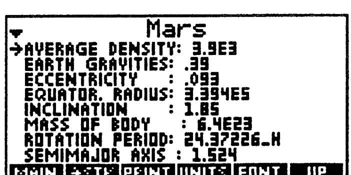
Solar System Data

Upon choosing Solar System Data from Reference Data, the following screen appears:



Browse through the list to find the desired planet and press [ENTER].

Example: Look up the properties of Mars. To do this, make sure the pointer is at "Mars" and press [ENTER]. The following screen appears:



Browse through this screen to find the desired property, or use the search mode. (For more information, refer to "Using the Search Mode" in Chapter 1.) When you have found the desired property, press [ENTER] to display the description and value on a full screen, →STK to copy the value to the stack, or PRINT to print the value on an IR printer.

When you have finished browsing the list, press UP to return to Reference Data, MAIN to return to the Main menu, or [ATTN] to quit the Physics Pac.

Summary of Operations

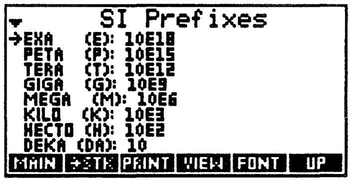
Screen	Softkeys
Solar System Data	MAIN →STK PRINT UNITS FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UNITS	Pressing this key toggles units, stripping or appending units to all values.
UP	Moves up one level in the menu structure, returning to Reference Data.
[ATTN]	Quits the Physics Pac to the HP 48SX stack.
[ENTER]	Displays the screen title, the item label, and the value, all expanded to one screen.
[ON]–[MTH]	Dumps the current screen to an IR printer.
[→] [VISIT]	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

SI Prefixes

Upon choosing SI Prefixes from Reference Data, the following screen appears:



Press ENTER to display a prefix and value on a full screen, press →STK to copy a prefix to the stack or PRINT to print a prefix on an IR printer.

When you have finished browsing the list, press UP to return to Reference Data, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Chapter 7

Reference Formulas

Reference Formulas includes over a hundred common formulas and pictures, including moments of inertia, object centroids, trigonometric, and hyperbolic functions, organized into five sections for quick reference.

This chapter covers:

- ❑ Using Reference Formulas
- ❑ Moments of Inertia
- ❑ Object Centroids
- ❑ Trig/Hyp Definitions
- ❑ Trig/Hyp Pictures
- ❑ Trig/Hyp Relations

Using Reference Formulas

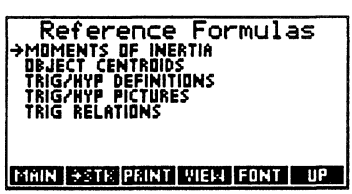
To get to Reference Formulas, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press [PHYS] to enter the Physics Pac library directory.

❸ Press the first softkey, [PHYS], to start the Physics Pac.

❹ At the Main menu, make sure the pointer is at "Reference Formulas" and press [ENTER]:



Items in Reference Formulas

Each item in Reference Formulas is briefly described below and is discussed in detail in the various sections of this chapter.

Item	Description
Moments of Inertia	Moments of inertia for various objects.
Object Centroids	Centroids of various objects.
Trig/Hyp Definitions	Definitions of the basic trigonometric and hyperbolic functions.
Trig/Hyp Pictures	Graphs of basic trigonometric/hyperbolic functions.
Trig Relations	Common trigonometric relations.

Summary of Operations

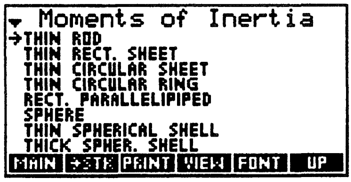
Screen	Softkeys
Reference Formulas	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure, returning to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Displays the screen title, the item label, and the equation, all expanded to one screen.

For a complete summary of operations, refer to Appendix B, "Summary of Operations."

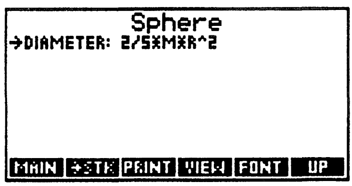
Moments of Inertia

Upon choosing Moments of Inertia from Reference Formulas, the following screen appears:



Browse through the list to find the desired object and press ENTER.

Example: Look up the moment of inertia of a sphere. To do this, make sure the pointer is at "Sphere" and press ENTER. The following screen appears:

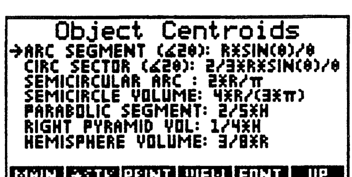


Press ENTER to display the moment of inertia in the EquationWriter, press →STK to copy the moment of inertia to the stack or PRINT to print the moment of inertia on an IR printer.

When you have finished viewing the moment of inertia, press UP to return to Moments of Inertia, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Object Centroids

Upon choosing Object Centroids from Reference Formulas, the following screen appears:

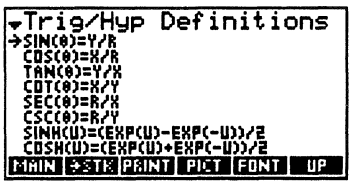


Browse through the list to find the desired object centroid. Press ENTER to display the centroid in the EquationWriter, press →STK to copy the centroid to the stack or PRINT to print the centroid on an IR printer.

When you have finished viewing the centroids, press UP to return to Reference Formulas, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Trig/Hyp Definitions

Upon choosing Trig/Hyp Definitions from Reference Formulas, the following screen appears:



Browse through the list to find the desired definition. Press ENTER to display the definition in the EquationWriter, press →STK to copy the definition to the stack or PRINT to print the definition on an IR printer. Press PICT to view an illustrative diagram.

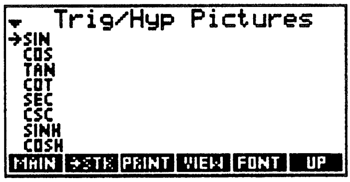
When you have finished viewing the definitions, press UP to return to Reference Formulas, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Using COT, SEC, CSC, etc.

The HP 48SX does not include the COT, SEC, CSC, ACOT, ASEC, ACSC, COTH, SECH, CSCH, ACOTH, ASECH, or ACSCH functions as commands, but the Physics Pac defines them to work correctly when used in algebraics or programs. For more information, refer to "Hyperbolic Commands" and "Trigonometric Commands" in Chapter 10.)

Trig/Hyp Pictures

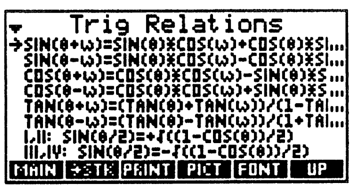
Upon choosing Trig/Hyp Pictures from Reference Formulas, the following screen appears:



Browse through the list to find the desired picture and press ENTER to view it. When you have finished viewing the picture, press ATTN or ENTER to return to the list, and then press UP to return to Reference Formulas, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Trig/Hyp Relations

Upon choosing Trig/Hyp Relations from Reference Formulas, the following screen appears:



Browse through the list to find the desired relation. Press ENTER to display the relation in the EquationWriter, press →STK to copy the relation to the stack or PRINT to print the relation on an IR printer. Press PICT to view an illustrative diagram.

When you have finished viewing the relations, press UP to return to Reference Formulas, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Chapter 8

Taylor Expansion

The Taylor Expansion performs expansions of arbitrary functions of arbitrary variables to arbitrary orders about arbitrary points. It expands the functionality of the HP 48SX built-in command TAYLR, which only performs MacLaurin expansions about zero.

This chapter covers:

- ❑ Using the Taylor Expansion
- ❑ Expanding a Function

Using the Taylor Expansion

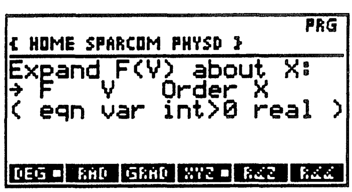
To get to Taylor Expansion, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press PHYS to enter the Physics Pac library directory.

❸ Press the first softkey, PHYS, to start the Physics Pac.

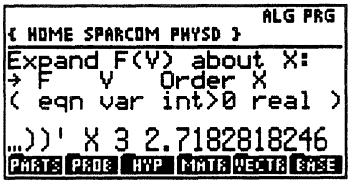
❹ At the Main menu, make sure the pointer is at "Taylor Expansion" and press [ENTER]:



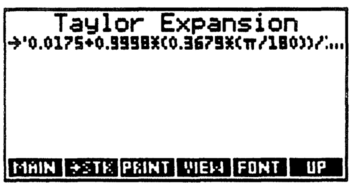
Expanding a Function

Taylor Expansion takes as input a function, an independent variable, an integer order to which to expand, and a real point about which to expand.

Example: Find the Taylor series of the function $\sin(\ln(x))$ about the point $x = e$ to the 3rd order. To do this, type in ['] [SIN] [→] [LN] [α] X [▶] [▶] [▶] [SPC] [α] X [SPC] 3 [SPC] 2.7182818246 as your input:



Press [ENTER] to calculate the specified Taylor expansion. After a delay, the result will appear:



The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press [UP] or [MAIN] to return to the Main menu, or [ATTN] to quit the Physics Pac.

> **NOTE: The setting of system flag –2 determines whether or not symbolic constants (e.g., π in the example) are manipulated numerically or symbolically. (For more information, refer to Chapter 9 of the HP 48SX Owner's Manual, "Common Math Functions.")**

Simplifying the Result

To simplify the result of a Taylor expansion, follow these steps:

❶ Press [→STK] and then [ONE] to copy the result to the stack.

❷ Press [ATTN] to quit the Physics Pac.

❸ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❹ Find and press PHYS to enter the Physics Pac library directory.

❺ Press the fifth softkey, SIMPL, to simplify the expression.

For more information, refer to "Miscellaneous Commands" in Chapter 10.)

Summary of Operations

Screen	Softkeys
Result Screen	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Moves up one level in the menu structure.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Moves down one level in the menu structure, entering the selected integral section.

For a complete summary of operations, refer to Appendix B, "Summary of Operations.

Chapter 9

Vector Analysis

Vector Analysis includes common formulas and functions for the following: dot product, cross product, the del operator, gradient, divergence, curl, and Laplacian. All of these have corresponding programmable functions, and are capable of interactively manipulating symbolic expressions in rectangular, cylindrical, or spherical coordinates.

This chapter covers:

- ❑ Using Vector Analysis
- ❑ Dot Products
- ❑ Cross Products
- ❑ Del Operator (∇)
- ❑ Gradient
- ❑ Divergence
- ❑ Curl
- ❑ Laplacian
- ❑ Simplifying Results

Using Vector Analysis

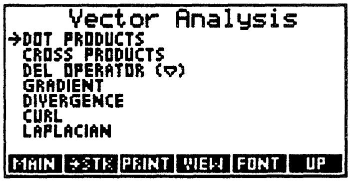
To get to Vector Analysis, follow these steps:

❶ Press [⬅][LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press PHYS to enter the Physics Pac library directory.

❸ Press the first softkey, PHYS , to start the Physics Pac.

❹ At the Main menu, make sure the pointer is at "Vector Analysis" and press [ENTER]:



Items in Vector Analysis

Each item in Vector Analysis is briefly described below and is discussed in detail in the various sections of this chapter.

Item	Description
Dot Products	Common formulas and a dot product function.
Cross Products	Common formulas and a cross product function.
Del Operator (∇)	Common formulas involving the del operator.
Gradient	Definition and formulas in various coordinate systems and a gradient function.
Divergence	Definition and formulas in various coordinate systems and a divergence function.
Curl	Definition and formulas in various coordinate systems and a curl function.
Laplacian	Definition and formulas in various coordinate systems and a Laplacian function.

Summary of Operations

Screen	Softkeys
Vector Analysis	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.

UP	Moves up one level in the menu structure, returning to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Physics Pac to the HP 48SX stack.
ENTER	Displays the screen title, the item label, and the value, all expanded to one screen, or displays an equation in the EquationWriter.
ON–MTH	Dumps the current screen to an IR printer.

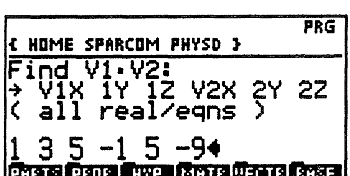
For a complete summary of operations, refer to Appendix B, "Summary of Operations."

Dot Products

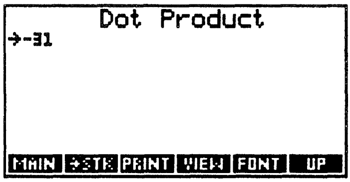
Upon choosing Dot Products from Vector Analysis, the following screen appears:

This is a list of common formulas involving dot products. The dot product function can be invoked in two ways: by pressing SOLVE, or by using the SDOT function described in "Vector Analysis Commands" in Chapter 10.

Example: Find the dot product of the two vectors $\begin{bmatrix}1 & 3 & 5\end{bmatrix}$ and $\begin{bmatrix}-1 & 5 & -9\end{bmatrix}$. To do this, press SOLVE and type in 1 SPC 3 SPC 5 SPC 1 +/- SPC 5 SPC 9 +/- as your input:



Press ENTER to calculate the numeric dot product. The following screen appears:



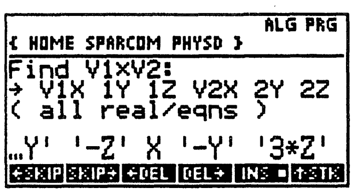
The result can be copied to the stack or printed on an IR printer. When you have finished viewing the result, press UP to return to Dot Products, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Cross Products

Upon choosing Cross Products from Vector Analysis, the following screen appears:

This is a list of common formulas involving cross products. The cross product function can be invoked in two ways: by pressing SOLVE, or by using the SCROS function described in "Vector Analysis Commands" in Chapter 10.

Example: Find the cross product of the two vectors $\begin{bmatrix}2x & 5y & -z\end{bmatrix}$ and $\begin{bmatrix}x & -y & 3z\end{bmatrix}$. To do this, press SOLVE and type in ['] 2 [*] [α] X [►] [SPC] ['] 5 [*] [α] Y [►] [SPC] ['] [+/-] [α] Z [►] [SPC] [α] X [SPC] ['] [+/-] [α] Y [►] [SPC] ['] 3 [*] [α] Z as your input:

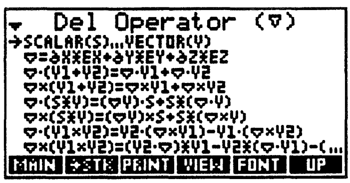


Press ENTER to calculate the symbolic cross product. The following screen appears:

The three results are the x-, y-, and z-components of the symbolic cross product. The results can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the results, press UP to return to Cross Products, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Del Operator (∇)

Upon choosing Del Operator (∇) from Vector Analysis, the following screen appears:



This is a list of common formulas involving the del operator.

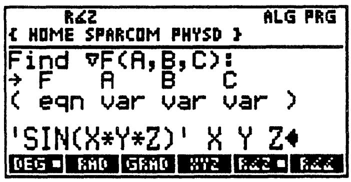
The formulas can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished browsing the list, press UP to return to Vector Analysis, MAIN to return to the Main menu, or ATTN to quit the Physics Pac.

Gradient

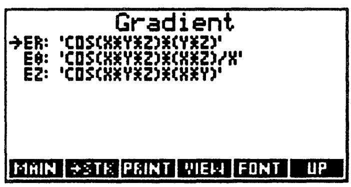
Upon choosing Gradient from Vector Analysis, the following screen appears:

This information describes the gradient function and provides reference formulas for three coordinates systems: rectangular, cylindrical, and spherical. The gradient function can be invoked in two ways: by pressing SOLVE, or by using the SGRAD function described in "Vector Analysis Commands" in Chapter 10.

Example: Find the gradient of sin(xyz) in cylindrical coordinates. To do this, press SOLVE and type in ['] [SIN] [α] [α] X [*] Y [*] Z [α] [►] [►] [SPC] [α] [α] X [SPC] Y [SPC] Z [α] as your input. Then press the fifth softkey R<Z to set cylindrical coordinates:



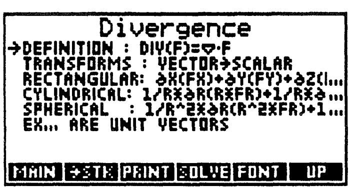
Press [ENTER] to calculate the symbolic gradient. The following screen appears:



The three results are the r-, θ-, and z-components of the symbolic gradient. The results can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the results, press UP to return to Gradient, MAIN to return to the Main menu, or [ATTN] to quit the Physics Pac.

Divergence

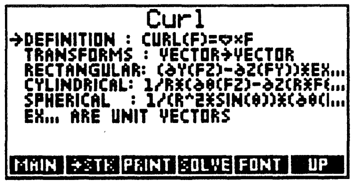
Upon choosing Divergence from Vector Analysis, the following screen appears:



This information describes the divergence function and provides reference formulas for three coordinates systems: rectangular, cylindrical, and spherical. The divergence function can be invoked in two ways: by pressing SOLVE, or by using the SDIV function described in “Vector Analysis Commands” in Chapter 10. Refer above to “Gradient” for a relevant example.

Curl

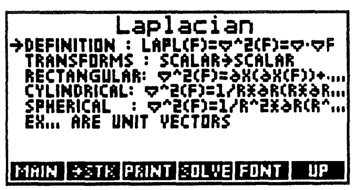
Upon choosing Curl from Vector Analysis, the following screen appears:



This information describes the curl function and provides reference formulas for three coordinates systems: rectangular, cylindrical, and spherical. The curl function can be invoked in two ways: by pressing SOLVE, or by using the SCURL function described in “Vector Analysis Commands” in Chapter 10. Refer above to “Gradient” for a relevant example.

Laplacian

Upon choosing Laplacian from Vector Analysis, the following screen appears:



This information describes the Laplacian function and provides reference formulas for three coordinates systems: rectangular, cylindrical, and spherical. The Laplacian function can be invoked in two ways: by pressing SOLVE, or by using the SLAPL function described in “Vector Analysis Commands” in Chapter 10. Refer above to “Gradient” for a relevant example.

Simplifying Results

To simplify the results of any vector analysis operation, follow these steps:

1. Press →STK and then either ONE or ALL to copy one or all items to the stack.
2. Press [ATTN] to quit the Physics Pac.
3. Press [←] [LIBRARY] to display all libraries available to your HP 48SX.
4. Find and press PHYS to enter the Physics Pac library directory.
5. Press the fifth softkey, SIMPL, to simplify the expression or list.

(For more information, refer to "Miscellaneous Commands" in Chapter 10.)

Chapter 10

Programmable Commands

Programmable Commands describes the syntax and behavior of the commands located in the Physics Library menu. Most of the programmable commands are also functions, which can be used in algebraic expressions, and all can be included as a part of user-language RPL programs.

This chapter covers:

- Hyperbolic Commands
- Polynomial Solver Command
- Taylor Expansion Command
- Trigonometric Commands
- User-Defined Integral Commands
- Vector Analysis Commands
- Miscellaneous Commands

Hyperbolic Commands

This section describes the syntax and behavior of COTH, SECH, CSCH, ACOTH, ASECH, and ACSCH, which are not defined by the HP 48SX.

COTH, SECH, CSCH, ACOTH, ASECH, ACSCH

These are all standard hyperbolic functions, and all allow the same types of arguments and return the same types of results. The syntax table is shown only for COTH.

Input Stack Levels	Output Stack Levels
1: algebraic	1: 'INV(TANH(algebraic))'
or	or
1: complex number	1: COTH(complex)
or	or
1: variable name	1: 'INV(TANH(name))'
or	or
1: real number	1: COTH(real)

Polynomial Solver Command

This section describes the syntax and behavior of PROOT.

PROOT

PROOT is a command that performs the polynomial solver function. It is identical to the interactive Polynomial Solver function described in Chapter 2, "Polynomial Solver."

Input Stack Levels	Output Stack Levels
1: list of real or complex (coefficients)	1: list of real or complex (roots)

Taylor Expansion Command

This section describes the syntax and behavior of TYLRX.

TYLRX

TYLRX is a command that finds the Taylor series expansion of an arbitrary function of an arbitrary variable about an arbitrary point. It expands the functionality of the HP 48SX command TAYLR by allowing specification of the point about which to expand the series.

Input Stack Levels	Output Stack Levels
4: algebraic (function)	
3: name (independent variable)	
2: integer (order)	
1: real (point about which to expand)	1: algebraic (series expansion)

Trigonometric Commands

This section describes the syntax and behavior of COT, SEC, CSC, ACOT, ASEC, and ACSC, which are not defined by the HP 48SX.

COT, SEC, CSC, ACOT, ASEC, ACSC

These are all standard trigonometric functions, and all allow the same types of arguments and return the same types of results. The syntax table is shown only for COT.

Input Stack Levels	Output Stack Levels
1: algebraic	1: 'INV(TAN(algebraic))'
or	or
1: complex number	1: COT(complex)
or	or
1: variable name	1: 'INV(TAN(name))'
or	or
1: real number	1: COT(real)

User-Defined Integral Commands

This section describes the syntax and behavior of INDEF and DEFIN, which are used to store user-defined integrals.

INDEF, DEFIN

INDEF and DEFIN are commands that store integrals into the user-defined integrals section of Integral Tables in the Physics Pac. The integrals are stored in the variable 'USRINTEG' in the 'SPARCOM' directory of your HP 48SX.

Input Stack Levels	Output Stack Levels
1: algebraic	1: empty
or	or
1: tagged algebraic	1: empty

For an example describing the entry of a user-defined integral, refer to Chapter 4, "Integral Tables."

Vector Analysis Commands

This section describes the syntax and behavior of SDOT, SCROS, SGRAD, SDIV, SCURL, and SLAPL.

SDOT

SDOT is a command that calculates the dot product of two vectors, V1 and V2.

Input Stack Levels	Output Stack Levels
6: real or algebraic (V1x)	
5: real or algebraic (V1y)	
4: real or algebraic (V1z)	
3: real or algebraic (V2x)	
2: real or algebraic (V2y)	
1: real or algebraic (V2z)	1: real or algebraic (V1·V2)

SCROS

SCROS is a command that calculates the cross product of two vectors, V1 and V2.

Input Stack Levels	Output Stack Levels
6: real or algebraic (x-comp. of V1)	
5: real or algebraic (y-comp. of V1)	
4: real or algebraic (z-comp. of V1)	
3: real or algebraic (x-comp. of V2)	3: real or algebraic (x-comp. V1×V2)
2: real or algebraic (y-comp. of V2)	2: real or algebraic (y-comp. V1×V2)
1: real or algebraic (z-comp. of V2)	1: real or algebraic (z-comp. V1×V2)

SGRAD

SGRAD is a command that calculates the vector gradient of a scalar function $F(c_1,c_2,c_3)$, where (c_1,c_2,c_3) are the three independent variables or coordinates, commonly (x,y,z) for rectangular, (r,θ,z) for cylindrical, or (r,θ,ϕ) for spherical. However, (c_1,c_2,c_3) are not restricted to those names. The gradient is returned as a list of three algebraics.

The coordinates in which the gradient will be calculated are determined by the setting of your HP 48SX polar flags (system flags –15 and –16). To set the coordinates, press [⬅] [MODES] [NXT] [NXT] and then either XYZ for rectangular, R∠Z for cylindrical, or R∠∠ for spherical. (For more information, refer to Chapter 12 of the HP 48SX Owner's Manual, "Vectors.")

Input Stack Levels	Output Stack Levels
4: algebraic (*F*)	
3: variable name (first coordinate)	
2: variable name (second coordinate)	
1: variable name (third coordinate)	1: list of 3 algebraics (gradient ∇F)

SDIV

SDIV is a command that calculates the scalar divergence of a vector function $\vec{F}(c_1,c_2,c_3)$, where (c_1,c_2,c_3) are the three independent variables or coordinates, commonly (x,y,z) for rectangular, (r,θ,z) for cylindrical, or (r,θ,ϕ) for spherical. However, (c_1,c_2,c_3) are not restricted to those names. The divergence is returned as a single algebraic.

The coordinates in which the divergence will be calculated are determined by the setting of your HP 48SX polar flags (system flags –15 and –16). To set the coordinates, press [⬅] [MODES] [NXT] [NXT] and then either **XYZ** for rectangular, **R∠Z** for cylindrical, or **R∠∠** for spherical. (For more information, refer to Chapter 12 of the HP 48SX Owner's Manual, "Vectors.")

Input Stack Levels	Output Stack Levels
6: real or algebraic ($\vec{F}_x$ or $\vec{F}_r$)	
5: real or algebraic ($\vec{F}_y$ or $\vec{F}_\theta$)	
4: real or algebraic ($\vec{F}_z$ or $\vec{F}_\phi$)	
3: variable name (first coordinate)	
2: variable name (second coordinate)	
1: variable name (third coordinate)	1: algebraic (divergence $\nabla \cdot F$)

SCURL

SCURL is a command that calculates the vector curl of a vector function $\vec{F}(c_1,c_2,c_3)$, where (c_1,c_2,c_3) are the three independent variables or coordinates, commonly (x,y,z) for rectangular, (r,θ,z) for cylindrical, or (r,θ,ϕ) for spherical. However, (c_1,c_2,c_3) are not restricted to those names. The curl is returned as a list of three algebraics.

The coordinates in which the curl will be calculated are determined by the setting of your HP 48SX polar flags (system flags –15 and –16). To set the coordinates, press [⬅] [MODES] [NXT] [NXT] and then either **XYZ** for rectangular, **R∠Z** for cylindrical, or **R∠∠** for spherical. (For more information, refer to Chapter 12 of the HP 48SX Owner's Manual, "Vectors.")

Input Stack Levels	Output Stack Levels
6: real or algebraic ($\vec{F}_x$ or $\vec{F}_r$)	
5: real or algebraic ($\vec{F}_y$ or $\vec{F}_\theta$)	
4: real or algebraic ($\vec{F}_z$ or $\vec{F}_\phi$)	
3: variable name (first coordinate)	
2: variable name (second coordinate)	
1: variable name (third coordinate)	1: list of 3 algebraics (curl $\nabla \times F$)

SLAPL

SLAPL is a command that calculates the scalar Laplacian of a scalar function $F(c_1, c_2, c_3)$, where (c_1, c_2, c_3) are the three independent variables or coordinates, commonly (x, y, z) for rectangular, (r, θ, z) for cylindrical, or (r, θ, ϕ) for spherical. However, (c_1, c_2, c_3) are not restricted to those names. The Laplacian is returned as a single algebraic.

The coordinates in which the Laplacian will be calculated are determined by the setting of your HP 48SX polar flags (system flags –15 and –16). To set the coordinates, press [⬅] [MODES] [NXT] [NXT] and then either [XYZ] for rectangular, [R∠Z] for cylindrical, or [R∠∠] for spherical. (For more information, refer to Chapter 12 of the HP 48SX Owner's Manual, "Vectors.")

Input Stack Levels	Output Stack Levels
4: algebraic (F)	
3: variable name (first coordinate)	
2: variable name (second coordinate)	
1: variable name (third coordinate)	1: algebraics (Laplacian $\nabla^2 F$)

Miscellaneous Commands

This section describes the syntax and behavior of SIMPL and PCON.

SIMPL

SIMPL is a command that completely simplifies an algebraic or list of algebraics by repeated EXPANs and COLCTs. All other object types are ignored.

Input Stack Levels	Output Stack Levels
1: algebraic	1: simplified algebraic
or	or
1: list of algebraics	1: list of simplified algebraics

PCON

PCON is not intended for user use. It is a program that provides *some* constants from the Constant Library to equations and is necessary so that constant calls appear efficiently in equations copied to the stack by the user. PCON does not provide access to all of the constants in the Constant Library.

SLVINTEG

SLVINTEG is not intended for user use. It is a program that provides access to the integral-solving routine and must be present in the Physics Pac library menu so that you can more easily edit the USRINTEG file containing the user-defined integrals. (For more information, refer above to "User-Defined Integral Commands.")

Appendix A

Warranty and Service

Pocket Professional™ Support

You can get answers to your questions about using your Pocket Professional™ Pac from Sparcom. If you don't find the information in this manual or in the HP 48SX Owner's Manual, contact us in one of the following ways:

❶ E-Mail

From Internet: support@sparcom.com
From Compuserve: >Internet:support@sparcom.com
From FidoNet: To:support@sparcom.com

❷ Standard Mail

Sparcom Corporation
897 NW Grant Avenue
Corvallis, OR 97330
Attn: Technical Support Department

❸ Telephone

(503) 757–8416
9 a.m. – 5 p.m. Pacific Standard Time

❹ FAX

(503) 753–7821

Limited One-Year Warranty

What is Covered

A Pocket Professional™ Pac is warranted by Sparcom Corporation against defects in material and workmanship for one year from the date of original purchase. If you sell your card or give it as a gift, the warranty is automatically transferred to the new owner and remains in effect for the original one-year period. During the warranty period, we will repair or replace (at no charge) a product that proves to be defective, provided you return the product and proof of purchase, shipping prepaid, to Sparcom.

What is Not Covered

This warranty does not apply if the product has been damaged by accident or misuse or as the result of service or modification by any entity other than Sparcom Corporation.

No other warranty is given. The repair or replacement of a product is your exclusive remedy. ANY OTHER IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS IS LIMITED TO THE ONE-YEAR DURATION OF THIS WRITTEN WARRANTY. IN NO EVENT SHALL SPARCOM CORPORATION BE LIABLE FOR CONSEQUENTIAL DAMAGES. Products are sold on the basis of specifications applicable at the time of manufacture. Sparcom shall have no obligation to modify or update products, once sold.

If the Card Requires Service

Sparcom will repair a card, or replace it with the same model or one of equal or better functionality, whether it is under warranty or not.

Service Charge

There is a fixed charge for standard out-of-warranty repairs. This charge is subject to the customer's local sales or value-added tax, wherever applicable. Cards damaged by accident or misuse are not covered by fixed charges. These charges are individually determined based on time and material.

Shipping Instructions

If your card requires service, ship it to the address above and:

1. Include your return address and a description of the problem.
2. Include a proof of purchase date if the warranty has not expired.
3. Include a purchase order, along with a check or credit card number and expiration date (VISA or MasterCard), to cover the standard repair charge.
4. Ship your card, postage prepaid, in protective packaging adequate to prevent damage. Shipping damage is not covered by the warranty, so insuring the shipment is recommended.

Cards are usually serviced and re-shipped within five working days.

Environmental Limits

The reliability of a Pocket Professional™ Pac depends upon the following temperature and humidity limits:

1. Operating Temperature: 0 to 45° C (32 to 113° F).
2. Storage Temperature: –20 to 60° C (–4 to 140° F).
3. Operating and Storage Humidity: 90% relative humidity at 40° C (104° F) maximum.

Appendix B

Summary of Operations

Summary of Screen Softkeys

Screen	Softkeys					
Categories Screen	MAIN	→STK	PRINT	VIEW	FONT	UP
Constant Library	MAIN	→STK	PRINT	UNITS	FONT	UP
Equations Screen	MAIN	MARK	VARS	SOLVE	PICT	UP
	MAIN	→STK	PRINT	SOLVE	FONT	UP
	MAIN	EQWR	PLOT	SOLVE	FONT	UP
Function Menu	ROOT	ISECT	SLOPE	AREA	EXTR	EXIT
	F X	F'	NXEQ			
Graphics Environment	ZOOM	Z-BOX	CENT	COORD	LABEL	FCN
	DOT+	DOT-	LINE	TLINE	BOX	FIRCL
	MARK	REPL	SUB	DEL	+ -	KEYS
Integral Section	MAIN	→STK	PRINT	SOLVE	FONT	UP
Integral Tables	MAIN	→STK	PRINT	VIEW	FONT	UP
Main	ABOUT	→STK	PRINT	VIEW	FONT	QUIT
Reference Data	MAIN	→STK	PRINT	VIEW	FONT	UP
Reference Formulas	MAIN	→STK	PRINT	VIEW	FONT	UP
Result Screen	MAIN	→STK	PRINT	VIEW	FONT	UP
Solar System Data	MAIN	→STK	PRINT	UNITS	FONT	UP

Solver Screen	MAIN	KNOW	WANT	CALC	CONV	UP
	MAIN	EQNS	VARS	HALT	PICT	UP
	MAIN	→STK	PRINT	CALC	FONT	UP
	MAIN	CLEAR	PURG	CALC	UNITS	UP
Text Editing	←SKIP	SKIP→	←DEL	DEL→	INS	↑STK
Topics Screen	MAIN	EQNS	VARS	SOLVE	PICT	UP
	MAIN	→STK	PRINT	SOLVE	FONT	UP
Variables Screen	MAIN	EQNS	VIEW	SOLVE	PICT	UP
	MAIN	→STK	PRINT	SOLVE	FONT	UP
Vector Analysis	MAIN	→STK	PRINT	VIEW	FONT	UP

Summary of Softkey Actions

Key	Action
ABOUT	Displays a screen containing the revision number and product information about the Physics Pac. Pressing any key erases the screen and returns to the previous menu or to the HP 48SX stack.
AREA	Displays the area under the function defined by the X axis value of the mark and cursor.
CALC	Stores variables values and systematically iterates through the set of marked equations in an attempt to find values for all wanted variables. Also, stores the known and found values into global variables in the 'PHYSD' directory.
CLEAR	Resets values of all current variables to zero, but does not change the global copies, which are only affected by CALC and PURG operations.
CONV	Converts a variable to different units, if units are on.
COORD	Displays the coordinates of the cursor position.
DEL→	Deletes all characters between the cursor's current position and the first character of the next word.
←DEL	Deletes all characters in the current word prior to the cursor.
EQNS	Displays the equations screen for the current topic.
EQWR	Displays the equation selected by the pointer in the EquationWriter.
F'	Plots the first derivative the current function.
F(X)	Displays the function value at the X axis value of the cursor, and moves the cursor to that point on the function.
FCN	Displays the Function menu for further analysis.
FONT	Toggles between the small and large fonts.
HALT	Halts the Physics Pac so that operations can be performed on the HP 48SX stack. Pressing CONT or ⬅ CONT returns to the Physics Pac, while pressing KILL terminates the Physics Pac.
INS	Toggles between insert and type-over modes.
KNOW	Toggles the variable selected by the pointer between known and unknown status, adding or removing a triangular tag.
MAIN	Returns to the Main menu.

MARK	Places a mark (X) at the cursor location.
MARK	Toggles the equation selected by the pointer between marked and unmarked status, adding or removing a triangular tag. Only variables in the marked set of equations will appear in the solver and variable screens. If no equations are marked, all will be used.
PICT	Displays the picture for the current topic, if one exists.
PLOT	Plots the equation selected by the pointer, prompting for x-axis and y-axis values. Plotting is only allowed for equations of the form $y = f(a,b,\ldots)$, and all but one of the variables on the right-hand side of the equation must be held constant (i.e., known).
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
PURG	Purges the global copies (in the 'PHYSD' directory) of the current set of variables, but does not change the values currently stored inside the Physics Pac.
QUIT	Quits the Physics Pac to the HP 48SX stack.
ROOT	Moves the cursor to the nearest root and displays the coordinate of the root.
SKIP→	Moves the cursor to the beginning of the next word.
←SKIP	Moves the cursor to the beginning of the current word.
SLOPE	Displays the slope of the function at the X axis value of the cursor, and moves the cursor to the point on the function at which the slope was calculated.
SOLVE	In Equation Library: Displays the solver screen for the current topic. At Integral Tables: Solves the integral selected by the pointer. In general: Executes a solving routine based on the type of data shown.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
↑STK	Activates the Interactive Stack, allowing arguments to be copied from the stack to the command line for editing by pressing ECHO.
SUB	Copies the rectangle bounded by the mark and the cursor location to the stack as a graphics object (GROB).

UNIT	Indicates that units are currently turned on. Pressing this key turns off units, automatically converting all variable values to SI units and then stripping the units.
UNITS	Indicates that units are currently turned off. Pressing this key turns on units, automatically appending standard SI units to the values.
UP	Moves up one level in the menu structure.
VARS	Displays the variable screen for the current topic, including descriptions and default units.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
WANT	Toggles the variable selected by the pointer between wanted and unwanted status, adding or removing a question tag.
▲ ▼ ◄ ►	At Graphics environment: Moves the cursor in the indicated direction. When prefixed with ↱, moves the cursor to the edge of the screen in the indicated direction.
ATTN	At command line: Clears the command line if there is text present, or aborts text entry if the command line is already blank.
	In general: Quits the Physics Pac to the HP 48SX stack.
	At Graphics environment: Exits the plot and returns to the equations screen.
ENTER	At command line: Accepts the current command line as the entry and returns to the previous menu or list.
	In general: Moves down one level in the menu structure.
	At categories screen: Displays the topics screen for the category selected by the pointer.
	At equations screen: Displays the equation selected by the pointer in the EquationWriter.
	At solver screen: Prompts for a value for the variable selected by the pointer.
	At topics screen: Displays the equations screen for the topic selected by the pointer.
	At variable and reference data screens: Displays the screen title, the item label, and the value, all expanded to one screen.
ON–MTH	Dumps the current screen to an IR printer.

[←] [REVIEW]	Temporarily displays the plot status menu, including the axis ranges, until [REVIEW] is released.
[STO]	Copies PICT to the stack as a graphics object (GROB).
[→] [VISIT]	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.

Appendix C

Equation Library Reference

Equation Library Reference lists the categories, topics, equations, variables, units, and pictures contained in the Physics Pac. The Equation Library consists of 11 categories and over 250 equations.

Categories and Topics

Category/Topic	# Eqns	# Vars	Picture	Page #
Angular Mechanics				
Angular Mechanics	14	14	Yes	104
Banked Curves	3	5	Yes	105
Circular Motion	12	15	Yes	105
Momentum/Precession	5	8	No	107
Parallel Axis Theorem	1	4	No	107
Vertical Motion	2	4	No	108
Electrical Circuits				
Capacitor Basics	8	17	Yes	109
Capacitor (Cylinder)	2	6	No	110
Capacitor (Plate)	3	7	Yes	110
Capacitor (Sphere)	2	5	No	111
Divider (Current)	2	6	Yes	111
Divider (Voltage)	2	6	Yes	111
Inductor Basics	8	18	Yes	112
Inductor (Solenoid)	1	5	Yes	113
Inductor (Toroid)	1	6	Yes	113
Ohm's Law	4	4	No	114
Resistor Basics	6	14	Yes	114
Transformers	5	9	Yes	116
Electric Fields				
Coulomb's Law	5	8	No	117
Dipole	3	7	Yes	117
Disk	1	4	No	118

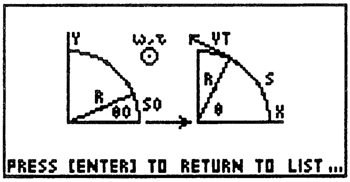
Line	1	3	No	118
Lorentz Force	1	6	No	119
Ring	1	4	No	119
Sheet	1	2	No	120
Surface	1	2	No	120
Forces/Energy/Work				
Angular Forces	14	14	Yes	121
Coulomb's Law	5	8	No	121
Drag Force	1	5	No	121
Frictional Forces	2	5	No	121
Gravitational Forces	4	7	No	122
Hooke's Law	8	13	Yes	122
Linear Forces	14	14	No	122
Lorentz Force	1	6	No	122
Gravitation				
Escape Velocity	1	3	No	123
Gravitation	4	7	No	123
Free Falling Object	10	11	No	124
Orbits (Circular)	4	7	No	125
Orbits (Elliptical)	5	10	Yes	125
Projectile Motion	7	12	Yes	126
Terminal Velocity	1	5	No	127
Linear Mechanics				
Center of Mass	2	14	No	128
Collisions (Elastic)	3	6	Yes	128
Collisions (Inelastic)	1	4	Yes	129
Linear Mechanics	14	14	No	130
Rocket Science	2	8	No	131
Magnetism				
Charged Particle	1	5	Yes	132
Cyclotron	4	8	No	132
Dipole	2	5	Yes	133
Solenoid	1	4	Yes	133
Toroid	1	6	Yes	134
Wire (Loop)	1	6	No	135
Wire (Straight)	2	8	Yes	135
Wires (Parallel)	1	6	Yes	136
Optics				
Brewster's Law	2	4	Yes	137
Reflection/Refraction	6	10	Yes	137
Spherical Mirrors	5	6	Yes	138
Spherical Refraction	3	7	Yes	139
Thin Lenses	4	8	Yes	140

Two-Slit Diffraction	5	11	Yes	140
Oscillations				
Mass-Spring System	8	13	Yes	142
Pendulum (Conical)	6	9	Yes	143
Pendulum (Simple)	4	7	Yes	143
Pendulum (Torsional)	5	10	Yes	144
Simple Harmonic Motion	5	9	No	145
Two-Body System	4	7	No	146
Special Relativity				
Doppler Effect	3	5	No	147
Energy/Mass/Momentum	9	10	No	147
Gallilean Transform	2	6	Yes	148
Length/Time Dilation	3	6	Yes	148
Lorentz Transform	6	12	Yes	149
Waves				
Doppler Effect	1	5	Yes	151
Organ Pipes	2	6	No	151
Sound Waves	6	11	No	152
Waves	6	12	No	152

Angular Mechanics

Angular Mechanics

These equations describe the fundamental of Newtonian angular motion. They cover the concepts of work, torque, moments of inertia, and angular velocity and acceleration.



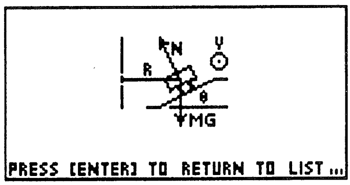
Equations		
$\tau=I\cdot\alpha$	$Ki=\frac{1}{2}\cdot I\cdot\omega i^2$	$Kf=\frac{1}{2}\cdot I\cdot\omega f^2$
$W=Kf-Ki$	$W=\tau\cdot(\theta f-\theta i)$	$Pf=\tau\cdot\omega f$
$Pavg=\frac{W}{t}$	$\omega f=\omega i+\alpha\cdot t$	$\theta f=\theta i+\omega avg\cdot t$
$\theta f=\theta i+\omega i\cdot t+\frac{1}{2}\cdot\alpha\cdot t^2$	$\theta f=\theta i+\omega f\cdot t-\frac{1}{2}\cdot\alpha\cdot t^2$	$\omega f^2=\omega i^2+2\cdot\alpha\cdot(\theta f-\theta i)$
$\omega avg=\frac{1}{2}\cdot(\omega i+\omega f)$	$\omega avg=\frac{\theta f-\theta i}{t}$	

Variables	Descriptions	Units
θi	initial angular displacement	°
θf	final angular displacement	°
ωi	initial angular velocity	°/s
ωf	final angular velocity	°/s
ωavg	average angular velocity	°/s
α	angular acceleration	$°/s^2$
τ	torque	N·m
I	moment of inertia	$kg\cdot m^2$
Ki	initial kinetic energy	J
Kf	final kinetic energy	J

W	work	J
Pf	final power	W
Pavg	average power	W
t	time	s

Banked Curves

These equations describe a vehicle moving along a banked curve. They allow calculation of the bank angle for a specified maximum velocity and allow you to vary the radius of the curve as well.

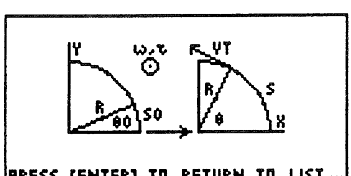


Equations		
$N\cdot SIN(\theta)=\frac{m\cdot v^2}{r}$	$N\cdot COS(\theta)=m\cdot g$	$TAN(\theta)=\frac{v^2}{r\cdot g}$

Variables	Descriptions	Units
N	normal force	N
θ	bank angle	°
m	mass	kg
v	velocity	m/s
r	turn radius	m

Circular Motion

These equations describe the fundamentals of circular motion at a constant radius, and cover the topics of centripetal force, arc length, and tangential and total acceleration.



Equations		
$Fc=m\cdot ac$	$ac=\omega^2\cdot r$	$at=\alpha\cdot r$
$vt=\omega\cdot r$	$ac=\frac{vt^2}{r}$	$a^2=at^2+ac^2$
$\omega=2\cdot\pi\cdot f$	$T=\frac{1}{f}$	$s=r\cdot\theta$
$x=r\cdot COS(\theta)$	$y=r\cdot SIN(\theta)$	$r^2=x^2+y^2$

Variables	Descriptions	Units
Fc	centripetal force	N
m	mass	kg
vt	tangential velocity	m/s
ac	centripetal acceleration	m/s^2
at	tangential acceleration	m/s^2
a	total acceleration	m/s^2
θ	angular displacement	°
ω	angular velocity	°/s
α	angular acceleration	$°/s^2$
T	period	s
f	frequency	Hz
s	arc distance	m
x	x position	m
y	y position	m
r	radius	m

Momentum/Precession

These equations cover the basics of angular momentum and precession, based on the moment of inertia and the angular velocity.

Equations		
$L=I\cdot\omega$	$I=m\cdot r^2$	$\Omega=\frac{m\cdot g\cdot r}{I\cdot\omega}$
$\omega=2\cdot\pi\cdot f$	$T=\frac{1}{f}$	

Variables	Descriptions	Units
L	angular momentum	$kg\cdot m^2/s$
I	moment of inertia	$kg\cdot m^2$
ω	angular velocity	°/s
m	mass	kg
r	radius	m
Ω	precession rate	°/s
T	period	s
f	frequency	Hz

Parallel Axis Theorem

The parallel axis theorem relates the moment of inertia of a body about its centroid (center of mass) to the moment of inertia about a point a distance r from the center of mass.

Equations
$I=Icm+m\cdot r^2$

Variables	Descriptions	Units
I	moment of inertia	$kg\cdot m^2$
Icm	I, center of mass	$kg\cdot m^2$
m	mass	kg
r	axis separation	m

Vertical Motion

These equations describe vertical motion in a gravitational field and the critical velocity.

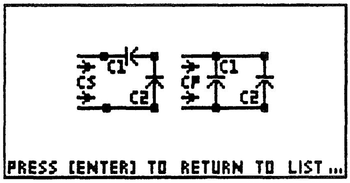
Equations	
$vmin^2=4\cdot g\cdot r+vmax^2$	$vc=\sqrt{g\cdot r}$

Variables	Descriptions	Units
r	radius	m
vmin	minimum velocity	m/s
vmax	maximum velocity	m/s
vc	critical velocity	m/s

Electrical Circuits

Capacitor Basics

These equations cover the basics of capacitor behavior, including the relations for calculating serial and parallel capacitance.



Equations		
$I=\frac{C\cdot\Delta V}{\Delta t}$	$\Delta V=Vf-Vi$	$\Delta t=tf-ti$
$q=C\cdot V$	$UC=\frac{1}{2}\cdot C\cdot V^2$	$UE=\frac{1}{2}\cdot\varepsilon 0\cdot E^2$
$Cp=C1+C2$	$\frac{1}{Cs}=\frac{1}{C1}+\frac{1}{C2}$	

Variables	Descriptions	Units
I	current	A
C	capacitance	F
ΔV	voltage difference	V
Δt	time difference	s
Vi	initial voltage	V
Vf	final voltage	V
ti	initial time	s
tf	final time	s
q	charge	C
V	voltage	V
UC	energy stored	J
UE	energy density	J/m^3
E	electric field	N/C
Cp	parallel capacitance	F
Cs	series capacitance	F
C1	capacitance 1	F
C2	capacitance 2	F

Capacitor (Cylinder)

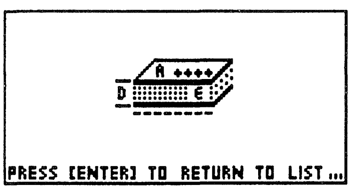
These equations cover the capacitance of a cylinder, or a coaxial cable. Fringing effects are ignored.

Equations	
$C=\dfrac{2\cdot\pi\cdot\varepsilon\cdot l}{LN\left(\dfrac{ro}{ri}\right)}$	$\varepsilon=k\cdot\varepsilon 0$

Variables	Descriptions	Units
C	capacitance	F
ε	permittivity	F/m
l	length	m
ro	outer radius	m
ri	inner radius	m
k	dielectric constant	-

Capacitor (Plate)

These equations cover the capacitance of a plate capacitor, including the electric field between the plates. Fringing effects are ignored.



Equations		
$C=\dfrac{\varepsilon\cdot A}{d}$	$\varepsilon=k\cdot\varepsilon 0$	$E=\dfrac{V}{d}$

Variables	Descriptions	Units
C	capacitance	F
ε	permittivity	F/m
A	area	m^2
d	separation	m
k	dielectric constant	-
E	electric field	N/C
V	voltage	V

Capacitor (Sphere)

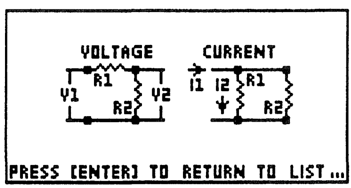
These equations cover the capacitance of a sphere. Fringing effects are ignored.

Equations	
$C=\frac{4\cdot\pi\cdot\varepsilon\cdot ri\cdot ro}{ro-ri}$	$\varepsilon=k\cdot\varepsilon 0$

Variables	Descriptions	Units
C	capacitance	F
ε	permittivity	F/m
ri	inner radius	m
ro	outer radius	m
k	dielectric constant	-

Divider (Current)

These equations describe current dividers and voltage dividers.



Equations	
$I2=\frac{I1\cdot R2}{R1+R2}$	$V2=\frac{V1\cdot R2}{R1+R2}$

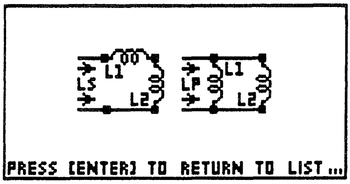
Variables	Descriptions	Units
I1	current in	A
I2	current out	A
V1	voltage in	V
V2	voltage out	V
R1	resistance 1	Ω
R2	resistance 2	Ω

Divider (Voltage)

Refer above to "Divider (Current)" in "Electrical Circuits."

Inductor Basics

These equations cover the basics of inductor behavior, including the relations for calculating serial and parallel inductance.

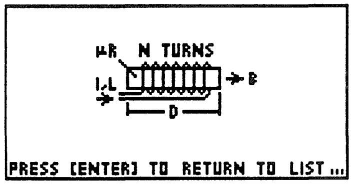


Equations		
$V=\frac{-L\cdot\Delta I}{\Delta t}$	$\Delta I=If-Ii$	$\Delta t=tf-ti$
$N\cdot\phi=L\cdot I$	$UL=\frac{1}{2}\cdot L\cdot I^{2}$	$UB=\frac{1}{2\cdot\mu 0}\cdot B^{2}$
$Ls=L1+L2$	$\frac{1}{Lp}=\frac{1}{L1}+\frac{1}{L2}$	

Variables	Descriptions	Units
V	voltage	V
L	inductance	H
ΔI	current	A
Δt	current difference	s
I	time difference	A
Ii	initial current	A
If	final current	A
ti	initial time	s
tf	final time	s
N	turns	-
ϕ	magnetic flux	Wb
UL	energy stored	J
UB	energy density	J/m^3
B	magnetic field	T
Ls	series inductance	H
Lp	parallel inductance	H
L1	inductance 1	H
L2	inductance 2	H

Inductor (Solenoid)

This equation calculates the inductance of a solenoid, based on the number of turns per unit length and the cross-sectional area of the solenoid.

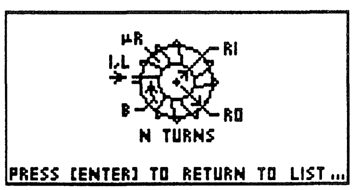


Equations
$L=\mu 0 \cdot \mu r \cdot n^{2} \cdot A \cdot d$

Variables	Descriptions	Units
L	inductance	H
μr	relative permittivity	-
n	turns/unit length	1/m
A	cross-section	m^2
d	length	m

Inductor (Toroid)

This equation calculates the inductance of a toroid, based on the total number of turns and the dimensions of the toroid.



Equations
$L=\frac{\mu 0 \cdot \mu r \cdot N^{2} \cdot w}{2 \cdot \pi} \cdot LN\left(\frac{ro}{ri}\right)$

Variables	Descriptions	Units
L	inductance	H
μr	relative permittivity	-
N	turns	-
w	width	m
ri	inner radius	m
ro	outer radius	m

Ohm's Law

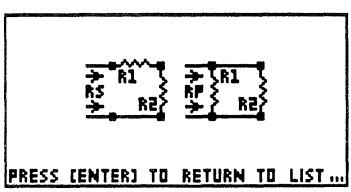
These equations explain the basic Ohm's law relations.

Equations		
$V=I\cdot R$	$P=V\cdot I$	$P=I^2\cdot R$
$P=\frac{V^2}{R}$		

Variables	Descriptions	Units
V	voltage	V
I	current	A
R	resistance	Ω
P	power	W

Resistor Basics

These equations govern the fundamentals of resistance, including temperature dependence, conductivity, and relations for calculating the serial and parallel resistance.

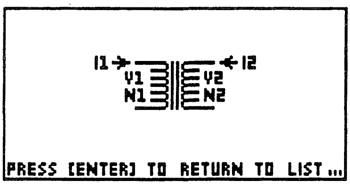


Equations		
$R=\frac{\rho\cdot l}{A}$	$G=\frac{\sigma\cdot A}{l}$	$\rho=\frac{1}{\sigma}$
$R'=R\cdot(1+\alpha\cdot(Tf-Ti))$	$Rs=R1+R2$	$\frac{1}{Rp}=\frac{1}{R1}+\frac{1}{R2}$

Variables	Descriptions	Units
R	resistance (temperature Ti)	Ω
σ	resistivity	Ω·m
l	length	m
A	cross-section	m^2
G	conductance	S
ρ	conductivity	S/m
α	resistance temperature coefficient	1/K
R′	resistance (temperature Tf)	Ω
Ti	initial temperature	K
Tf	final temperature	K
Rs	series resistance	Ω
Rp	parallel resistance	Ω
R1	resistance 1	Ω
R2	resistance 2	Ω

Transformers

These equations describe an ideal transformer.



Equations		
$\frac{V1}{V2}=\frac{N1}{N2}$	$I1 \cdot N1=I2 \cdot N2$	$R2'=\frac{R2}{at^2}$
$at=\frac{N2}{N1}$	$V2=I2 \cdot R2$	

Variables	Descriptions	Units
V1	primary voltage	V
V2	secondary voltage	V
N1	primary turns	-
N2	secondary turns	-
I1	primary current	A
I2	secondary current	A
R2	load resistance from secondary	Ω
R2′	load resistance from primary	Ω
at	turns ratio	-

Electric Fields

Coulomb's Law

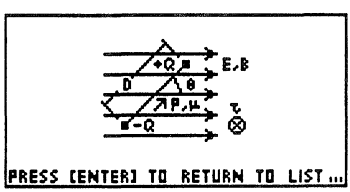
These equations describe Coulomb's law, the relationship between electric force, charge, and distance. They include relations to calculate the electric force due to an electric field and to calculate the potential at a given distance from a charge.

Equations		
$F=\frac{1}{4\cdot\pi\cdot\varepsilon 0}\cdot\left(\frac{q1\cdot q2}{r^2}\right)$	$F=q1\cdot E1$	$F=q2\cdot E2$
$V1=\frac{1}{4\cdot\pi\cdot\varepsilon 0}\cdot\left(\frac{q1}{r}\right)$	$V2=\frac{1}{4\cdot\pi\cdot\varepsilon 0}\cdot\left(\frac{q2}{r}\right)$	

Variables	Descriptions	Units
F	force	N
q1	charge 1	C
q2	charge 2	C
r	distance	m
E1	electric field at q1	N/C
E2	electric field at q2	N/C
V1	electric potential from q1	V
V2	electric potential from q2	V

Dipole

These equations describe an electric dipole. They cover torque and the energy stored by the dipole's interaction with an electric field.



Equations		
$p=q\cdot d$	$\tau=p\cdot E\cdot SIN(\theta)$	$U=-p\cdot E\cdot COS(\theta)$

Variables	Descriptions	Units
p	dipole moment	C·m
q	charge	C
d	separation	m
τ	torque	N·m
E	electric field	N/C
θ	angle	°
U	potential energy	J

Disk

This equation gives the electric field due to a disk of charge at any point along the perpendicular z axis.

Equations
$E=\frac{\sigma}{2\cdot\epsilon 0}\cdot\left(1-\frac{z}{\sqrt{z^2+r^2}}\right)$

Variables	Descriptions	Units
E	electric field	N/C
ρ	surf charge density	C/m^2
r	disk radius	m
z	distance	m

Line

This equations gives the electric field due to a line of charge at a distance r from the line.

Equations
$E=\frac{\lambda}{2\cdot\pi\cdot\epsilon 0\cdot r}$

Variables	Descriptions	Units
E	electric field	N/C
λ	linear charge density	C/m
r	distance	m

Lorentz Force

This equation describes the Lorentz force, which results from a charge moving through electric and magnetic fields.

Equations
$F=q\cdot E+q\cdot v\cdot B\cdot SIN(\theta)$

Variables	Descriptions	Units
F	Lorentz force	N
q	charge	C
E	electric field	N/C
v	velocity	m/s
B	magnetic field	T
θ	angle	°

Ring

This equation gives the electric field due to a ring of charge at any point along the perpendicular z axis.

Equations
$E=\frac{1}{4\cdot\pi\cdot\epsilon 0}\cdot\left(\frac{q\cdot z}{\left(z^2+r^2\right)^{\frac{3}{2}}}\right)$

Variables	Descriptions	Units
E	electric field	N/C
q	charge	C
r	ring radius	m
z	distance	m

Sheet

This equation gives the electric field due to a sheet of charge.

Equations
$E=\frac{\sigma}{2\cdot\epsilon 0}$

Variables	Descriptions	Units
E	electric field	N/C
ρ	surf charge density	C/m^2

Surface

This equation gives the electric field due to the surface of a charged conductor.

Equations
$E=\frac{\sigma}{\epsilon 0}$

Variables	Descriptions	Units
E	electric field	N/C
ρ	surf charge density	C/m^2

Forces/Energy/Work

Angular Forces

Refer above to “Angular Mechanics” in “Angular Mechanics.”

Coulomb’s Law

Refer above to “Coulomb’s Law” in “Electric Fields.”

Drag Force

This equation describes the drag force associated with an object moving through a fluid (including air).

Equations
$F=Cd\cdot\left(\frac{\rho\cdot v^2}{2}\right)\cdot A$

Variables	Descriptions	Units
F	drag force	N
Cd	drag coefficient	-
σ	fluid density	kg/m^3
v	velocity	m/s
A	cross-sectional area	m^2

Frictional Force

These equations describe the static and kinetic frictional forces encountered by an object at rest or moving along a surface.

Equations	
$fs=\mu s\cdot N$	$fk=\mu k\cdot N$

Variables	Descriptions	Units
fs	static frictional force	N
fk	kinetic frictional force	N
μs	static frictional coefficient	-

μk	kinetic frictional coefficient	-
N	normal force	N

Gravitational Forces

Refer below to "Gravitation" in "Gravitation."

Hooke's Law

Refer below to "Mass-Spring System" in "Oscillations."

Linear Forces

Refer below to "Linear Mechanics" in "Linear Mechanics."

Lorentz Force

Refer above to "Lorentz Force" in "Electric Fields."

Gravitation

Escape Velocity

This equation yields the escape velocity necessary for an object to escape a planet. The object mass is assumed to be negligible in comparison with the planet mass.

Equations
$v=\sqrt{\frac{2 \cdot G \cdot m}{r}}$

Variables	Descriptions	Units
v	escape velocity	m/s
m	planet mass	kg
r	planet radius	m

Gravitation

These equations cover the basics of gravitation, including the relationship between gravitational force, mass, and distance, and gravitational potential energy stored by two separated masses.

Equations		
$F=\frac{G \cdot m1 \cdot m2}{r^2}$	$a1=\frac{G \cdot m2}{r^2}$	$a2=\frac{G \cdot m1}{r^2}$
$U=\frac{-G \cdot m1 \cdot m2}{r}$		

Variables	Descriptions	Units
F	attractive force	N
m1	mass 1	kg
m2	mass 2	kg
r	separation	m
a1	m1 acceleration	m/s^2
a2	m2 acceleration	m/s^2
U	potential energy	J

Free Falling Object

These equations describe the motion of a freely falling object in the Earth's gravitational field. They cover the concepts of gravitational potential energy, kinetic energy, and total energy.

Equations		
$vf=vi-g\cdot t$	$yf=yi+vi\cdot t-\frac{1}{2}\cdot g\cdot t^2$	$yf=yi+vf\cdot t+\frac{1}{2}\cdot g\cdot t^2$
$vf^2=vi^2-2\cdot g\cdot (yf-yi)$	$Ki=\frac{1}{2}\cdot m\cdot vi^2$	$Kf=\frac{1}{2}\cdot m\cdot vf^2$
$Ui=m\cdot g\cdot yi$	$Uf=m\cdot g\cdot yf$	$E=Ki+Ui$
$E=Kf+Uf$		

Variables	Descriptions	Units
t	time	s
m	mass	kg
yi	initial y position	m
yf	final y position	m
vi	initial velocity	m/s
vf	final velocity	m/s
Ki	initial kinetic energy	J
Kf	final kinetic energy	J
Ui	initial potential energy	J
Uf	final potential energy	J
E	total energy	J

Orbits (Circular)

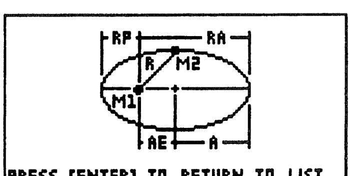
These equations cover Kepler's 3rd law of motion, which involves the period, separation, and masses of two objects. Included are relations to determine the velocity of a circular orbit, the centripetal force of such an orbit, and the kinetic energy of the orbiting object. The equations are *not* simplified for the case where the central mass is much greater than the orbiting mass.

Equations		
$T^2=\frac{4\cdot\pi^2}{G\cdot(m1+m2)}\cdot a^3$	$v^2=\frac{G\cdot m2}{a}$	$Fc=\frac{m2\cdot v^2}{a}$
$K=\frac{G\cdot m1\cdot m2}{2\cdot a}$		

Variables	Descriptions	Units
T	period	s
m1	central mass	kg
m2	orbiting mass	kg
a	separation	m
v	velocity	m/s
Fc	centripetal force	N
K	kinetic energy	J

Orbits (Elliptical)

These equations cover Kepler's 3rd law of motion, which involves the period, separation, and masses of two objects. Included are relations to determine the aphelion and perihelion distances, based on the eccentricity of the orbit. The equations are *not* simplified for the case where the central mass is much greater than the orbiting mass, and the velocity and kinetic energy of the orbiting mass at any point along the orbit can be calculated.

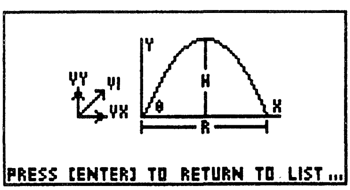


Equations		
$T^2=\frac{4\cdot\pi^2}{G\cdot(m1+m2)}\cdot a^3$	$v^2=G\cdot(m1+m2)\cdot\left(\frac{2}{r}-\frac{1}{a}\right)$	$ra=a\cdot(1+E)$
$rp=a\cdot(1-E)$	$K=\frac{1}{2}\cdot m2\cdot v^2$	

Variables	Descriptions	Units
T	period	s
m1	central mass	kg
m2	orbiting mass	kg
r	separation	m
ra	aphelion	m
rp	perihelion	m
a	semimajor axis	m
v	velocity	m/s
E	eccentricity	-
K	kinetic energy	J

Projectile Motion

These equations describe projectile motion in the Earth's gravitational field. The maximum height and range for the projectile can be determined as well.



Equations		
$xf=xi+vi\cdot COS(\theta)\cdot t$	$yf=yi+vi\cdot SIN(\theta)\cdot t-\frac{1}{2}\cdot g\cdot t^2$	$vx=vi\cdot COS(\theta)$
$vy=vi\cdot SIN(\theta)-g\cdot t$	$vf^2=vx^2+vy^2$	$R=\frac{vi^2}{g}\cdot SIN(2\cdot\theta)$

$$H=yi+\frac{vi^2\cdot SIN(\theta)^2}{2\cdot g}$$

Variables	Descriptions	Units
θ	initial angle	°
vi	initial velocity	m/s
vf	final velocity	m/s
t	time	s
xf	initial x position	m
xi	final x position	m
yf	initial y position	m
yi	final y position	m
vx	x velocity	m/s
vy	y velocity	m/s
R	maximum range	m
H	maximum height	m

Terminal Velocity

This equation governs the terminal velocity encountered by an object moving through a fluid (or air).

Equations
$v=\sqrt{\frac{2\cdot m\cdot g}{Cd\cdot \rho\cdot A}}$

Variables	Descriptions	Units
v	terminal velocity	m/s
m	mass	kg
Cd	drag coefficient	-
σ	fluid density	kg/m^3
A	cross-sectional area	m^2

Linear Mechanics

Center of Mass

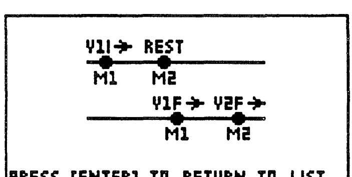
These two equations allow you to calculate the center of mass of up to four distinct objects. If fewer than four objects are desired, simply leave the remaining masses zero.

Equations	
$xcm=\frac{x1\cdot m1+x2\cdot m2+x3\cdot m3+x4\cdot m4}{m1+m2+m3+m4}$	$ycm=\frac{y1\cdot m1+y2\cdot m2+y3\cdot m3+y4\cdot m4}{m1+m2+m3+m4}$

Variables	Descriptions	Units
xcm	center of mass x position	m
ycm	center of mass y position	m
x1	m1 x position	m
x2	m2 x position	m
x3	m3 x position	m
x4	m4 x position	m
y1	m1 y position	m
y2	m2 y position	m
y3	m3 y position	m
y4	m4 y position	m
m1	mass 1	kg
m2	mass 2	kg
m3	mass 3	kg
m4	mass 4	kg

Collisions (Elastic)

These equations describe a one-dimensional elastic collision between two objects.

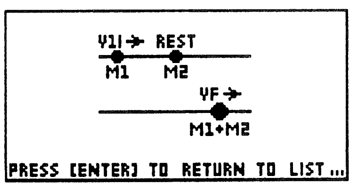


Equations		
$v1f=\frac{m1-m2}{m1+m2}\cdot v1i$	$v2f=\frac{2\cdot m1}{m1+m2}\cdot v1i$	$vcm=\frac{m1}{m1+m2}\cdot v1i$

Variables	Descriptions	Units
m1	mass 1	kg
m2	mass 2	kg
v1i	m1 initial velocity	m/s
v1f	m1 final velocity	m/s
v2f	m2 final velocity	m/s
vcm	center of mass velocity	m/s

Collisions (Inelastic)

This equation describes a one-dimensional inelastic collision between two objects.



Equations
$vf=\frac{v1i\cdot m1}{m1+m2}$

Variables	Descriptions	Units
vf	final velocity	m/s
v1i	m1 initial velocity	m/s
m1	mass 1	kg
m2	mass 2	kg

Linear Mechanics

These equations describe the underlying relationships of Newtonian linear mechanics, and cover the concepts of kinetic energy, work, and power.

Equations		
$F=m\cdot a$	$Ki=\frac{1}{2}\cdot m\cdot vi^2$	$Kf=\frac{1}{2}\cdot m\cdot vf^2$
$W=Kf-Ki$	$W=F\cdot(xf-xi)$	$Pf=F\cdot vf$
$Pavg=\frac{W}{t}$	$vf=vi+a\cdot t$	$xf=xi+vavg\cdot t$
$xf=xi+vi\cdot t+\frac{1}{2}\cdot a\cdot t^2$	$xf=xi+vf\cdot t-\frac{1}{2}\cdot a\cdot t^2$	$vf^2=vi^2+2\cdot a\cdot(xf-xi)$
$vavg=\frac{1}{2}\cdot(vi+vf)$	$vavg=\frac{xf-xi}{t}$	

Variables	Descriptions	Units
xi	initial position	m
xf	final position	m
vi	initial velocity	m/s
vf	final velocity	m/s
vavg	average velocity	m/s
a	acceleration	m/s^2
F	force	N
m	mass	kg
Ki	initial kinetic energy	J
Kf	final kinetic energy	J
W	work	J
Pf	final power	W
Pavg	average power	W
t	time	s

Rocket Science

These equations are simple relations describing rockets and other varying mass objects.

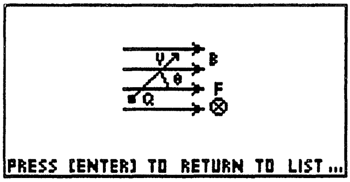
Equations	
$R \cdot u = m \cdot a$	$vf = vi + u \cdot LN\left(\frac{mi}{mf}\right)$

Variables	Descriptions	Units
R	fuel consumption	kg/s
u	exhaust gas velocity	m/s
m	rocket mass	kg
a	acceleration	m/s^2
vi	initial velocity	m/s
vf	final velocity	m/s
mi	initial rocket mass	kg
mf	final rocket mass	kg

Magnetism

Charged Particle

This equation describes the force encountered by a charged particle moving in a magnetic field.



Equations
$F=q \cdot v \cdot B \cdot SIN(\theta)$

Variables	Descriptions	Units
F	force	N
q	charge	C
v	velocity	m/s
B	magnetic field	T
θ	angle	°

Cyclotron

These equations are relations explaining the behavior of a cyclotron.

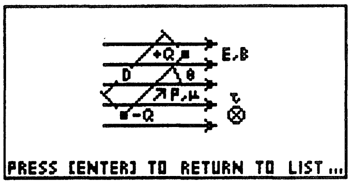
Equations		
$r=\frac{m \cdot v}{q \cdot B}$	$\omega=\frac{q \cdot B}{m}$	$f=\frac{\omega}{2 \cdot \pi}$
$T=\frac{1}{f}$		

Variables	Descriptions	Units
r	radius	m
m	mass	kg

v	velocity	m/s
q	charge	C
B	magnetic field	T
f	frequency	Hz
ω	angular frequency	°/s
T	period	s

Dipole

These equations describe a magnetic dipole and cover the concepts of torque, magnetic moment, and potential energy stored in a dipole configuration.

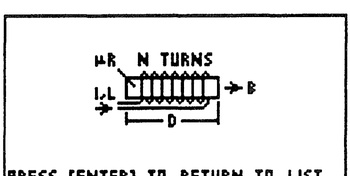


Equations	
$\tau=\mu\cdot B\cdot SIN(\theta)$	$U=-\mu\cdot B\cdot COS(\theta)$

Variables	Descriptions	Units
τ	torque	N·m
μ	dipole moment	J/T
B	magnetic field	T
θ	angle	°
U	potential energy	J

Solenoid

This equation gives the magnetic field created by a solenoid, based on the number of turns per unit length.

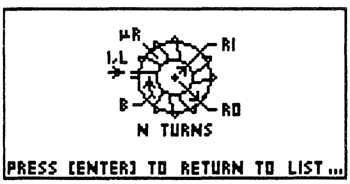


Equations
$B = \mu 0 \cdot \mu r \cdot I \cdot n$

Variables	Descriptions	Units
B	magnetic field	T
μr	relative permittivity	-
I	current	A
n	turns/unit length	1/m

Toroid

This equation gives the magnetic field generated by a toroid at a radius r, where ro < r < ri .



Equations
$B = \frac{\mu 0 \cdot \mu r \cdot I \cdot N}{2 \cdot \pi \cdot r}$

Variables	Descriptions	Units
B	magnetic field	T
μr	relative permittivity	-
I	current	A
N	turns	-
r	radius	m

Wire (Loop)

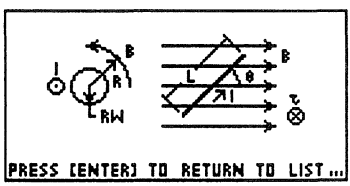
This equation describes the torque applied to a wire loop placed in a magnetic field. The torque acts to align the loop with the field.

Equations
$\tau = N \cdot I \cdot A \cdot B \cdot \mathrm{SIN}(\theta)$

Variables	Descriptions	Units
τ	torque	N·m
N	turns	-
I	current	A
A	loop area	m^2
B	magnetic field	T
θ	angle	°

Wire (Straight)

These equations describe the magnetic field and force due to a straight conductor. The magnetic field is correctly calculated according to a different relation inside the conductor.



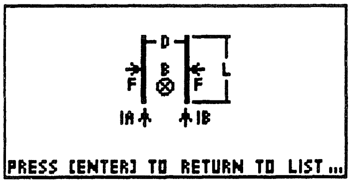
Equations	
$B = \frac{\mu 0 \cdot \mu r \cdot I}{2 \cdot \pi \cdot r}$	$F = I \cdot l \cdot B \cdot \mathrm{SIN}(\theta)$

Variables	Descriptions	Units
B	magnetic field	T
μr	relative permittivity	-
I	current	A
r	radius	m
rw	wire radius	m
F	force	N

l	length	m
θ	angle	°

Wires (Parallel)

This equation describes the attractive force between two parallel wires with current flowing in the same direction.



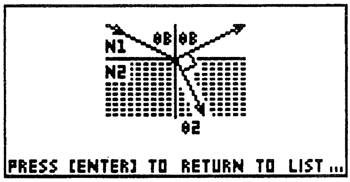
Equations
$F=\frac{\mu 0\cdot \mu r\cdot l\cdot Ia\cdot Ib}{2\cdot \pi\cdot d}$

Variables	Descriptions	Units
F	force	N
μr	relative permittivity	-
l	wire length	m
Ia	wire A current	A
Ib	wire B current	A
d	separation	m

Optics

Brewster's Law

These equations introduce Brewster's Law, which covers the case when the angle between the reflected and refracted rays is 90°.

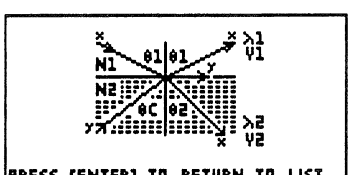


Equations	
$TAN(\theta b)=\frac{n2}{n1}$	$\theta b+\theta 2=90\_°$

Variables	Descriptions	Units
θb	Brewster's angle	°
n1	index of refraction 1	-
n2	index of refraction 2	-
θ2	angle of refraction	°

Reflection/Refraction

These equations cover Snell's Law and the basics of reflection and refraction of a light ray encountering a plane surface boundary between two mediums of differing indices of refraction. The incoming and outgoing wavelengths and velocities can also be found, as can the critical angle, which is the angle at which total internal reflection occurs.

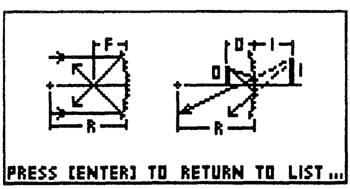


Equations		
$n1 \cdot SIN(\theta 1) = n2 \cdot SIN(\theta 2)$	$n1 = \frac{c}{v1}$	$n2 = \frac{c}{v2}$
$\lambda 1 = \frac{\lambda}{n1}$	$\lambda 2 = \frac{\lambda}{n2}$	$\theta c = ASIN\left(\frac{n1}{n2}\right)$

Variables	Descriptions	Units
n1	index of refraction 1	-
n2	index of refraction 2	-
θ1	angle of incidence	°
θ2	angle of refraction	°
θc	critical angle	°
v1	light velocity in 1	m/s
v2	light velocity in 2	m/s
λ	wavelength in vacuum	m
λ1	wavelength in 1	m
λ2	wavelength in 2	m

Spherical Mirrors

These equations govern object, image, and focal distance for spherical mirrors. Use negative values of r for convex mirrors.

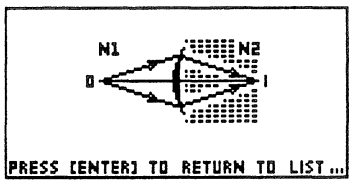


Equations		
$\frac{1}{O} + \frac{1}{I} = \frac{1}{F}$	$F = \frac{1}{2} \cdot r$	$\frac{1}{O} + \frac{1}{I} = \frac{2}{r}$
$m = \frac{-I}{O}$	$m' = -m^2$	

Variables	Descriptions	Units
O	object distance	m
I	image distance	m
F	focal length	m
r	curvature radius	m
m	lateral magnification	-
m'	longitudinal magnification	-

Spherical Refraction

These equations govern object and image distance for spherical refraction between two mediums of differing indices of refraction.

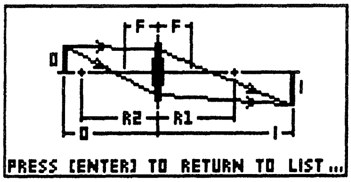


Equations		
$\frac{n1}{O}+\frac{n2}{I}=\frac{n2-n1}{r}$	$m'=\frac{n2}{n1}\cdot m^2$	$m=\frac{-n1\cdot O}{n2\cdot I}$

Variables	Descriptions	Units
O	object distance	m
I	image distance	m
r	curvature radius	m
n1	index of refraction 1	-
n2	index of refraction 2	-
m	lateral magnification	-
m'	longitudinal magnification	-

Thin Lenses

These equations are the standard thin lens approximations, and predict image and object distances based on the radii of curvature of the sides of the thin lens.

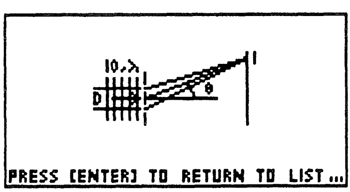


Equations		
$\frac{1}{O}+\frac{1}{I}=\frac{1}{F}$	$\frac{1}{F}=(n-1)\cdot\left(\frac{1}{r1}-\frac{1}{r2}\right)$	$m=\frac{-I}{O}$
$m'=m^2$		

Variables	Descriptions	Units
O	object distance	m
I	image distance	m
F	focal length	m
r1	curvature radius 1	m
r2	curvature radius 2	m
n	lens index of refraction	-
m	lateral magnification	-
m'	longitudinal magnification	-

Two-Slit Diffraction

These equations cover two-slit diffraction of an incoming plane wave.



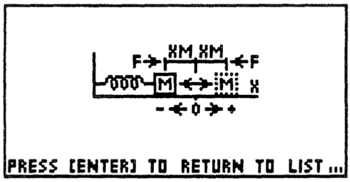
Equations		
$d \cdot SIN(\theta max) = m \cdot \lambda$	$d \cdot SIN(\theta min) = \left(m + \frac{1}{2}\right) \cdot \lambda$	$I = 4 \cdot I0 \cdot COS\left(\frac{\phi}{2}\right)^2$
$\phi = \frac{2 \cdot \pi \cdot d}{\lambda} \cdot SIN(\theta)$	$\lambda = \frac{ym \cdot d}{m \cdot r}$	

Variables	Descriptions	Units
d	slit spacing	m
m	0,1,2,	-
λ	wavelength	m
θ	angle	°
θmax	maxima angle	°
θmin	minima angle	°
φ	phase	°
I	intensity	W/m^2

Oscillations

Mass-Spring System

These equations include Hooke's Law and explain the behavior of a mass-spring system. The mass position, kinetic energy, and potential energy vary according to the frequency of oscillation and the spring constant.

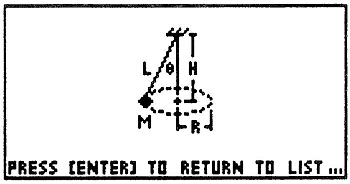


Equations		
$F=-k\cdot x$	$\omega=\sqrt{\frac{k}{m}}$	$x=xm\cdot\cos(\omega\cdot t+\phi)$
$K=\frac{1}{2}\cdot k\cdot xm^2\cdot\sin(\omega\cdot t+\phi)^2$	$U=\frac{1}{2}\cdot k\cdot xm^2\cdot\cos(\omega\cdot t+\phi)^2$	$E=\frac{1}{2}\cdot k\cdot xm^2$
$\omega=2\cdot\pi\cdot f$	$T=\frac{1}{f}$	

Variables	Descriptions	Units
F	spring force	N
k	spring constant	N/m
x	displacement	m
xm	maximum displacement	m
m	mass	kg
ω	angular frequency	°/s
T	period	s
f	frequency	Hz
Φ	phase constant	°
t	time	s
K	kinetic energy	J
U	potential energy	J
E	total energy	J

Pendulum (Conical)

These equations describe the motion of a conical pendulum, including the centripetal force acting on the oscillating mass.

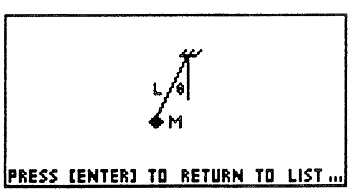


Equations		
$\omega=\sqrt{\frac{g}{H}}$	$F=m\cdot\omega^2\cdot r$	$H=l\cdot COS(\theta)$
$r=l\cdot SIN(\theta)$	$\omega=2\cdot\pi\cdot f$	$T=\frac{1}{f}$

Variables	Descriptions	Units
ω	angular frequency	°/s
F	centripetal force	N
m	mass	kg
θ	cone angle	°
l	length	m
r	radius	m
H	cone height	m
T	period	s
f	frequency	Hz

Pendulum (Simple)

These equations describe the motion of a simple pendulum, including the restoring force acting on the oscillating mass.

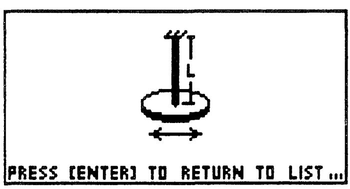


Equations		
$\omega=\sqrt{\frac{g}{l}}$	$F=-m\cdot g\cdot SIN(\theta)$	$\omega=2\cdot\pi\cdot f$
$T=\frac{1}{f}$		

Variables	Descriptions	Units
F	restoring force	N
ω	angular frequency	°/s
m	mass	kg
θ	angle	°
l	length	m
T	period	s
f	frequency	Hz

Pendulum (Torsional)

These equations describe the motion of a torsional pendulum, including the restoring force acting on the rotating mass. The material properties of the shaft come into play.



Equations		
$\omega=\sqrt{\frac{k}{I}}$	$\tau=-k\cdot\theta$	$k=\frac{Gm\cdot J}{l}$
$\omega=2\cdot\pi\cdot f$	$T=\frac{1}{f}$	

Variables	Descriptions	Units
ω	angular frequency	°/s
τ	restoring torque	N·m
k	torsional constant	J
θ	angle	°
I	moment of inertia	$kg \cdot m^2$
G	shear modulus elasticity	Pa
J	polar moment inertia	m^4
l	length	m
T	period	s
f	frequency	Hz

Simple Harmonic Motion

These equations describe simple harmonic motion.

Equations		
$x=xm \cdot COS(\omega \cdot t+\varnothing)$	$v=-\omega \cdot xm \cdot SIN(\omega \cdot t+\varnothing)$	$a=-\omega^2 \cdot xm \cdot COS(\omega \cdot t+\varnothing)$
$\omega=2 \cdot \pi \cdot f$	$T=\frac{1}{f}$	

Variables	Descriptions	Units
x	displacement	m
xm	amplitude	m
t	time	s
v	velocity	m/s
a	acceleration	m/s^2
T	period	s
f	frequency	Hz
ω	angular frequency	°/s
Φ	phase constant	°

Two-Body System

These equations describe a two-body system by means of the reduced mass and oscillation frequency.

Equations		
$\mu=\frac{m1 \cdot m2}{m1+m2}$	$\omega=\sqrt{\frac{k}{\mu}}$	$\omega=2 \cdot \pi \cdot f$
$T=\frac{1}{f}$		

Variables	Descriptions	Units
μ	reduced mass	kg
m1	mass 1	kg
m2	mass 2	kg
k	spring constant	N/m
ω	angular frequency	°/s
T	period	s
f	frequency	Hz

Special Relativity

Doppler Effect

These equations present the relativistic simplifications of the Doppler effect.

Equations		
$fl=f\cdot\sqrt{\dfrac{1-\frac{v}{c}}{1+\frac{v}{c}}}$	$ft=\dfrac{f}{\gamma}$	$\gamma=\dfrac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

Variables	Descriptions	Units
f	proper frequency	Hz
fl	longitudinal frequency	Hz
ft	transverse frequency	Hz
v	velocity	m/s
γ	Lorentz factor	-

Energy/Mass/Momentum

These equations relate relativistic energy, mass, and momentum.

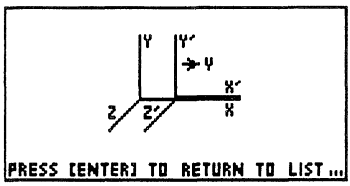
Equations		
$m'=\gamma\cdot m$	$p=m\cdot v$	$p'=m'\cdot v$
$K=\frac{1}{2}\cdot m\cdot v^2$	$K'=m\cdot c^2\cdot(\gamma-1)$	$Em=m\cdot c^2$
$E=m\cdot c^2\cdot\gamma$	$E^2=(p'\cdot c)^2+\left(m\cdot c^2\right)^2$	$\gamma=\dfrac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

Variables	Descriptions	Units
m	rest mass	kg
m′	relativistic mass	kg
p	classical momentum	kg·m/s
p′	relativistic momentum	kg·m/s
K	classical kinetic energy	J
K′	relativistic kinetic energy	J

Em	mass energy	J
E	total energy	J
v	velocity	m/s
γ	Lorentz factor	-

Gallilean Transform

These equations describe the basic Gallilean transformation of an object from the observer frame to the object (prime) frame. All other properties (y, z, vy, vz, ax, ay, and az) remain unchanged during a Gallilean transformation, and are therefore not included.

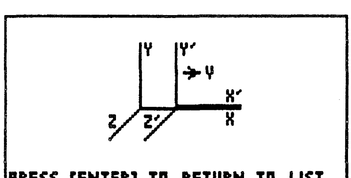


Equations	
$x'=x-v\cdot t$	$vx'=vx-v$

Variables	Descriptions	Units
v	velocity of prime frame	m/s
t	time	s
x	x position	m
x′	x position (prime)	m
vx	x velocity	m/s
vx′	x velocity (prime)	m/s

Length/Time Dilation

These equations describe length and time dilation. The proper length is the length of the object as measured in the object (prime) frame. The dilated length is that seen by an observer with respect to whom the object is moving.

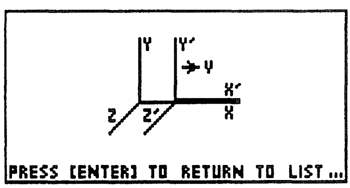


Equations		
$t=t'\cdot\gamma$	$l=\frac{l'}{\gamma}$	$\gamma=\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

Variables	Descriptions	Units
t	time	s
t′	proper time (prime)	s
l	length	m
l′	proper length (prime)	m
v	velocity of prime frame	m/s
γ	Lorentz factor	-

Lorentz Transform

These equations describe the basic Lorentz transformation of an object from the observer frame to the object (prime) frame. All other properties (y, z, ax, ay, and az) remain unchanged during a Lorentz transformation, and are therefore not included.



Equations		
$x'=(x-v\cdot t)\cdot\gamma$	$t'=\left(t-\frac{v\cdot x}{c^2}\right)\cdot\gamma$	$vx'=\frac{vx-v}{1-\frac{v\cdot vx}{c^2}}$
$vy'=\frac{vy}{1-\frac{v\cdot vx}{c^2}}\cdot\left(\frac{1}{\gamma}\right)$	$vz'=\frac{vz}{1-\frac{v\cdot vx}{c^2}}\cdot\left(\frac{1}{\gamma}\right)$	$\gamma=\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

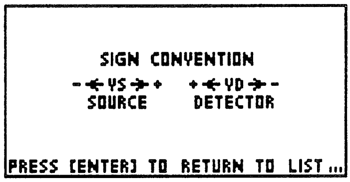
Variables	Descriptions	Units
x	x position	m
x′	x position (prime)	m
t	time	s
t′	time (prime)	s
vx	x velocity	m/s
vx′	x velocity (prime)	m/s

vy	y velocity	m/s
vy´	y velocity (prime)	m/s
vz	z velocity	m/s
vz´	z velocity (prime)	m/s
v	velocity of prime frame	m/s
γ	Lorentz factor	-

Waves

Doppler Effect

These equations describe the Doppler effect. Note the sign conventions displayed in the picture.



Equations
$f' = \frac{f \cdot (v+vd)}{v-vs}$

Variables	Descriptions	Units
f	frequency	Hz
f′	Doppler frequency	Hz
v	sound velocity	m/s
vd	detector velocity	m/s
vs	source velocity	m/s

Organ Pipes

These equations describe open and closed pipe frequencies for various acoustical purposes.

Equations	
$fo = \frac{v \cdot no}{2 \cdot l}$	$fc = \frac{v \cdot nc}{4 \cdot l}$

Variables	Descriptions	Units
fo	open pipe frequency	Hz
fc	closed pipe frequency	Hz
no	1,2,3,	-
nc	1,3,5,	-
l	pipe length	m

v	sound velocity	m/s

Sound Waves

These equations describe the fundamentals of sound waves. The unit of decibels is defined by storing 1 into the variable 'dB' in the 'PHYSD' directory.

Equations		
$v=\sqrt{\frac{B}{\rho}}$	$I=\frac{1}{2}\cdot\rho\cdot v\cdot\omega^2\cdot sm^2$	$\beta=10\cdot LOG\left(\frac{I}{ref}\right)$
$\Delta Pm=v\cdot\rho\cdot\omega\cdot sm$	$\omega=2\cdot\pi\cdot f$	$fb=f-f'$

Variables	Descriptions	Units
v	speed of sound	m/s
B	bulk modulus elasticity	Pa
σ	density	kg/m^3
I	sound intensity	W/m^2
sm	longitudinal amplitude	m
fl	sound level	dB
ΔPm	maximum pressure change	Pa
ω	angular frequency	°/s
f	frequency 1	Hz
f′	frequency 2	Hz
fb	beat frequency	Hz

Waves

These equations describe basic transverse and longitudinal waves. They cover the concepts of wave number, wavelength, maximum amplitude, and velocity.

Equations		
$y=ym\cdot SIN(k\cdot x-\omega\cdot t)$	$s=sm\cdot COS(k\cdot x-\omega\cdot t)$	$k=\frac{2\cdot\pi}{\lambda}$
$\omega=\frac{2\cdot\pi}{T}$	$T=\frac{1}{f}$	$v=\lambda\cdot f$

Variables	Descriptions	Units
y	transverse displacement	m
ym	transverse amplitude	m
s	longitudinal displacement	m
sm	longitudinal amplitude	m
k	angular wave number	°/m
λ	wavelength	m
x	x position	m
ω	angular frequency	°/s
t	time	s
f	frequency	Hz
T	period	s
v	wave velocity	m/s

Appendix D

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W, X, Y, Z