Chapter 27
The Equation Library

The Equation Library is a collection of equations and commands that enable you to solve simple science and engineering problems. The library consists of more than 300 equations grouped into 15 technical subjects containing more than 100 problem titles. Each problem title contains one or more equations that help you solve that type of problem. Appendix M contains a table of the groups and problem titles available in the Equation Library.

Note: the examples in this chapter assume that the operating mode is RPN and that flag –117 is set. (Flag –117 should be set whenever you use the numeric solver to solve equations in the equations library.)

WARNING: You can delete the Equation Library if you need more room on your calculator. Libraries 226 and 227 in port 2 constitute the Equation Library, and they can be deleted just like any user-created library. However, if you are thinking of deleting these libraries but there is some likelihood that you will need to use the Equation Library in the future, you should copy them to a PC, using the HP 48/49 Calculator Connectivity Kit, before deleting them on the calculator. You will then be able to re-install the libraries later when you need to use the Equation Library. (Deleting a library is explained in chapter 26.)

Solving a Problem with the Equation Library

Follow these steps for solving an equation using the Equation Library.

1. Press APPS ▲ ENTER to start the Equation Library.
2. Set the unit options you want by pressing the menu keys.
3. Highlight the subject you want (for example, Fluids) and press ENTER.
4. Highlight the title you want (for example, Pressure at Depth) and press ENTER.
5. The first equation is displayed. Press to display subsequent equations.
6. Press to start the Solver.

7. For each known variable, type its value and press the corresponding menu key. If a variable is not shown, press NXT to display further variables.

8. Optional: supply a guess for an unknown variable. This can speed up the solution process or help to focus on one of several solutions. Enter a guess just as you would the value of a known variable.

9. Press ↰ followed by the menu key of the variable for which you are solving. If you want to solve all the equations in the selected title, press ↰ SOLV. The Solver then calculates values for all the variables not previously defined by you.

Using the Solver

When you select a subject and a title in the Equation Library, you specify a set or one or more equations. Then, when you press SOLV, you leave the Equation Library catalogs and start solving the equations you've selected.

When you press SOLV in the Equation Library, the application does the following:

- The set of equations is stored in the appropriate variable: *EQ* for one equation, *EQ* and *Mpar* for more than one equation. (*Mpar* is a reserved variable used by the Multiple-Equation Solver.) Note: because *EQ* and *Mpar* are variables, you can have a different *EQ* and *Mpar* for each directory in memory.

- Each variable is created and set to zero *unless it already exists*. (If the variable name has been used by the solver before, then it is a global variable and therefore already exists: until you purge it.)

- Each variable's units are set to the conditions you specified: SI or English, and units used or not used—*unless the variable already exists* and has units dimensionally consistent with what you specified. (To change from English to SI units or vice versa, you must first purge the existing variables *or* explicitly enter the units with the values.)

- The appropriate solver is started: the SOLVR for one equation, the Multiple-Equation Solver for more than one equation.

Using the menu keys

The actions of the unshifted and shifted variable menu keys for both solvers are identical. Notice that the Multiple Equation Solver uses two forms of menu labels: black and white. The NXT key displays additional menu labels, if required. In addition, each solver has special menu labels. You can tell which solver is started by looking at the special menu labels.

Actions for Solver Menu Keys

Operation	SOLVE application	Multiple-Equation Solver
Store value		
Solve for value		 
Recall value		 
Evaluate equation		
Next equation (if applicable)		
Undefine all		
Solve for all		
Progress catalog		
Set states		

Browsing in the Equation Library

When you select a subject and title in the Equation Library, you specify a set of one or more equations. You can get the following information about the equation set from the Equation Library catalogs:

- The equations themselves and the number of equations.
- The variables used and their units. (You can also change the units.)
- A picture of the physical system (for most equation sets).

Viewing equations

All equations have a *display form* and some applications also have a *calculation form*. The display form gives the equation in its basic form, the form you would see in books. The calculation form includes computational refinements. If an equation has a computational form, an * appears in the upper left corner of the equation display.

Operations for viewing Equations and Pictures

Key	Action	Example
EXIT NXEQ	Shows the display form of current or next equation in EquationWriter format.	$B = \frac{\mu 0 \cdot \mu r \cdot I}{2 \cdot \pi \cdot r}$
ENTER	Shows the display form of current or next equation as an algebraic object. ENTER or ▼ shows the next equation, ▲ shows the previous.	'B=(μ0*μr*I)/ (2*à*r)'
EDIT	Shows calculation form by putting a list containing the current set of equations on the stack.	{'B=IFTE(r<rw,CO NST(μ0)*μr*I*r/ (2*à*rw^2),CONST (μ0)*μr*I/ (2*à*r))' }

Viewing variables and selecting units

After you select a subject and title, you can view the catalog of names, descriptions, and units for the variables in the equation set by pressing UNITS. The table below summarizes the operations available to you in the Variable catalogs.

Operations in Variable catalogs

Key	Action
NXT	Toggles between the catalog of descriptions and the catalog of units.
SI ENG	Makes SI or English units active, unless this conflicts with the units already defined for an existing (global) variable. Purge existing variables (or enter the specific units) to eliminate conflicts.
UNITS	Toggles between units used and units not used.
CHNGS	Creates or changes all equation variables to have indicated unit type and usage.
PURGE	Purges all equation variables for this title in the current directory. This also eliminates SI vs. English units conflicts.

Viewing the picture

After you select a subject and title, you can view the picture of the problem (if the title has a picture).

To see the picture, press PICT. While the picture is displayed, you can:

- Press [STO] to store the picture in *PICT*, the graphics memory. Then you can use [RCL] PICT (or [RCL] PICTURE) to view the picture again after you have quit the Equation Library.
- Press a menu key or to view other equation information.

Using the Multiple-Equation Solver

The Equation Library starts the Multiple-Equation Solver automatically if the equation set contains more than one equation. However, you can also start it up explicitly using your own set of equations (see "Defining a set of equations" on page 27-8).

When the Equation Library starts the Multiple-Equation Solver, it first stores the equation set in *EQ* and stores a copy of the equation set, the list of variables, and additional information in *Mpar*. *Mpar* is then used to set up the Solver menu for the current equation set. (Note that although you can view and edit *EQ* directly like any other variable, *Mpar* can only be edited indirectly (by executing commands that modify it) as it is structured as library data dedicated to the Multiple-Equation Solver application.)

The following table summarizes the actions for the solver menu keys. The [NXT] key shows additional menu labels.

Solver Menu Keys

Operation	Key	Action
Store value	[X] [X]	Creates a variable if necessary, and makes it user-defined. If the value has no units, the units of the previous value are appended, if any.
Solve for value	[←] [X] [←] [X]	Creates a variable if necessary, solves for its value, and makes it not user-defined.
Recall value	[→] [X] [→] [X]	Recalls value of variable to the stack.

Undefined all		Makes all variables not user-defined, but does not specify their values.
Solve for all		Creates variables if necessary and solves for all that are not user-defined (or as many as possible).
Progress catalog		Shows information about the last solution.
User-defined		Sets states to *user-defined* for variable or list of variables on the stack.
Calculated		Sets states to *not user-defined* (calculated result) for variable or list of variables on the stack

The menu labels for the variable keys are white at first, but change during the solution process as described below.

Because a solution involves many equations and many variables, the Multiple-Equation Solver must keep track of variables that are user-defined and not defined—those it can't change and those it can. In addition, it keeps track of variables that it used or found during the last solution process.

The menu labels indicate the states of variables. They are automatically adjusted as you store variables and solve for variables. You can check that variables have proper states when you supply guesses and find solutions.

Notice that ▪ marks the variables that were used in the last solution—their values are compatible with each other. Other variables may not have compatible values because they aren't involved in the solution.

Meanings of Menu Labels

Label	Meaning
	Value *x0* is not defined by you and not used in the last solution. It can change with the next solution.
	Value *x0* is not defined by you, but it was found in the last solution. It can change in the next solution.
	Value *x0* is defined by you and not used in the last solution. It cannot change in the next solution (unless you solve only for this variable).
	Value *x0* is defined by you and used in the last solution. It cannot change in the next solution (unless you solve only for this variable).

Defining a set of equations

When you design a set of equations, you should do it with an understanding of how the Multiple-Equation Solver uses the equations to solve problems.

The Multiple-Equation Solver uses the same process you'd use to solve for an unknown variable (assuming that you were not allowed to create additional variables). You'd look through the set of equations for one that has only one variable that you didn't know. You'd then use the root-finder to find its value. Then you would do this again until you've found the variable you want.

You should choose your equations to allow likely unknown variables to occur individually in equations. You must avoid having two or more unknown variables in all equations. You can also specify equations in an order that's best for your problems.

For example, the following three equations define initial velocity and acceleration based on two observed distances and times. The first two equations alone are mathematically sufficient for solving the problem, but each equation contains two unknown variables. Adding the third equation allows a successful solution because it contains only one of the unknown variables.

$$x_1 = v_0 + a \cdot t_1$$

$$x_2 = v_0 + a \cdot t_2$$

$$(x_2 - x_1) = a \cdot (t_2 - t_1)$$

To create more robust equations, you can include functions that ensure proper and faster calculations—for example, CONST and TDELTA, UBASE, EXP, and IFTE.

If your equations use any of the following functions, their variables won't necessarily be detected by the Multiple-Equation Solver: Σ, ∫, ∂, |, QUOTE, APPLY, TVROOT, and CONST.

The list of equations in *EQ* may contain menu definitions, but those definitions are ignored by MINIT when it creates *Mpar*. However, you can reorder the menu labels using MITM (described below).

To create a set of equations for the Multiple-Equation Solver

1. Enter each equation in the set onto the stack.
2. Press ▲ to begin the Interactive Stack and then move the cursor up to the level containing the first equation you entered.
3. Press  to combine them into a list.
4. Press ' ALPHA E ALPHA Q STO▶ to store the list into the *EQ* variable.
5. Press APPS ▲ ENTER  to create *Mpar* and prepare the equation set for use with the Multiple-Equation Solver.

6. Press [illegible] to launch the solver with the new set of equations.

To change the title and menu for a set of equations

1. Make sure that the set of equations is the current set (as they are used when the Multiple-Equation Solver is launched).
2. Enter a text string containing the new title onto the stack.
3. Enter a list containing the variable names in the order you want them to appear on the menu. Use a " " to insert a blank label. You must include *all* variables in the original menu and no others, and you must match uppercase and lowercase characters.
4. Press (APPS) (▲) (ENTER) [illegible].

Interpreting results from the Multiple-Equation Solver

The Multiple-Equation Solver solves for variables by repeatedly looking through the set of equations for one that contains only one variable that's unknown (not user-defined and not found by the solver during this solution). It then uses the root-finder to find that value. It continues eliminating unknown variables until it solves for the variable you specified (or until it can't solve for any more variables). Each time the Multiple-Equation Solver starts solving for a variable, only the variables with black menu labels are known.

During the solution process, the Multiple-Equation Solver shows the variable it is currently solving for. It also shows the type of root found (zero, sign-reversal, or extremum) or the problem if no root is found (bad guesses or constant).

The following messages indicate errors in the problem setup:

- `Bad Guess(es)`. Units may be missing or inconsistent for a variable. For a list of guesses, at least one of the list elements must have consistent units.
- `Too Many Unknowns`. The solver eventually encountered only equations having at least two unknowns. Either enter other known values, or change the set of equations.

- Constant? The initial value of a variable may be leading the root-finder in the wrong direction. Supply a guess in the opposite direction from a critical value. (If negative values are valid, try one.)

Checking solutions

The variables having a ◡ mark in their menu labels are related for the most recent solution. They form a compatible set of values satisfying the equations used. The values of any variables without marks may not satisfy the equations because those variables were not involved in the solution process.

If any solutions seem improper, check for the following problems:

- Wrong units. A known or found variable may have units different from those you assumed. These are global variables. If the variable existed before this calculation, then its unit system (SI or English) takes priority. To correct the units, either purge the variables before solving the equation, or enter the specific units you want.

- No units. If you are not using variables, your implied units may not be compatible among your variables or with the implied units of constants or functions. The current angle mode sets the implied units for angles.

- Multiple roots. An equation may have multiple roots, and the solver may have found an inappropriate one. Supple a guess for the variable to focus the search in the appropriate range.

- Wrong variable states. A known or unknown variable may not have the appropriate state. A known variable should have a black menu label, and an unknown variable should have a white label.

- Inconsistent conditions. If you enter values that are mathematically inconsistent for the equations, the application may give results that satisfy some equations but not all. This includes over-specifying the problem, where you enter values for more variables than are needed to define a physically realizable problem—the extra values may create an impossible or illogical problem. (The solutions satisfy the equations the solver used, but the solver doesn't try to verify that the solution satisfies all of the equations.)

- Not related. A variable may not be involved in the solution (no ▪ mark in the label), so it is not compatible with the variables that were involved.
- Wrong direction. The initial value of a variable may be leading the root-finder in the wrong direction. Supply a guess in the opposite direction from a critical value. (If negative values are valid, try one.)