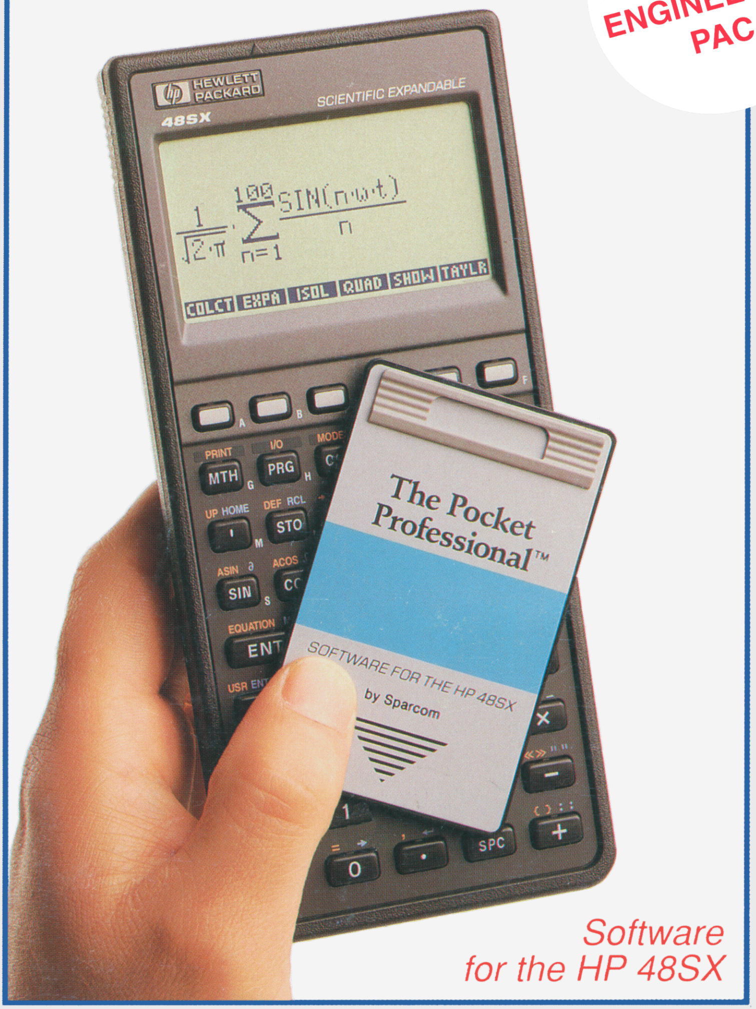
Sparcom

Pocket Professional™

OWNER'S MANUAL

MECHANICAL ENGINEERING PAC



Software for the HP 48SX

The Pocket Professional™

Mechanical Engineering Application Pac

Owner's Manual

SPARCOM®

Edition 2 August, 1991

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Notice

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Acknowledgements

 Sparcom wishes to express appreciation to Hewlett-Packard's staff for their encouragement and support in the development of the Pocket Professional Mechanical Engineering Application Pac.

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Mechanical Engineering Application Pac Changes

The following changes were made to the Mechanical Engineering Application 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.

<u>HP 48GX USERS ONLY</u>: 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.

Mechanical Engineering Application Pac Manual Changes

These changes apply to the Mechanical Engineering Application Pac Manual, Edition 2, August 1991.

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General: On the HP 48GX, the [ATTN] key has been replaced by CANCEL.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 3-3: Using the Constants Library: On the HP 48GX, press [PRG] TYPE [NXT] DTAG instead of [PRG] OBJ [NXT] DTAG to de-tag an object.

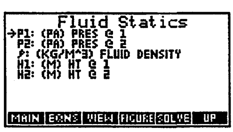
Changes for Version 2.5

General: Because the constants have been updated, some of the examples may differ slightly from the manual.

Page 1-3: Accessing the Mechanical Engineering Application Pac: Picture menu keys should read MEAP MCON ABOUT instead of MEAP ECON DEREC DERUB ABOUT.

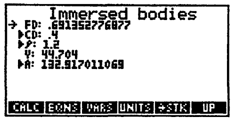
Page 1-6: Using the Search Mode: The search mode is now case-insensitive.

Page 1-9: Viewing Variable Definitions: Picture should be:



Page 1-16: Finding and Selecting the Equation: If you are continuing the previous example, move the pointer to the *second* equation in the list and press SELECT, to *de*select the second equation.

Page 1-16: Tagging and Entering the Variables: If you are continuing the previous example, after entering the other values at the solver screen, move the pointer to V and press KNOW to unmark V as known (required for plotting); then, press UNIT to turn units off (for faster plotting). This results in the following screen:



Page 1-20: Loading Values from the Stack: First Method: →STK should be ↑STK.

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Page 2-6: Cantilever Beam – Uniform Load: Example: Solve equations 3 and 4.

Page 2-7: Cantilever Beam – Moment: Example: Solve equations 3 and 4.

Page 2-9: Simple Beam – Uniform Load: Equation 1 should contain $+x^3$ instead of $-x^3$

Page 2-9: Simple Beam – Uniform Load: Equation 2 should contain $+4x^3$ instead of $-4x^3$.

Page 2-11: Simple Beam – Moment: Example: Solve equations 3 and 4.

Page 2-24: Manometers: Example: Solve equations 2 and 4 instead of 3 and 4.

Page 2-26: Immersed Bodies: Example: Solve equations 1 and 3.

Page 2-32: Thermodynamics/Ideal Gas Law: Variable description for Vs1 should be "specific volume state 1."

Page 2-33: Thermodynamics/Ideal Gas Law: Example: RG=6.8479_Btu/(lb*°R).

Page 2-49: Semi-Infinite Solid: Example: Solve equations 1, 2, 3, and 4.

Page 2-50: Blackbody Radiation: Example: Solve equations 1 and 3 for first part of example and equation 2 for second part of example.

Page 2-56: Inclined Planes: Equation 5 should be deleted.

Page 2-57: Inclined Planes: Example: Solve equations 1 and 2.

Page 2-59: Axial Load: Example 2: Solve equations 4 and 5.

Page 2-62: Torsion: Variable γ should have angle units instead of no units.

Page 2-62: Torsion: Example 1: t=418.8790_MPa, γ=0.4_°.

Page 2-64: Principal Stresses: Equation 2 should contain $COS(2\cdot\Theta)-\tau xy\cdot SIN(2\cdot\Theta)$ instead of $COS(2\cdot\Theta)+\tau xy\cdot SIN(2\cdot\Theta)$.

Page 2-65: Principal Stresses: Example: Solve equations 1 and 2; σy1=–60705.081_Pa.

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Page 2-68: Simple and Compound Pendulums: Example 2: Solve equation 2.

Page 2-72: Natural Frequency – Beams: Example: Solve equation 1; fn1=1.5381_Hz.

Page 2-74: Helical Springs: Equation 7 should be $\frac{4\cdot C-1}{4\cdot C-4}+\frac{.615}{C}$ instead of $\frac{2\cdot C+1}{2\cdot C}$.

Page 2-75: Helical Springs: Example: Solve equations, 2, 6, 7, 8, and 9; Ds=1_in; Ks=1.1448, C=10, τ=4518714961.02_Pa, k=947.76_N/m, y=105.51_cm.

Page 3-3: Using the ECON Function: ECON should be MCON.

Page 3-3: Using the ECON Function: Picture menu keys should read MEAP MCON ABOUT instead of MEAP ECON DEREC DERUB ABOUT.

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Chapter 1
Getting Started

In This Chapter

- ☐ Welcome
- ☐ Installing and Removing the Card
- ☐ Using the Main Menu
- ☐ Using the Equation Library
- ☐ What You Should Know About the Solver
- ☐ Summary of Functions
- ☐ Summary of Softkeys

Welcome

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™ Mechanical Engineering Application Pac into your HP 48SX, your calculator is instantly transformed into an electronic "textbook," ready to efficiently solve your mechanical engineering problems. The software is organized into six sections: Equation Library, Steam Tables, Vector Analysis, Thermocouples, Constants Library and Reference Library. . . all available in an efficient, menu-driven format.

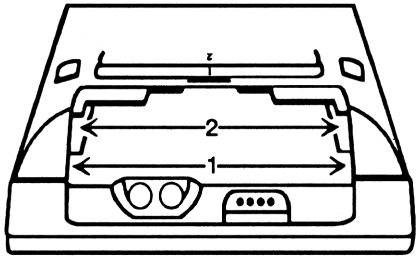
Installing and Removing the Card

The HP 48SX has two ports for installing plug-in cards. You can install your Mechanical Engineering Application Pac card in either port. Be sure to **turn off the calculator** while installing or removing the card. Otherwise, user memory may be erased.

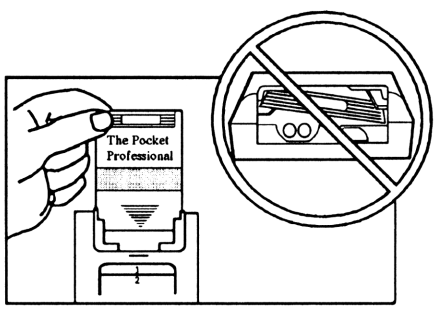
To Install the Application Card

1. Turn off the calculator. Do not press [ON] until you have completed the installation procedure.

2. Remove the port cover. Press against the grip lines and push forward. Lift the cover to expose the two plug-in ports.



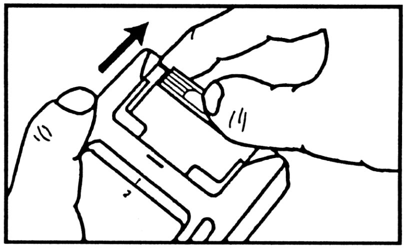
3. Select either empty port for the Pocket Professional card.
4. Position the card just outside the slot. Point the triangular arrow on the card toward the calculator port opening, as shown.
5. Slide the card firmly into the slot. After you first feel resistance, push the card about 1/4 inch further, until it is fully seated.



6. Replace the port cover.

To Remove an Application Card

1. Turn the calculator off. Do not press [ON] until you have completed the procedure.
2. Remove the port cover. Press against the card's grip and slide the card out of the port.

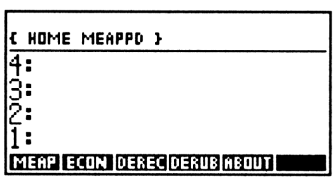


3. Replace the port cover. If you want to remove a RAM card that contains merged memory, **you must free the** merged memory **before** removing the card. Otherwise, you are likely to lose data stored in user memory. See the *HP 48SX Owner's Manual* for instructions.

Accessing the Mechanical Engineering Application Pac

After you turn on your calculator by pressing [ON], there are three ways to start the software.

First Method: Press [←] [LIBRARY] to display all libraries available to the HP 48SX. Find and press **MEAP** to enter the Mechanical Engineering Application Pac library directory. The screen displays new menu keys or "softkeys" along the bottom, as shown:



Press the **MEAP** softkey again to start the application. The **ECON** softkey accesses the Constants Library function, described in Chapter 3.

The **DERME** and **DERUB** are functions required by the software, but are not available to the user.

Pressing the **ABOUT** softkey displays a screen containing the revision number of the Mechanical Engineering Application Pac. (Press [ATTN] to exit the revision screen).

Second Method: Type in [α][α] MEAPP [ENTER].

Third Method: Add the command "MEAPP" 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, press CST, then press **MEAP** to start the application.

Using the Main Menu

After you start the application, the main menu screen appears:

```
   MECHANICAL ENG APP
→EQUATION LIBRARY
  STEAM TABLES
  VECTOR ANALYSIS
  THERMOCOUPLES
  CONSTANTS LIBRARY
  REFERENCE LIBRARY

|    |    |    |    |FONT|QUIT|
```

The main menu lists the six major areas of application in a menu-driven format. Menu-driven means that the information is selected by moving the pointer to an item in the menu and pressing ENTER.

Applications in the Main Menu

Each application in the main menu is briefly described below and is discussed in detail in the next four chapters of this manual.

Equation Library	Allows you to solve, plot and analyze over 300 equations commonly used by mechanical engineers.
Constants Library	Lists over 20 constants in three categories: universal constants, magnetic properties, and mechanical/thermal properties.
Steam Tables	Calculates entropy, enthalpy, internal energy and specific volume of saturated and superheated steam.
Vector Analysis	Adds, computes cross and dot products of vectors specified by magnitude and direction.
Thermocouples	Computes thermocouple data (emf or temperature) for standard thermocouples.

Reference Library	Includes reference data for the physical properties of water, orifice coefficients of water, valve and fitting loss coefficients, and relative roughness of various materials.

The "softkeys" located along the bottom of each screen give you options that relate to the information displayed on any given screen. The following softkeys appear along the bottom of the main menu. A summary of common softkeys used throughout the software is given at the end of this chapter.

FONT Toggles between the large (case-sensitive) and small (uppercase) fonts for easier viewing of results.

UP Moves up one level in the menu structure.

Moving Around the Screen

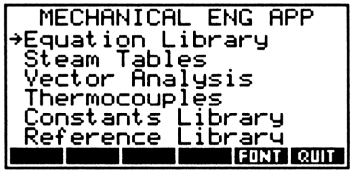
Use the ▲ and ▼ keys to move the pointer up and down in the menu list. Pressing ◀ ▼ moves the pointer to the bottom of the screen, or pages down (one screen at a time) if the pointer is already at the bottom of the screen. Pressing ◀ ▲ moves the pointer to the top of the screen, or pages up. Pressing ▶ ▼ moves the pointer to the bottom of the list and ▶ ▲ moves the pointer to the top of the list.

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. Press ▶ VISIT to display the rest of the text. Press ATTN or ENTER to return to the original display of the item.

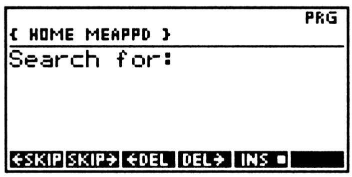
Changing the Font Size

The default font for the Mechanical Engineering Application Pac displays information in the small font with uppercase letters only. Pressing FONT displays the information in a larger font, which is case-sensitive. The font size remains (shown below) until you press FONT again:



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 the [α] key to display the following screen:



The calculator is now in *alpha* entry mode, as indicated by the alpha (α) annunciator at the very top of the screen. Alpha entry mode overrides the function of the standard keyboard. This means that each key that has a white capital letter printed to its lower right loses its original function and types that letter onto the command line when pressed. (See the *HP 48SX Owner's Manual*, "The Keyboard and Display", for a complete description of how the alpha mode operates). Type the first letter or letters of the name you want to search for, to create the *search string*, and press [ENTER]. **The search function is case-sensitive**. To enter a lower case letter in the alpha entry mode, precede the letter with the [↰] key.

Press [ATTN] to return to the main menu.

Editing Text Entries

The search mode softkeys, shown on the screen above, are command line editing keys. They are built into the HP 48SX and allow you to edit the search string. Their functions are summarized below:

←SKIP	Moves the cursor to the beginning of the current word.
SKIP→	Moves the cursor to the beginning of the next word.

←DEL	Deletes all the characters in the current word to the left of the cursor.
DEL→	Deletes all the characters from the cursor's current position to the first character of the next word.
INS	Toggles between insert and typeover modes.

Using the Equation Library

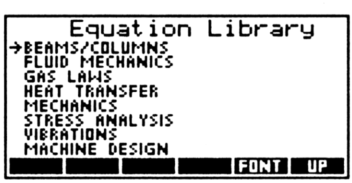
The Equation Library contains over 300 equations commonly used by today's mechanical engineering professionals and students. The Equation Library enables you to:

- Select the equation category and topic from the main menu.
- List all the equations in a topic.
- Solve a specific equation or set of equations.
- View a description of the variables, and show a figure if available.
- Plot the equation.

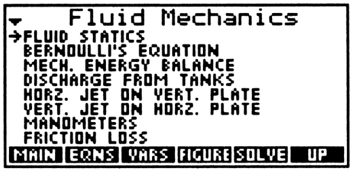
The next few pages show you how to solve a single equation. Solving multiple equations systematically is discussed later in chapter. For example, let's suppose you want to calculate the pressure of a fluid with a density of 1.05_g/cm^3 at point 2, 125 feet below point 1. Assume that pressure at point 1 is 1_atm.

Accessing Equations

The first step in solving this problem is to locate the necessary equation in the Equation Library. At the main menu, move the pointer to EQUATION LIBRARY and press [ENTER]. This displays the list of six main categories:



Move the pointer to FLUID MECHANICS , and press [ENTER] to display the list of topics in this category:



Selecting and Displaying Equations

Move the pointer to the topic FLUID STATICS and press ENTER, or press the softkey **EQNS**, to display the equation set for fluid statics:

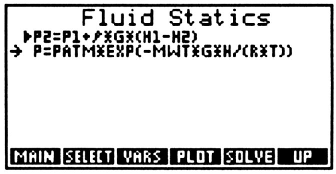
This screen lists all the equations in the current topic. In this case, there are two. For this example, the static pressure P2 at depth h2 is given by the first equation in the set:

$$P2 = P1 + \rho \cdot g \cdot (h1 - h2)$$

where ρ is the density of fluid, P1 is the pressure at height h1, and P2 is the pressure at height h2, and g is the acceleration of gravity constant and is automatically entered from the constants library; no user entry is needed.

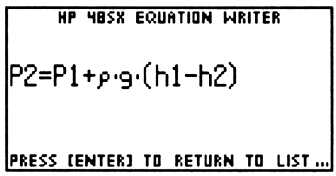
Commonly recognizable symbols such as R, the universal gas constant, or *k* the Boltzmann's constant are automatically extracted from the constants library and no user entry is required. Such variables do not appear in the variable list.

You can solve both of the equations of this set sequentially, iteratively and systematically, or solve only the equation that you select. To select an equation, move the pointer to it and press **SELECT**. This places a triangular tag in front of the equation. If no equations are selected, all the equations in the set are solved sequentially:



Solving multiple equations is discussed later in this chapter.

If you want to view an equation in its full "textbook" form, move the pointer to the equation and press [ENTER]:

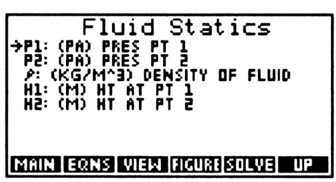


Press [ENTER] or [ATTN] to return to the equation list.

When displaying a lengthy equation from the Equation Library, pressing [◄] or [►] scrolls the screen to the left or to the right revealing the entire equation. Pressing [↰] [►] moves the display window to the end of the equation, and pressing [↰][◄] moves the display window to the beginning of the equation.

Viewing Variable Definitions

You can view a list that defines all the variables in the selected equation, or set of equations, by pressing the **VARS** softkey at the equations screen. The screen below displays the definitions screen for the first equation of the FLUID STATICS topic:

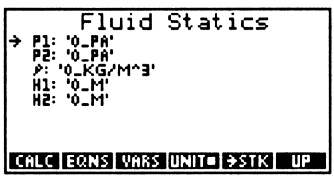


To continue solving the problem, you need to use the solver function.

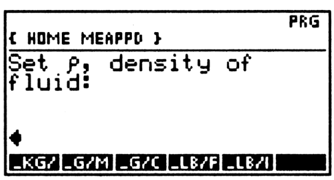
Using the Solver Function

The Sparcom "solver" is a software function that simplifies the job of setting up equations to be calculated by the HP 48SX. The solver function is discussed in more detail later in this chapter, under "What You Need to Know About the Solver."

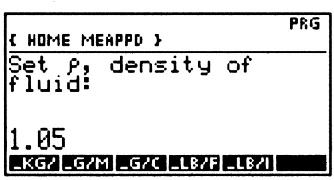
Enter the solver function of the software by pressing **SOLVE**. At the solver screen, the units key becomes available. To work with units for this example, press the **UNITS** toggle key until it reads **UNIT■** The variables for the selected equation(s) now appear on the screen, with units, waiting for you to enter values:



To enter the density, move the pointer to ρ and press [ENTER]. This displays the following screen:



Enter the value for density at the prompt:



After the density is entered, there are two ways to assign units to your entry. The easiest way is by selecting one of the unit softkeys provided on the menu line.

If you choose **not** to add units, just press [ENTER] at the prompt, and the software will assign SI units. In some cases, more units are available than the six softkeys displayed in the first screen. In these cases, press [NXT] to display the additional units. For a complete description of units supported by the HP 48SX and their respective symbols, see the *HP 48SX Owner's Manual*. For this example, press **_G/C** to add units of g/cm^3 to your entry:

```
                              PRG
{ HOME MEAPPD }
Set ρ, density of
fluid:

1.05_g/cm^3
_KG/ _G/M _G/C _LB/F _LB/I
```

Press [ENTER] This returns you to the solver screen with 1.05_g/cm^3 stored into the variable, ρ:

```
      Fluid Statics
   P1: '0_PA'
   P2: '0_PA'
  ▸ρ: '1.05_G/CM^3'
→ H1: '0_M'
   H2: '0_M'

CALC EQNS VARS UNIT□ →STK  UP
```

The triangular tag indicates that ρ is a known variable. Repeat this procedure for the other known variables, P1, h1 and h2. This results in the following screen:

```
      Fluid Statics
→▸P1: '1_ATM'
   P2: '0_PA'
  ▸ρ: '1.05_G/CM^3'
  ▸H1: '0_M'
  ▸H2: '-125_FT'

KNOW WANT CLEAR PURGE CONV  UP
```

With four of the five variables known in this equation, you may now solve the equation for the density by pressing **CALC**. After a few moments, the calculator returns to this screen with the calculated value of P2:

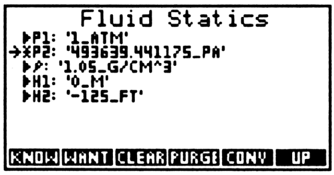
```
      Fluid Statics
  ▸P1: '1_ATM'
→×P2: '493639.441175_PA'
  ▸ρ: '1.05_G/CM^3'
  ▸H1: '0_M'
  ▸H2: '-125_FT'

CALC EQNS VARS UNIT□ →STK  UP
```

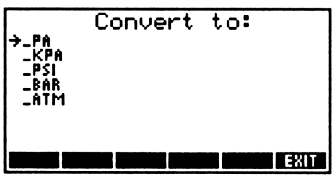
The * by P2 indicates that this value was calculated and was not initially specified.

Converting Data to Different Units.

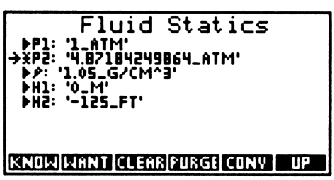
Suppose you want to convert the pressure at point 2 (P2) from Pascals to atmospheres. First press the [NXT] key to reveal the next page of softkeys available for this display:



Move the pointer to the variable P2 and press **CONV**. This lists a select set of possible units for P2:



Move the pointer to _atm and press [ENTER]:



This converts the pressure in Pascals to atmospheres. If you want to use the data for further calculations, move the pointer to the data item and press [NXT] and then press **→STK** to place it on the calculator stack.

Options After Solving the Equation

Pressing [ATTN] exits the software and places you in the calculator operating environment. Pressing **CLEAR** resets all entries in the current topic to zero. Pressing **PURGE** deletes the global copies of each variable in the currently selected set of equations that reside in the MEAPPD directory.

To return to the main menu screen press **UP** multiple times. At the main menu, a new RESUME SOLVING entry will have been added to the list, as shown:

```
  MECHANICAL ENG APP
→RESUME SOLVING...
 EQUATION LIBRARY
 STEAM TABLES
 VECTOR ANALYSIS
 THERMOCOUPLES
 CONSTANTS LIBRARY
 REFERENCE LIBRARY

|    |    |    |    |FONT|QUIT|
```

Selecting the RESUME SOLVING function returns you directly to the equation set you were working with, with all previous entries still intact.

Managing Units

When solving an equation, **UNITS** (a toggle key) controls whether the calculations are performed in your choice of units, or in *Systeme Internationale d'Unites* (SI) units. When the **UNITS** softkey appears, it means that all entries are converted to SI units and the unit designations are removed. **UNIT■** indicates that the software is managing units, and that all values will contain the unit designations that you specify. *All values entered without unit designations are assumed to be in (SI) units.*

Note: Using designated units usually increases processing time.

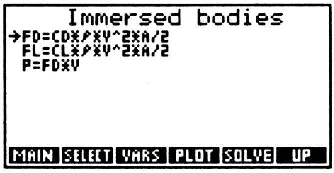
Solving Multiple Equations

For many problems, the result of one calculation acts as the input to another. The Mechanical Engineering Application Pac is capable of solving multiple equations systematically.

Selecting the Equation Set

This example shows how to calculate the forces on an object moving in a fluid . From the Equation Library menu screen, move the pointer to FLUID MECHANICS and press [ENTER]. This category contains nine topics. Move the pointer to IMMERSED BODIES and press [ENTER].

The equations for this topic are displayed on the screen:



These are the three equations in their written form:

$$Fd = \frac{Cd \cdot \rho \cdot V^2 \cdot A}{2} \qquad Fl = \frac{Cl \cdot \rho \cdot V^2 \cdot A}{2}$$

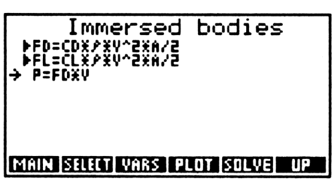
$$P = Fd \cdot V$$

To view the variables for this equation set, press **VARS**. All the variables for the IMMERSED BODIES topic are listed in the following table:

Variable	Description	Eqn Units
Fd	drag force	1_N
Fl	lift force	1_N
Cd	drag coefficient	1
Cl	lift coefficient	1
ρ	fluid density	1_kg/m^3
V	fluid velocity	1_m/s
A	area normal to flow	1_m^2
P	power	1_W

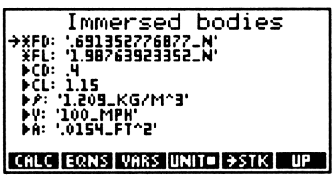
Solving the Equation Set

At the equations screen, move the pointer to the first two equations and press the **SELECT** softkey to "tag" these equations to be solved. The following screen displays these two selected equations indicated by the triangular tags:



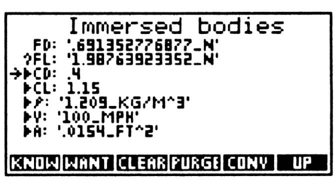
Press **SOLVE** to enter the solver function for these two equations. Enter all the information pertaining to the problem at one time, using the procedure described previously. Press **CALC** to start the solver. The solver then steps through each equation in the list, solving those equations that contain sufficient data to calculate an unknown variable. When all known variables are found, or all remaining equations have more than one unknown variable, the solver stops. It then lists the variables it can't find, and returns to the solver screen. The given variables and calculated results for both selected equations are shown below:

Given	**Result**
Cd = 0.40	Fd = .691352776877_N
Cl = 1.15	Fl = 1.98763923352_N
ρ = 1.209_kg/m^3	
V = 100_mph	
A = 0.0154_ft^2	



Tagging Variables

If you want to solve for only one variable in the list, you can tag it as "wanted." Move the pointer to the variable you want to tag, press NXT to display the additional softkeys for this screen, and press **WANT**. This places a "?" tag in front of the variable you want to solve for:



If you tag Fl and press **CALC**, the solver stops when it finds a value for Fl, rather than solving for the entire set. It is possible to tag more than one variable in the list as "wanted."

Plotting One Equation

Any equation in the Equation Library that is of the form y = f(a,b,c . . .) can be easily plotted using the Mechanical Engineering Application Pac. To plot an equation, the dependent variable on the left (y) and the desired independent variable (a or b or c . . .) on the right side must be unknown (no triangular tag). However, all other variables must be known.

Finding and Selecting the Equation

As an example, plot the variation of drag force as a function of velocity. The equations that describe drag force are filed in the FLUID MECHANICS category, under the topic IMMERSED BODIES. Move the pointer to the first equation in the list and press **SELECT**. Press [ENTER] to view the written out form of the equation, or **VARS** to view the subset of variables for this equation. The equation and a table of its variables are shown below:

$$Fd = \frac{Cd \cdot \rho \cdot V^2 \cdot A}{2}$$

Variable	Description	Eqn Units
Fd	drag force	1_N
Cd	drag coefficient	1
ρ	fluid density	1_kg/m^3
V	fluid velocity	1_m/s
A	area normal to flow	1_m^2

Tagging and Entering the Variables

To plot the drag force curve (Fd versus V), Cd, ρ, and A must be tagged as known variables. Press **SOLVE** to specify values for the following known variables:

Cd = 0.4
ρ = 1.20_kg/m^3
A = 1430.7068_ft^2

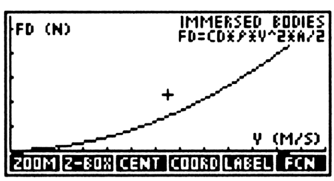
With these three variables entered, return to the equations screen by pressing **EQNS**. **Position the pointer at the first equation** and press **PLOT**. Since this equation is of the proper form, and all but Fd and V have been specified, it may be plotted.

Entering the X and Y Coordinates

The first prompt asks whether you want to erase the previous plot and reset the axes, **YES**, or whether you want the new plot drawn over any existing graphics already on the screen, **NO**. To continue with this example, at the prompt enter **YES** to clear all previous plots from the screen.

Now enter the minimum and maximum values for the x coordinate for the graph. Type the coordinates for the plot on the same line, separated by a space (use the [SPC] key). For this example plot, select the no units option (**UNITS**), then enter 1 100 for V (the assumed units are _m/s). This results in the following screen:

The plot function now prompts for the limits of the y-axis (in this case, Fd, the drag force in _N units). You can either enter the lower and upper limits for y, or allow the system to auto range when [ENTER] is pressed. For this example, press [ENTER] to auto range a plot of Fd versus V over the range of 1 to 100_m/s, shown below:



Plotting Speed

If units are on (the **UNIT■** key is displayed at the solver screen) a plot can take up to 10 minutes to display. If you turn the units off (i.e., toggle the units key to remove the box) the plot function performs in approximately one tenth of the time.

However, as described earlier in this chapter under "Managing Units," when you turn off units, all values are converted to SI units. Therefore, when you enter the x-axis coordinates, you need to enter them as low limit and upper limit. The plot will also be displayed in SI units.

Softkeys for the Plot Function

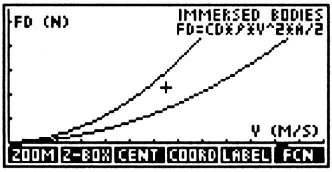
The softkeys shown in the above plot are plot function keys in the HP 48SX. For example, pressing COORD displays the (x,y) coordinates of any point on the screen indicated by the cursor. For a description of the behavior of the plot function softkeys, see Chapter 18 of the *HP 48SX Owner's Manual.*

Note that the SLOPE and F keys, inside the HP 48SX FCN submenu, are supported by the Mechanical Engineering Application Pac only when units are off. You can remove the softkeys from the plot to expose more of the graph by pressing NXT NXT and KEYS. Press ATTN to interrupt the plotting of an equation or to return to the equation screen.

Multiple Plots

In some cases, you may want to graph several versions of an equation on the same axes. To do this, simply answer NO to the "Clear plot first?" prompt after you have pressed PLOT.

For example, suppose you are interested in plotting a new drag force curve for a higher density (e.g., $\rho = 2.4\_kg/m^3$). Return to the solver screen by pressing SOLVE and enter the new value for Fd. Then go to the equations screen, move the pointer to the drag force equation, and press PLOT. At the prompt, press NO. The new graph will plot over the previous one, as shown:



There is no limit to the number of graphs that may be plotted on a given axis. However, the HP 48SX plot/graphics function keys support only the most recent plot.

What You Should Know About the Solver

The examples in this chapter show how the Sparcom's solver makes it easy to specify values and units for equation variables. The solver screen displays the status of each variable in the selected equation set:

- Unknown value (no triangular tag)
- Known value (triangular tag)
- Wanted value ("?" tag)
- Calculated value ("*" tag)

Equation variables show units used by the user.

Once you set these parameters, 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 calculator to use, or the solver will provide a "guess" value 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.

Speeding Up Computing Time

You can speed up computing time by providing the calculator a "guess" value close to the expected solution. At the variables screen, enter your guess value into the "unknown" variable. The variable will then be tagged as "known" (triangle). Press the **KNOW** softkey to toggle the variable back to "unknown" (no tag). Now press **CALC**.

"Bad Guess" Message

If the calculator displays the message, "Bad Guess(es)," after you press the **CALC** softkey, it indicates an error has been made in setting up the problem. Go back through the set up process and check for errors in the data specification.

We urge you to read Chapter 17 of the *HP 48SX Owner's Manual* for a detailed discussion on using the HP 48SX root finder function.

Loading Values from the Stack

There are two ways to enter a value into the Sparcom solver directly from the calculator stack:

First Method: Make sure the value you want is on the stack. Press **MEAP**, then choose an equation set to solve, or select RESUME SOLVING to return to the equation set you're working with. At the variables screen, move the pointer to the variable that will incorporate the value currently on the stack and press [ENTER]. A prompt message asks you to enter the value. Press [⬅] [+/-] to reveal the command line editing keys. Press the **→STK** softkey to invoke a limited version of the HP 48SX Interactive Stack. Move the pointer to the appropriate stack level and press **ECHO** then [ENTER]. This takes you back to the "Enter value" prompt message. Press [ENTER] again to store the echoed value into the current variable and return to the solver screen.

Second Method: Alternatively, store the desired value into a global variable in the MEAPPD directory under the same name as the equation variable. When the solver is entered, it will automatically recall the value and load it into the selected equation variable. Remember to use the **KNOW** softkey to tag the variable as known.

Memory Requirements

The Mechanical Engineeering Application Pac requires some RAM memory in order to work. This memory is used for temporary storage, and for saving variables such as equations to be plotted later. You may encounter errors if the available memory is less than about 4000 bytes.

Sparcom's "MEAPPD" Directory

When you plug in the Mechanical Engineering Application Pac for the first time, the software creates its own directory, MEAPPD, in the HOME directory of the HP 48SX. ALL operations performed by the software take place in the MEAPPD directory. It is, therefore, the only place where global variables are created or purged by the solver. If you purge this directory by mistake, it will be recreated in its entirety, but all the values that you previously stored will be lost.

MEpar

The variable MEpar is created in the MEAPPD directory and is utilized to provide a direct path from the main menu to the solver level. MEpar is created (or rewritten) whenever the equation, solver, or variable levels of the the Equation Library are exited.

There are three possible exit routes that trigger an MEpar update:

1) Pressing ATTN to quit the software and exit to the calculator stack.
2) Pressing UP to return to the topic level.
3) Pressing MAIN to return to the main menu level.

Summary of Softkeys

CALC Stores all variable values and iterates through the set of selected equations in an attempt to find values for all wanted variables. After completion of the solver process, the user is returned to the solver level, where newly found variables are marked with "*".

CLEAR Resets the values of the current variable set to zero.

EQNS Enters the equation level of the current topic.

FIGURE Displays a figure for the currently selected topic or displays "No figure".

FONT Toggles between small and large display font.

KNOW Toggles the currently selected variable between known and unknown, adding or removing the triangular tag.

MAIN Returns to the main menu.

PLOT Prompts the user for x-axis and y-axis values (with option for autoscale y). This feature only works for equations of the form y = f(a,b, ...) where y and one variable on the right are unknown.

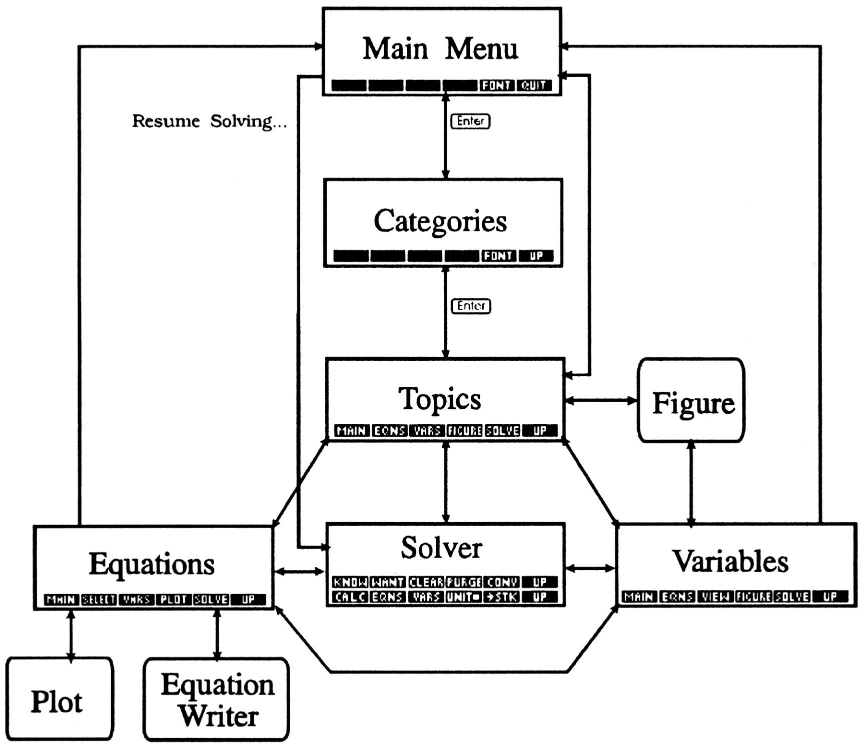
PURGE Purges the global copies (in the MEAPPD directory) of the current variable set displayed in the solver level.

QUIT Exits the Mechanical Engineering Application Pac.

SELECT	Marks or unmarks the currently selected equation with the triangular tag. Only variables in the marked equations will appear in the solver and variable levels (with the exception of constants). If no equations are selected, all will be used.
SOLVE	Enters the solver level of the currrent topic, and executes SOLVE function on the tagged equations, or if none are tagged all equations are solved systematically
→STK	Copies selected entry to calculator stack.
UNIT■	Toggle key. Indicates that units are on.
UNITS	Toggle key. Indicates units are off. When off, all variables are assumed to be SI, if entered with no units, and are converted to SI units even if entered in other units.
UP	Moves up one level in the menu structure.
VARS	Enters the variable level for the current topic.
VIEW	Displays the full text entry for a variable description or value if the description is too wide to fit on the screen.
WANT	Toggles the currently selected variable between wanted and not wanted, adding or removing the symbol "?". If no variables are marked "wanted," all variables are assumed to be wanted.
[ENTER]	Prompts for the value of the currently selected variable. If the selected variable already contains a value, that value is copied to the command line for editing. Pressing [ATTN] clears the command line, or returns you to the variables screen if the command line is already empty.
[ATTN]	This key is generally used to exit the current operation or application.

Summary of Functions

The following figure diagrams the basic flow and function of each level of the Equation Library and Sparcom solver. On the following page, the softkeys available at each level are explained in more detail.



Notes:

Chapter 2
Equation Library

In This Chapter

The Equation Library contains over 300 equations organized into eight main categories. Each category contains several topics. Each topic includes an equation set, a complete list of all variables, a full set of units for these variables. In addition to listing what is in the software, this chapter provides illustrations for several topics and at least one example for each equation set.

- ☐ Beams
- ☐ Fluid Mechanics
- ☐ Gas Laws
- ☐ Heat Transfer
- ☐ Mechanics
- ☐ Stress Analysis
- ☐ Vibrations
- ☐ Machine Design

Beams

The first two topics in this category focus on the computing properties of beams. The remaining topics cover load effects of simple and cantilever beams.

- Hollow Rectangle/I/C Beams
- L/T/U Beams
- Cantilever Beam-Point Load
- Cantilever Beam-Uniform Load
- Cantilever Beam-Moment
- Simple Beam-Point Load
- Simple Beam-Uniform Load
- Simple Beam-Moment
- Simple Beam-Linear Load

Hollow Rectangle/I/C Beams

This topic describes the cross-sectional properties of rectangular I and C sections. Properties computed include area of cross section, moment of inertia, gyration radius, section modulus and distance of center of gravity from the top. The illustration below (not available in the software) shows the dimensional details.

1) $A = B \cdot H - bi \cdot hi$

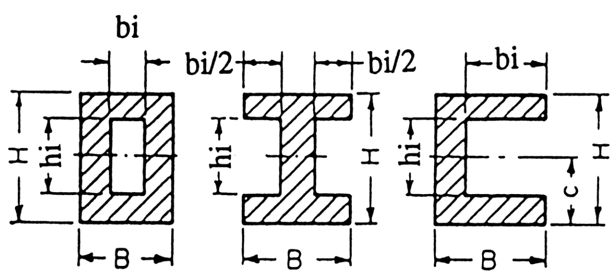
2) $y1 = \frac{H}{2}$

3) $Ix = \frac{B \cdot H^3 - bi \cdot hi^3}{12}$

4) $r = \left(\frac{B \cdot H^3 - bi \cdot hi^3}{12 \cdot (B \cdot H - bi \cdot hi)}\right)^{1/2}$

5) $SM = \frac{B \cdot H^3 - bi \cdot hi^3}{6 \cdot H}$

Variable	Description	Eqn Units
A	area of cross section	1_m^2
B	outer width	1_m
bi	inner width	1_m
H	outer height	1_m
hi	inner height	1_m
y1	distance/center of mass	1_m
Ix	area moment	1_m^4
r	gyration radius	1_m
SM	section modulus	1_m^3



Example: A hollow rectangular beam has an outer height of 6_in and an inner height of 12.5_cm. The inner and outer widths are 8_in and 24_cm. Find its section properties. Solve for all equations to get the results.

Given	**Result**
B = 24_cm	y1 = 0.07620_m

bi = 8_in	r = 0.05809_m
H = 6_in	Ix = 3.772E-5_m^4
hi = 12.5_cm	A = 0.01118_m^2
	SM = 0.00050_m^3

L/T/U Beams

This equation set describes the cross-sectional properties of L, T and U beams. Properties include cross-sectional area, coordinates of the center of mass, area moment of inertia and the radius of gyration. The picture below illustrates the dimensional conventions for these beams.

1) $Area = B \cdot H - bi \cdot (H - d)$

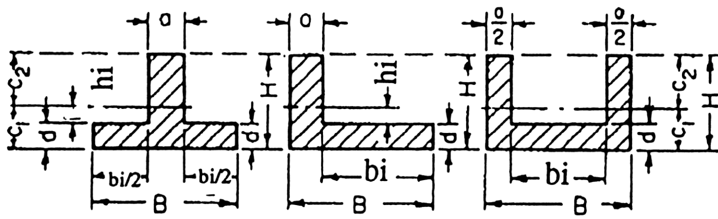
2) $C1 = \frac{1}{2} \cdot \left(\frac{a \cdot H^2 + bi \cdot d^2}{a \cdot H + bi \cdot d}\right)$

3) $C2 = H - C1$

4) $Ix = \frac{1}{3} \cdot \left(B \cdot C1^3 - bi \cdot hi^3 + a \cdot C2^3\right)$

5) $r = \left(\frac{Ix}{B \cdot d + a \cdot (H - d)}\right)^{1/2}$

Variable	Description	Eqn Units
Area	area of cross section	1_m^2
B	overall width	1_m
bi	inner width	1_m
H	overall height	1_m
hi	CM distance from flange top	1_m
d	flange thickness	1_m
C1	CM distance from top	1_m
C2	CM distance from bottom	1_m
a	side thickness	1_m
Ix	area moment of cross section	1_m^4
r	gyration radius	1_m



Example: A U beam has an outer width of 8_in, an inner width of 6_in, an outer height of 6_in and a flange thickness of 4_cm. The center of mass line is located 1_cm away from the inner flange plane. Find the section properties. Using all the equations in the set we get:

Given	**Result**
B = 8_in	Area = 0.0138_m^2
bi = 6_in	C1 = 0.04183_m
H = 6_in	C2 = 0.1106_m
hi = 1_cm	Ix = 1.6352E-5_m^4
a = 1_in	r = 3.859E-2_m
d = 4_cm	

Cantilever Beam-Point Load

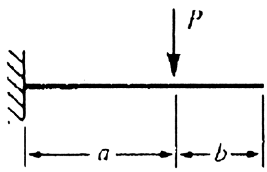
The four equations listed here describe deflection, slope at any point along the beam, and specifically, deflection and slope at the free end of a cantilever beam with a point load.

These equations assume that the beam weight is negligible. Only one point load is allowed in the equation set, and the superposition principle should be applied if more than one point load is to be considered. The illustration shows details of the problem set up.

1) $v = \frac{P \cdot x^2}{6 \cdot E \cdot I} \cdot (3 \cdot a - x)$ 2) $v1 = \frac{P \cdot x}{2 \cdot E \cdot I} \cdot (2 \cdot a - x)$

3) $\delta b = \frac{P \cdot a^2}{6 \cdot E \cdot I} \cdot (3 \cdot L - a)$ 4) $\Theta b = \frac{P \cdot a^2}{2 \cdot E \cdot I}$

Variable	Description	Eqn Units
v	deflection at x	1_m
v1	slope at x	1
P	load	1_N
x	distance from fixed end	1_m
a	load location from fixed end	1_m
L	beam length	1_m
E	Young's modulus	1_Pa
I	area moment of inertia	1_m^4
δb	displacement at free end	1_m
Θb	angle at free end	1_°



Example: A 25-foot-long cantilever beam has a point load of 10000_lbf at a distance of 17_ft from the fixed end. Find the deflection at the load point, and the deflection and slope at the free end. Assume E = 30 x 10^6_psi and I = 1880_in^4.

Given	Result
P = 10000_lbf	v = 1.2745E-2_m
a = 17_ft	δb = 2.1741E-2_m
L = 25_ft	Θb = 0.2114_°
E = 30E6_psi	
I = 1880_in^4	
x = 17_ft	

Cantilever Beam-Uniform Load

The four equations listed here describe deflection, slope at any point along the beam, and specifically deflection and slope at the free end of a cantilever beam with a uniform load.

Beam weight can be included in the uniformly distributed load. The illustration below shows details of the beam for this load condition.

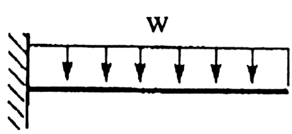
1) $v = \frac{w \cdot x^2}{24 \cdot E \cdot I} \cdot \left(6 \cdot L^2 - 4 \cdot L \cdot x + x^2\right)$

2) $v1 = \frac{w \cdot x}{6 \cdot E \cdot I} \cdot \left(3 \cdot L^2 - 3 \cdot L \cdot x + x^2\right)$

3) $\delta b = \frac{w \cdot L^4}{8 \cdot E \cdot I}$

4) $\Theta b = \frac{w \cdot L^3}{6 \cdot E \cdot I}$

Variable	Description	Eqn Units
v	deflection at x	1_m
v1	slope at x	1
w	uniform load	1_N/m
x	distance from fixed end	1_m
L	beam length	1_m
E	Young's modulus	1_Pa
I	area moment	1_m^4
δb	displacement at free end	1_m
Θb	angle at free end	1_°



Example: A 25-foot-long cantilever beam has a uniformly distributed load of 200_lb/m. The Young's modulus for the beam material is 10 x 10^6_psi, and has an area moment of 180_in^4. Find the maximum deflection and slope at the free end.

Given	Result
w = 200_lbf/m	δb = 0.0726_m
L = 25_ft	Θb = 0.7277_°
E = 10E6_psi	
I = 180_in^4	

Cantilever Beam-Moment

These equations describe deflection, slope at any point along the beam, and specifically deflection and slope at the free end of a cantilever beam for a moment applied at a distance a from the clamped end . These equations assume that the beam weight is negligible.

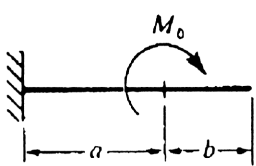
1) $v = \dfrac{M0 \cdot a}{2 \cdot E \cdot I} \cdot (2 \cdot x - a)$

2) $v1 = \dfrac{M0 \cdot x}{E \cdot I}$

3) $\delta b = \dfrac{M0 \cdot a}{2 \cdot E \cdot I} \cdot (2 \cdot L - a)$

4) $\Theta b = \dfrac{M0 \cdot a}{E \cdot I}$

Variable	Description	Eqn Units
v	deflection at x	1_m
v1	slope at x	1
M0	moment	1_N·m
x	distance from fixed end	1_m
a	location of M0 from fixed end	1_m
L	length of beam	1_m
E	Young's modulus	1_Pa
I	area moment	1_m^4
δb	displacement at free end	1_m
Θb	angle at free end	1_°



Example: Using the cantilever beam described in the previous example, suppose you have a moment M0 at a distance of 16_ft from the free end with a value of 17600_N·m. Find the deflection and slope at the free end.

Given
M0 = 17600_N·m
a = 16_ft
L = 25_ft
E = 10E6_psi
I = 180_in^4

Result
δb = 8.6096E-2_m
Θb = 0.9520_°

Simple Beam-Point Load

The seven equations in this set describe deflection slope at any location along the beam, slope at either end of the beam, location maximum deflection, and value of maximum deflection. The assumed load condition is a point load. Additional assumptions include negligible weight contribution from the beam.

$$1)\ v = \frac{P \cdot b \cdot x}{6 \cdot E \cdot L \cdot I} \cdot \left(L^2 - b^2 - x^2\right)$$

$$2)\ v1 = \frac{P \cdot b}{6 \cdot E \cdot L \cdot I} \cdot \left(L^2 - b^2 - 3 \cdot x^2\right)$$

$$3)\ \Theta a = \frac{P \cdot a \cdot b \cdot (L + b)}{6 \cdot L \cdot E \cdot I}$$

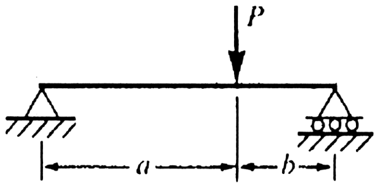
$$4)\ \Theta b = \frac{P \cdot a \cdot b \cdot (L + a)}{6 \cdot L \cdot E \cdot I}$$

$$5)\ \delta c = \frac{P \cdot b \cdot (3 \cdot L^2 - 4 \cdot b^2)}{48 \cdot E \cdot I}$$

$$6)\ x1 = \left(\frac{L^2 - b^2}{3}\right)^{1/2}$$

$$7)\ \delta max = \frac{P \cdot b \cdot (L^2 - b^2)^{3/2}}{9 \cdot \sqrt{3} \cdot L \cdot E \cdot I}$$

Variable	Description	Eqn Units
v	deflection at x	1_m
v1	slope at x	1
P	uniform load	1_N
x	distance from fixed end	1_m
a	location from end	1_m
L	beam length	1_m
E	Young's modulus	1_Pa
I	area moment	1_m^4
Θa	angle at left end	1_°
Θb	angle at right end	1_°
x1	distance to maximum deflection	1_m
δc	deflection at center	1_m
δmax	maximum deflection	1_m
b	location from right end	1_m



Example: A simple beam 20_ft long has a point load of 2500_lbf at a distance of 12_ft from the left support. Compute deflection at center, maximum deflection, and end slopes. Use 30_GPa for E and 140_in^4 for I. Use equations 3, 4, 5, 6 and 7 to solve the problem.

Given	Result
P = 2500_lbf	δc = 2.83401E-2_m
a = 12_ft	δmax = 2.8468E-2_m
L = 20_ft	Θa = 0.7585_°
E = 30_GPa	Θb = 0.8668_°
I = 140_in^4	x1 = 3.2257_m
b = 8_ft	

Simple Beam-Uniform Load

These five equations describe deflection, slope along any location along the beam, slope at either end of the beam, and value of maximum deflection. The assumed load condition is a uniformly distributed load. Effect of beam weight can be included in the load conditions if necessary.

1) $$v = \frac{w \cdot x}{24 \cdot E \cdot I} \cdot \left(L^3 - 2 \cdot L \cdot x^2 - x^3\right)$$

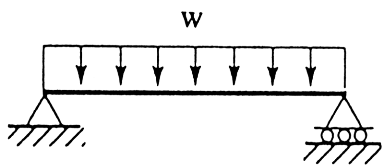
2) $$v1 = \frac{w}{24 \cdot E \cdot I} \cdot \left(L^3 - 6 \cdot L \cdot x^2 - 4 \cdot x^3\right)$$

3) $$\Theta a = \frac{w \cdot L^3}{24 \cdot E \cdot I}$$

4) $$\Theta b = \Theta a$$

5) $$\delta max = \frac{5 \cdot w \cdot L^4}{384 \cdot E \cdot I}$$

Variable	Description	Eqn Units
v	deflection at x	1_m
v1	slope at x	1
w	distributed load	1_N/m
x	distance from fixed end	1_m
L	beam length	1_m
E	Young's modulus	1_Pa
I	area moment	1_m^4
Θa	angle at left end	1_°
Θb	angle at right end	1_°
δmax	deflection at center	1_m



Example: A 20_ft simple beam is subjected to a uniformly distributed load of 100_N/ft. The beam is made of a material with an elastic modulus of 30 x 10^6_psi and has a moment of inertia of 210_in^4. Find the maximum deflection and slope at either end. Use equations 3-5 to solve the problem.

Given	Result
w = 100_N/ft	δmax = 3.2629E-4_m
L = 20_ft	Θa = 0.0098_°
E = 30E6_psi	Θb = 0.0098_°
I = 210_in^4	

Simple Beam-Moment

This equation set describes deflection, slope along any location along the beam, and slope at either end of the beam. The load condition assumed here is a moment located at a distance a from the fixed end of the beam. The calculations are made assuming contributions from the load. No other loads are considered in this computation.

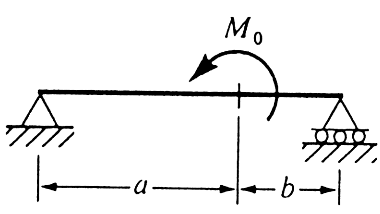
$$1)\ v = \frac{M0 \cdot x}{6 \cdot L \cdot E \cdot I} \cdot \left(6 \cdot a \cdot L - 3 \cdot a^2 - 2 \cdot L^2 - x^2\right)$$

$$2)\ v1 = \frac{M0}{6 \cdot L \cdot E \cdot I} \cdot \left(6 \cdot a \cdot L - 3 \cdot a^2 - 2 \cdot L^2 - 3 \cdot x^2\right)$$

$$3)\ \Theta a = \frac{M0}{6 \cdot L \cdot E \cdot I} \cdot \left(6 \cdot a \cdot L - 3 \cdot a^2 - 2 \cdot L^2\right)$$

$$4)\ \Theta b = \frac{M0}{6 \cdot L \cdot E \cdot I} \cdot \left(3 \cdot a^2 - L^2\right)$$

Variable	Description	Eqn Units
v	deflection at x	1_m
v1	slope at x	1
M0	moment	1_N·m
x	distance from fixed end	1_m
a	location of load from left end	1_m
L	beam length	1_m
E	Young's modulus	1_Pa
I	area moment	1_m^4
Θa	angle at left end	1_°
Θb	angle at right end	1_°



Example: A 20_ft long simple beam has a moment of 2600_N·m applied 11_ft from the left end. The beam has a moment of inertia of 210_in^4 and an elastic modulus of 30_GPa. Find the slopes at either end.

Given	Result
M0 = 2600_N·m	Θa = 2.2654E-2_°
a = 11_ft	Θb = -5.339E-3_°
L = 20_ft	

E = 30_GPa
I = 210_in^4

Simple Beam-Linear Load

The seven equations in this set focus on deflection, slope at any location along the beam, slope at either end of the beam, and the location and value of maximum deflection. The assumed load is uniformly increasing from 0 at the fixed end to a value w0 at the freely supported end.

1) $v = \frac{w0 \cdot x}{360 \cdot E \cdot L \cdot I} \cdot \left(7 \cdot L^4 - 10 \cdot L^2 \cdot x^2 + 3 \cdot x^4\right)$

2) $v1 = \frac{w0}{360 \cdot E \cdot L \cdot I} \cdot \left(7 \cdot L^4 - 30 \cdot L^2 \cdot x^2 + 15 \cdot x^4\right)$

3) $\delta c = \frac{5 \cdot w0 \cdot L^4}{768 \cdot E \cdot I}$

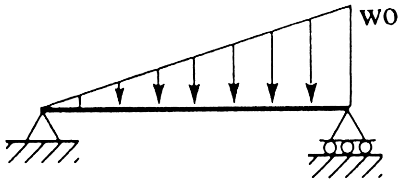
4) $\delta max = .00652 \cdot \left(\frac{w0 \cdot L^4}{E \cdot I}\right)$

5) $\Theta a = \frac{7 \cdot w0 \cdot L^3}{360 \cdot E \cdot I}$

6) $\Theta b = \frac{w0 \cdot L^3}{45 \cdot E \cdot I}$

7) $x1 = .5193 \cdot L$

Variable	Description	Eqn Units
v	deflection at x	1_m
v1	slope at x	1
w0	load rate at free end	1_N/m
x	distance from fixed end	1_m
L	beam length	1_m
E	Young's modulus	1_Pa
I	area moment	1_m^4
Θa	angle at left end	1_°
Θb	angle at right end	1_°
x1	distance to maximum deflection	1_m
δc	deflection at center	1_m
δmax	maximum deflection	1_m



Example: A 20_ft long simple beam has a linear load increasing from 0 at one end to 1000_lbf/m at the other. Find the maximum slope at either end, given an elastic modulus of 30_GPa and an area moment of 210_in^4. Use equations 4-6 to solve the problem.

Given	Result
w0 = 1000_lbf/m	Θa = 0.4281_°
L = 20_ft	Θb = 0.4893_°
E = 30_GPa	δmax = 0.01527_m
I = 210_in^4	

Fluid Mechanics

In this category, fundamental fluid flow equations are contained in the following topics:

- Fluid Statics
- Bernoulli's Equation
- Mechanical Energy Balance
- Discharge from Tanks
- Horizontal Jet on Vertical Plate
- Vertical Jet on Horizontal Plate
- Manometers
- Friction Loss
- Immersed Bodies

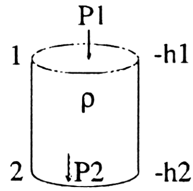
Fluid Statics

These equations describe static fluids when in equilibrium, $\Sigma F = 0$. The pressure-at-depth equation (1) is for constant density (incompressible) fluids. The barometric equation (2) is used for an isothermal perfect gas.

1) $P2 = P1 + \rho \cdot g \cdot (h1 - h2)$

2) $P = Patm \cdot e^{-\left(\frac{MWT \cdot g \cdot h}{R \cdot T}\right)}$

Variable	Description	Eqn Units
P	pressure	1_Pa
P1	pressure at point 1	1_Pa
P2	pressure at point 2	1_Pa
Patm	pressure at reference level	1_Pa
ρ	density of fluid	1_kg/m^3
h	height above reference level	1_m
h1	height at point 1	1_m
h2	height at point 2	1_m
T	temperature	1_K
MWT	molecular weight of gas	1_kg/mol



Example 1: Use equation 1 to find the pressure at the bottom of a full, 5-foot-high tank of ethylene glycol.

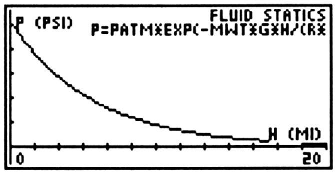
Given	**Result**
P1 = 14.7_psi	P2 = 17.1125_psi
ρ = 69.48_lb/ft^3	
h1 = 5_ft	
h2 = 0_ft	

Example 2: What is the pressure of air (average molecular weight = 29_g/mol) at a height of 1.0 mile above sea level? Plot the pressure of air versus height above sea level. (Assume T = 59 °F, neglect temperature gradient). Use second equation.

Given	**Result**
Patm = 14.696_psi	P = 12.1419_psi
T = 59_°F	
MWT = 29_g/mol	
h = 1.0_mi	

Plotting the barometric equation yields: (be sure to unmark the variable "h" prior to generating this plot)

x1 = 0
x2 = 20
y1 = -2
y2 = 16



Bernoulli's Equation

A frictionless, streamlined flow of an incompressible fluid obeys Bernoulli's equation if no shaft work is performed.

1) $\frac{\Delta P}{\rho} + \frac{V2^2 - V1^2}{2} + g \cdot \Delta h = 0$

2) $V1^2 \cdot \left(1 - \left(\frac{A1}{A2}\right)^2\right) = 2 \cdot \left(\frac{\Delta P}{\rho} + g \cdot \Delta h\right)$

3) $V2^2 \cdot \left(\left(\frac{A2}{A1}\right)^2 - 1\right) = 2 \cdot \left(\frac{\Delta P}{\rho} + g \cdot \Delta h\right)$

4) $\Delta h = h2 - h1$ 5) $\Delta P = P2 - P1$ 6) $Q = A1 \cdot V1$

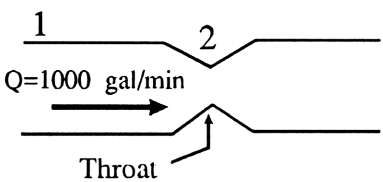
7) $Q = A2 \cdot V2$ 8) $M = \rho \cdot Q$ 9) $A1 = \frac{\pi \cdot D1^2}{4}$

10) $A2 = \frac{\pi \cdot D2^2}{4}$

Variable	Description	Eqn Units
ΔP	pressure difference	1_Pa
P1	pressure at point 1	1_Pa
P2	pressure at point 2	1_Pa
ρ	density of fluid	1_kg/m^3
V1	velocity at point 1	1_m/s
V2	velocity at point 2	1_m/s
Δh	height difference	1_m
h1	height at point 1	1_m
h2	height at point 2	1_m
A1	cross section area at point 1	1_m^2

A2	cross section area at point 2	1_m^2
Q	volumetric flow rate	1_m^3/s
M	mass flow rate	1_kg/s
D1	pipe diameter at point 1	1_m
D2	pipe diameter at point 2	1_m

Example: A Venturi meter reading gives a pressure drop in a pipe 12.3_psi from point (1) to point (2).



The throat's (point 2) cross sectional area is known to be .0513_ft^2 and the volumetric flow rate at point 1 is 1000_gal/min. What is the cross sectional area of the pipe at point 1? (ρ H_2O = 62.43_lb/ft^3). Use equations 1 and 2, and 6-10.

Given	Result
A2 = .0513_ft^2	A1 = 0.2861_ft^2
ΔP = -12.3_psi	V1 = 7.7866_ft/s
ρ = 62.43_lb/ft^3	V2 = 43.4309_ft/s
Δh = 0_m	D1 = 7.2430_in
Q = 1000_gal/min	D2 = 3.067_in
	M = 139.0946_lb/s

Mechanical Energy Balance

The mechanical energy balance equation is valid for flow of an incompressible fluid where friction from fluid movement is included. Heat loss and internal energy changes from non-friction sources are neglected.

1) $$\frac{\Delta P}{\rho} + \frac{V2^2 - V1^2}{2} + g \cdot \Delta h + F = \frac{Ws}{M}$$

2) $$V1^2 \cdot \left(1 - \left(\frac{A1}{A2}\right)^2\right) = 2 \cdot \left(\frac{\Delta P}{\rho} + g \cdot \Delta h + F - \frac{Ws}{M}\right)$$

3) $V2^2 \cdot \left(\left(\frac{A2}{A1} \right)^2 - 1 \right) = 2 \cdot \left(\frac{\Delta P}{\rho} + g \cdot \Delta h + F - \frac{Ws}{M} \right)$

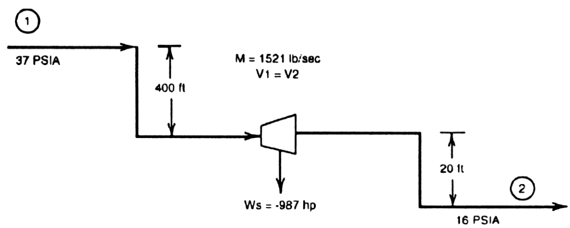
4) $\Delta h = h2 - h1$ 5) $\Delta P = P2 - P1$ 6) $Q = A1 \cdot V1$

7) $Q = A2 \cdot V2$ 8) $M = \rho \cdot Q$ 9) $A1 = \frac{\pi \cdot D1^2}{4}$

10) $A2 = \frac{\pi \cdot D2^2}{4}$

Variable	Description	Eqn Units
ΔP	pressure difference	1_Pa
P1	pressure at point 1	1_Pa
P2	pressure at point 2	1_Pa
ρ	density of fluid	1_kg/m^3
V1	velocity at point 1	1_m/s
V2	velocity at point 2	1_m/s
Δh	height difference	1_m
h1	height at point 1	1_m
h2	height at point 2	1_m
A1	cross section area at point 1	1_m^2
A2	cross section area at point 2	1_m^2
Q	volumetric flow rate	1_m^3/s
M	mass flow rate	1_kg/s
D1	pipe diameter at point 1	1_m
D2	pipe diameter at point 2	1_m
F	friction loss from pipe (head loss)	1_m^2/s^2
Ws	shaft work	1_W

Example: A lake supplies water for a turbine to generate energy. The same diameter pipe is used from lake to discharge (V1 = V2). At 400 feet above the turbine, the pressure is 37_psi, and at the discharge point the pressure is 16_psi. The discharge point is 20_ft below the turbine. ρH_2O = 62.3_lb/ft^3.



What is the friction loss from the pipe? Choose an arbitrary value for V1 and set V2 to V1. Use equations 1, 4 and 5.

Given	**Result**
V1 = 10_m/s	F = 111.6353_ft·lbf/lb
V2 = 10_m/s	ΔP = -21_psi
P2 = 16_psi	Δh = -420_ft
P1 = 37_psi	
ρ = 62.3_lb/ft^3	
h2 = -420_ft	
h1 = 0_ft	
Ws = -987_hp	
M = 1521_lb/s	

Discharge from Tanks

The configuration and area of an orifice determine water discharge parameters, such as velocity, volumetric flow rate and time to empty. The equations for this section assume a constant area tank filled with water with only one nozzle and no influx of water during discharge.

1) $V = Cv \cdot \sqrt{2 \cdot g \cdot h}$

2) $Cv = \dfrac{Cd}{Cc}$

3) $Q = Cc \cdot A0 \cdot Cv \cdot \sqrt{2 \cdot g \cdot h}$

4) $Q = Cd \cdot A0 \cdot \sqrt{2 \cdot g \cdot h}$

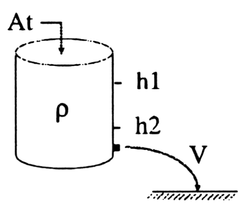
5) $ghead = \dfrac{Pgage}{\rho \cdot g}$

6) $t = \dfrac{2 \cdot At \cdot (\sqrt{h10} - \sqrt{h20})}{Cd \cdot A0 \cdot \sqrt{2 \cdot g}}$

7) $h10 = h1 + ghead$

8) $h20 = h2 + ghead$

Variable	Description	Eqn Units
V	orifice velocity	1_m/s
ghead	gauge pressure head	1_m
h1	tank water height 1	1_m
h2	tank water height 2	1_m
h10	tank static head 1	1_m
h20	tank static head 2	1_m
A0	orifice area	1_m^2
At	tank cross section area	1_m^2
Cv	velocity coefficient	1
Cd	discharge coefficient	1
Cc	contraction coefficient	1
t	discharge time	1_s
h	fluid height	1_m
Q	volumetric flow rate	1_m^3/s
Pgage	gauge pressure	1_Pa
ρ	density of fluid	1_kg/m^3



Example: A constant gauge pressure of 30_psi is used to empty a tank of water. The tank has a smooth, well-tapered nozzle, a height of 10_ft and a constant cross sectional area of 37.5_ft^2. The density of H_2O is 62.43_lb/ft^3. How long will it take to empty the tank? The orifice cross sectional area is .00351_ft^2. Use the entire equation set.

Appropriate discharge coefficients can be found in the reference section of this software. See Chapter 5.

Given	Result
At = 37.5_ft^2	h10 = 79.1976_ft
A0 = .00351_ft^2	h20 = 69.1976_ft
ρ = 62.43_lb/ft^3	ghead = 69.1976_ft
Pgage = 30_psi	t = 1562.7_sec

h = 10_ft
h1 = 10_ft
h2 = 0_ft
Cv = .98
Cd = .99
Cc = .99

Horizontal Jet on Vertical Plate

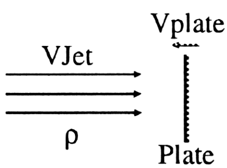
This equation adapts the linear momentum equation:

$$F = \frac{d\,(M \cdot V)}{dt}$$

for a horizontal jet hitting a vertical plate. The horizontal jet is assumed to have a uniform velocity distribution and hits the surface of the plate normally. Thus, there is no y direction force, only x direction.

$$Fx = -\rho \cdot (Vjet + Vplate)^2 \cdot A$$

Variable	Description	Eqn Units
Fx	plate force	1_N
ρ	fluid density	1_kg/m^3
Vjet	jet velocity	1_m/s
Vplate	plate velocity	1_m/s
A	area normal to flow	1_m^2



Example: Beaver Cleaver sticks his hand out of the window of Ward's souped-up '57 Bel Air. The velocity of the Bel Air is 110_mph. Assuming Beaver holds his hand normal to the flow of the air, what is the force on Beaver's hand? The area of Beaver's hand is 15_in^2, ρ of air at 20_°C = 1.204_kg/m^3 and the air is static.

Given	Result
ρ = 1.204_kg/m^3	Fx = -6.334_lbf
Vjet = 0_mph	
Vplate = 110_mph	

A = 15_in^2

Vertical Jet on Horizontal Plate

The equations below adapt the linear motion equation,

$$F = \frac{d\,(M \cdot V)}{dt}$$

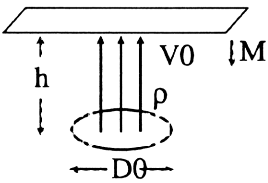
for a vertical jet hitting a horizontal plate. In the case of an equilibrium height of a plate with a weight, the Bernoulli, momentum, and continuity equations are combined to define "heq" in terms of initial nozzle velocity.

1) $Fy = -\rho \cdot V0 \cdot A0 \cdot \sqrt{V0^2 - 2 \cdot g \cdot h}$

2) $heq = \frac{V0^2}{2 \cdot g} - \frac{1}{2 \cdot g} \cdot \left(\left(\frac{M \cdot g}{\rho \cdot A0 \cdot V0} \right)^2 \right)$

3) $A0 = \frac{\pi}{4} \cdot D0^2$

Variable	Description	Eqn Units
Fy	Y direction force	1_N
ρ	fluid density	1_kg/m^3
V0	initial fluid velocity	1_m/s
A0	fluid area	1_m^2
h	height from nozzle	1_m
heq	height at equilibrium	1_m
M	mass of plate and weight	1_kg
D0	nozzle diameter	1_m



Example: A plate weighs 50 pounds and is supported by a vertical jet of water. The exit diameter of the nozzle is 4 inches and the velocity at the nozzle is 30_ft/sec. The water density is 998.3_kg/m^3. What is the equilibrium height of the board? Use equations 2 and 3.

Given	**Result**
V0 = 30_ft/sec	heq = 12.4757_ft
D0 = 4_in	A0 = 12.5663_in^2
M = 50_lb	
ρ = 998.3_kg/m^3	

Manometers

This topic includes equations 1 and 2 for general manaometers, and equations 3 and 4 for differential manaometers.

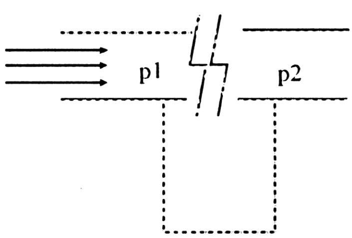
1) $\Delta p = \rho 1 \cdot g \cdot d1 - \rho 2 \cdot g \cdot d2 - \rho f \cdot g \cdot h$

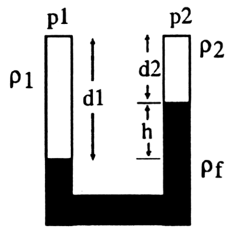
2) $\Delta p = (\rho - \rho f) \cdot g \cdot h$

3) $\Delta p = p2 - p1$

4) $\rho f = SPGR \cdot \rho H2O$

Variable	**Description**	**Eqn Units**
p1	point 1 pressure	1_Pa
p2	point 2 pressure	1_Pa
Δp	pressure difference	1_Pa
ρ1	fluid density point 1	1_kg/m^3
ρ2	fluid density point 2	1_kg/m^3
ρf	manometer fluid density	1_kg/m^3
d1	manometer fluid depression 1	1_m
d2	manometer fluid depression 2	1_m
h	manometer fluid height difference	1_m
SPGR	specific gravity ratio	1
ρ	fluid density 1=2	1_kg/m^3





Example: A differential manometer is used to measure pressure drop in a pipe line. Mercury is used as the manometer fluid has a SPGR = 13.546. The relative difference between the first and second arm is 3.0 inches. What is the pressure drop if water at 20_°C is flowing through the pipe? Use equations 3 and 4.

Given	Result
SPGR = 13.546	Δp = -1.36_psi
h = 3.0_in	ρf = 845.67_lb/ft^3
ρ = 62.19_lb/ft^3	

Friction Loss

The following equations allow for the measurement of kinetic or potential energy that is converted to thermal energy. The equations apply to a round pipe that is in full flow. The fluid must be incompressible and heat losses and internal energy change due to anything but friction are negligible. (This equation set uses the DARCY friction factor function).

1) $FL = \dfrac{f \cdot L \cdot Vavg^2}{2 \cdot D} + \dfrac{Ksum \cdot Vavg^2}{2}$

2) $Le = \dfrac{2 \cdot FL \cdot D}{f \cdot Vavg^2}$

3) $\mathrm{Re} = \dfrac{\rho \cdot Vavg \cdot D}{\mu}$

4) $J = \dfrac{\mu}{\rho}$

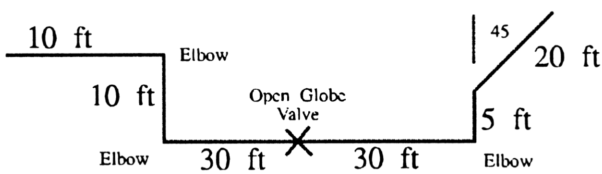
5) $Q = Vavg \cdot A$

6) $\mathrm{Re} = \dfrac{Vavg \cdot D}{J}$

7) $D = \sqrt{(4 \cdot A) / \pi}$

8) $f = DARCY(Re, \varepsilon, D)$

Variable	Description	Eqn Units
FL	friction loss	1_m^2/s^2
f	DARCY friction factor	1
L	pipe length	1_m
Vavg	average velocity	1_m/s
D	pipe internal diameter	1_m
ε	pipe roughness	1_m
Re	Reynold's number	1
Le	equivalent length	1_m
Ksum	summation of minor loss items	1
Q	volumetric flow rate	1_m^3/s
ρ	fluid density	1_kg/m^3
J	kinematic viscosity	1_m^2/s
A	cross section area	1_m^2
μ	dynamic viscosity	1_Pa·s



Example: Given the picture above, what is the equivalent length of a straight pipe with the same flow rate, friction factor and heat loss? Use all the equations to solve the problem.

Appropriate minor loss values are listed in the reference section of this software. See Chapter 5.

Given	Result
L = 105_ft	Le = 220.5985_ft
Ksum = 9	FL = 103.5144_ft^2/s^2
Q = 80_gal/min	f = .019905
D = 3.068_in	Re = 82465.6171
ρ = 62.3_lb/ft^3	A = 4.769 E-3_m^2
ε = .020_mm	
J= 1.00 x 10^-6_m^2/s	

Immersed Bodies

Lift and drag forces act upon an object as it moves through a fluid such as air. The equations below assume that the fluid flow behind the object is turbulent.

1) $Fd = \dfrac{Cd \cdot \rho \cdot V^2 \cdot A}{2}$

2) $Fl = \dfrac{Cl \cdot \rho \cdot V^2 \cdot A}{2}$

3) $P = Fd \cdot V$

Variable	Description	Eqn Units
Fd	drag force	1_N
Fl	lift force	1_N
Cd	drag coefficient	1
Cl	lift coefficient	1
ρ	fluid density	1_kg/m^3
V	fluid velocity	1_m/s
A	area normal to flow	1_m^2
P	power	1_W

Example: John J. Gorilla, golf's long drive champion, wants to know the amount of power needed for his standard long drive. Calculate the drag force and power needed to overcome aerodynamic drag just after impact.

Given

ρ = 1.204_kg/m^3
Cd = 0.40
A = 0.01539_ft^2
V = 100_mph

Result

Fd = .1547_lbf
P = 0.0412_hp

Gas Laws

The equations in this topic describe the pressure, volume, temperature and thermodynamic relationships of ideal gases. Z-factor equations for a real gas are also included. *Note that all equations in this section presume values for work and heat on a mass basis*, thus: W = 3.4_Btu/lb or Q = 5_J/kg. These equations are included under the following seven topics:

- Ideal Gas Laws
- Gas-Constant Pressure
- Gas-Constant Volume
- Gas-Constant Temperature
- Thermodymanics/Ideal Gas Law
- Real Gas Law
- Polytropic Process

Ideal Gas Laws

The behavior of an ideal gas can be described by the equations below.

1) $p \cdot Vs = RG \cdot T$

2) $p \cdot V = n \cdot R \cdot T$

3) $RG = \frac{R}{MWT}$

4) $V = Vs \cdot m$

5) $m = n \cdot MWT$

6) $Cp - Cv = RG$

7) $Cp = \frac{k \cdot RG}{k - 1}$

8) $Cv = \frac{RG}{k - 1}$

9) $k = \frac{Cp}{Cv}$

Variable	Description	Eqn Units
p	pressure	1_Pa
Vs	specific volume	1_m^3/kg
RG	specific gas constant	1_J/(kg·K)
T	temperature	1_K
V	volume	1_m^3

n	number of moles	1_mol
MWT	molecular weight	1_kg/mol
m	mass of gas	1_kg
Cp	specific heat constant pressure	1_J/(kg·K)
Cv	specific heat constant volume	1_J/(kg·K)
k	specific heat ratio	1

Example: Calculate the mass of CO_2 in a 500_ft^3 tank, if the pressure is 14.696_psi and the temperature is 68_°F. The molecular weight of CO_2 is 44.01. Use equations 2-5.

Given	Result
V = 500_ft^3	RG = .0451_Btu/(lb·°R)
p = 14.696_psi	Vs = 8.7612_ft^3/lb
T = 68_°F	m = 57.0699_lb
MWT = 44.01_g/mol	n = 588.1952_mol

Gas-Constant Pressure

For a closed system, an ideal gas that is subjected to an isobaric process is described by the following equations.

1) $\frac{Vs2}{Vs1} = \frac{T2}{T1}$

2) $V1 = m \cdot Vs1$

3) $V2 = m \cdot Vs2$

4) $m = MWT \cdot n$

5) $\Delta Vs = Vs2 - Vs1$

6) $RG = \frac{R}{MWT}$

7) $W12 = p \cdot \Delta Vs$

8) $W12 = RG \cdot (T2 - T1)$

9) $Q = Cp \cdot (T2 - T1)$

10) $Q = Cv \cdot (T2 - T1) + p \cdot \Delta Vs$

Variable	Description	Eqn Units
Vs2	specific volume, state 2	1_m^3/kg
Vs1	specific volume, state 1	1_m^3/kg
T2	temperature, state 2	1_K
T1	temperature, state 1	1_K
V1	volume 1	1_m^3

V2	volume 2	1_m^3
m	mass	1_kg
MWT	molecular weight	1_kg/mol
n	number of moles	1_mol
ΔVs	specific volume diff	1_m^3/kg
RG	gas specific constant	1_J/(kg·K)
W12	work to change 1 to 2	1_J/kg
p	pressure	1_Pa
Q	heat	1_J/kg
Cp	specific heat, constant pressure	1_J/(kg·K)
Cv	specific heat, constant volume	1_J/(kg·K)

Example: The temperature rise of nitrogen (N_2) for a constant pressure process is 48 _K. What is the amount of work performed, heat generated, and specific volume after the process is completed? At the beginning of the process, the chamber has a volume of 10_l with .75_mol of N_2 present. The initial temperature is 400_K. Specific heat at constant volume is 1.041_kJ/(kg·K). Use equations 1-9.

Given	Result
V1 = 10_l	W12 = 6.1290_Btu/lb
T2 = 448_K	Q = 21.4824_Btu/lb
T1 = 400_K	Vs1 = 0.4760_l/g
n = .75_mol	Vs2 = .5331_l/g
MWT = 28.0134_g/mol	RG = 55.2_ft·lbf/(lb·°R)
Cp = 1.041_kJ/(kg·K)	m = .0463_lb
	Cv = .744_kJ/(kg·K)
	V2 = 11.2_l
	ΔVs = .05712_l/g
	p = 249599.0127_Pa

Gas-Constant Volume

For a closed system, an ideal gas that is subjected to a constant volume process is described by the following equations.

1) $\frac{p2}{p1} = \frac{T2}{T1}$ 2) $RG = \frac{R}{MWT}$ 3) $V = Vs \cdot m$

4) $m = MWT \cdot n$ 5) $Q = Cv \cdot (T2 - T1)$

6) $Q = \frac{Cv \cdot Vs \cdot \Delta p}{RG}$

7) $\Delta p = p2 - p1$

Variable	**Description**	**Eqn Units**
p2	pressure, state 2	1_Pa
p1	pressure, state 1	1_Pa
T2	temperature, state 2	1_K
T1	temperature, state 1	1_K
RG	specific gas constant	1_J/(kg·K)
MWT	molecular weight	1_kg/mol
V	volume	1_m^3
Vs	specific volume	1_m^3/kg
m	mass	1_kg
n	number of moles	1_mol
Q	quantity of heat	1_J/kg
Cv	specific heat constant volume	1_J/(kg·K)
Δp	pressure difference	1_Pa

Example: What amount of heat is used when Argon, at a constant volume, is heated from 0_°C to 100_°C? Cv is 3.199_kJ/(kg·K). Use equation 5.

Given
Cv = 3.199_kJ/(kg·K)
T2 = 100_°C
T1 = 0_°C

Result
Q = 319.9_kJ/kg

Gas-Constant Temperature

For a closed system, an ideal gas that is subjected to an isothermal process is described by the following equations.

1) $\frac{p2}{p1} = \frac{Vs1}{Vs2}$

2) $RG = \frac{R}{MWT}$

3) $V1 = Vs1 \cdot m$

4) $V2 = Vs2 \cdot m$

5) $m = MWT \cdot n$

6) $Q = W$

7) $W = RG \cdot T \cdot LN\left(\frac{Vs2}{Vs1}\right)$

8) $W = RG \cdot T \cdot LN\left(\frac{p1}{p2}\right)$

Variable	Description	Eqn Units
p2	pressure at state 2	1_Pa
p1	pressure at state 1	1_Pa
Vs1	specific volume, state 1	1_m^3/kg
Vs2	specific volume, state 2	1_m^3/kg
RG	specific gas constant	1_J/(kg·K)
MWT	molecular weight	1_kg/mol
V1	volume, state 1	1_m^3
m	mass	1_kg
n	number of moles	1_mol
Q	quantity of heat	1_J/kg
W	work	1_J/kg
T	temperature	1_K
V2	volume, state 2	1_m^3

Example: Air, with a molecular weight of 29_g/mol, undergoes a constant temperature process. Assuming 10 pounds of air at 1_atm is compressed to 3_atm. What is the amount of heat given off by the system? The ambient temperature is 59_°F. Use equations 2, 5, 6 and 8.

Given	Result
p1 = 1_atm	RG = .28689_kJ/kg·K)
p2 = 3_atm	n = 156.41_mol
m = 10_lb	Q = -39.046_Btu/lb
MWT = 29_g/mol	W = -39.046_Btu/lb
T = 59_°F	

Thermodynamics/Ideal Gas Law

These equations describe thermodynamic properties of an ideal gas with constant specific heats and no internal heat sources.

1) $\Delta u = Cv \cdot (T2 - T1)$

2) $\Delta u = u2 - u1$

3) $\Delta h = Cp \cdot (T2 - T1)$

4) $\Delta h = h2 - h1$

5) $Cp - Cv = RG$

6) $RG = \dfrac{R}{MWT}$

7) $\Delta s = Cv \cdot LN\left(\dfrac{T2}{T1}\right) + RG \cdot LN\left(\dfrac{Vs2}{Vs1}\right)$

8) $\Delta s = Cp \cdot LN\left(\frac{T2}{T1}\right) - RG \cdot LN\left(\frac{p2}{p1}\right)$

9) $\Delta s = Cp \cdot LN\left(\frac{Vs2}{Vs1}\right) + Cv \cdot LN\left(\frac{p2}{p1}\right)$

10) $\Delta s = s2 - s1$

11) $V1 = Vs1 \cdot MWT \cdot n1$

12) $V2 = Vs2 \cdot MWT \cdot n2$

Variable	Description	Eqn Units
p1	pressure state 1	1_Pa
p2	pressure state 2	1_Pa
T2	temperature state 2	1_K
T1	temperature state 1	1_K
Cv	specific heat at constant volume	1_J/(kg·K)
Cp	specific heat at contant pressure	1_J/(kg·K)
RG	specific gas constant	1_J/(kg·K)
MWT	molecular weight	1_kg/mol
Δu	Δ specific internal energy	1_J/kg
u2	internal energy state 2	1_J/kg
u1	internal energy state 1	1_J/kg
Δh	specific enthalpy	1_J/kg
h2	specific enthalpy state 2	1_J/kg
h1	specific enthalpy state 1	1_J/kg
Δs	Δ entropy	1_J/(kg·K)
s2	specific entropy state 2	1_J/(kg·K)
s1	specific entropy state 1	1_J/(kg·K)
V1	volume state 1	1_m^3
Vs1	specific volume state 2	1_m^3/kg
n1	number of moles state 1	1_mol
n2	number of moles state 2	1_mol
V2	volume state 2	1_m^3
Vs2	specific volume state 2	1_m^3/kg

Example: Calculate the temperature drop for an isentropic expansion of air from 821_°R at 5_atm to 1_atm. Assume that the molecular weight of air is 29_g/mol and Cp = .240_Btu/(lb·°R). Use equations 6 and 8.

Given **Result**

$\Delta s = 0$
$T1 = 821\_°R$
$p1 = 5\_atm$
$p2 = 1\_atm$
$MWT = 29\_g/mol$
$Cp = .240\_Btu/(lb \cdot °R)$
$RG = .0685\_Btu/(lb \cdot °R)$
$T2 = 518.5327\_°R$

Real Gas Law

The real gas law equations below are based upon the principle of corresponding states. The compressibility factor, Z, is calculated from the reduced temperature and reduced volume and is used to "correct" for non-ideal behavior. Z factor can be computed based on what is known, such as T, Tc, pc, Vm, Vs, MWT, and n. Choose Z factors ZF1, ZF2, ZF3 or ZF4 accordingly. The functions used to calculate Z are valid in low and medium pressures, that is for pR < 6.0, and are unavailable for use outside the scope of this topic.

1) $p \cdot Vs = Z \cdot RG \cdot T$

2) $RG = \frac{R}{MWT}$

3) $m = n \cdot MWT$

4) $p \cdot V = n \cdot Z \cdot R \cdot T$

5) $V = m \cdot Vs$

6) $pR = \frac{p}{pc}$

7) $TR = \frac{T}{Tc}$

8) $Z = ZF1\,(T, Tc, pc, Vm)$

9) $Z = ZF2\,(T, Tc, pc, Vs, MWT)$

10) $Z = ZF3\,(T, Tc, pc, V, n)$

11) $Z = ZF4\,(T, Tc, pc, Vs, RG)$

Variable	Description	Eqn Units
p	pressure	1_Pa
Vs	specific volume	1_m^3/kg
V	volume	1_m^3
T	temperature	1_K
RG	specific gas constant	1_J/(kg·K)
MWT	molecular weight	1_kg/mol
m	mass	1_kg
n	number of moles	1_mol
Z	Z factor	1

pR	reduced pressure	1
pc	critical pressure	1_Pa
TR	reduced temperature	1
Tc	critical temperature	1_K
Vm	molar volume	1_m^3/mol

Example: 25 moles of oxygen (O_2) is contained in a 10 liter cylinder at -10_°C. Estimate the pressure in the cylinder. Use equations 4 and 10.

Given	**Result**
Tc = 154.4_K	Z=0.9539
pc = 49.7_atm	p=51.528_atm
T = -10_°C	
V = 10_l	
n = 25_mol	

Polytropic Process

Useful equations for analyzing ideal gases are those derived from the polytropic process where Pv^{γ} = constant. Several different process states can be analyzed by assigning γ its particular value.

γ equals (when)	Type of State Change
0	isobaric
1	isothermal
K	isentropic
∞	constant volume process

1) $\frac{p2}{p1} = \left(\frac{Vs1}{Vs2}\right)^{\gamma}$

2) $\frac{T2}{T1} = \left(\frac{Vs1}{Vs2}\right)^{\gamma - 1}$

3) $V1 = Vs1 \cdot m$

4) $V2 = Vs2 \cdot m$

5) $m = n \cdot MWT$

Variable	Description	Eqn Units
p2	pressure state 2	1_Pa
p1	pressure state 1	1_Pa
Vs1	specific volume state 1	1_m^3/kg
Vs2	specific volume state 2	1_m^3/kg

V1	volume state 1	1_m^3
V2	volume state 2	1_m^3
T2	temperature state 2	1_K
T1	temperature state 1	1_K
n	number of moles	1_mol
γ	polytropic constant	1
MWT	molecular weight	1_kg/mol
m	mass of gas	1_kg

Example: During an isothermal process the pressure goes from 1_atm to 2_atm. If the specific volume initially was 1_ft^3/lb, what is the final specific volume? Use equation 1.

Given	Result
p1 = 1_atm	Vs2 = .5_ft^3/lb
p2 = 2_atm	
Vs1 = 1_ft^3/lb	
γ = 1	

Heat Transfer

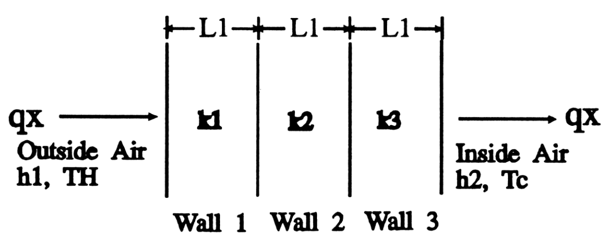
In this category, conductive, convective, and radiative forms of heat transfer are described in the following topics:

- Steady State - Conduction & Convection
- Heat Conduction-Cylindrical, Spherical Wall
- Forced Convection-Flat Plate (Heat)
- Forced Convection-Flat Plate (Drag)
- Lumped Cap Analysis
- Negligible Surface Resistance
- Semi-Infinite Solid
- Blackbody Radiation
- Radiant Heat Exchange

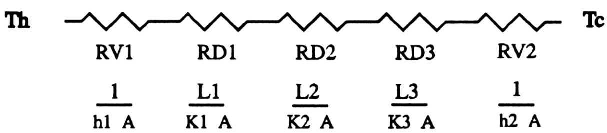
Steady State - Conduction & Convection

The equation below uses the resistance analog to solve for steady-state conduction and convection. The resistance analog means that more than one wall configuration can be solved by the equation set. Up to a three-layer wall with convection on both sides can be solved for in this topic.

Wall Configuration



Resistance Analog



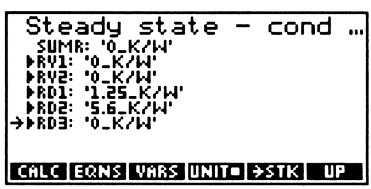
In the first example, a three-layer wall with convection on both sides is used. Thus:

SUMR = RV1 + RD1 + RD2 + RD3 + RV2

is the appropriate equation. In example 2, a two-layer wall with no convection is used. Thus:

SUMR = RD1 + RD2

is the appropriate equation. In order to solve example 2, RV1, RD3 and RV2 must be "known" to be zero:



1) $qx = \dfrac{Th - Tc}{SUMR}$ 2) $SUMR = RV1 + RD1 + RD2 + RD3 + RV2$

3) $RV1 = \dfrac{1}{h1 \cdot A}$ 4) $RV2 = \dfrac{1}{h2 \cdot A}$ 5) $RD1 = \dfrac{L1}{K1 \cdot A}$

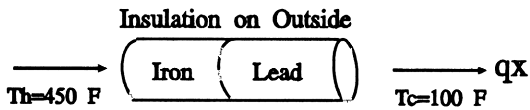
6) $RD2 = \dfrac{L2}{K2 \cdot A}$ 7) $RD3 = \dfrac{L3}{K3 \cdot A}$ 8) $U = \dfrac{1}{SUMR}$

Variable	Description	Eqn Units
qx	energy transfer rate	1_W
Th	hot temperature	1_K
Tc	cold temperature	1_K
SUMR	summation of resistances	1_K/W
RV1	convective resistance at 1	1_K/W
RV2	convective resistance at 2	1_K/W
RD1	conductive resistance at 1	1_K/W
RD2	conductive resistance at 2	1_K/W
RD3	conductive resistance at 3	1_K/W
L1,L2,L3	length of conduction at 1, 2, 3	1_m
K1,K2,K3	thermal conductivity at 1, 2, 3	1_W/(m·K)
h1,h2	convective heat transfer coefficient	1_W/(m^2·K)
A	area	1_m^2
U	overall heat transfer coefficient	1_W/K

Example 1: A 75_m^2 wall is constructed of 15_cm thick concrete k1=1.21_W/(m·K), 5_cm thick rock wool k2=.040_W/(m·K), and 1.25_cm thick plaster board k3=.51_W/(m·K). The outside wind (-2_°C) blows 20_m/s (h1=34.0_W/(m^2·K)). The inside air at 20_°C is nearly still (h2=9.36_W/(m^2·K)). What is the energy transfer rate, qx?

Given	Result
A = 75_m^2	RV1 = 3.921 x 10^-4_K/W
K1 = 1.21_W/(m·K)	RV2 = 1.4245 x 10^-3_K/W
K2 = .040_W/(m·K)	RD1 = 1.652 x 10^-3_K/W
K3 = .51_W/(m·K)	RD2 = 1.667 x 10^-2_K/W
h1 = 34.0_W/(m^2·K)	RD3 = 3.2679 x 10^-4_K/W
h2 = 9.36_W/(m^2·K)	SUMR = 2.0463 x 10^-2_K/W
Th = 20_°C	qx = 1075.11_W
Tc = -2_°C	U = 48.87_W/K
L1 = 15_cm	
L2 = 5_cm	
L3 = 1.25_cm	

Example 2: An insulated rod is composed of a 20 inch section of iron



(K=44.1_Btu/(h·ft·°F)), and lead (K=20.3_Btu/(h·ft·°F)). Calculate the energy transfer rate if one end is at 450_°F and the other end is at 100_°F. The cross-sectional area is 3.14_in^2. Select equations 1, 2, 5, 6 and 8 for this problem.

Given	Result
A = 3.14_in^2	RD1 = .8665_°F·h/Btu
Th = 450_°F	RD2 = 1.8825_°F·h/Btu
Tc = 100_°F	SUMR = 2.7491_°F·h/Btu
K1 = 44.1_Btu/(h·ft·°F)	qx = 127.31_Btu/h
K2 = 20.3_Btu/(h·ft·°F)	U = .3637_Btu/(h·°F)
L1 = 10_in	
L2 = 10_in	
*RV1 = 0_K/W	
*RV2 = 0_K/W	
*RD3 = 0_K/W	

*In order for SUMR equation to work, RV1, RV2, and RD3 must be set ("known") to zero.

Heat Conduction-Cylindrical, Spherical Wall

The equations below solve heat conduction problems through a single layer cylinder, a two-layer cylinder and a spherical wall.

Single layer cylinder
$$qr1 = \frac{2 \cdot \pi \cdot k1 \cdot L \cdot (T1 - T2)}{LN\left(\frac{r2}{r1}\right)}$$

2-layer cylinder
$$qr2 = \frac{2 \cdot \pi \cdot L \cdot (T1 - T3)}{\frac{1}{k1} \cdot LN\left(\frac{r2}{r1}\right) + \frac{1}{k2} \cdot LN\left(\frac{r3}{r2}\right)}$$

Spherical wall
$$qs = \frac{4 \cdot \pi \cdot k \cdot (T1 - T2)}{\frac{1}{r1} - \frac{1}{r2}}$$

Variable	Description	Eqn Units
qr1	energy transfer rate	1_W
qr2	energy transfer rate	1_W
qs	energy transfer rate	1_W
k	thermal conductivity of sphere	1_W/(m·K)
k1	thermal conductivity, layer 1	1_W/(m·K)
k2	thermal conductivity, layer 2	1_W/(m·K)
L	length of cylinder	1_m
T1	temperature at 1	1_K
T2	temperature at 2	1_K
T3	temperature at 3	1_K
r1	radius at 1	1_m
r2	radius at 2	1_m
r3	radius at 3	1_m

Example: A one inch, schedule 160, pipe is subjected to outside and inside surface temperatures of 150_°F and 250_°F, respectively. Calculate the heat flow per foot of pipe. Internal radius = .407 inches, external radius = .657 inches. Use the single layer equation.

Given	Result
k1 = 22.9_Btu/(h·ft·°R)	qr1 = 30046.7_Btu/h
r1 = .407_in	
r2 = .657_in	
T1 = 250_°F	
T2 = 150_°F	
L = 1_ft	

Forced Convection-Flat Plate (Heat)

Equations for analyzing heat transfer from laminar flow on a two-dimensional plate are listed below. The fluid has a constant viscosity and is considered incompressible. ($Re_{X,L} < 5 \times 10$^5, .6 < Pr < 15).

1) $Nux = .332 \cdot \sqrt{Rex} \cdot Pr^{\frac{1}{3}}$

2) $NuL = .664 \cdot \sqrt{ReL} \cdot Pr^{\frac{1}{3}}$

3) $Rex = \dfrac{V\infty \cdot x}{\eta}$

4) $ReL = \dfrac{V\infty \cdot L}{\eta}$

5) $Nux = \frac{hx \cdot x}{k}$

6) $NuL = \frac{hL \cdot L}{k}$

7) $hL = 2 \cdot hx$

8) $\Delta T = Ts - T\infty$

9) $qL = hL \cdot \Delta T$

10) $qx = hx \cdot \Delta T$

11) $Pr = \frac{\eta}{\alpha}$

12) $\eta = \frac{\mu}{\rho}$

13) $\alpha = \frac{k}{\rho \cdot Cp}$

Variable	Description	Eqn Units
Nux	Nusselt number at x	1
NuL	Nusselt number at L	1
Rex	Reynold's number at x	1
ReL	Reynold's number at L	1
V∞	velocity of fluid	1_m/s
Pr	Prandtl number	1
hx	location convection heat transfer coeff	1_W/(m^2·K)
hL	mean convection heat tranfer coeff	1_W/(m^2·K)
x	distance from edge	1_m
L	mean distance	1_m
k	thermal conductivity	1_W/(m·K)
ΔT	temperature difference	1_K
Ts	surface temperature	1_K
T∞	final temperature	1_K
qL	mean heat transfer rate	1_W/m^2
qx	local heat transfer rate	1_W/m^2
η	kinematic viscosity	1_m^2/s
μ	dynamic viscosity	1_Pa·s
α	thermal diffusivity	1_m^2/s
ρ	density	1_kg/m^3
Cp	heat capacity	1_J/(kg·K)

Example: Air at 70_°F with a uniform free stream velocity (V∞ = 50_ft/s) is moving parallel to a smooth flat plate heated to a uniform surface temperature of 212_°F. η = 0.21 x 10^-3_ft^2/s, k = 0.0164_Btu/(h·ft·°F) and Pr = 0.72. What is the length of the laminar boundary layer? Use equation 3.

Given **Result**

η = 0.21 x 10^-3_ft^2/s	x = 2.10_ft (critical length)
V∞ = 50_ft/s	
Rex = 5 x 10^5 (transition)	

What is the local heat-transfer coefficient at the critical length? Use equations 1 and 5.

Given	**Result**
Rex = 5 E5	hx = 1.643_Btu/(h·ft^2·°F)
x = 2.1_ft	Nux = 210.4
k = 0.0164_Btu/(h·ft·°F)	
Pr = 0.72	

What is the mean heat capacity coefficient over the portion of the plate covered by the laminar boundary layer? Use equations 2 and 6.

Given	**Result**
ReL = 5 x 10^5	hL = 3.286_Btu/(h·ft^2·°F)
Pr = 0.72	NuL = 420.8
L = 2.1_ft	
k = 0.0164_Btu/(h·ft·°F)	

Forced Convection-Flat Plate (Drag)

Equations for analyzing skin-friction drag and boundary layer thickness for laminar flow over a two-dimensional plate are given below.

1) $Cfx = \frac{.664 \cdot 1}{\sqrt{Rex}}$

2) $CfL = \frac{1.328}{\sqrt{ReL}}$

3) $CfL = 2 \cdot Cfx$

4) $\delta t = \frac{\delta}{Pr^{\frac{1}{3}}}$

5) $\delta = \frac{5 \cdot x}{\sqrt{Rex}}$

6) $Ff = \frac{CfL \cdot \rho \cdot V\infty^2}{2} \cdot A$

7) $Rex = \frac{V\infty \cdot x}{\eta}$

8) $ReL = \frac{V\infty \cdot L}{\eta}$

9) $\eta = \frac{\mu}{\rho}$

Variable	Description	Eqn Units
Cfx	location skin friction coefficient	1
CfL	mean skin friction coefficient	1
Rex	location Reynold's number	1
ReL	mean Reynold's number	1
δt	thermal thickness	1_m
δ	boundary layer thickness	1_m
Pr	Prandtl number	1
x	distance from edge	1_m
L	mean distance	1_m
Ff	skin friction drag	1_N
V∞	fluid velocity	1_m/s
A	area	1_m^2
η	kinematic viscosity	1_m^2/s
μ	dynamic viscosity	1_Pa·s
ρ	density	1_kg/m^3

Example: Air at 70_°F with a uniform free-stream velocity (V∞ = 50_ft/s) is moving parallel to a smooth flat plate heated to a uniform surface temperature of 212_°F. What is the thickness of the hydrodynamic and thermal boundary layers at the critical length? Use equations 4 and 5.

Given	Result
x = 2.10_ft	δ = 0.0148_ft
Rex = 5 x 10^5	δt = 0.0166_ft
Pr = .72	

What is the force from skin-friction if the area of the plate is 10_ft^2? Use equations 2 and 6.

Given	Result
A = 10_ft^2	CfL = 1.878 x 10^-3
V∞ = 50_ft/s	Ff = 0.04750_lbf
ρ = 0.0651_lb/ft^3	
ReL = 5 x 10^5	

Lumped Cap Analysis

In unsteady-state conduction, if there is an extremely small internal temperature gradient, then lumped analysis can be performed, Bi < 0.1.

1) $\Theta = \dfrac{T - T\infty}{Ti - T\infty}$

2) $Bi = \dfrac{h \cdot L}{k}$

3) $\Theta = e^{-Bi \cdot Fo}$

4) $Fo = \dfrac{\alpha \cdot t}{L^2}$

5) $\alpha = \dfrac{k}{\rho \cdot cp}$

Variable	Description	Eqn Units
Θ	normalized temperature	1
T	body temperature	1_K
T∞	constant surface temperature	1_K
Ti	initial body temperature	1_K
Bi	Biot modulus	1
α	thermal diffusivity	1_m^2/s
t	time	1_s
L	length parameter	1_m
k	thermal conductivity	1_W/(m·K)
ρ	density	1_kg/m^3
cp	specific heat	1_J/(kg·K)
Fo	Fourier modulus	1
h	convective heat transfer coefficient	1_W/(m^2·K)

Note: L is the ratio of body volume divided by the surface area.

Geometry	L equals
long cylinder	D/4
sphere	D/6
cube	S/6
long parallelpiped	S/4

Where: D = diameter and S = length of side of square

Example: A 1_cm diameter steel sphere at 600_°C is cooled to 90_°C in an air stream. The air stream's temperature is 25_°C. How much time does this take?

Step 1: Check for Biot modulus <0.1. Use equation 2.

Given
h = 113_W/(m^2·K)
k = 42__W/(m·K)
L = .16667_cm
Thus, lumped cap analysis can be used.

Result
Bi = .00448

Step 2: Solve for all equations.

Given
Bi = .00448
T∞ = 25_°C
Ti = 600_°C
T = 90_°C
L = .16667_cm
k = 42_W/(m·K)
ρ = 7865.5_kg/m^3
cp = .459_kJ/(kg·K)

Result
Θ = .11304
α = 1.16 x 10^-5_m^2/s
t = 116.1_s
Fo = 486

Negligible Surface Resistance

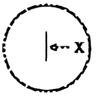
Temperatures at the center of objects of typical geometrical shapes are covered by the following set of equations. It is assumed that there is an initial uniform temperature and a constant surface temperature. The functions are valid from 0.12 <τ < 1.2.

1) $\Theta = \dfrac{Tc - T\infty}{Ti - T\infty}$

2) $\tau = \dfrac{\alpha \cdot t}{x^2}$

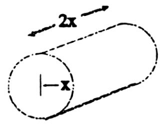
3) $\alpha = \dfrac{k}{\rho \cdot cp}$

4) Θ = TSPH (τ)



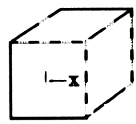
Sphere
(TSPH)

5) $\Theta = \text{TCYL}(\tau)$



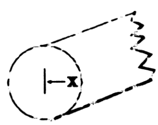
Cylinder
(TCYL)

6) $\Theta = \text{TCUB}(\tau)$



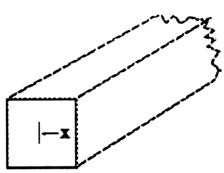
Cube
(TCUB)

7) $\Theta = \text{TCYLINF}(\tau)$



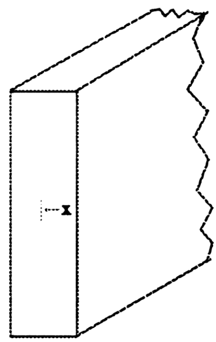
Cylinder (infinite)
(TCYLINF)

8) $\Theta = \text{TPARINF}(\tau)$



Parallelpiped
(TPARINF)

9) $\Theta = \text{TSLAB}(\tau)$



Slab (Infinite)
(TSLAB)

Variable	Description	Eqn Units
Θ	normalized temperature	1
Tc	centerline temperature	1_K
T∞	final temperature	1_K
Ti	initial uniform temperature	1_K
α	thermal diffusivity	1_m^2/s
t	time	1_s
x	centerline to surface length	1_m
k	thermal conductivity	1_W/(m·K)
ρ	density	1_kg/m^3
cp	specific heat	1_J/(kg·K)
τ	Fourier modulus	1

Example: A sphere of lead (x=.1_ft), initially at a temperature of 98_°C, is dropped into a vigorously agitated tank of water maintained at 0_°C by an external refrigerator unit. The average properties of the lead sphere during cooling are given as: ρ=708_lb/ft^3, cp=0.03_Btu/(lb·°F) and K=20.3_Btu/(h·ft·°F). How many seconds will it take for the center of the sphere to attain a temperature of 18.3_°C? Use equations 1, 2, 3 and 4.

Given	Result
ρ = 708_lb/ft^3	α = 0.956_ft^2/h
cp = 0.03_Btu/(lb·°R)	Θ = 0.187
k = 20.3_Btu/(h·ft·°F)	t = 9.06_s
Ti = 98_°C	τ = .24
Tc = 18.3_°C	

T∞ = 0_°C
x = .1_ft

Semi-Infinite Solid

The six equations in this topic describe transient heat conduction solution for a semi-infinite solid. Error function and complementary error function are computed using an internal program that is not available for use in other topics.

1) $\eta = \dfrac{x}{2 \cdot \sqrt{\alpha \cdot t}}$

2) $\Theta = \dfrac{T - T\infty}{Ti - T\infty}$

3) $\lambda = \dfrac{h \cdot \sqrt{\alpha \cdot t}}{k}$

4) $\Theta = ERF(\eta) + e^{\left(2 \cdot \lambda \cdot \left(\eta + \frac{\lambda}{2}\right)\right)} \cdot ERFC(\eta + \lambda)$

5) $\dfrac{q}{A} = \dfrac{k \cdot (T\infty - Ti)}{\sqrt{\pi \cdot \alpha \cdot t}} \cdot e^{-x^2 / (4 \cdot \alpha \cdot t)}$

6) $\alpha = \dfrac{k}{\rho \cdot cp}$

Variable	Description	Eqn Units
η	similarity parameter	1
x	distance	1_m
α	thermal diffusivity	1_m^2/s
t	time	1_s
Θ	normalized temperature	1
T	temperature	1_K
T∞	final temperature	1_K
Ti	initial temperature	1_K
λ	lambda parameter	1
h	convective heat transfer coefficient	1_W/(m^2·K)
k	thermal conductivity	1_W/(m·K)
q	heat flow rate	1_W
A	area	1_m^2
ρ	density	1_kg/m^3
cp	specific heat	1_J/(kg·K)

Example: Assume that the Alaskan tundra has a constant and uniform temperature of -7_°C to a depth of several meters. On a very particular spring day, a Hawaiian air mass (T∞ = 20_°C) moves over the tundra for a period of eight hours. The convective coefficient between air and surface is 13.14_W/(m^2·K). Assume tundra properties of α = 4.65 x 10^-7_m^2/s and k = 0.865_W/(m·K). Calculate (a) surface temperature at 5 hours and (b) depth at which T = 0_°C after 8 hours.

A. Surface temperature at 5 hours:

Given	**Result**
x = 0_m	Θ = .34059
T∞ = 20_°C	η = 0
Ti = -7_°C	λ = 1.3897
α = 4.65 x 10^{-7}_m^2/s	T = 10.80_°C
k = 0.865_W/(m·K)	
t = 5_h	
h = 13.14_W/(m^2·K)	

B. Depth at which T = 0 °C after 8 hours:

Given	**Result**
T = 0_°C	x = .1314_m
T∞ = 20_°C	Θ = .74074
Ti = -7_°C	λ = 1.7579
α = 4.65 x 10^{-7}–m^2/s	η = .56787
k = 0.865_W/(m·K)	
t = 8_h	
h = 13.14_W/(m^2·K)	

Note: Problem B takes over three minutes to calculate.

Blackbody Radiation

A blackbody is one which neither reflects nor transmits any thermal energy. The following equations describe this behavior. PLAM21 computes the normalized fraction of emitted radiation in the wavelength range $\lambda 1$ to $\lambda 2$ for the blackbody temperature of T.

1) $Eb = \sigma \cdot T^4$

2) $$Eb\lambda = \frac{c1 \cdot \lambda^{-5}}{e^{c2/(\lambda \cdot T)} - 1}$$

3) $\lambda max \cdot T = c3$

4) $frac = PLAM21\ (\lambda 2, \lambda 1, T)$

5) $Eb12 = frac \cdot Eb$

6) $q = Eb \cdot A$

Variable	Description	Eqn Units
Eb	total emissive power	1_W/m^2
Ebλ	monochromatic emissive power	1_W/m^2·μm
T	temperature	1_K
λ	wavelength	1_m
λmax	maximum emissivity wavelength	1_m
frac	total energy fraction	1
Eb12	emissive power λ1, λ2	1_W/m^2
q	heat flux	1_W
A	area	1_m^2
λ1	wavelength 1	1_m
λ2	wavelength 2	1_m

The PLAM21 function takes over 6 minutes to converge on an answer.

Example: A blackbody has a temperature of 450_°C. At what wavelength does maximum monochromatic emissive power occur? What is the total emissive power? (use equations 1 and 2)

Given	Result
T = 450_°C	λmax = 4.0069_μm
	Eb = 15505.1_W/m^2

What is the maximum monochromatic emission power?

Given	Result
T = 450_°C	Ebλ = 2545.404_W/(m^2·μm)
λ = 4.00_μm	

Radiant Heat Exchange

When the heat transfer rate is at equilibrium between two gray and opaque surfaces, the following equations can be used.

1) $$q12 = \frac{Eb1 - Eb2}{\frac{1-\varepsilon 1}{\varepsilon 1 \cdot A1} + \frac{1}{A1 \cdot F12} + \frac{1-\varepsilon 2}{\varepsilon 2 \cdot A2}}$$

2) $Eb1 = \sigma \cdot T1^4$

3) $Eb2 = \sigma \cdot T2^4$

4) $A1 \cdot F12 = A2 \cdot F21$

5) $q12 = A1 \cdot \varepsilon 1 \cdot \sigma \cdot \left(T1^4 - T2^4\right)$ when A2 >> A1

Variable	Description	Eqn Units
q12	heat flow rate	1_W
Eb1	emissive power at 1	1_W/m^2
Eb2	emissive power at 2	1_W/m^2
T1	temperature 1	1_K
T2	temperature 2	1_K
A1	area 1	1_m^2
A2	area 2	1_m^2
ε1	emissivity 1	1
ε2	emissivity 2	1
F12	view factor 1	1
F21	view factor 2	1

Example: The equilibrium temperature of a chromnickel (ε = .68) cannonball is 700_°F. The temperature of the furnace walls is 1200_°F. What is the heat transfer rate? The surface area of the cannonball is 1.40_ft^2. Use equation 5.

Given	Result
T1 = 700_°F	q12 = -9418.7935_Btu/h
T2 = 1200_°F	
A1 = 1.40_ft^2	
ε1 = .68	

Mechanics

This category covers six topics of interest to mechanical engineers concerning laws of motion.

- Linear Motion
- Angular Motion
- Force, Work, Power
- Forces in Angular Motion
- Elastic Collisions (1D)
- Inclined Planes

Linear Motion

Five equations describe the relationships between initial and final velocity, distance travelled, acceleration and time of travel. These equations assume that the linear motion is characterized by constant acceleration.

1) $x = xo + vo \cdot t + \frac{1}{2} \cdot a \cdot t^2$

2) $x = xo + v \cdot t - \frac{1}{2} \cdot a \cdot t^2$

3) $x = xo + \frac{1}{2} \cdot (v + vo) \cdot t$

4) $v = vo + a \cdot t$

5) $v^2 = vo^2 + 2 \cdot a \cdot (x - xo)$

Variable	Description	Eqn Units
x	distance at t	1_m
xo	distance at t=0	1_m
vo	initial velocity	1_m/s
t	time of travel	1_s
a	acceleration	1_m/s^2
v	velocity at t	1_m/s

Example 1: You brake your Mazda RX7 from 80_mph to 45_mph over a displacement of 100 yards. What is the decceleration, assuming it to be

constant, and the elapsed time? Select equations 4 and 5 to solve the problem.

Given	**Result**
x = 100_yd	a = -4.7808_m/s^2
xo = 0_m	t = 3.2727_s
vo = 80_mph	
v = 45_mph	

Example 2: If you continue to decelerate at the rate from Example 1, how much further distance will the car travel before coming to a halt? Using equation 4, you can find time t and use it to solve for x using equations 1, 2 or 3.

Given	**Result**
xo = 0_m	x = 42.3237_m
vo = 45_mph	t = 4.2078_s
v = 0_mph	
a = -4.7808_m/s^2	

Angular Motion

Three equations in this topic cover the relationships between angular displacement, initial and final angular velocity, angular acceleration, and time.

1) $\Theta = \Theta o + \omega o \cdot t + \frac{1}{2} \cdot \alpha \cdot t^2$

2) $\Theta = \Theta o + \omega \cdot t - \frac{1}{2} \cdot \alpha \cdot t^2$

3) $\omega = \omega o + \alpha \cdot t$

Variable	**Description**	**Eqn Units**
Θ	final angular displacement	1_°
Θo	initial angular displacement	1_°
ωo	initial angular velocity	1_r/s
ω	final angular velocity	1_r/s
t	time	1_s
α	angular acceleration	1_r/s^2

Example: A rotating shift spinning at an initial angular velocity of 10_r/s changes its angular velocity at a constant rate to a final velocity of 125_r/min in 30 seconds. Find the angular displacement and angular acceleration.

Given	Result
Θo = 0	α = -.2639_r/s^2
ωo = 10_r/s	Θ = 181.25_r
ω = 125_r/min	
t = 30_s	

Force, Work, Power

The five equations in this set focus on Newton's second law; power, force and velocity relationships; and initial and final kinetic energy for linear motion.

1) $F = m \cdot a$ 2) $P = F \cdot v$

3) $v = \frac{1}{2} \cdot (vi + vf)$ 4) $vf = vi + a \cdot t$

5) $Ki = \frac{1}{2} \cdot m \cdot vi^2$ 6) $Kf = \frac{1}{2} \cdot m \cdot vf^2$

Variable	Description	Eqn Units
F	force	1_N
m	mass	1_kg
a	acceleration	1_m/s^2
P	power	1_W
v	avg velocity	1_ m/s
vf	final velocity	1_m/s
vi	initial velocity	1_m/s
t	time	1_s
Ki	initial kinetic energy	1_J
Kf	final kinetic energy	1_J

Example: You are starting a Porsche 911 from rest to a velocity of 100_mph in 15_seconds. What is the force required to move this 2600_lb vehicle? What is the average power required during this time interval and find its initial and final energy.

Given	**Result**
m = 2600_lb	F = 790.1468_lbf
vf = 100_mph	a = 35200_ft/min^2
vi = 0_mph	P = 105.3529_hp
t = 15_s	Ki = 0_Btu
	Kf = 869161.5044_ft·lbf
	v = 50_mph

Forces in Angular Motion

Five equations under this topic define relationships between radial forces, acceleration and power.

$$1)\ F = m \cdot \omega^2 \cdot r \qquad 2)\ v = \omega \cdot r \qquad 3)\ ar = \frac{v^2}{r}$$

$$4)\ \omega = 2 \cdot \pi \cdot n \qquad 5)\ P = \tau \cdot \omega$$

Variable	Description	Eqn Units
F	force	1_N
m	mass	1_kg
ω	angular velocity	1_r/s
r	radius	1_m
v	velocity	1_m/s
ar	radial acceleration	1_m/s^2
τ	torque	1_N·m
P	power	1_W
n	rotational speed	1_1/s

Example 1: A drum with a radius 1.5_ft is spinning at a speed of 240 revolutions per minute. Find the centripetal force on a 1_oz mass on the circumference. Find the radial acceleration and tangential velocity. Use the first four equations to solve the problem.

Given	**Result**
m = 1_oz	ω = 25.1327_r/s
r = 1.5_ft	F = 8.1871_N
n = 240_1/min	v = 11.4907_m/s
	ar = 288.7925_m/s^2

Elastic Collisions (1D)

These two equations cover one-dimensional elastic collisions for a mass m1, with an initial velocity, v1i, colliding with a mass, m2, initially at rest.

1) $v1f = \dfrac{m1 - m2}{m1 + m2} \cdot v1i$

2) $v2f = \dfrac{2 \cdot m1}{m1 + m2} \cdot v1i$

Variable	Description	Eqn Units
v1f	final velocity of m1	1_m/s
m1	mass m1	1_kg
m2	mass m2	1_kg
v1i	initial velocity of m1	1_m/s
v2f	final velocity of m2	1_m/s

Example: A 10_oz billiard ball travelling at 25_ft/s strikes a 12_oz billiard ball at rest. Find the velocities of the two balls after collision.

Given	Result
m1 = 10_oz	v1f = -2.2728_ft/s
m2 = 12_oz	v2f = 22.7272_ft/s
v1i = 25_ft/s	

Inclined Planes

There are six equations in this topic describing the forces of a mass, m1, sliding down an inclined plane subject to a friction. The mass, m1, is being held by a suspended mass, m2.

1) $\mu = TAN\,(\Theta f)$

2) $Fp = \dfrac{m1 \cdot g \cdot SIN\,(\Theta + \Theta f)}{COS\,(\Theta f)}$

3) $Fh = m1 \cdot g \cdot TAN\,(\Theta + \Theta f)$

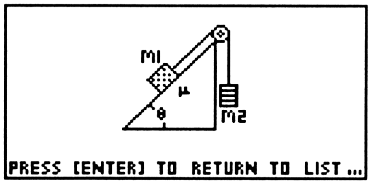
4) $F = m2 \cdot g$

5) $Fp = F$

6) $Fh \cdot COS\,(\Theta) = m2 \cdot g$

Variable	Description	Eqn Units
μ	friction coefficient	1
Θf	angle friction	1_°
Θ	angle plane	1_°
Fp	force along plane	1_N
Fh	horizontal force	1_N

m1	mass sliding down	1_kg
m2	mass	1_kg
F	force due gravity	1_N



Example: A 1.25_kg mass slides down a 30_° inclined plane with a coefficient of friction of 0.1. What is the angle of friction and force parallel to the inclined plane?

Given	Result
μ = 0.1	Fp = 7.1907_N
Θ = 30_°	Θf = 5.7106_°
m1 = 1.25_kg	

Stress Analysis

The seven topics in this category focus on analytical expressions for stress analysis under a variety of conditions, including shear stress analysis, principal stresses and Mohr's circle.

- Normal Stress/Strain
- Axial Load
- Dynamic Load
- Torsion
- Pure Shear
- Principal Stresses
- Mohr's Circle

Normal Stress/Strain

The six equations in this set give the basic relationships between stress, force, area, elongation, and shear stress.

1) $\sigma = \frac{P}{A}$ 2) $\varepsilon = \frac{\delta}{L}$ 3) $\sigma = E \cdot \varepsilon$

4) $ecc = \frac{\sigma}{E} \cdot (1 - 2 \cdot v)$ 5) $\tau = G \cdot \gamma$

6) $G = \frac{E}{2 \cdot (1 + v)}$

Variable	Description	Eqn Units
σ	normal stress	1_Pa
P	force	1_N
A	area	1_m^2
E	Young's modulus	1_Pa
ε	normal strain	1
ecc	eccentricity	1
τ	shear stress	1_Pa
G	shear modulus	1_Pa
γ	shear strain	1
v	Poisson's ratio	1
L	length	1_m
δ	elongation	1_m

Example: A prismatic bar has a cross section of 800_mm^2 and a length of 2.8_m subject to an axial force of 125_kN. The measured elongation is 1.4_mm, and has a Young's modulus of 75_GPa. If the shear modulus is 40_GPa, find the Poisson's ratio and eccentricity.

Given	Result
P = 125_kN	σ = 156250000_Pa
A = 800_mm^2	ε = 0.0005
E = 75_GPa	v = -0.0625
G = 40_GPa	ecc = 0.002344
γ = 0.05	τ = 2000_MPa
L = 2.8_m	
δ = 1.4_mm	

Axial Load

These five equations describe properties of an axially loaded member and thermal strain.

$$1)\ \delta = \frac{P \cdot L}{E \cdot A} \qquad 2)\ k = \frac{E \cdot A}{L} \qquad 3)\ f = \frac{L}{E \cdot A}$$

$$4)\ \varepsilon t = \alpha \cdot \Delta t \qquad 5)\ \delta t = \varepsilon t \cdot L$$

Variable	Description	Eqn Units
δ	displacement	1_m
P	load	1_N
L	length	1_m
E	Young's modulus	1_Pa
A	area	1_m^2
k	stiffness	1_N/m
f	compliance	1_m/N
εt	thermal strain	1
α	coefficient of thermal expansion	1_1/K
Δt	temperature change	1_K
δt	thermal elongation	1_m

Example 1: An axially-loaded member, with an area of 500_mm^2 and 20_ft long, is subjected to an axial load of 12_klbf. The modulus of elasticity is 155_GPa. Find the elongation, spring constant, and compliance. Use equations 1, 2, and 3 to solve this problem.

Given	Result
P = 12_klbf	δ = 4.1987E-3_m
L = 20_ft	k = 12713254.5932_N/m
E = 155_GPa	f = 7.8658E-8_m/N
A = 500_mm^2	

Example 2: A 100-foot-long bar has an expansion coefficient of 0.00005_1/°F. Find the thermal strain and thermal elongation for a temperature change of 45_°C.

Given	Result
L = 100_ft	δt = 0.12344_m

$\alpha = 0.00005\_1/°F$ $\quad$ $\varepsilon t = 0.00405$
$\Delta t = 45\_°C$

Dynamic Load

A sliding collar on a prismatic bar represents a simple case of a dynamic load. The equations below show some basic relationships.

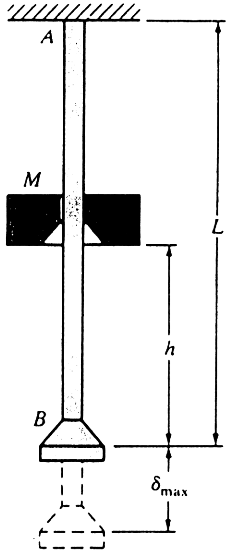
$$1)\ \delta max = \frac{W \cdot L}{E \cdot A} + \left(\left(\frac{W \cdot L}{E \cdot A}\right)^2 + \frac{2 \cdot W \cdot L \cdot h}{E \cdot A}\right)^{1/2}$$

$$2)\ \sigma max = \frac{E \cdot \delta max}{L}$$

$$3)\ \sigma st = \frac{W}{A}$$

$$4)\ \sigma max = \sigma st + \left(\sigma st^2 + \frac{2 \cdot h \cdot E \cdot \sigma st}{L}\right)^{1/2}$$

Variable	Description	Eqn Units
δmax	maximum elongation	1_m
σmax	maximum tensile stress	1_Pa
W	load	1_N
L	length of bar	1_m
E	Young's modulus	1_Pa
A	area	1_m^2
h	elevation of flange	1_m
σst	static stress	1_Pa



Example: A 10_m prismatic bar has a 1_kN load lifted 786_mm from the bottom. The bar has a cross sectional area of 0.00025_ft^2 and an elastic modulus of 256_GPa. Find the maximum elongation, maximum stress, and static stress.

Given	Result
W = 1_kN	δmax = 5.3128E-2_m
L = 10_m	σmax = 1360079023.01_Pa
E = 256_GPa	σst = 43055641.6668_Pa
A = 0.00025_ft^2	
h = 786_mm	

Torsion

Torsion refers to the twisting of a structural member when loaded by couples that produce rotation about its longitudinal axis. The following equations describe this phenomenon.

1) $\tau = G \cdot \gamma$

2) $\gamma = r \cdot \Theta$

3) $\varphi = \dfrac{T \cdot L}{G \cdot Ip}$

4) $Ip = \dfrac{\pi \cdot d^4}{32}$

5) $\tau max = \dfrac{T \cdot r}{Ip}$

Variable	Description	Eqn Units
τ	shear stress	1_Pa
G	shear modulus	1_Pa
γ	shear strain	1
r	radius	1_m
Θ	twist angle per unit length	1_°/m
ϕ	angle of twist	1_°
T	torque	1_N·m
L	length	1_m
Ip	polar moment of inertia, circular bar	1_m^4
d	diameter	1_m
τmax	maximum shear stress	1_Pa

Example 1: A shaft with a radius of 5_cm experiences a twist of 8_°/m. The shear modulus of elasticity is 60_GPa. What is the shear stress experienced by the shaft? Use equations 1 and 2.

Given	Result
G = 60_GPa	τ = 66666666.67_Pa
r = 5_cm	γ = 1.1111E-3
Θ = 8_°/m	

Example 2: For the shaft in Example 1, find the total twist and maximum shear stress, if the shaft is 10_ft long, for an applied torque of 5000_N·m. Use equations 3, 4 and 5.

Given	Result
G = 60_GPa	ϕ = 1.4824_°
r = 0.05_m	τmax = 25464790.8947_Pa
T = 5000_N·m	Ip = 9.8175E-6_m^4
L = 10_ft	
d = 0.1_m	

Pure Shear

When a solid is subjected to torsion, shear stresses are developed over cross sections and on longitudinal planes. These equations describe pure shear.

1) $\gamma = \frac{\tau}{G}$

2) $\varepsilon max = \frac{\tau}{E} \cdot (1 + v)$

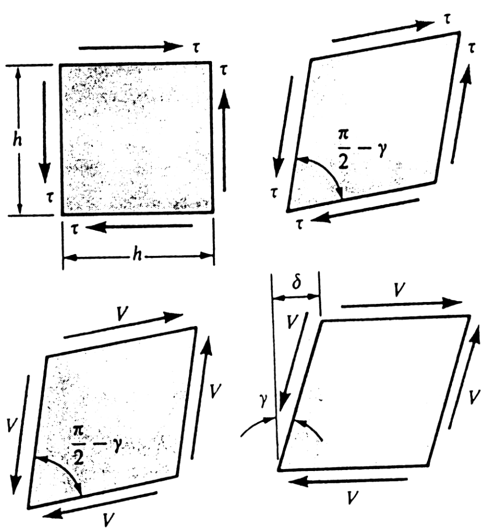
3) $\varepsilon max = \sqrt{1 + SIN(\gamma)} - 1$

4) $G = \frac{E}{2 \cdot (1 + v)}$

5) $\sigma\Theta = \tau \cdot SIN(2 \cdot \Theta)$

6) $\tau\Theta = \tau \cdot COS(2 \cdot \Theta)$

Variable	Description	Eqn Units
γ	shear strain	1
τ	shear stress	1_Pa
G	shear modulus	1_Pa
εmax	maximum strain	1
E	Young's modulus	1_Pa
v	Poisson's ratio	1
$\sigma\Theta$	normal shear stress	1_Pa
$\tau\Theta$	shear stress	1_Pa
Θ	angle	1_°



Example: A prismatic bar material has a shear modulus of 50_GPa, and a Young's modulus of 160_GPa. For a shear strain of 1%, find the shear stress, maximum strain and Poisson's ratio. Use equations 1, 3 and 4 to solve the problem.

Given	**Result**
γ = 0.01	τ = 500.000_MPa
G = 50_GPa	εmax = 5.000E-3
E = 160_GPa	v = 0.600

Example 2: For a shear strain of 1%, what is the maximum strain? Use equation 3.

Given	**Result**
γ = 0.01	εmax = 0.004987

Principal Stresses

The four equations in this topic describe the relationship between stresses along x and y axes and stresses along rotated axes.

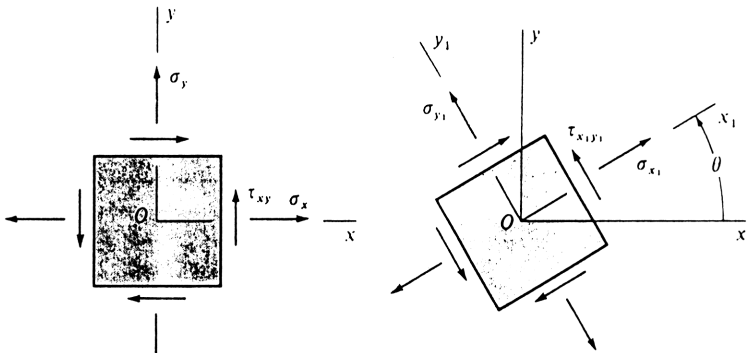
1) $$\sigma x1 = \frac{\sigma x + \sigma y}{2} + \frac{\sigma x - \sigma y}{2} \cdot COS\,(2 \cdot \Theta) + \tau xy \cdot SIN\,(2 \cdot \Theta)$$

2) $$\sigma y1 = \frac{\sigma x + \sigma y}{2} - \frac{\sigma x - \sigma y}{2} \cdot COS\,(2 \cdot \Theta) + \tau xy \cdot SIN\,(2 \cdot \Theta)$$

3) $$\tau x1y1 = \frac{-(\sigma x - \sigma y)}{2} \cdot SIN\,(2 \cdot \Theta) + \tau xy \cdot COS\,(2 \cdot \Theta)$$

4) $$\sigma x1 + \sigma y1 = \sigma x + \sigma y$$

Variable	**Description**	**Eqn Units**
σx1	normal stress along rotated x-axis	1_Pa
σy1	normal stress along rotated y-axis	1_Pa
σx	normal stress along x-axis	1_Pa
σy	normal stress along y-axis	1_Pa
Θ	rotational angle	1_°
τxy	shear stress	1_Pa
τx1y1	rotated shear stress	1_Pa



Example: Calculate principal stresses along a 30_° rotated axis of a system subject to stress of 150000_Pa along the x-axis and 100000_Pa along the y-axis at a shear stress of 200000_Pa.

Given	Result
σx = 150000_Pa	σx1 = 310705.0808_Pa
σy = 100000_Pa	σy1 = 285705.0808_Pa
Θ = 30_°	
τxy = 200000_Pa	

Mohr's Circle

The eight equations in this topic cover interrelationships among principal, normal, maximum and minimum stresses, and angles of rotation.

1) $$\sigma 1 = \frac{\sigma x + \sigma y}{2} + \left(\left(\frac{\sigma x - \sigma y}{2}\right)^2 + \tau xy^2\right)^{1/2}$$

2) $$\sigma 2 = \frac{\sigma x + \sigma y}{2} - \left(\left(\frac{\sigma x - \sigma y}{2}\right)^2 + \tau xy^2\right)^{1/2}$$

3) $\sigma 1 + \sigma 2 = \sigma x + \sigma y$

4) $SIN(2 \cdot \Theta p1) = \dfrac{\tau xy}{\left(\left(\dfrac{\sigma x - \sigma y}{2}\right)^2 + \tau xy^2\right)^{1/2}}$

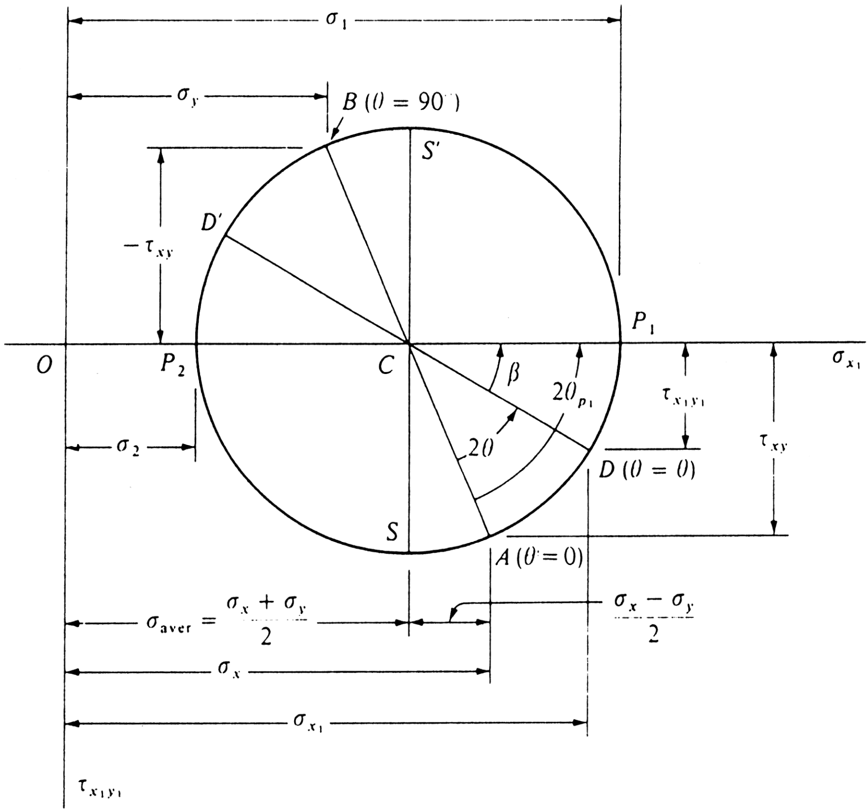
5) $\Theta p2 = \Theta p1 + 90$

6) $\Theta s = \Theta p1 - 45$

7) $\tau max = \dfrac{\sigma 1 - \sigma 2}{2}$

8) $\sigma avg = \dfrac{\sigma x + \sigma y}{2}$

Variable	Description	Eqn Units
σ1	maximum principal normal stress	1_Pa
σ2	minimum principal normal stress	1_Pa
σavg	normal stress on plane of max shear	1_Pa
σx	normal stress in x-direction	1_Pa
σy	normal stress in y-direction	1_Pa
τxy	shear stress	1_Pa
Θp1	angle to plane of max principal normal stress	1_°
Θs	angle to plane of max shear stress	1_°
Θp2	angle to plane of min principal normal stress	1_°
τmax	max principal normal stress	1_Pa



Example: For a beam system, the normal x and y stresses are 120_kPa and 90_kPa, respectively. If the system experiences a 75_kPa shear stress, find the maximum and minimum principal normal stresses.

Given	**Result**
σx = 120_kPa	σ1 = 181485.2927_Pa
σy = 90_kPa	σ2 = 28514.7073_Pa
τxy = 75_kPa	Θp1 = 39.3450_°

Vibrations

The five topics in this category describe oscillation/frequency relationships in typical mechanical engineering applications.

- Simple and Compound Pendulums
- Damped and Free Vibration
- Natural Frequency-Spring System
- Natural Frequency-Beams
- Vibration Isolation

Simple and Compound Pendulums

These two equations define the period of oscillations of a simple or compound pendulum.

1) $ts = 2 \cdot \pi \cdot \sqrt{len / g}$ 2) $tc = 2 \cdot \pi \cdot \sqrt{I / (m \cdot g \cdot h)}$

Variable	Description	Eqn Units
ts	simple pendulum period	1_s
tc	compound pendulum period	1_s
len	simple pendulum length	1_m
I	moment of intertia	1_kg·m^2
m	compound pendulum mass	1_kg
h	distance of center of mass	1_m

Example 1: A simple pendulum has a period of 1.25_s. Find its length, using equation 1.

Given	Result
ts = 1.25_s	len = 0.3881_m

Example 2: A compound pendulum has a moment of inertia of 50_kg·m^2, and a mass of 75_kg. The center of mass is 8_in away from the point of oscillation. Find its period.

Given	Result
I = 50_kg·m^2	tc = 3.6343_s
m = 75_kg	

h = 8_in

Damped and Free Vibration

The six equations in this topic focus on the basics of damped oscillation of a spring system. Equations 1 and 6 show the relationship between natural radian frequency and cyclical frequency. Equations 2-5 describe the impact of viscous damping on natural frequency, including conditions for critical damping.

1) $\omega = \sqrt{k/m}$

2) $\alpha = \dfrac{C}{2 \cdot m}$

3) $\omega d = \sqrt{\omega^2 - \alpha^2}$

4) $\omega d = \omega \cdot \left(1 - \left(\dfrac{C}{Cc}\right)^2\right)^{1/2}$

5) $Cc = 2 \cdot \sqrt{k \cdot m}$

6) $\omega = 2 \cdot \pi \cdot f$

Variable	Description	Eqn Units
ω	natural radian frequency	1_r/s
f	frequency	1_Hz
α	damping component	1_1/s
C	coefficient of viscous damping	1_kg/s
Cc	critical damping coefficient	1_kg/s
ωd	damped radian frequency	1_r/s
m	mass	1_kg
k	spring constant	1_N/m

Example 1: A spring has a spring constant of 18_N/m. A mass of 4_oz is suspended. What is the radian and cyclical frequency? Use equations 1 and 6.

Given	Result
m = 4_oz	ω = 12.5989_r/s
k = 18_N/m	f = 2.0052_Hz

Example 2: Design a damped spring system with a vibration frequency of 10_Hz and a damped radian frequency of 50_r/s for a 4_oz mass. Find the

critical damping parameter. Use equations 1 and 6 to find the natural frequency and spring constant. Use equation 3 to find damping component α. Find the coefficient of damping from equation 2, and round off the design using equation 5.

Given	Result
f = 10_Hz	ω = 62.8319_r/s
ωd = 50_r/s	k = 447.6772_N/m
m = 4_oz	α = 38.0505_r/s
	C = 8.6297_kg/s
	Cc = 14.2500_kg/s

Natural Frequency-Spring System

This topic describes the natural radian frequency of four simple spring systems.

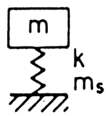
$$1)\quad \omega n = \left(\frac{k}{m + \frac{1}{3}\cdot ms}\right)^{1/2}$$

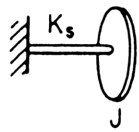
$$2)\quad \omega s = \left(\frac{k\cdot(m1+m2)}{m\cdot m2}\right)^{1/2}$$

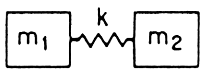
$$3)\quad \omega t = \sqrt{Ks\,/\,J}$$

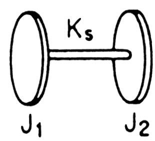
$$4)\quad \omega t2 = \left(\frac{Ks\cdot(J1+J2)}{J1\cdot J2}\right)^{1/2}$$

Variable	Description	Eqn Units
k	spring constant	1_N/m
m	mass	1_kg
ms	spring mass	1_kg
m1	mass 1	1_kg
m2	mass 2	1_kg
ωn	natural frequency (spring + mass)	1_r/s
ωs	natural frequency (spring + 2 masses)	1_r/s
ωt	natural frequency (torsion)	1_r/s
ωt2	natural frequency (2 torsion bars)	1_r/s
Ks	stiffness constant	1_N·m
J	polar moment	1_kg·m^2
J1	polar moment 1	1_kg·m^2
J2	polar moment 2	1_kg·m^2









Example: A spring with a stiffness constant of 275_N/m has a spring mass of 12_oz. If a mass of 8_oz is suspended from this spring, what is its natural frequency? Use the first equation to solve this problem.

Given	**Result**
k = 275_N/m	ωn = 28.4317_r/s
m = 8_oz	
ms = 12_oz	

Natural Frequency-Beams

These four equations cover the natural frequencies of a cantilever beam, a simple fixed beam, a structured spring and a simple free beam.

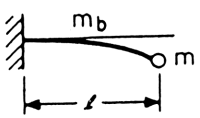
$$1)\ fn1 = \frac{1}{2 \cdot \pi} \cdot \left(\frac{3 \cdot E \cdot I}{(m + .23 \cdot mb) \cdot len^3}\right)^{1/2}$$

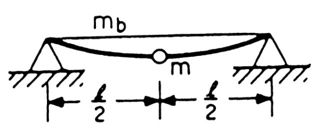
$$2)\ fn2 = \frac{1}{2 \cdot \pi} \cdot \left(\frac{48 \cdot E \cdot I}{(m + .5 \cdot mb) \cdot len^3}\right)^{1/2}$$

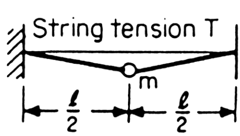
3) $fn3 = \frac{1}{2 \cdot \pi} \cdot \left(\frac{4 \cdot T}{m \cdot len}\right)^{1/2}$

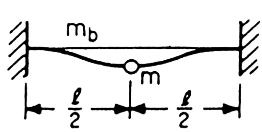
4) $fn4 = \frac{1}{2 \cdot \pi} \cdot \left(\frac{192 \cdot E \cdot I}{(m + .37 \cdot mb) \cdot len^3}\right)^{1/2}$

Variable	Description	Eqn Units
fn1	natural frequency cantilever beam	1_Hz
fn2	natural frequency simple fixed beam	1_Hz
fn3	natural frequency structured spring	1_Hz
fn4	natural frequency simple free beam	1_Hz
E	Young's modulus	1_Pa
I	area moment of inertia	1_m^4
m	mass	1_kg
mb	beam mass	1_kg
T	string tension	1_N
len	length of beam	1_m









Example: A 2600_lb load is placed on a 20_ft cantilever beam weighing 1000_lb. Assuming Young's modulus to be 30_GPa and the area moment of inertia to be 725_in^4, find the frequency.

Given	Result
E = 30_GPa	fn1 = 1.5381_s

I = 725_in^4
m = 2600_lb
mb = 1000_lb
len = 20_ft

Vibration Isolation

The equations in this topic describe the basics of how noise vibrations generated by machines (such as motors, turbines, and internal combustion engines) are coupled to their environment, and how to reduce the coupled noise.

1) $f = \frac{1}{2 \cdot \pi} \cdot \sqrt{g / \delta}$

2) $\delta = \frac{meq \cdot g}{k}$

3) $\eta = 1 - \frac{1}{\left(\frac{ff}{f}\right)^2 - 1}$

4) $TR = \beta \cdot \left(1 + \frac{2 \cdot c \cdot ff}{cc \cdot f}\right)^{1/2}$

5) $\beta = \frac{1}{\left(\left(1 - (ff / f)^2\right)^2 + \left(\frac{2 \cdot c \cdot ff}{(cc \cdot f)}\right)^2\right)^{1/2}}$

Variable	Description	Eqn Units
f	frequency of vibration	1_Hz
ff	forcing frequency	1_Hz
δ	displacement	1_m
k	spring constant	1_N/m
meq	equipment mass	1_kg
η	efficiency of isolation	1
TR	transmissibility ratio	1
β	magnification factor	1
c	coefficient of viscous damping	1_N·s/m
cc	critical damping	1_N·s/m

Machine Design

The Equation Library includes three topics involving the design of mechanical elements. No attempt has been made to cover the area of machine design comprehensively.

- Helical Springs
- Frequency of Helical Springs
- Viscosity & Petrof's Law

Helical Springs

These equations describe deflection and stresses in helical springs. A helical spring with a wire diameter, d, and a mean spring diameter, D, is subjected to a force, F. The first equation shows the relationship between the maximum stress in the wire and the applied force. The second equation expresses the stress relationship in terms of a new parameter ks. The last two equations show the relationship between deflection, force, spring parameters and spring rate.

1) $\tau max = \frac{T \cdot d}{2 \cdot J} + \frac{F}{A}$

2) $\tau = \frac{Ks \cdot (8 \cdot F \cdot Ds)}{\pi \cdot d^3}$

3) $T = \frac{F \cdot Ds}{2}$

4) $J = \frac{\pi \cdot d^4}{32}$

5) $A = \frac{\pi \cdot d^2}{4}$

6) $C = \frac{Ds}{d}$

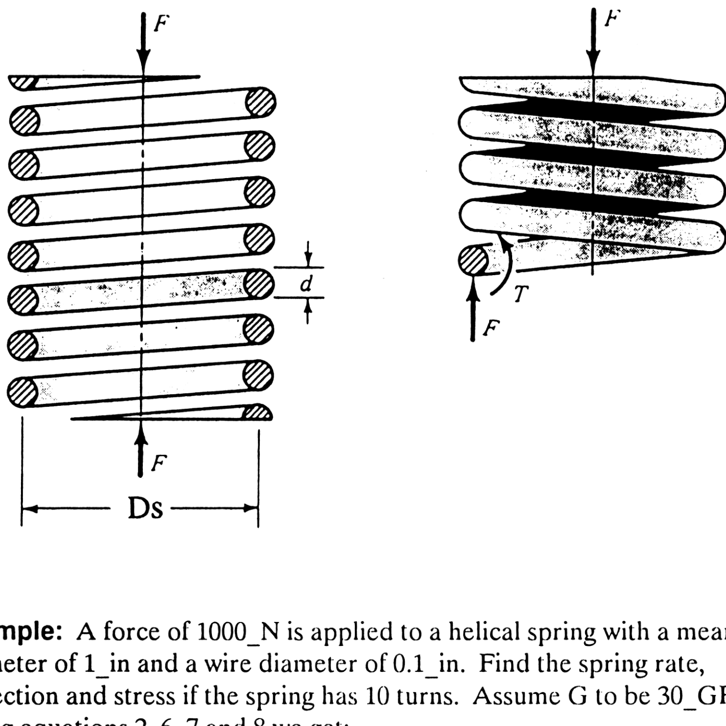
7) $Ks = \frac{2 \cdot C + 1}{2 \cdot C}$

8) $y = \frac{8 \cdot F \cdot Ds^3 \cdot N}{d^4 \cdot G} \cdot \left(1 + \frac{1}{2 \cdot C^2}\right)$

9) $k = \frac{d^4 \cdot G}{8 \cdot Ds^3 \cdot N} \cdot \left(\frac{1}{\left(1 + \frac{1}{(2 \cdot C^2)}\right)}\right)$

Variable	**Description**	**Eqn Units**
F	axial force	1_N
Ds	mean spring diameter	1_m

d	wire diameter	1_m
A	wire cross section	1_m^2
J	moment of inertia	1_m^4
T	torsion	1_N·m
τ	maximum shear stress	1_Pa
τmax	shear stress	1_Pa
C	spring index	1
Ks	shear stress correction factor	1
G	modulus of rigidity	1_Pa
N	no. turns in the spring	1
y	deflection	1_m
k	spring rate	1_N/m



Example: A force of 1000_N is applied to a helical spring with a mean diameter of 1_in and a wire diameter of 0.1_in. Find the spring rate, deflection and stress if the spring has 10 turns. Assume G to be 30_GPa. Using equations 2, 6, 7 and 8 we get:

Given	**Result**
F = 1000_N	Ks = 1.0508
Ds = 2.5_cm	C = 9.8425

d = 0.1_in
N = 10
G = 30_GPa

τ = 4082244731.6_Pa
k = 993.866_N/m
y = 1.0062_m

Frequency of Helical Springs

Physical properties of a spring influence the mechanical vibration characteristics of a helical spring. The six equations in this topic identify natural frequencies of vibration based on spring constant and mass.

1) $\omega = \pi \cdot \sqrt{k / m}$

2) $f = \frac{1}{2} \cdot \sqrt{k / m}$

3) $fs = \frac{1}{4} \cdot \sqrt{k / m}$

4) $m = A \cdot L \cdot \rho$

5) $m = \frac{\pi^2 \cdot d^2 \cdot Ds \cdot Na \cdot \rho}{4}$

6) $A = \frac{\pi \cdot d^2}{4}$

Variable	Description	Eqn Units
ω	natural frequency	1_r/s
k	spring rate	1_N/m
m	spring mass	1_kg
f	frequency	1_Hz
fs	frequency fixed at one end	1_Hz
A	area of cross section	1_m^2
L	length of spring	1_m
ρ	density	1_kg/m^3
d	wire diameter	1_m
Ds	mean spring diameter	1_m
Na	number of coils	1

Example: A spring with 25 turns is made of a 0.2_in diameter wire, has a mean diameter of 1.65_in and a density of 6_g/cm^3. The spring constant is 18000_N/m. Find the length of the spring and its natural frequency.

Given
k = 18000_N/m
ρ = 6_g/cm^3
d = 0.1_in
Ds = 1.65_in

Result
ω = 1332.3799_r/s
f = 212.0548_Hz
fs = 106.0274_Hz
A = 5.067E-6_m^2

Na = 25

L = 3.2916_m
m = 0.1001_kg

Viscosity & Petroff's Law

These eight equations describe Newton's law of viscosity and Petroff's law, introduce dynamic viscosity, and use the Sommerfeld number to describe force, torque and friction factor, and bearing frictional forces.

1) $\tau = \frac{F}{A}$

2) $\tau = \frac{2 \cdot \pi \cdot r \cdot \mu \cdot N}{c}$

3) $T = \frac{4 \cdot \pi^2 \cdot r^3 \cdot l \cdot \mu \cdot N}{c}$

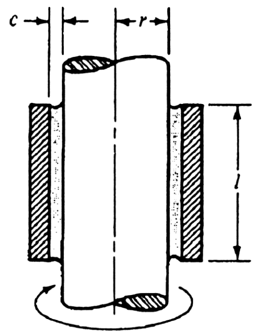
4) $T = 2 \cdot r^2 \cdot fp \cdot l \cdot P$

5) $fp = \frac{\frac{2 \cdot \pi^2 \cdot \mu \cdot N}{P} \cdot r}{c}$

6) $S = \frac{\left(\frac{r}{c}\right)^2 \cdot \mu \cdot N}{P}$

7) $\frac{fp \cdot r}{c} = 2 \cdot \pi^2 \cdot S$

Variable	Description	Eqn Units
τ	shear stress	1_Pa
F	force	1_N
A	area of cross section	1_m^2
r	shaft radius	1_m
μ	dynamic viscosity	1_Pa·s
N	shaft rotation in rev/s	1_1/s
c	radial clearance	1_m
T	torque	1_N·m
l	length of bearing	1_m
fp	Petrof's coefficient	1
P	pressure on projected area	1_Pa
S	Sommerfeld number	1



Example: A force of 1000_N is acting on an area of 12_in^2. Find the stress produced using equation 1.

Given	Result
F = 1000_N	τ = 129166.925_Pa
A = 12_in^2	

Chapter 3
Constants Library

In This Chapter

The Constants Library is a collection of physical constants commonly used in mechanical engineering. This chapter covers:

- ☐ Types of Constants
- ☐ Using the Constants Library
- ☐ Using the ECON Function
- ☐ Constants Library Softkeys

Types of Constants

The Constants Library lists the symbols, descriptions and SI units of three classifications of constants, shown below:

Universal Constants

pi	
R	Universal gas constant
NA	Avogadro's number
Vm	Molar volume
StdT	Standard temperature
StdP	Standard pressure
εo	Permittivity of vacuum
c	Velocity of light in vacuum
h	Planck's constant
k	Boltzmann's constant
σ	Stefan-Boltzmann
c1	Spectral 1
c2	Spectral 2
c3	Wien's displacement

Magnetic Properties

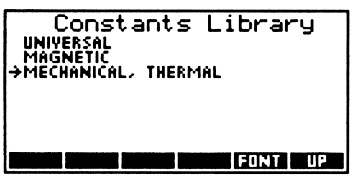
μo	Permeability of vacuum
ϕo	Magnetic flux quantum
F	Faraday's constant
μe	Electron magnetic moment
μP	Proton magnetic moment

Mechanical, Thermal

G	Gravitational constant
g	Acceleration of gravity
ρH_2O	Density of H2O at 20 °C
λH_2O	Refractive index of H_2O at 20 °C
cpH_2O	Heat capacity of H_2O at 20 °C
HfH_2O	Heat of fusion of H_2O
HvH_2O	Heat of vaporization of H_2O

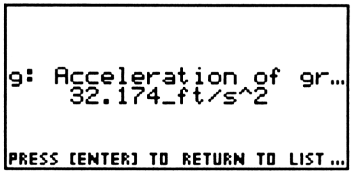
Using the Constants Library

Select CONSTANTS LIBRARY from the main menu screen. The Constants Library menu displays three classes of constants:



Example: Suppose you want to find the acceleration of gravity. Use the cursor keys to move the pointer to the MECHANICAL, THERMAL menu item and press ENTER to display the following screen:

Move the pointer to ACCELERATION OF GRAVITY. Five softkeys are available at this level and are described at the end of this chapter. To view the value for this constant, press the **VALUE** softkey. This results in the following display:



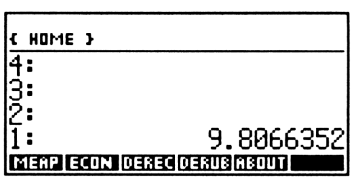
To place the constant's value on the stack, press [ENTER] or the **→STK** softkey. The screen flashes a "Value to stack" message, places the value on the stack as a tagged object, then returns to the MECHANICAL, THERMAL menu. The value(s) you entered on the stack become available for calculation when you exit the software. To remove the tag once the value is on the stack press [PRG] **OBJ** [NXT] **DTAG**.

Using the ECON Function

You can extract the value of any constant without entering the Mechanical Engineering Application Pac with the ECON( ) function. In all cases, the constant name must be prefixed with a '$' symbol, accessed by [α][⬅][4]. For example, suppose you want to retrieve the acceleration of gravity:

User Program Method

Inside a user program, use the commands '$g' ECON or 'ECON($g)' EVAL to retrieve the acceleration of gravity in SI units of m/s^2.



Stack Method

Type '$g' into level 1 of the stack and press the **ECON** library softkey or type the letters ECON and press [ENTER].

The constant value will have SI units if units are selected (i.e., if flag 61 is clear); otherwise, the value will have no units.

Constants Library Softkeys

VALUE	Displays the value of the constant with units on the screen. Press ENTER to return to the constants list.
→STK	Places a copy of the selected constant on the calculator stack. Whether or not the value has units appended is controlled by the units key setting, which can be toggled at the Equation Library screen.
FONT	Toggles between large and small display fonts.
UP	Moves up one level in the menu structure.
MAIN	Exits to the main menu.

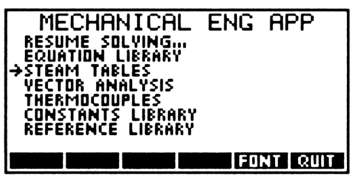
Chapter 4
Analysis

In This Chapter

This chapter describes three sets of tools used to solve common problems in mechanical engineering.

- ☐ Steam Tables
- ☐ Vector Analysis
- ☐ Thermocouples

The following sections should be read in order, as some information is common to all three topics. These topics are accessed directly from the main menu, shown below:



From the main menu, move the pointer to STEAM TABLES and press [ENTER].

Steam Tables

Steam Tables is a collection of programs organized as a powerful computational engine designed to calculate thermodynamic properties of steam in a user-friendly environment. Calculations of thermodynamic properties are covered for saturated and superheated steam.

Steam properties are a complex function of temperature, pressure, volume, critical temperature, critical pressure, and molecular weight. The properties listed in this software have been tabulated over a decade. Best fit routines have been developed and agreed upon through the International Formulation

Committee. In cases where it is impossible to get good curve fits, regions of interest have been divided into two or three ranges with separate equation sets. The following tables list all steam properties available in the software.

Saturated Steam Properties

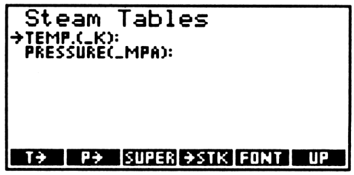
Variable	Description	Units
T(s)	saturation temperature	1_K
P (s)	saturation pressure	1_mPa
V (f)	specific volume - liquid	1_m^3/kg
V (g)	specific volume - vapor	1_m^3/kg
H (f)	enthalpy - liquid	1_KJ/kg
H (fg)	latent heat of vaporization	1_KJ/kg
H (g)	enthalpy - vapor	1_KJ/kg
S(f)	entropy - liquid	1_KJ/(kg·K)
S (fg)	S (g) - S (f)	1_KJ/(kg·K)
S (g)	entropy - vapor	1_KJ/(kg·K)
U (f)	internal energy - liquid	1_kJ/kg·K)
U (g)	internal energy - vapor	1_kJ/kg·K)

Superheated Steam Properties

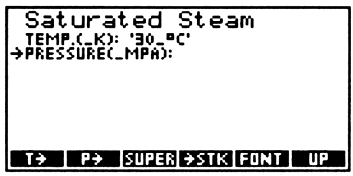
Variable	Description	Units
Temp	given temperature	1_K
Sat Press	given pressure	1_mPa
Sat Temp	corresponding temperature	1_K
Specific Vol	specific volume	1_m^3/kg
Enthalpy	enthalpy	1_KJ/kg
Entropy	entropy	1_KJ/(kg·K)

Using Steam Tables

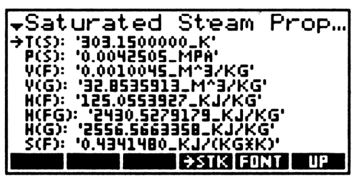
Once you have selected STEAM TABLES at the main menu, the first screen displays two menu items: temperature and pressure. To compute *saturated* steam properties, you can enter a value for either temperature or pressure. Properties of *superheated* steam require you to enter values for both temperature and pressure.



Example: Suppose you want to calculate the properties of saturated steam at 30_°C. First, move the pointer to Temp. and press ENTER. At the cursor type in 30. To complete the entry, add the units symbol by pressing the appropriate softkey, in this case _°C and press ENTER. The following screen displays:



To view the calculated thermodynamic properties, press T→:



The steam table engine reports all its calculations in SI units. When entering values you may use any compatible units supported by the HP 48SX.

The saturated steam properties can also be computed by allowing a value for pressure and pressing the sofkey P→. The results from this computation are similar to those reported in the screen above.

Ranges of Temperature and Pressure

The computed results are valid only for the following finite ranges of temperature and pressure:

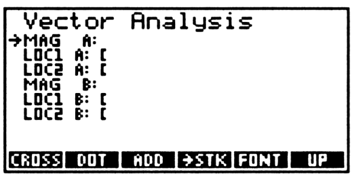
Saturated	Superheated
Temperature: 273.16 - 647.3 K	> Saturated temperature

Pressure: 0.006113 - 22.08 MPa	Pressure: 0.006113 - 22.08 MPa

Vector Analysis

Vectors are quantities having both magnitude and direction, such as displacement, force, velocity, momentum and acceleration. This software tool enables you to perform many of the common tasks in vector algebra, such as combining to obtain scalar product, vector product, vector addition and vector subtraction.

After you select VECTOR ANALYSIS at the main menu and press ENTER, the following screen displays:



Specifying Vectors

Ususally vectors are specified by a magnitude and a direction. The vector analysis function in the Mechanical Engineering Application Pac is limited to two or three-dimensional vectors.

To specify a vector, you need to enter its magnitude and two points to determine the direction. This procedure is used because in problems such as structural anaylsis, the direction of a vector is inferred by the beginning and end points of a structural member, and magnitude is entered separately . In addition, this approach allows you to enter vectors originating at several points in space. If you choose to specify the direction using only one vector, you need to enter the value in Location 2, and enter [0 0 0] in Location 1.

Once the computation is complete, the result is displayed as vector B and the system is ready to receive a new vector. This feature allows you continual use of the interface to solve vector analysis problems.

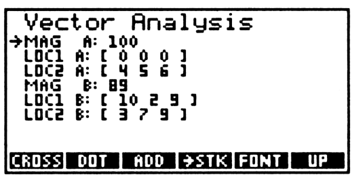
The new softkeys available in the vector analysis function are described below.

CROSS Takes the vector product of two vectors and presents a new vector.

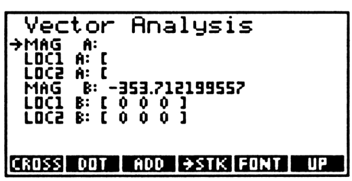
DOT Takes the scalar product of two vectors and presents a new scalar quantity.

ADD Adds two vectors specified.

Example: Two force vectors have magnitudes of 100 and 89. The direction of the first vector is specified to be along a line from a [0 0 0] to [4 5 6], while the second vector is specified to be along a line from [10 2 9] to [3 7 9]. Find the scalar product. After the data has been entered you should see the following screen:



Press **DOT** to reveal the following results:



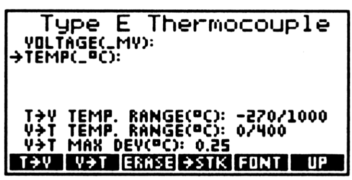
Thermocouples

This analysis tool is designed to convert a temperature to a thermocouple output in millivolts and vice versa. The software has the ability to handle T, E, J, K and S type thermocouples. The implied assumption for a reference temperature is 0_°C. The thermocouple computations are based on the IPTS-68 standards.

Using the Thermocouples Function

Select THERMOCOUPLES at the main menu. The first screen lists the five types of thermocouple values supported by the software. As an example, suppose you want to find the corresponding temperature of an E type thermocouple showing a 22.13 millivolt reading.

First, move the pointer to TYPE E and press [ENTER] to display the following screeen:



Press [ENTER]. At the prompt type 22.13 and press [ENTER] again. The screen displays this value as voltage in millivolts. Next, press the **V→T** softkey to initiate the voltage-to-temperature conversion calculation (314.059_°C):

Basis for Temperature/Voltage Conversions

The temperature-to-voltage conversion is based on a 12th to 14th order polynomial, ensuring very precise calculations. The voltage-to-temperature conversion is based on a 5th or 6th order polynomial. A maximum deviation listing or applicable temperature ranges are displayed on each screen.

Summary of Softkeys

ADD	Adds two vectors.
CROSS	Takes the vector product of two vectors and presents a new vector.
DOT	Takes the scalar product of two vectors and presents a new scalar quantity.
FONT	Toggles between small and large display fonts.
→STK	Copies selected entry to calculator stack.
UP	Moves up one level in the menu structure.
T→	Computes saturated steam properties given T.
P→	Computes saturated steam properties given P.
SUPER	Computes superheated steam properties.
T→V	Converts temperature specified in °C to voltage in mV.
VC→T	Converts voltage specified in mV to temperature in °C.
ERASE	Clears voltage and temperature values.

Notes

Chapter 5

Reference Library

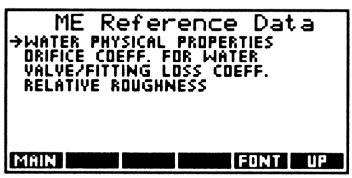
In This Chapter

The Reference Library is a collection of data, divided into four topics, that are commonly used in fluid mechanics calculations.

- ☐ Reference Library Topics
- ☐ Using the Referency Library

Reference Library Topics

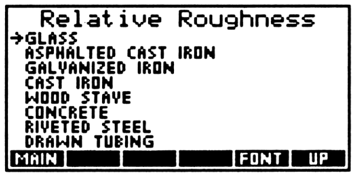
Selecting the REFERENCE LIBRARY from the main menu displays the topics. A description of each topic is listed in the table below:



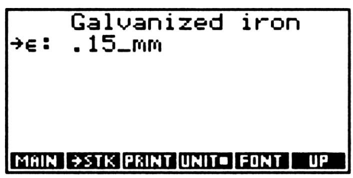
Water Physical Properties	Lists density, dynamic viscosity, and kinematic viscosity for water at 0 °C to 100 °C.
Orifice Coefficients for Water	Gives the coefficient of discharge, contraction, and velocity for 8 different nozzle configurations.
Valve and Fitting Loss Coefficients	Lists K values for 13 different valve and fitting configurations.
Relative Roughness	Gives the relative roughness of eight types of pipes.

Using the Reference Library

Suppose you need the relative roughness of galvanized iron for a pipe flow calculation. Use the cursor keys to move the pointer to the RELATIVE ROUGHNESS menu item and press [ENTER]. This displays the following screen:



Move the pointer to GALVANIZED IRON and press [ENTER]. This displays the relative roughness of iron:



Press [ENTER] to copy this value onto the calculator stack. You need to exit the software to continue your calculation on the stack.

Reference Library Softkeys

→STK	Copies selected entry to calculator stack.
PRINT	Allows you to print a data field or the entire list of data to an IR printer.
ALL	Sends all the data in a list to an IR printer.
ONE	Sends the data in the field selected by the pointer to an IR printer.
UNITS	Toggle key. Indicates units are off. When off, all variables are assumed to be SI.
UNIT■	Toggle key. Indicates that units are on.

Appendix A
Warranty and Service

Pocket Professional Support

You can get answers to your questions about using your Pocket Professional card from Sparcom. If you don't find the information in this manual or in the HP 48SX *Owner's Manual*, contact us in writing, at :

Sparcom Corporation
Attn: Technical Support Dept.
897 NW Grant Avenue, Corvallis, OR 97330, U.S.A. (503) 757-8416

or send E-mail:

from **Internet:**	support@sparcom.com
from **Compuserve:**	>Internet:support@sparcom.com
from **FidoNet:**	To:support@sparcom.com

Limited One-Year Warranty

What Is Covered

The Pocket Professional 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 CORP. 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 Sparcom Corporation, 897 NW Grant Avenue, Corvallis, OR 97330, U.S.A.

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

Cards are usually serviced and reshipped within five working days.

Environmental Limits

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

- Operating temperature: 0 to 45 °C (32 to 113 °F).
- Storage temperature: -20 to 60 °C (-4 to 140 °F).
- Operating and storage humidity: 90% relative humidity at 40 °C (104 °F) maximum.

Appendix B
Bibliography

Mechanical Engineering References

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Young, Warren C., *Roark's Formulas for Stress and Strain,* Sixth Edition, McGraw-Hill Book Co., NY, 1989.

Appendix C
Questions and Answers

Questions Commonly Asked

Q. I can't find the MEAPP subdirectory in the Library menu. How can I verify that the card and the calculator are functioning properly?

A. There are several possibilities:

a. Check to make sure that the card is properly seated in the calculator port.

b. Turn the calculator off and on.

c. The calculator checks the application card when it turns on. If an "Invalid Card Data" or a "Port Not Available" message is displayed, the card may require service.

Q. What do three dots (...) mean at the end of a display line?

A. The three dots indicate that the object is too long to show on one line. To view the complete object, use the cursor keys to move the arrow to the object and press [→] [VISIT]. Pressing [ENTER] or [ATTN] returns you to the original display of the item.

Q. I'm using the Equation Library to solve a problem. After selecting the equations and entering values for the variables, the calculator displays "Too many unknowns." What's wrong?

A. Not enough variables were specified to completely solve the problem. You will have to specify more values and solve again.

Q. I'm using the Equation Library to solve a problem. After selecting the equations, I'm ready to enter values for my variables. I find that some of the variables have values already displayed. What's wrong?

A. The variables with values displayed indicate that these variable names have been used in solving another equation. To start with a clean slate of values, you can use MEAPP to reset the values of all variables to 0.

Q. While using the Equation Library, I turned units off and all the numbers changed. What's wrong?

A. In no-units mode, the Equation Library assumes that all values are SI in order for the equations to solve correctly. Therefore, when units are turned off, all values are first converted to SI units, then the unit tags are eliminated.

Q. While using the Equation Library to solve an equation set, intermediate answers are given. Why?

A. The Sparcom's equation solver engine has the ability to solve a set of equations in a systematic fashion. The result of computation from each equation is reported, to keep you informed of the solver's progress.

Q. The calculator displays "Bad Guess(es)" while running the Equation Library. What's wrong?

A. The HP 48SX root finder encountered variable values or units that prevented a solution. You may need to start the root finding process by providing a "guess" value. See Chapter 1 for details.

Q. While solving for an angle, I got an answer that was too large: For example, 8752 degrees instead of the expected answer of 112 degrees.

A. The calculated result may be offset by integer multiples of 360 degrees. By entering a "guess" value, or by solving in no-units mode, you should be able to avoid this problem.

Q. I solved a problem some time ago, and I'm trying to recall those calculated values for a problem I'm working on now. The values from the past calculation have changed. What's wrong?

A. Most likely, the same variable name was used in solving another equation, so you will not be able to recall the old values.

Q. While searching a list of information, I used the alpha key, but the search function didn't work. Why?

A. Since the search function is case-sensitive, it's very possible that you entered the letters in the incorrect case.

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Notes:

Sparcom

Sparcom Corporation
897 NW Grant Avenue
Corvallis, OR 97330

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