Using Your HP-41

# ADVANTAGE

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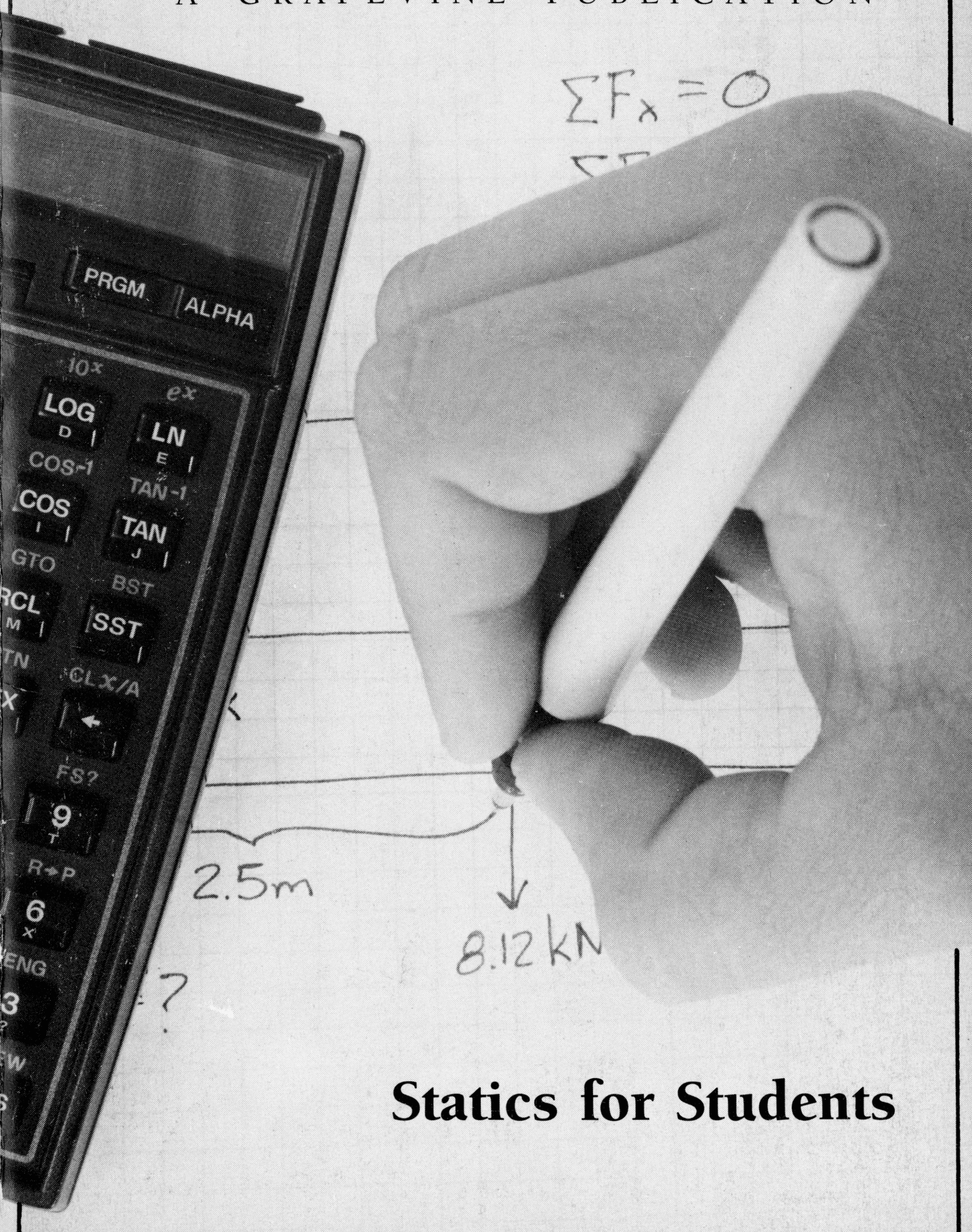


# Statics for Students

# USING YOUR HP-41 ADVANTAGE: STATICS FOR STUDENTS


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For the sake of brevity, the terms "Advantage," "Advantage Module," or "HP-41 Advantage" have been used herein to denote "The HP-41 Advantage Advanced Solutions Pac," which is the proper and reserved name for Hewlett-Packard's plug-in module and its instruction manual for the HP-41 handheld computer system. We extend our thanks to Hewlett-Packard Company for producing such top-quality products and documentation.


## ACKNOWLEDGEMENTS

Equations and formulas used in this book and its program may be found in "Engineering Mechanics Volume 1:STATICS," by J. L. Meriam © 1978 John Wiley & Sons, Inc., New York.

Special thanks and salutes are due to Chris Bunsen, who conceived and developed the HP-41 Advantage, and who encouraged the development of this book.

Cover photo by Tom Brennan.





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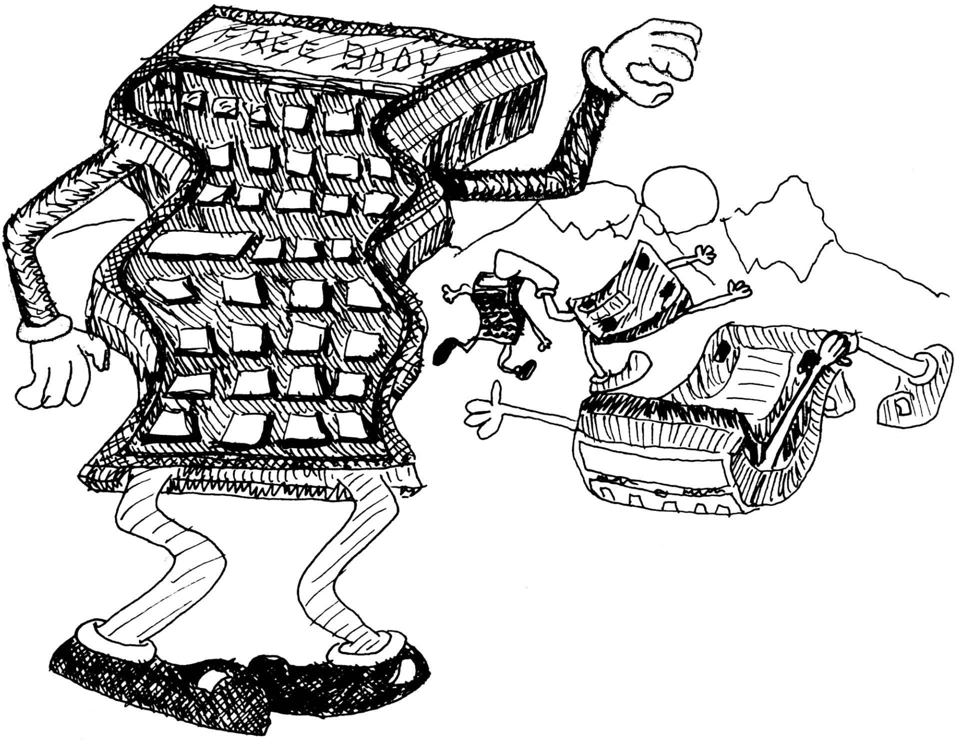



# Using the "Free Body" Program

# LOADING THE PROGRAM

In order to use this program, you'll need (at least):

- an HP-41CV or HP-41CX
- the HP-41 Advantage module
- this book
- just a little time to read through this, load the program, and practice with it.

(You probably knew all of that, but we needed to warm up here a little bit.)

Now, assuming that you have everything on this checklist, the first step is to load the program.

Starting on page 52, you'll find two program listings and two sets of bar code. The first program listing is for the HP-41CV without an X-functions module. The second listing is for the HP-41CX (or CV with X-functions).

The first set of bar code is marked "CV" because (strangely enough) it's written for the HP-41CV, while the other one is marked "CX" because it's written to take "Advantage" of Extended Functions and Extended Memory. You'll need to load the program appropriate for your equipment.

But before you do that... .

A word from our sponsor:

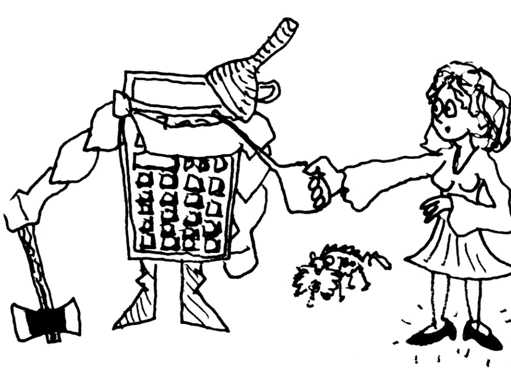
## ARE YOU RUSTY ?

In this book, you'll need to be able to follow keystroke procedures, load, pack and execute a program, etc. We really don't have the room here to remind you, so we're going to assume you know these things. For example, do you know:

- How to read keystroke notation? (e.g. [XEQ] [ALPHA] SIZE [ALPHA] 228)
- How USER mode works?
- How to select FIX, ENG or SCI notation?
- How the Stack works, including [+],[−],[×],[÷],[X◄►Y],[R↓], [STO] and [RCL]?
- How to SIZE and PACK your calculator's memory?
- How to read and key in program steps such as:

```
DSE IND Z            "⊢:AB C D"
ARCL 19              FC?C 03
X<> 00
```

- How to move around in–and edit–a program (in case you mis-key some step)?



If these things are new to you (or have faded into the last module of your brain's Extended Memory), you'll have a LOT of difficulty in continuing here until you take a slight detour for a refresher course. We recommend one of the following:

- Look up in your Owner's handbook whatever is on this checklist that you don't remember;

- Read "An Easy Course in Programming the HP-41," by Chris Coffin and Ted Wadman (see page 79 for details).

(Our favorite suggestion is the second one.)

... OK, if you're all refreshed and reminded, it's time to load the "Free Body" program.

# PREPARING YOUR CALCULATOR'S MEMORY

The "CV" version uses 178 program registers; the "CX" version uses 167 registers;

To run the "CV" version, you need to have a certain number of data registers available that depends on the problem. A SIZE of 60 will handle all of the problems in this book. (To set the SIZE to 60 registers, press [XEQ] [ALPHA] SIZE [ALPHA] 060.) If you need to know exactly what the SIZE needs to be for a particular problem, turn to page 35.

The HP-41CX version uses only register 00. But it requires you to have a little bit of empty extended memory. To work all the problems in this book, you'll need to have about 41 empty registers of extended memory. If you need to know exactly how many registers you need in extended memory to solve a particular problem, turn to page 35.

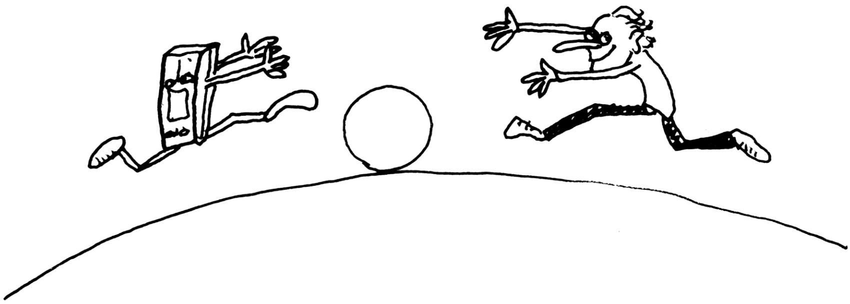
You may have to clear other programs from your calculator in order to fit this one in. Once you have made sufficient space for the program:

IF you have an HP-41 Wand, you can connect that now, turn to the appropriate set of barcode, and read it in.

Once you have loaded the program by Wand, go to page 9.

If you don't have a Wand...we have some good news and some bad news.

The good news is that very shortly, you will have totally mastered all aspects of keying in an HP-41 program. The bad news is: this is because you have about 600 lines of code to key in.



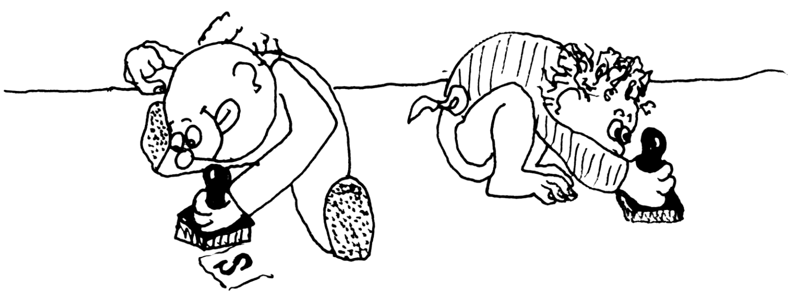
Now, before you hit the ceiling, consider this:

If you have a card reader or another such storage device, the first thing you'll be doing–once the program is correctly loaded, packed, and run a couple times–is to make yourself a copy (and a back-up copy, preferably). For heavens sake, do so!

If you don't have a card reader or storage device, but you have enough Extended Memory, you can store the program there when you're not using it (but when you are, you'll need to copy it into RAM, that is:main memory). Admittedly, this isn't strictly convenient, but it beats the heck out of the alternative.

In either case, right before you start keying it in, you'll see "00 REG nnn" in the display. *Make a note* of that number nnn (it needs to be greater than or equal to 178 for the CV-version, 167 for the CX-version, write down that number). Then... start poking them keys!

When you get the appropriate program keyed in, press [SHIFT] [GTO] [.] [.]. This will pack the program and put an END on it. Now, in program mode, you will see "00 REG nnn". This time, nnn should be exactly 178 (167 for the CX-version) less than when you started keying in the program. If it is, you most likely keyed it in correctly (whew!). If it isn't, you screwed up somewhere and you'll need to go back and check each line to make sure it's keyed in correctly.




If you have a printer, get a listing of the program to make the comparision.

Chances are, you have either skipped or duplicated some step. Another common error is neglecting to use the [XEQ] key properly. That is, instead of pressing [XEQ] [ALPHA] function [ALPHA], you press [ALPHA] function [ALPHA]. If you're guilty of this heinous crime, the evidence will be unmistakable: A program line that appears in our listing without quotation marks (" ") appears in your listing with quotation marks (or in the display with the little superscript T). This is a no-no! The written quotes and that T in the display should exactly correspond and this is the only difference between the printed listing and the way things should look in your display. Everything else should look *Exactly* the same. Please–don't go on from this point until you can arrive at the correct "00 REG nnn" reading.

# A GENERAL DESCRIPTION

If you're just getting started in your statics class, and you'd like to see our perspective of what statics is all about before you start working with the program, then read the next chapter first (starting on page 36). If you're anxious to crunch some numbers and you're comfortable with the basics of statics, continue reading.

The "Free Body" program gives you a way to draw a picture of a two dimensional, static, free body for your calculator, including known forces and the orientation of three unknown forces. Once you've drawn the picture for your calculator, you can choose between summing up the known forces (including the moments about one point), solving for three unknowns, changing the picture, or starting over.

If you choose the option of solving for three unknowns, then the solution gets stored as three additional knowns. This allows you to solve multiple-step structures problems easily, as you will see.

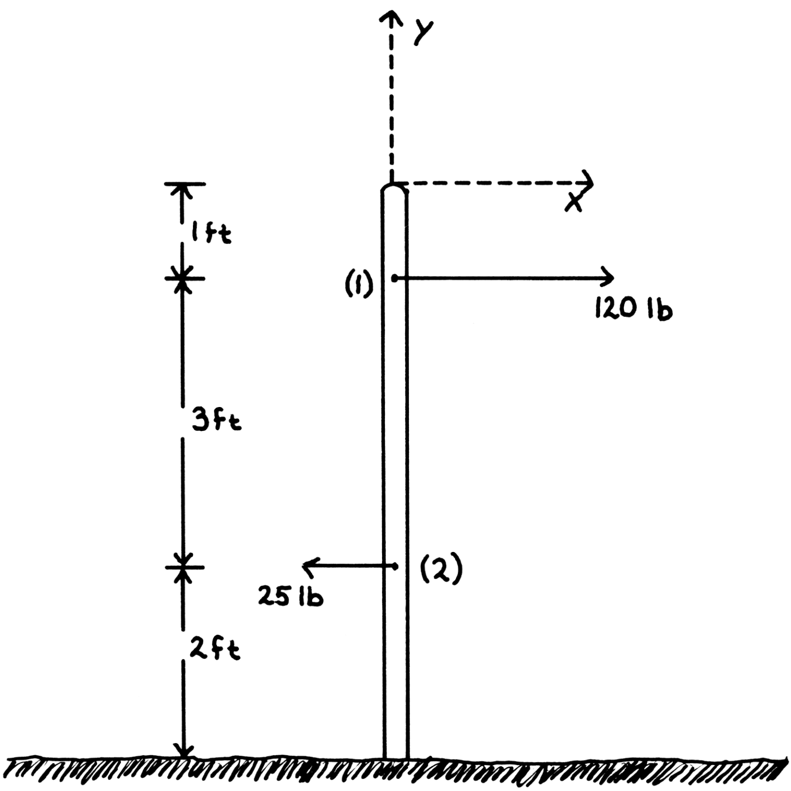
If you've just input the program, there will be a few pauses in execution the first time you run it. Be patient, the HP-41 is compiling GTO and XEQ statements.

Because the "Free Body" program was designed primarily to use in a classroom or in a "homework" situation, it was not designed for use with the printer. It will work fine if a printer is attached, but it won't print anything meaningful.

## SUMMING FORCE VECTORS

As a start on using the "Free Body" program, let's take a look at this simple problem.

Find the distance down from the top of the post at which a force S must act in order to completely balance the effects of the other two forces. What is the magnitude and direction of S?




In order to solve this problem, you need to calculate the sum of all the known forces and the sum of the moments about some point.

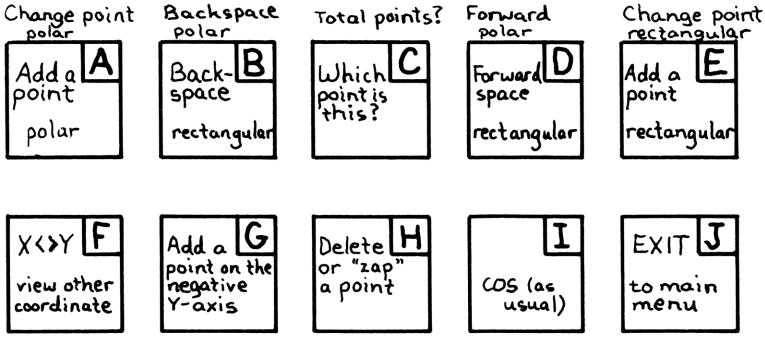
The first thing you need to do is to establish a coordinate system and number the points of interest.

Set up an X,Y axis that you can refer to when you're working the problem. Points of interest are places on the structure where a known force is acting or where you wish to calculate an acting force (more on this subject later). In the problem at hand, we just wish to sum forces and moments, so the only points of interest are those points with known forces acting on them. Since our points of interest lie on the Y-axis, we will input them in rectangular coordinates. In the coordinate system we have set up, point 1 is at (0,−1) and point 2 is (0,−4).

First, execute the program: [XEQ] [ALPHA] FB [ALPHA]. The program uses the top row of keys (shifted and unshifted) and the second row (except the [I] key) in USER mode. If you have anything assigned to these keys, that function in the program won't work. You can clear global key assignments by pressing [SHIFT] [ASN] [ALPHA] [ALPHA] and the key you wish to clear; or, if you have an HP-41CX, you can clear all key assignments with [XEQ] [ALPHA] CLKEYS [ALPHA].

When you execute the program, the display flashes "INPUT POINTS" and then "P POINTS R." This display signifies that you are in what's called the "point editor." This is where you input the points of interest.

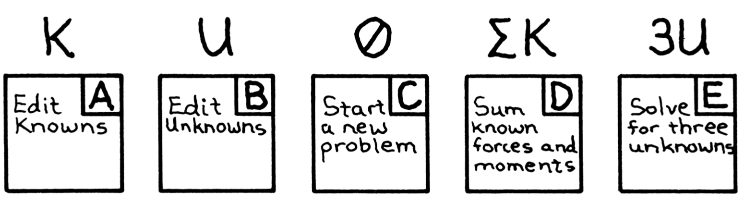
In this "point editor" the top two rows of keys take on the following meanings.



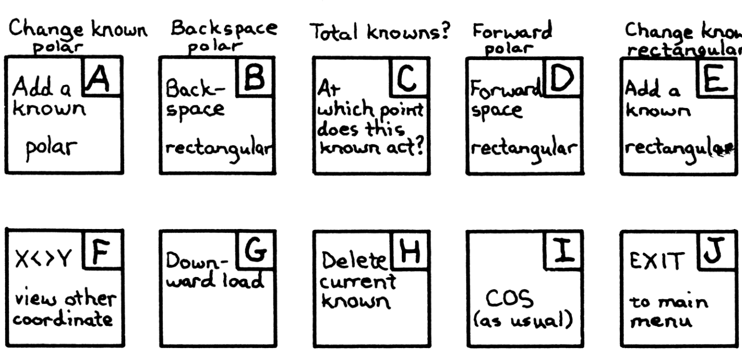
In the menu "P POINTS R" the P and R tell you which side means "this input is in Polar coordinates" and "this input is in Rectangular coordinates," respectively.

For the problem at hand, the two points of interest are (0,−1) and (0,−4) in rectangular coordinates. Input point 1 by pressing 1 [CHS] [ENTER] 0 [E]. The calculator will stop with 0.0000 in the display. Press [X◄►Y] to see the Y coordinate. Press [C] to ask what point this is (this is optional). Or press [SHIFT] [C] to ask how many total points have been input (also optional). To add point 2, press 4 [CHS] [ENTER] 0 [E].

The program has functions that allow you to review the points you've input, change them if they're incorrect, or delete them. But, since you just input two points, you've probably got them right, press [J] to go on to the main menu.




For this problem, all we have is knowns, so we need to press [A] to get to the "known editor." When you press [A], the display shows "P KNOWNS R." This is the "known editor." It is similar to the "point editor" in function.



To input the first known force in this problem, just press 0 [ENTER] 120 [E] and the calculator will prompt you with "AT POINT?" Press 1 [R/S].

To input the second known, press 0 [ENTER] 25 [CHS] [E] and when the calculator prompts you with "AT POINT?" press 2 [R/S]. Do you understand what you've done so far? If not you may want to press [J] then [C] to start completely over and go back to the start of this problem. Pay attention to the meanings of the top two rows of keys as you enter and exit the "point editor" and "known editor."

If you're satisfied with your understanding so far, press [J] to go back to the main menu.

| | | | | |
|---|---|---|---|---|
| K | U | Ø | ΣK | 3U |

What we are shooting for in this problem is the sum of the moments around the top of the post (the origin of our coordinate system) and the sum of the forces. Press the [D] key to calculate these. The calculator will display:

ΣM= -2Ø (Press [R/S])

ΣFY= Ø.ØØØØ ([R/S])

ΣFX=95.ØØØØ

At this point you can press [◄–] and do further calculations with the sum of the Fx (in the X-register), the sum of the Fy (in the Y-register), and the sum of the moments (in the Z-register).

To finish the problem, we need to divide the sum of the moments by the sum of the forces in the X-direction.
Press [X◄►Y] [R↓] [÷] to get the distance from the top of the post that the resultant force must act.

To summarize this problem:

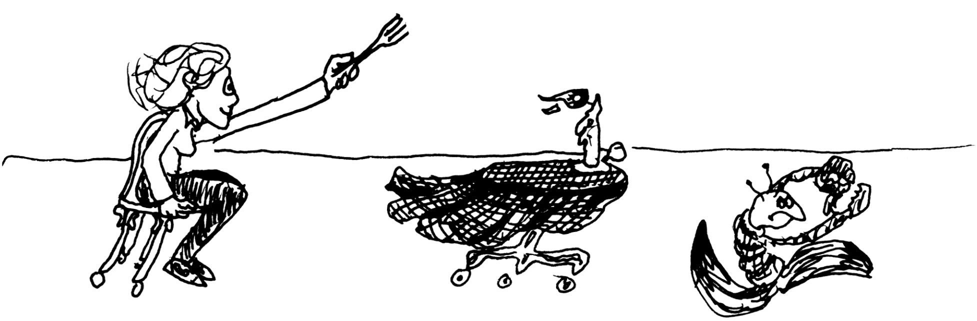
1. You established a coordinate system and input the points on the post that had known forces on them.

2. You input those known forces.

3. You summed the knowns (moments and forces).

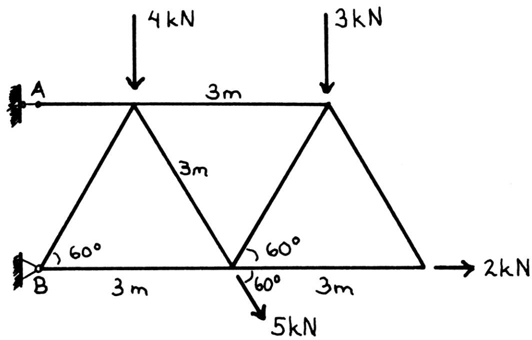
4. You used these results to get the answer to the problem.

Now, press [R/S] to go back to the main menu.



## CALCULATING REACTIONS

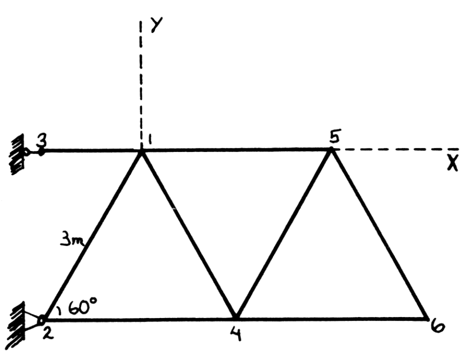
Compute the supporting reactions at points A and B.




First, if the main menu (K U 0 SK 3U) is still in your display, press [C] to start a new problem. Or press [XEQ] [ALPHA] FB [ALPHA].

As we pointed out earlier, the first thing you need to do is establish a coordinate system and number your points of interest.

This setup appeared best to us:



Notice that every angle in the structure is 60° and every member is 3 meters long (with the exception of 3–1).

Point 1 is at (0,0). Press 0 [ENTER] [E].

Point 2 is easiest to express in polar coordinates: 3 at an angle of –120°. Press 120 [CHS] [ENTER] 3 [A].

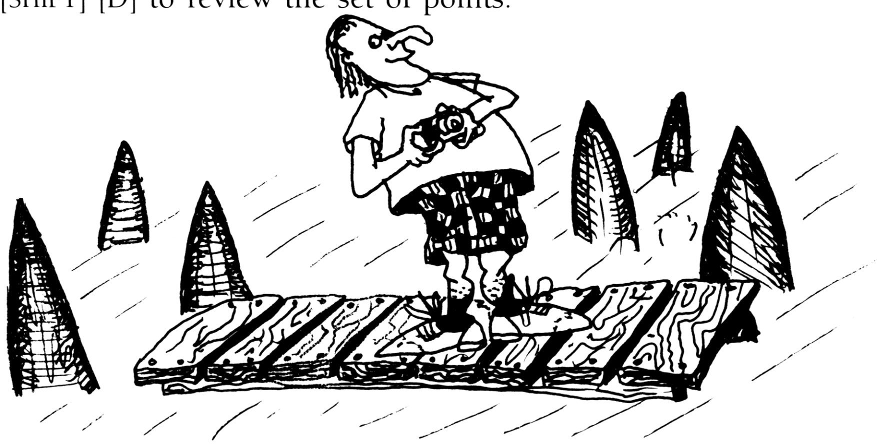
Point 3 is at (–1.5, 0). Press 0 [ENTER] 1.5 [CHS] [E].

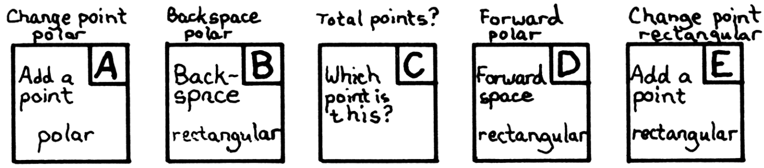
Point 4 is a distance 3 at an angle of –60°. Press 60 [CHS] [ENTER] 3 [A].

Point 5 is 0 [ENTER] 3 [E] (rectangular coordinates).

Point 6 is 4.5 in the X-direction and has the same Y-coordinate as point 4 (this is a little trick). Press [B] to backspace to point 4 and view it in rectangular coordinates. Press [C] to ensure yourself that you're at point 4. Press [X◄►Y] to look at the Y-coordinate of point 4. Now key in the X-coordinate of point 6 (that is 4.5) and press [E]. This places point 6 (4.5, –2.60) at the end of the list of points.

Now, you've input 6 points of interest. Each of these points has either a known load or an unknown load associated with it. Take a little time here and review the points. Don't press the [A], [E], or [H] keys as these will alter the set of points you have input. Play with the functions that allow you to move around in your set of points. Use [B], [SHIFT] [B], [C], [SHIFT] [C], [D], and [SHIFT] [D] to review the set of points.






Notice that when you're viewing point 6 and you press [D] to forward space, it will show you point 1. The "point editor" (as well as the "known editor") wraps around on both forward space and back space.

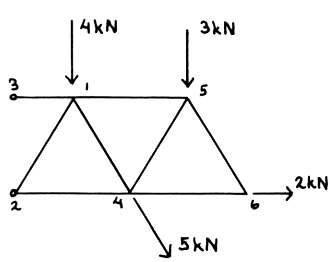
If you lose track of which point currently resides in the X and Y registers, press [C] and the calculator will tell you.

If you're viewing a point in rectangular coordinates and you'd like to see it in polar coordinates, press [B] [SHIFT] [D].

If you notice that you input an extra point, you can forward space or backspace to that point and use [H] to delete it. Bear in mind, however, that by deleting a point in the middle of a list of points, you are decreasing the point numbers of all the points below it in the list.

When you're satisfied with the set of points, press [J] to go to the main menu. You cannot go back to change, add or delete points once you have reached the main menu, except by starting over.


Now add the knowns to the picture. There are four knowns: one each at points 1, 5, 4, and 6. Press [A] to go to the "known editor."



Two of these knowns (the ones at points 1 and 5) are downward loads (i.e., in the negative Y-direction). The program has the [G] key dedicated to downward loads. All you have to do is key in the magnitude of the load and press [G] (the downarrow on this key reminds you what it's used for). Key in 4 [G]. The calculator prompts you with "AT POINT?"
Key in 1 [R/S].

3 [G] 5 [R/S] (input known at point 5)

60 [CHS] [ENTER] 5 [A] 4 [R/S] (input known at point 4)

0 [ENTER] 2 [A] 6 [R/S] (input known at point 6)

That's all you need to do to input the knowns for this problem. You can review them just like you reviewed the points.

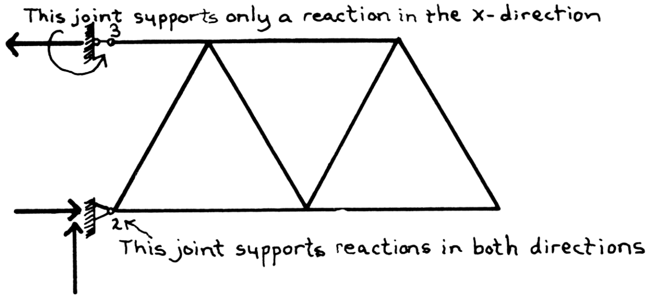
Press [D] to view the first known that you input in rectangular coordinates. The calculator will display 0.0000; press [X◄►Y] to see −4.0000; press [C] to see "AT POINT 1." There's a known load, with a Y-value of −4 at point 1. That's what you want, right?

Press [SHIFT] [D] to view the second known that you input in polar coordinates. The calculator displays 3.0000; press [X◄►Y] to see −90.0000; press [C] to see "AT POINT 5." There's a known load, with a magnitude of 3 and a direction of −90° at point 5. That's what you input, right?

Continue reviewing the knowns in the above manner, if you want. Whenever you're satisfied that everything's OK, press [J] to return to the main menu.

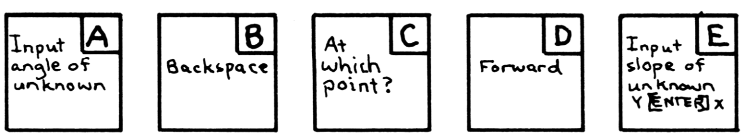
Once you're back to the main menu, the last thing you need to do is input the orientation of the unknown reactions and you can solve the problem.

You always need to input three unknowns. In this problem, there are three components to the reactions at points 3 and 2. Point 3 has only one component (an X-component), and at point 2, there can be an X-component and a Y-component reaction.




So there you have them (the three unknowns). They amount to the components of the supporting reactions. Press [B] from the main menu to input the orientation of these unknowns.

You will see the menu for the "unknown editor." This is where you input the unknowns. The top row of keys takes on the following meanings.




You can input the angle of orientation by pressing [A] or, if you have a slope (X and Y value), you can use the [E] key. In this problem, the angles of orientation are easiest to input:

180 [A] 3 [R/S] (The component at point 3 is acting at 180°)

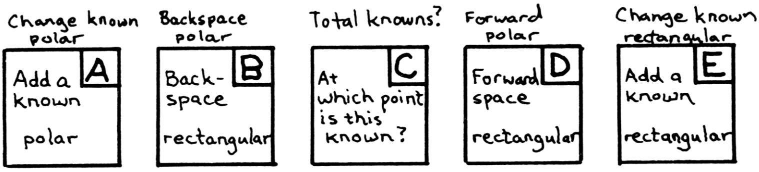
0 [A] 2 [R/S] (There's one component at point 2 acting at 0°

90 [A] 2 [R/S] and one acting at 90°)

After you have input three unknowns (and you must input three or you'll get screwy numbers for an answer), you will find yourself back at the main menu.

Now press the [E] (3U) key to solve for the magnitudes of the three unknowns. Once the calculator solves for these unknown forces, they become knowns on the free body and are stored right along with the other knowns that you input. The advantage to this feature will soon become apparent.

You'll notice that the program takes you right to the "known editor" and you can view the results like you view any known. When you see the menu "P KNOWNS R" come up, press [SHIFT] [C] and you'll see that there are a total of 7 known force vectors (you input only 4).




Press [SHIFT] [D] to view your first result. The display shows 12.5056; press [X◄►Y] to see the angle (180° just as you input); press [C] to see the point at which this new known is acting. (These results are stored in the order that you input them as unknowns if you forward space through them.) So the reaction at point 3 is 12.5056 in the negative X-direction. (Had you input 0° instead of 180° when you input this reaction as an unknown, the calculator would have corrected you in the result.)

Press [SHIFT] [D] to view the second result; 8.0056 at 0° at point 2 (this is the X-component of the total reaction at point 2). Press [STO] 01 to store the magnitude here.

Press [SHIFT] [D] to view the third and final result: 11.3301 at 90° at point 2 (this is the Y-component of the total reaction at point 2).

To calculate the total reaction at point 2 press [RCL] 01 [SHIFT] [R−P]. The calculator displays the magnitude. Press [X◄►Y] to see the angle.

Reactions: 12.5 @ 180° at point 3
13.9 @ 54.76° at point 2

Are you getting the hang of how this thing works? You should be getting comfortable with moving around in the "point editor." Let's look a little more at this problem for practice....

## SOLVING STRUCTURES

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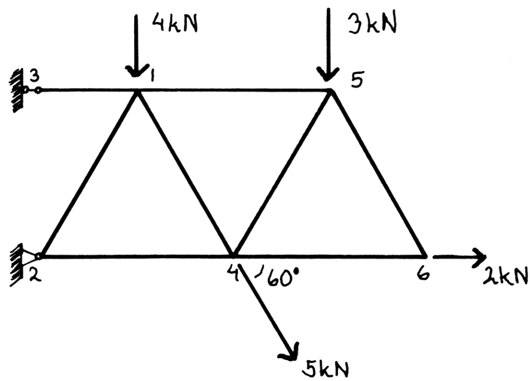
Staying with the structure in the last problem, what are the forces in members 1-5, 1-4, and 2-4?

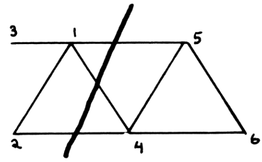



| | | |
|---|---|---|
| Answer: | 1-5: | 1.73 kN Tension |
| | 1-4: | 8.46 kN Tension |
| | 2-4: | 1.46 kN Compression |

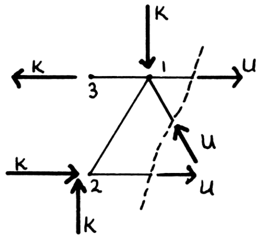
---

Don't start over! The points of the structure have already been input. You don't have to put them in again. Plus, you can use some of the knowns that you've already input.

The solution to this problem involves the "method of sections." You need to draw a line through the three members in which you're interested.



Then, you choose the section to one side or the other of that line to isolate as a "free body." At the risk of revealing our political bias, we chose the left side.




We replace the right side of the line with the unknown forces in the broken members. So we have a two-dimensional free body with a bunch of known forces acting on it and exactly three unknown forces (for which we know the angle that each acts). And, this is something the FB program can solve.

But don't press [XEQ] FB!

If you've just come from the previous problem (and the solution assumes you have, so if you haven't, go to page 15 and work forward), most of the data you need to arrive at the solution is already in the calculator.

Press [J], then [A] (K) to get to the "known editor."

What we need to do is reserve only those knowns acting at points 1, 2, and 3. We need to delete the knowns acting at points 4, 5, and 6. (Leave only those knowns that are acting on the free body that we've defined above.)

Press [D] [C] repeatedly until you see "AT POINT 5." Delete this known by pressing [H]. The display will show "ZAPPED" meaning that the known at point 5 is gone.

Press [D] [C] repeatedly until you see "AT POINT 4." Press [H] and, again you see "ZAPPED."

Now press [B] [C] repeatedly until you see "AT POINT 6." Press [H].

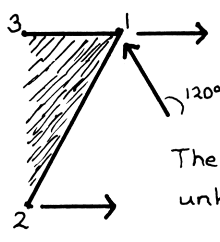
Now, by pressing [B] [C] or [D] [C] repeatedly, you'll see that you only have knowns left at points 1, 2, and 3. If you press [SHIFT] [C], you'll see there are a total of 4 knowns (one at point 1, one at point 3, and two components at point 2).

Press [J], this will take you back to the main menu.

| K | U | Ø | ΣK | 3U |
|---|---|---|---|---|

The orientation of the unknowns is different here than in the last problem, so press [B]. The "unknown editor" is at hand.

We've drawn the unknowns in the diagram, guessing at tension and compression. The calculator will correct any errors we make along these lines.




The free body with unknown forces.

Starting at the top, these unknowns are easy to input:

| | |
|---|---|
| 0 [A] 1 [R/S] | (0° acting at point 1) |
| 120 [A] 1 [R/S] | (120° acting at point 1) |
| 0 [A] 2 [R/S] | (0° acting at point 2) |

You're back at the main menu. Press 3U ([E]). When "P KNOWNS R" comes up, press [SHIFT] [D] to view the top unknown: 1.7321. Press [X◄►Y] to see that it is acting at 0°, as we guessed. You can press [C] to see that this new known resides at point 1, as we know.

Continue in the above manner to view the other two results:

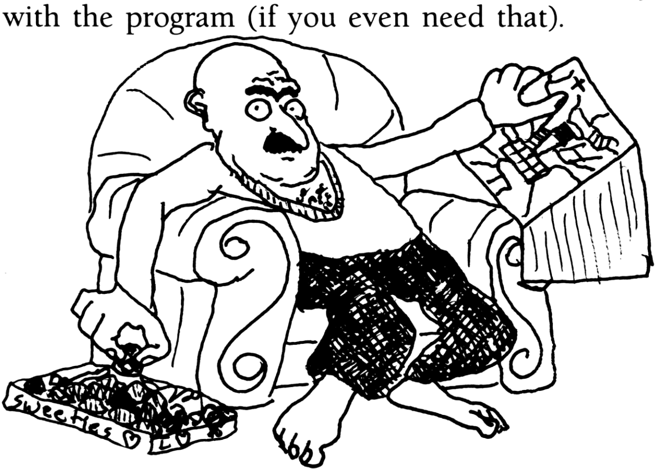
8.4641 @ −60° (point 1) We guessed compression here but the calculator shows us that it's actually tension.

1.4641 @ 180° (point 2) We guessed tension when it was compression.

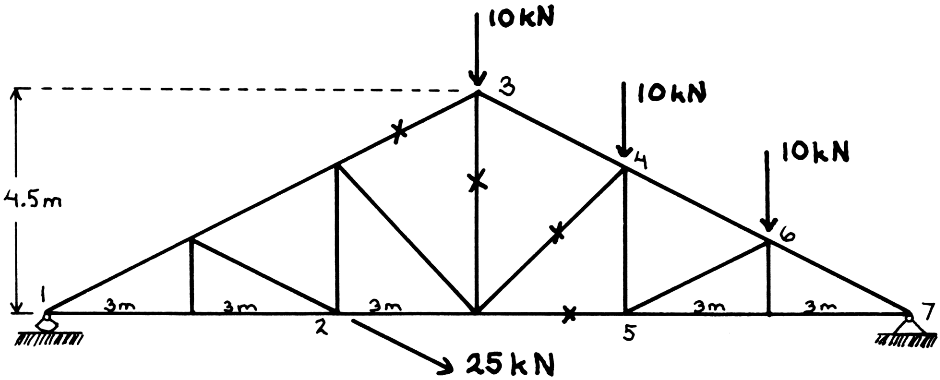
After solving the last problem, you see that if you can isolate a two-dimensional, static, free body with any number of known forces acting on it and three unknown forces, you can solve for those unknown forces quite easily.

Also, as you saw when you calculated the supporting reactions of that structure (the first part of the last problem), a single unknown force acting at an unknown angle can be broken into an unknown X-component and an unknown Y-component and then entered as two of the three unknowns.

Now, let's try another problem to get more of a feel for the way things work. In hoping that you're getting more comfortable with the way the "FB" program works, we're going to get a little lazy here and reduce the amount of explanation. Eventually, the roadmap on the inside of the back cover should be all you need to work with the program (if you even need that).



Calculate the forces in the members marked with an X.




Answer:
31.7 kN C    (26.6° at point 3)
18.3 kN T    (−90.0° at point 3)
14.1 kN C    (45° at point 4)
16.7 kN T    (180° at point 5)

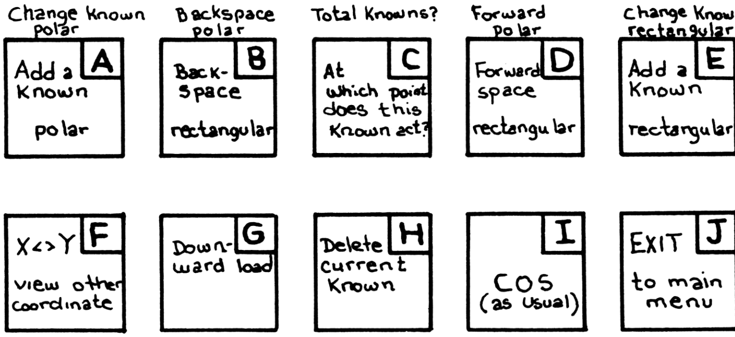
We set up an (X,Y) coordinate system with the origin at point 1 in the diagram. In this coordinate system, the points on the diagram that will be of interest sometime during the solution are:

| | |
|---|---|
| Point 1: | (0,0) |
| Point 2: | (6,0) |
| Point 3: | (9, 4.5) |
| Point 4: | (12, 3) |
| Point 5: | (12, 0) |
| Point 6: | (15, 1.5) |
| Point 7: | (18, 0) |

Input these points:

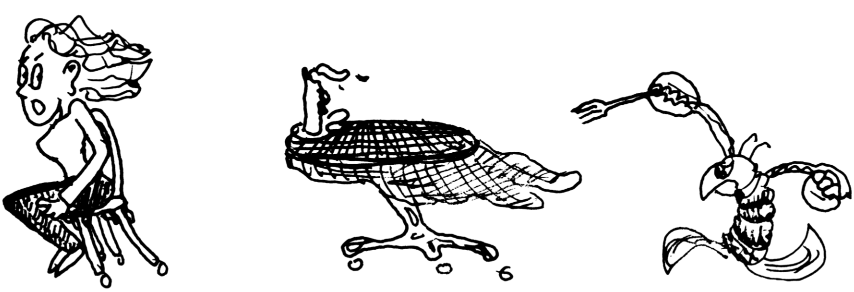
| KEYSTROKES | | | | DISPLAY |
|---|---|---|---|---|
| [XEQ] FB | | | (or [C] if at main menu) | P POINTS R |
| 0 | [ENTER] | [E] | (point 1) | 0.0000 |
| 0 | [ENTER] 6 | [E] | (point 2) | 6.0000 |
| 4.5 | [ENTER] 9 | [E] | (point 3) | 9.0000 |
| 3 | [ENTER] 12 | [E] | (point 4) | 12.0000 |
| 0 | [ENTER] 12 | [E] | (point 5) | 12.0000 |
| 1.5 | [ENTER] 15 | [E] | (point 6) | 15.0000 |
| 0 | [ENTER] 18 | [E] | (point 7) | 18.0000 |
| | | [SHIFT][C] | (check total points) | TOTAL:7 |
| | | [J] | (to main menu) | K U 0 SK 3U |

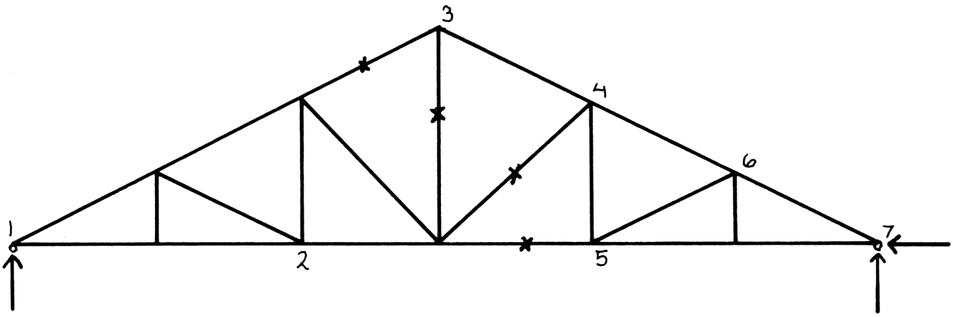
Now input the knowns:




| | KEYSTROKES | DISPLAY |
|---|---|---|
| | [A] (to "known editor") | P KNOWNS R |
| 30 | [CHS][ENTER] 25 [A] (known at: point 2) | AT POINT? |
| 2 | [R/S] | P NEXT K R |
| 10 | [G] (downward load) | AT POINT? |
| 3 | [R/S] (at point 3) | P NEXT K R |
| | [G] (another of the same) | AT POINT? |
| 4 | [R/S] (at point 4) | P NEXT K R |
| | [G] (another of the same) | AT POINT? |
| 6 | [R/S] (at point 6) | P NEXT K R |

Now, you've input the four knowns. Review them as you feel necessary and when you're satisfied with the picture, press [J] to go back to the main menu.

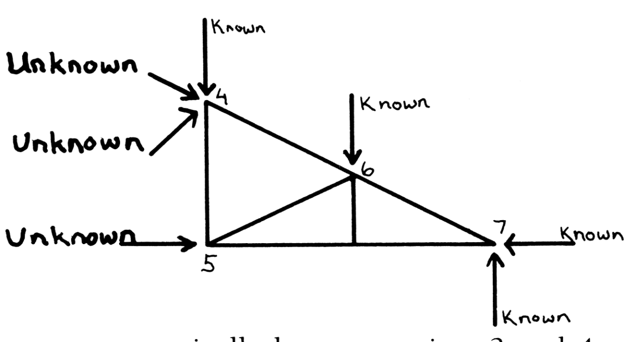





Next, input the orientation of the reactions:

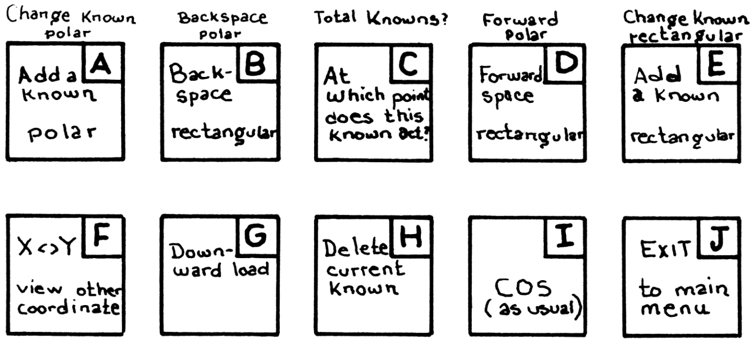
| KEYSTROKES | | | DISPLAY |
|---|---|---|---|
| | [B] | (to "unknown editor") | UNKNWN Y . X |
| 90 | [A] | (orientation of unknown) | AT POINT? |
| 1 | [R/S] | (at point 1) | 90.0000 |
| | [A] | (another of the same) | AT POINT? |
| 7 | [R/S] | (at point 7) | 90.0000 |
| 180 | [A] | (orientation of component) | AT POINT? |
| 7 | [R/S] | (at point 7) | K U 0 SK 3U |
| | [E] | (solve for these unknowns) | P KNOWNS R |

Now, you've solved the supporting reactions. Next you need to isolate a free body with just three unknowns. (The problem asks you to solve for four members; we have to do this in two steps.)




We cut the structure vertically between points 3 and 4 and replace the broken members with their unknown forces.

Then, we need to delete all the knowns that aren't on this body, that is, we need to delete the knowns at points 1, 2, and 3, right?



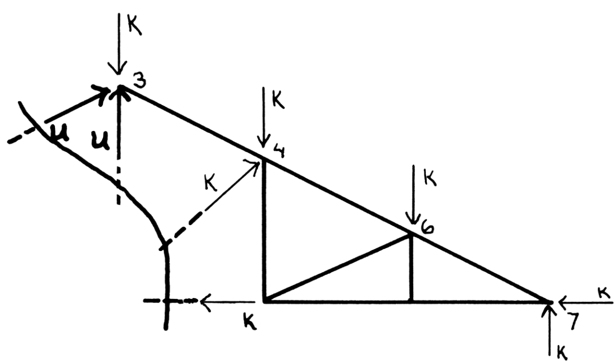

With P KNOWNS R in the display, continue:

| KEYSTROKES | DISPLAY |
|---|---|
| [SHIFT] [D] | 18.3333 |
| [X◄►Y] (18.3333 @ 90°) | 90.0000 |
| [C] | AT POINT: 1 |
| [H] | ZAPPED |
| [D] [C] | AT POINT: 2 |
| [H] | ZAPPED |
| [D] [C] | AT POINT: 7 |
| [D] [C] | AT POINT: 3 |
| [H] | ZAPPED |
| [D] [C] (forward space) | AT POINT: 7 |
| [D] [C] (forward space) | AT POINT: 7 |
| [D] [C] (forward space) | AT POINT: 4 |
| [D] [C] (forward space) | AT POINT: 6 |
| [D] [C] (forward space) | AT POINT: 7 |
| [SHIFT] [C] (number of remaining knowns) | TOTAL:4 |
| [J] (go back to main menu) | K U 0 SK 3U |

Now, input the orientation of the unknowns on the free body:

| KEYSTROKES | | DISPLAY |
|---|---|---|
| [B] | | ∠ UNKNWN Y/X |
| 4.5 [CHS][ENTER]9[E] | (slope of top unknown) | AT POINT? |
| 4 [R/S] | (at point 4) | −26.5651 |
| 45 [A] | (angle of 2nd unknown) | AT POINT? |
| 4 [R/S] | (at point 4) | 45.0000 |
| 0 [A] | (angle of 3rd unknown) | AT POINT? |
| 5 [R/S] | (at point 5) | K U 0 SK 3U |
| [E] | (solve for 3 unknowns) | P KNOWNS R |

Finally, you need to isolate another free body cutting through the four members that you wish to solve:



Unfortunately, there are only two unknown values on this diagram. The magnitudes of two of the vectors at point 3 we don't know, but everything else we do know. Is it that we know too much?

No, we can pretend we know less. All you need to do is represent one of the known vectors somewhere else on the body as an unknown. This way you can solve for it twice to reassure yourself you got it right the first time.

Here are the keystrokes:

| KEYSTROKES | DISPLAY |
|---|---|
| [SHIFT] [D] | 31.6776 |
| [X◄►Y] | −26.5651 |
| [C] | AT POINT:4 |
| [H] (delete this known) | ZAPPED |
| | |
| [SHIFT] [B] | 16.6827 |
| [C] | AT POINT:5 |
| | |
| [SHIFT] [D] | 14.1421 |
| [X◄►Y] | 45° |
| [C] | AT POINT:4 |
| [H] (delete this known) | ZAPPED |
| | |
| 10 [G] | AT POINT? |
| 3 [R/S] (Add known at point 3) | P NEXT K R |
| | |
| [SHIFT] [C] | TOTAL: 6 |
| | |
| [J] | K U 0 SK 3U |

That's it for the knowns. Now just input the unknowns and solve the problem. Press [B] to go to the "unknown editor."

| KEYSTROKES | | | DISPLAY |
|---|---|---|---|
| 4.5 | [ENTER]9[E] | (Slope of first unknown) | AT POINT? |
| 3 | [R/S] | (at point 3) | 26.5651 |
| 90 | [A] | (second unknown) | AT POINT? |
| 3 | [R/S] | (at point 3) | 90.0000 |
| 45 | [A] | (third unknown) | AT POINT? |
| 4 | [R/S] | (at point 4) | K U 0 SK 3U |
| | [E] | (solve for these unknowns) | P KNOWNS R |

(View the results)

| | | |
|---|---|---|
| [SHIFT][D] | (magnitude) | 31.6776 |
| [X◄►Y] | (angle) | 26.5651 |
| [C] | | AT POINT: 3 |
| [SHIFT][D] | (magnitude) | 18.3333 |
| [X◄►Y] | (angle) | −90.0000 |
| [C] | | AT POINT: 3 |
| [SHIFT][D] | (magnitude) | 14.1421 |
| [X◄►Y] | (angle) | 45.0000 |
| [C] | | AT POINT: 4 |
| [D][C] | (move ahead to known at point 5) | AT POINT: 7 |
| [D][C] | | AT POINT: 7 |
| [D][C] | | AT POINT: 4 |
| [D][C] | | AT POINT: 6 |
| [D][C] | | AT POINT: 5 |
| [B] [SHIFT] [D] | (view magnitude) | 16.6827 |
| [X◄►Y] | (angle) | 180.0000 |
| [C] | | AT POINT: 5 |

So...that's all there is to it. Solving for the internal forces in a structure is simply a matter of isolating several "free bodies" in sequence. And with this program, the process becomes simple.

Are you getting the feel for how you use the "3U" function in the program? Once you get the picture drawn correctly–get the appropriate known loads stored and the proper orientation of the three unknowns –the calculator takes over. As long as everything you put in is correct and complete, you'll get the right answers.

## SUMMARY AND IMPORTANT LIMITATIONS

Any time you can isolate a static, two-dimensional free body with any number of known forces acting on it and three unknown forces (or component forces), you can use the 3U part of the free body program to solve for those three unknowns. In your statics class, you will spend a lot of time doing just that.

The FB program is general enough to help you solve hundreds of statics problems. It won't allow you to get by without learning the concepts, but it will help you with some of the number crunching.

The 3U function of the program solves the system of three equations that follows:

$$\Sigma Fx = 0$$
$$\Sigma Fy = 0$$
$$\Sigma Mz = 0$$

And, because this is what it does, it has some limitations that you must notice.

1. It won't work if the free body is a point or a line. The free body has to be two dimensional.

2. If all the knowns and unknowns are acting at one point on the body, you probably won't get the right answers.

3. It works best for solving internal forces in multi-member structures, and solving for supporting reactions of statically determinate structures. When you start getting too fancy you may start getting bad answers.

4. It doesn't check to see if the data you've input is correct. Garbage in, garbage out.

See "notes," page 51.

The SK (sum the knowns) function in the program is a bit more liberal. Though it still operates under the GIGO principle outlined above, it will accept free bodies that are single points or lines. It is just a quick way to sum vectors (and moments about the origin if there are any).

## SIZING FOR A PARTICULAR PROBLEM

Usually, it's easiest to set a SIZE of 75 registers for the CV version (or clear about 60 registers of extended memory for the CX version) and just work your problems. If the program needs more registers, it will inform you. You can make more available and proceed with the problem you were working on (repeating whatever you did before you ran out of registers).

For a particular problem, here's a formula you can use for the SIZE you need to set on the CV version:

$$35 + (P \times 2) + (K \times 3)$$

P is the number of points of interest and K is the number of knowns acting on the body.

If you have Extended Functions, the formula will help you calculate the number of registers of Extended Memory that need to be empty to solve a problem using the CX version:

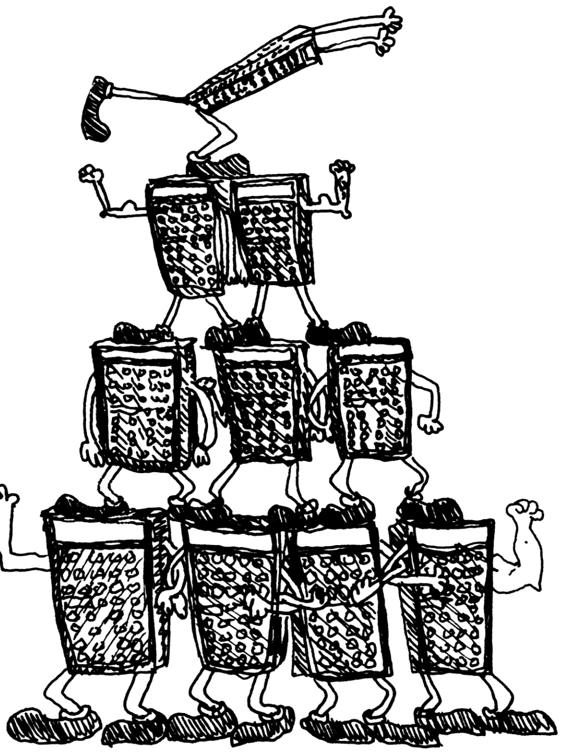
$$24 + (P \times 2) + (K \times 3)$$

P and K are described above.

---

## EXITING THE PROGRAM

To leave the program just press [GTO] [.] [.] and exit user mode by pressing [USER]. If you were using the "CX" version, you may want to purge files U, P, and K in extended memory. These files are created by the program.



# Statics With An HP-41

If you've just finished the last chapter and you feel like you have a good grip on things, you're done. Good luck in statics. But, if you lost track somewhere in the last chapter and have been blindly pressing keys for the last few pages, try reading this chapter and then, with a newfound enlightenment, go back and start again from page 9.

## WHAT IS STATICS?

Something that's static doesn't move. That's what a course in statics is all about–things that don't move. When you apply a force to something that isn't moving, one of two things will happen:

1. It will move.

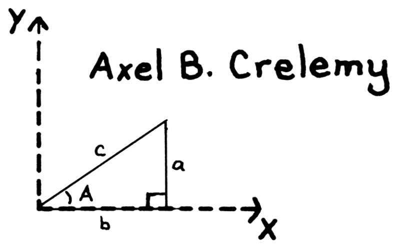
2. It won't move.

If it moves, you know that the force you're applying is overcoming any reaction forces that are resisting motion. The thing moves, goes from a static object to a dynamic object, and you study it in another course.

If it doesn't move, you know that the force that you're applying is not overcoming the reactions responsible for resisting motion. It remains static and you study it in a Statics course using this book, your HP-41, and your Advantage Module to help you breeze through.

## A LOOK AT THE BASICS

Most of the math encountered in a statics course (and in a lot of engineering courses) has its foundations in trigonometry and requires a good understanding of the "right triangle." Bear with us as we walk through an interesting (though perhaps tedious) look at a right triangle and its implications in statics. This description will help us to "speak" the same language and may remind you of some calculation tricks that you haven't been taking "advantage" of.




If we orient a right triangle on an X,Y axis with one of the acute angle points at the origin and one of the legs lying on the X-axis, it becomes easy to discuss and analyze. First, let's name the right triangle in the above picture Axel B. Crelemy (or Axel for short).

After naming the triangle, one of the first things we might notice is that Axel is a fairly simple individual. In fact, we can completely describe Axel by stating any two of the quantities a, A, b, and c. If we say, for example, b = 8 feet and a = 6 feet, we can sit down and draw Axel without hesitation. Once drawn, we can measure Axel's other characteristics.

Two particular descriptions of a right triangle are going to be common in statics courses and converting back and forth between these two descriptions will be a common calculating challenge. (1) When we describe Axel by stating the lengths of the leg in the X-direction (b) and the leg in the Y-direction (a) we are describing Axel using rectangular coordinates. (2) When we describe Axel by stating the value of the angle at the origin (A) and the length of the hypotenuse (c), we are describing Axel using polar coordinates.

One triangle: Axel

Two descriptions: Polar (c at an angle A)
Rectangular (X,Y)

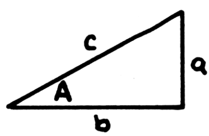
Now religious philosophers might argue that the polar description of a right triangle is more “eastern” and the rectangular description is more “western.” The polar description kind of implies a circle–no real beginning, no real ending (i.e., 28° = 388° = 748° = −332°, etc.), while the rectangular description is two intersecting lines implying a definite beginning and ending. Leave it to science to bring the two...uh, well anyway...

However you think about it, it is good to know the relationships between these two descriptions:

Polar to Rectangular

$b = c \cos A$

$a = c \sin A$

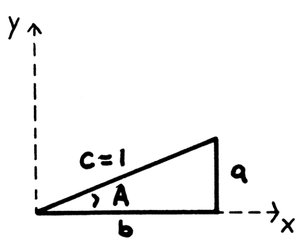



Rectangular to Polar

$c = \sqrt{a^2 + b^2}$

$A = \tan^{-1} \frac{a}{b}$

By the time you get to a course in statics, these trigonometric relationships should begin to be part of light conversation over breakfast. And, at mid-morning coffee, you should bring up the fact that if c = 1, the following relationships are true:




SIN A = a

COS A = b

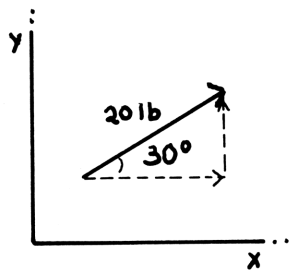
There are lots of memory tricks for remembering trigonometric relationships such as jingles like “SIN equal opposite over hypotenuse,” etc. It doesn’t matter what you use, just know ’em.

The reason we have brought up the subject of trigonometry in the first place is not so you can become an expert at triangle descriptions (unless that's your lifetime goal), but rather so you can work easily with vectors. Vectors are used throughout statics and engineering, and the program included in this book requires good skills in working with vectors before it can be of much use.

In statics, you will be concerned primarily with two types of vectors: force and distance. Plus, you will combine force and distance vectors to form other vectors called moments. If you're comfortable working with these three types of vectors, you will have little difficulty in statics.

# DESCRIBING VECTORS: [P−R] [R−P]

Like a triangle, a vector can be described using either rectangular or polar coordinates. Look at the following picture.

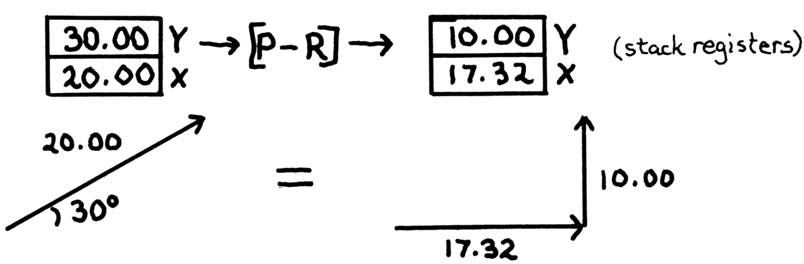



This picture shows a 20 lb force at an angle of 30° (Polar description). You can also describe this force using its X− and Y−components (Rectangular description).

Again, from trigonometry we know:

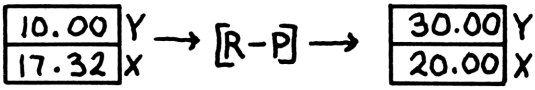
Y−component = 20 SIN (30) lb
X−component = 20 COS (30) lb

Two functions on your HP-41, [P−R] (Polar to Rectangular) and [R−P] (Rectangular to Polar), make converting back and forth between these two methods of describing vectors (or right triangles) real easy. To find the X− and Y−components in the previous picture, you would use the keystrokes 30 [ENTER] 20 [SHIFT] [P−R].



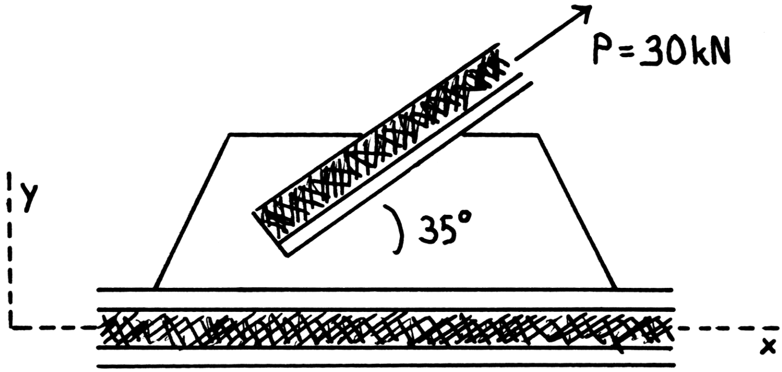
So, to convert from polar coordinates to rectangular coordinates, put the angle in the Y-register, the magnitude in the X-register and press [SHIFT] [P—R]. The X-component will then be in the X-register and the Y-component will be in the Y-register.

To convert from a rectangular description of a vector to a polar description, put the components in their respective registers and press [SHIFT] [R—P].




This notation is consistant throughout the program within this book. Whenever you are dealing with a two dimensional vector (be it force or distance) it will consist of two numbers. To view the entire vector, you'll have to press [X◄►Y] on the calculator. No big deal, right?

The majority of problems in statics involve "resolving vectors into their components" or using the [R—P] function on the HP—41. Before we get heavily into the program, let's try a few warm-up exercises that use these functions (you wouldn't want to strain any of your button pressing fingers, would you?)

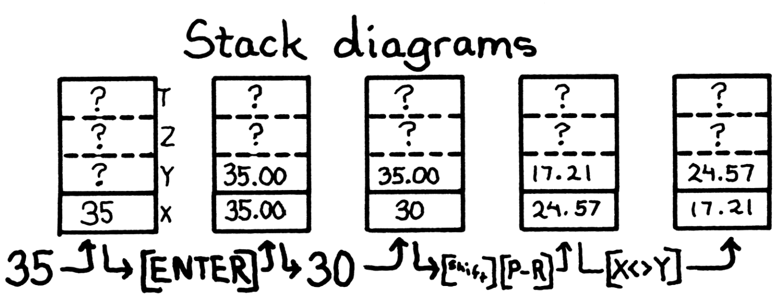


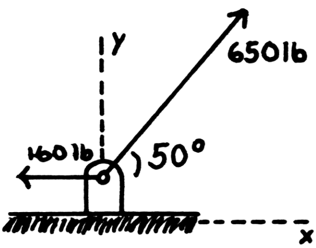

Calculate the X– and Y–components of the 30 kN force acting on the structural member.

Answer: Px = 24.57 kN
Py = 17.21 kN

---

This is an easy one on your HP-41. Just put the angle in the Y-register, the magnitude of the force in the X-register and press [SHIFT] [P–R]. The value of the X-component is then in the X-register and the Y-component is in the Y-register (press [X◄►Y] to view the Y-component).






If an anchor is subjected to the two forces shown, what is the magnitude and angle of the resultant force?

Answer: 560.71 lb @ 62.63°

---

This is a problem where you need to sum vectors (no big deal):

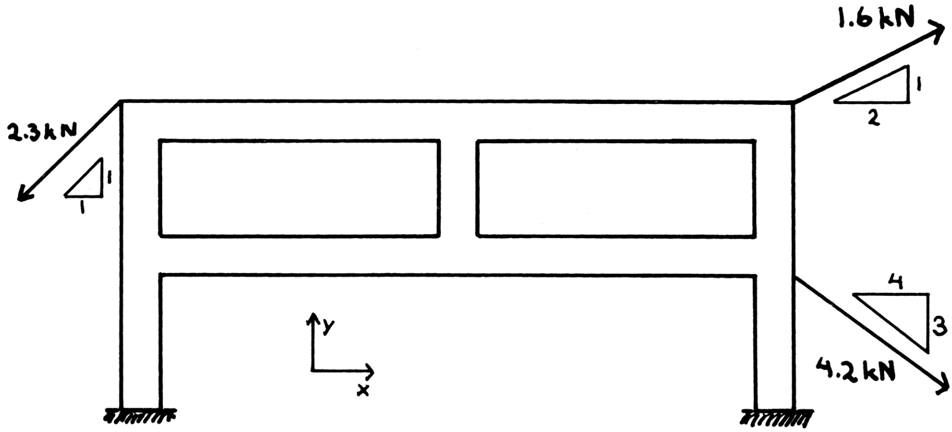
1. The X-component of the resultant vector is equal to the sum of all the X-components.
2. The Y-component of the resultant vector is equal to the sum of all the Y-components.

Since the 160 lb vector in the problem above has only an X-component (in the negative direction) the keystrokes on the HP-41 could be:

50 [ENTER] 650 [P−R] 160 [−] [R−P]
*(displays 560.71)*
[X◄►Y]
*(displays angle)*

[P−R] is used to resolve a vector (with a known angle and magnitude) into its X and Y components.

Here's another problem that involves summing vectors:




What is the resultant force vector?

Answer: 3.16i − 3.43j kN
or 4.67 kN @ −47.31°

The i, j notation above is a common one for expressing vectors in rectangular coordinates. The letter i represents a unit vector in the X-direction and j is a unit vector in the Y-direction. The X-coordinate is 3.17 and the Y-coordinate is −3.43. *Right?*

The little triangles are shown next to the forces to indicate the angle at which the forces are acting. You could use the old "TAN−1 (Y/X)" formula to get the angle, or you can use [R−P].

The advantage to using [R−P], in this case, is that the calculated angle reflects the proper orientation of the vector, whereas that orientation can be lost using [TAN−1] (ATAN). For example, you can calculate the angle at which the 2.3 kN force is acting by keying 1 [CHS] [ENTER] [R−P] [X◄►Y] to get an angle of −135°. But, if you use 1 [CHS] [ENTER] [÷] [TAN−1], you get an answer of 45°, so you have to keep closer track of what's going on.

So, using the little triangles, you can calculate the necessary angles. Remember, summing vectors is just a matter of resolving each vector into it's X and Y components and summing all the X-components into one resultant X-component and the same with the Y's.

You can sum the vectors in this problem using only the stack in your HP-41. Let's take a look at the keystrokes:

1 [CHS] [ENTER] [SHIFT] [R−P] [◄−] 2.3 [SHIFT] [P−R]
*(resolves the 2.3 kN force into its components)*

1 [ENTER] 2 [SHIFT] [R−P] [◄−] 1.6 [SHIFT] [P−R]
*(resolves the 1.6 kN force into its components)*

[STO] [+] [.] Z
[R↓]
[STO] [+] [.] Z
[R↓]
*(sums the components of above vectors)*

3 [CHS] [ENTER] 4 [SHIFT] [R−P] [◄−] 4.2 [SHIFT] [P−R]
*(breaks 4.2 kN force into its components)*

[STO] [+] [.] Z
[R↓]
[STO] [+] [.] Z
[R↓]
**(displays result: 3.16)**
[X◄►Y]
**(displays result: −3.43)**

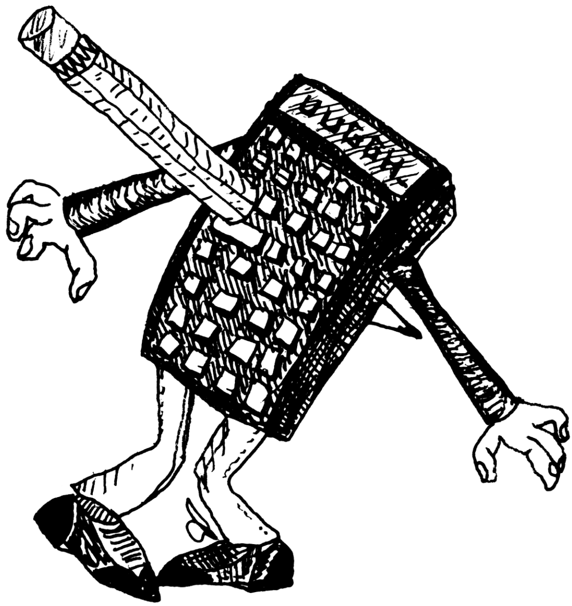
## THE ADVANTAGE OF THE HP-41

The last set of keystrokes represents one method of manually summing vectors. It's an "OK" method as long as you aren't solving this type of problem every day. However, when you're taking a class in statics, you are going to be summing vectors every day.

There's a vector calculator program in the HP-41 Advantage Module that you may find useful. Also, summing two dimensional vectors is a function of the "Free Body" program included with this book. The method of summing vectors on a free body is detailed in the previous chapter. To solve the previous problem using the vector calculator in the Advantage Module, you would use the following keystrokes:

[XEQ] [ALPHA] VC [ALPHA]
[SF] 04
0 [ENTER] 135 [CHS] [ENTER] 2.3 [P−R] [R/S]
0 [ENTER] 1 [ENTER] 2 [R−P] [CLX] 1.6 [P−R] [shift] [A]
[CF] 04
0 [ENTER] 3 [CHS] [ENTER] 4 [R−P] [CLX] 4.2 [P−R]
[shift] [A]
[R/S]
[R/S]

This vector calculator is especially useful when you're working in three dimensions. Trying to keep things straight without a program like this can be harrowing in three dimensions. But, in two dimensions (a lot of problems in statics involve only two dimensions), controlling flag 04 and worrying about the zero Z-component can be kind of a pain.



That's where the "Free Body" program comes in: It works in just two dimensions and has the capability of summing all the known vectors on any body in one quick step. You may find it more tailored to the problems you will be challenged with in statics.

Now, let's take a look at some of the principles that make statics what it is...

# THE BIG ZERO

Something that isn't moving has no net force acting on it. That is, when you sum up all the forces acting on a static object, the resultant is zero. Also, when you sum up all the moments acting on a static object (moments are Force X Distance vectors) the result is zero.

So statics is made up of a bunch of zeroes (no offense).

$$\sum \vec{F} = \emptyset$$

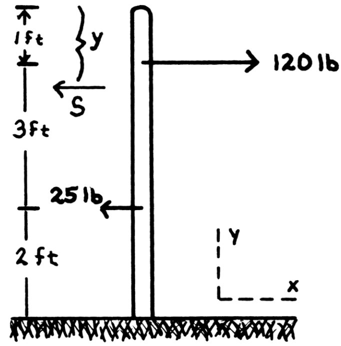
$$\sum \vec{M} = \emptyset$$

(And, as long as you can keep zero on your mind as you work your problems in statics....)

The following problem exemplifies the whole of statics principles. Beyond here, the problems look more complicated, but the principles are just as easy.

---

Calculate the distance y down from the top of the post at which a single horizontal force S must be applied in order to duplicate the external effects of the two known forces. What is the magnitude of S?




Answer: S = 95 lb, y = .21 ft

---

In this problem, all the forces act at different points of one line (the post). To solve it you fall back on the big zero.

1. Since all the forces act in the X-direction (as we've defined it), the equation for the sum of the forces follows:

$$\Sigma F = 0$$
$$120 - 25 - S = 0$$
$$S = 95 \text{ lb.}$$

2. The sum of the moments is zero. You can choose any point about which to sum the moments, as long as you don't change that point midway through the problem. If you choose to sum moments about the top of the flagpole, you get the equation:

$$120\,(1) + (-25)\,(4) - S\,(y) = 0$$

and since $S = 95\text{lb}$,

$$y = \frac{120 - 25\,(4)}{95} = 0.21 \text{ ft}$$

There are your answers. Once you know how to sum forces and moments for any situation while keeping track of all the details, then statics will seem like nothing. It is, afterall, zero you're concerned about.

# Notes

1. Don't press [R/S] while the FB program is busy working. This may cause an END OF ARRAY error. Purge files "A" and "V" if this error occurs, or CLRG if the CV is being used.

2.

# Program Listings and Barcode

Program FB: "CV" version (178 registers required)

```
01♦LBL "FB"
02♦LBL 17
03 "INPUT POINTS"
04 CF 21
05 AVIEW
06 SF 27
07 CF 29
08 CF 01
09 0
10 SF 25
11 STO 17
12 FS?C 25
13 GTO 00
14 "BIGGER SIZE"
15 PROMPT
16♦LBL 00
17 "R10"
18 3.002
19 MATDIM
20 "R17"
21 ASTO 00
22♦LBL 22
23 CF 00
24 CF 21
25 FS? 55
26 SF 21
27 "P  POINTS  R"
28 FS? 01
29 "P  KNOWNS  R"
30 AVIEW
31♦LBL 21
32 FIX 4
33 CF 02
34 STOP
35 GTO 22
36♦LBL F
37 X<>Y
38 GTO 21
39♦LBL J
40 FS? 01
41 GTO 23
42 GTO 16
43♦LBL G
44 -90
45 X<>Y
46♦LBL A
47 SF 00
48 P-R
49♦LBL E
50 XEQ 02
51 FC? 01
52 GTO 00
53 FC?C 25
54 .003
55♦LBL 00
56 FS? 01
57 GTO 00
58 FC?C 25
59 .002
60♦LBL 00
61 1
62 +
63 XEQ 12
64 FC?C 25
65 GTO 21
66 INT
67 MSIJ
68 RDN
69 MSR+
70 X<>Y
71 FS? 01
72 XEQ 01
73 FC? 01
74 MS
75 J-
76 X<>Y
77 FS?C 00
78 R-P
79 GTO 21
80♦LBL b
81 SF 02
82♦LBL d
83 SF 00
84 GTO D
85♦LBL B
86 SF 02
87♦LBL D
88 XEQ 02
89 FC?C 25
90 GTO 22
91 FS? 02
92 I-
93 FC? 02
94 I+
95 FC? 09
96 GTO 00
97 FS? 02
98 INT
99 FC? 02
100 0
101 MSIJ
102♦LBL 00
103 MRR+
104 MRR-
105 X<>Y
106 FS?C 00
107 R-P
108 GTO 21
109♦LBL a
110 P-R
111 SF 00
112♦LBL e
113 XEQ 02
114 FC? 01
115 GTO 00
116 FC?C 25
117 GTO 23
118♦LBL 00
119 FS? 01
120 GTO 00
121 FC?C 25
122 GTO 22
123♦LBL 00
124 RDN
125 MSR+
126 X<>Y
127 FS? 01
128 XEQ 01
129 FC? 01
130 MS
131 J-
132 X<>Y
```

```
133 FS?C 00
134 R-P
135 GTO 21
136♦LBL C
137 CLA
138 ARCL 00
139 SF 25
140 MRIJA
141 FC? 01
142 GTO 00
143 INT
144 .003
145 +
146 SF 25
147 MSIJ
148 SF 25
149 MR
150 "AT POINT: "
151 AIP
152 RDN
153 INT
154 MSIJ
155♦LBL 00
156 FS? 01
157 GTO 00
158 "POINT: "
159 AIP
160 GTO 00
161♦LBL c
162 XEQ 02
163 "TOTAL: "
164 AIP
165♦LBL 00
166 FC?C 25
167 "NO POINTS"
168 AVIEW
169 RDN
170 GTO 21
171♦LBL 08
172 "R17"
173 SF 25
174 DIM?
175 FC?C 25
176 GTO 17
177 INT
178 LASTX
179 FRC
180 1 E3
181 *
182 *
183 18
184 +
185 "R"
186 AIP
187 FC? 00
188 RTN
189 1
190 +
191 DIM?
192 INT
193 1 E3
194 ST* Y
195 CLX
196 LASTX
197 FRC
198 *
199 +
200 "R"
201 AIP
202 CF 00
203 RTN
204♦LBL 10
205 INT
206 X<=0?
207 GTO 00
208 CLA
209 MNAME?
210 ASTO L
211 "R17"
212 SF 25
213 MSIJA
214 CLA
215 ARCL L
216 DIM?
217 RDN
218 FS?C 25
219 RTN
220♦LBL 00
221 "BAD POINT"
222 RDN
223 CF 22
224 PROMPT
225 FC? 22
226 R↑
227 GTO 10
228♦LBL 12
229 SF 25
230 MATDIM
231 FS? 25
232 RTN
233 "GREATER SIZE"
234 AVIEW
235 RTN
236♦LBL 02
237 CLA
238 ARCL 00
239 SF 25
240 DIM?
241 RTN
242♦LBL 01
243 MSR+
244 "AT POINT?"
245 CF 27
246 PROMPT
247 XEQ 10
248 SF 27
249 MS
250 J-
251 RDN
252 "P  NEXT K  R"
253 AVIEW
254 RTN
255♦LBL H
256 XEQ 02
257 FC? 01
258 GTO 00
259 FC?C 25
260 GTO 23
261♦LBL 00
262 FS? 01
263 GTO 00
264 FC?C 25
```

```
265 GTO 17
266♦LBL 00
267 INT
268 MRIJA
269 1 E3
270 /
271 +
272 R<>R
273 DIM?
274 1
275 -
276 MATDIM
277 "ZAPPED"
278 AVIEW
279 INT
280 X≠0?
281 GTO 21
282 FC? 01
283 STO 17
284♦LBL 16
285 XEQ 08
286 ASTO 00
287 STO IND X
288♦LBL 23
289 CF 01
290 " K U 0 ΣK 3U"
291 PROMPT
292 GTO 23
293♦LBL F
294 X<>Y
295♦LBL b
296♦LBL c
297♦LBL d
298♦LBL e
299♦LBL J
300 GTO 23
301♦LBL 03
302♦LBL C
303 GTO 17
304♦LBL E
305 GTO 06
306♦LBL D
307 GTO 07
308♦LBL a
309 XEQ 08
310 STO IND X
311♦LBL A
312 SF 01
313 GTO 22
314♦LBL B
315 "R10"
316 0
317 MSIJA
318 MR
319 "∡ UNKNWN Y↑X"
320 AVIEW
321♦LBL 24
322 FIX 4
323 STOP
324♦LBL J
325 GTO 23
326♦LBL F
327♦LBL G
328♦LBL H
329♦LBL a
330♦LBL b
331♦LBL c
332♦LBL d
333♦LBL e
334 GTO 23
335♦LBL E
336 R-P
337 X<>Y
338♦LBL A
339 MSR+
340 CF 27
341 "AT POINT?"
342 PROMPT
343 XEQ 10
344 SF 27
345 MSR+
346 RDN
347 FC? 10
348 GTO 24
349 GTO 23
350♦LBL D
351 I+
352 FC? 09
353 GTO 00
354 0
355 MSIJ
356 GTO 00
357♦LBL B
358 I-
359 FC? 09
360 GTO 00
361 3
362 MSIJ
363♦LBL 00
364 MR
365 GTO 24
366♦LBL C
367 "AT POINT: "
368 J+
369 MR
370 J-
371 AIP
372 AVIEW
373 GTO 24
374♦LBL 07
375 SF 01
376♦LBL 06
377 XEQ 02
378 FC?C 25
379 GTO 23
380 0
381 MSIJA
382♦LBL 05
383 MRR+
384 MRR+
385 MRR+
386 FS? 10
387 SF 00
388 "R17"
389 MSIJA
390 RDN
391 MRR+
392 *
393 X<>Y
394 MR
395 *
396 -
```

```
397 +
398 CLA
399 ARCL 00
400 MRIJA
401 X<>Y
402 FC? 00
403 GTO 05
404 XEQ 08
405 .003
406 XEQ 12
407 FC?C 25
408 GTO 23
409 ASTO L
410 CLA
411 ARCL 00
412 "⊦,"
413 ARCL L
414 CSUM
415 CLX
416 LASTX
417 -1
418 "X,"
419 ARCL Y
420 "⊦,"
421 ARCL Y
422 MAT*
423 CLA
424 ARCL Y
425 CLX
426 .003
427 MSIJA
428 R↑
429 MS
430 FC?C 01
431 GTO 00
432 MRR-
433 CHS
434 "ΣM="
435 FIX 4
436 ARCL X
437 CF 27
438 PROMPT
439 "ΣFY="
440 MRR-
441 CHS
442 ARCL X
443 PROMPT
444 "ΣFX="
445 MRR-
446 CHS
447 ARCL X
448 PROMPT
449 CLA
450 ARCL 00
451 CLX
452 MSIJA
453 SF 27
454 GTO 23
455♦LBL 00
456 R↑
457 4
458 +
459 "R"
460 AIP
461 3.003
462 XEQ 12
463 FC?C 25
464 GTO 23
465 ASTO X
466 "R10"
467 0
468 MSIJA
469 CLA
470 RDN
471♦LBL 04
472 MRR+
473 1
474 P-R
475 ARCL Z
476 MRIJA
477 RDN
478 MSC+
479 X<>Y
480 MSC+
481 "R10"
482 MRIJA
483 RDN
484 MRR+
485 "R17"
486 MSIJA
487 RDN
488 MRR+
489 *
490 CHS
491 X<>Y
492 MR
493 *
494 +
495 CLA
496 ARCL T
497 MRIJA
498 X<>Y
499 MSC+
500 "R10"
501 MRIJA
502 R↑
503 CLA
504 FC? 10
505 GTO 04
506 SF 00
507 XEQ 08
508 TRNPS
509 ASTO X
510 CLA
511 ARCL Y
512 "⊦,"
513 ARCL X
514 MSYS
515 CLA
516 ARCL 00
517 DIM?
518 3
519 X<>Y
520 +
521 CLA
522 ARCL Y
523 0
524 MSIJA
525 X<>Y
526 1
527 ST+ L
528 X<>Y
```

```
MRC+
MRC+
MR
R↑
CLA
ARCL 00
MATDIM
X<> L
INT
MSIJ
R↑
MSC+
R↑
MSC+
R↑
MS
R↑
MSIJ
"R10"
.002
MSIJA
♦LBL 09
MRR-
MR
I+
J+
CLA
ARCL 00
MRIJA
RDN
MR
P-R
MSR+
RDN
MSR+
RDN
MSR+
RDN
"R10"
MRIJA
FC? 10
GTO 09
CLA
SF 01
ARCL 00
DIM?
3
-
INT
MSIJA
GTO 22
END
```

Barcode FB: "CV" version (178 registers required)

ROW 1: LINES 1-3

ROW 2: LINES 3-6

ROW 3: LINES 7-13

ROW 4: LINES 14-15

ROW 5: LINES 16-20

ROW 6: LINES 20-25

ROW 7: LINES 26-27

ROW 8: LINES 27-29

ROW 9: LINES 29-35

ROW 10: LINES 35-41

ROW 11: LINES 41-46

ROW 12: LINES 47-53

ROW 13: LINES 53-59

Barcode FB: "CV" version (continued)

ROW 14: LINES 59-65

ROW 15: LINES 65-72

ROW 16: LINES 73-79

ROW 17: LINES 80-85

ROW 18: LINES 86-91

ROW 19: LINES 91-97

ROW 20: LINES 98-106

ROW 21: LINES 106-113

ROW 22: LINES 113-119

ROW 23: LINES 119-126

ROW 24: LINES 127-133

ROW 25: LINES 133-140

ROW 26: LINES 140-146

Barcode FB: “CV” version (continued)

ROW 27: LINES 147-150

ROW 28: LINES 150-156

ROW 29: LINES 157-160

ROW 30: LINES 160-163

ROW 31: LINES 163-167

ROW 32: LINES 167-172

ROW 33: LINES 173-180

ROW 34: LINES 180-187

ROW 35: LINES 188-196

ROW 36: LINES 197-206

ROW 37: LINES 207-212

ROW 38: LINES 213-221

ROW 39: LINES 221-224

Barcode FB: "CV" version (continued)

ROW 40: LINES 225-232

ROW 41: LINES 233-233

ROW 42: LINES 234-243

ROW 43: LINES 243-245

ROW 44: LINES 246-252

ROW 45: LINES 252-254

ROW 46: LINES 255-260

ROW 47: LINES 260-267

ROW 48: LINES 268-275

ROW 49: LINES 276-281

ROW 50: LINES 281-286

ROW 51: LINES 287-290

ROW 52: LINES 290-294

Barcode FB: "CV" version (continued)

ROW 53: LINES 295-300

ROW 54: LINES 301-307

ROW 55: LINES 307-313

ROW 56: LINES 313-318

ROW 57: LINES 319-319

ROW 58: LINES 320-326

ROW 59: LINES 327-333

ROW 60: LINES 333-340

ROW 61: LINES 340-343

ROW 62: LINES 343-349

ROW 63: LINES 349-355

ROW 64: LINES 356-362

ROW 65: LINES 363-367

Barcode FB: "CV" version (continued)

ROW 66: LINES 367-371

ROW 67: LINES 371-378

ROW 68: LINES 378-385

ROW 69: LINES 385-391

ROW 70: LINES 391-400

ROW 71: LINES 401-406

ROW 72: LINES 406-412

ROW 73: LINES 412-418

ROW 74: LINES 419-425

ROW 75: LINES 426-431

ROW 76: LINES 432-437

ROW 77: LINES 438-444

ROW 78: LINES 444-450

Barcode FB: "CV" version (continued)

ROW 79: LINES 451-459

ROW 80: LINES 459-463

ROW 81: LINES 464-469

ROW 82: LINES 470-478

ROW 83: LINES 479-485

ROW 84: LINES 485-492

ROW 85: LINES 494-500

ROW 86: LINES 501-507

ROW 87: LINES 508-513

ROW 88: LINES 515-522

ROW 89: LINES 524-531

ROW 90: LINES 532-539

ROW 91: LINES 541-547

Barcode FB: “CV” version (continued)

ROW 92: LINES 548-552

ROW 93: LINES 554-560

ROW 94: LINES 562-567

ROW 95: LINES 569-574

ROW 96: LINES 576-580

Program FB: "CX" version (167 registers required)

```
01♦LBL "FB"
02♦LBL 17
03 "P"
04 SF 25
05 PURFL
06 1
07 SF 25
08 STO 00
09 FC?C 25
10 PSIZE
11 "INPUT POINTS"
12 CF 21
13 AVIEW
14 SF 27
15 CF 29
16 CF 01
17 "U"
18 3.002
19 XEQ 12
20 "P"
21 ASTO 00
22♦LBL 22
23 CF 00
24 CF 21
25 FS? 55
26 SF 21
27 "P  POINTS  R"
28 FS? 01
29 "P  KNOWNS  R"
30 AVIEW
31♦LBL 21
32 FIX 4
33 CF 02
34 STOP
35 GTO 22
36♦LBL F
37 X<>Y
38 GTO 21
39♦LBL J
40 FS? 01
41 GTO 23
42 GTO 16
43♦LBL G
44 -90
45 X<>Y
46♦LBL A
47 SF 00
48 P-R
49♦LBL E
50 XEQ 02
51 FC? 01
52 GTO 00
53 FC?C 25
54 .003
55♦LBL 00
56 FS? 01
57 GTO 00
58 FC?C 25
59 .002
60♦LBL 00
61 1
62 +
63 XEQ 12
64 FC?C 25
65 GTO 21
66 INT
67 MSIJ
68 RDN
69 MSR+
70 X<>Y
71 FS? 01
72 XEQ 01
73 FC? 01
74 MS
75 J-
76 X<>Y
77 FS?C 00
78 R-P
79 GTO 21
80♦LBL b
81 SF 02
82♦LBL d
83 SF 00
84 GTO D
85♦LBL B
86 SF 02
87♦LBL D
88 XEQ 02
89 FC?C 25
90 GTO 22
91 FS? 02
92 I-
93 FC? 02
94 I+
95 FC? 09
96 GTO 00
97 FS? 02
98 INT
99 FC? 02
100 0
101 MSIJ
102♦LBL 00
103 MRR+
104 MRR-
105 X<>Y
106 FS?C 00
107 R-P
108 GTO 21
109♦LBL a
110 P-R
111 SF 00
112♦LBL e
113 XEQ 02
114 FC? 01
115 GTO 00
116 FC?C 25
117 GTO 23
118♦LBL 00
119 FS? 01
120 GTO 00
121 FC?C 25
122 GTO 22
123♦LBL 00
124 RDN
125 MSR+
126 X<>Y
127 FS? 01
128 XEQ 01
129 FC? 01
130 MS
131 J-
132 X<>Y
133 FS?C 00
134 R-P
135 GTO 21
```

```
136♦LBL C
137 CLA
138 ARCL 00
139 SF 25
140 MRIJA
141 FC? 01
142 GTO 00
143 INT
144 .003
145 +
146 SF 25
147 MSIJ
148 SF 25
149 MR
150 "AT POINT: "
151 AIP
152 RDN
153 INT
154 MSIJ
155♦LBL 00
156 FS? 01
157 GTO 00
158 "POINT: "
159 AIP
160 GTO 00
161♦LBL c
162 XEQ 02
163 "TOTAL: "
164 AIP
165♦LBL 00
166 FC?C 25
167 "NO POINTS"
168 AVIEW
169 RDN
170 GTO 21
171♦LBL 08
172 "K"
173 SF 25
174 DIM?
175 FS?C 25
176 RTN
177 "P"
178 SF 25
179 DIM?
180 FC?C 25
181 GTO 17
182 RTN
183♦LBL 10
184 INT
185 X<=0?
186 GTO 00
187 CLA
188 MNAME?
189 ASTO L
190 "P"
191 SF 25
192 MSIJA
193 CLA
194 ARCL L
195 DIM?
196 RDN
197 FS?C 25
198 RTN
199♦LBL 00
200 "BAD POINT"
201 RDN
202 CF 22
203 PROMPT
204 FC? 22
205 R↑
206 GTO 10
207♦LBL 12
208 SF 25
209 MATDIM
210 FS? 25
211 RTN
212 "NEED MORE EXMEM"
213 AVIEW
214 RTN
215♦LBL 02
216 CLA
217 ARCL 00
218 SF 25
219 DIM?
220 RTN
221♦LBL 01
222 MSR+
223 "AT POINT?"
224 CF 27
225 PROMPT
226 XEQ 10
227 SF 27
228 MS
229 J-
230 RDN
231 "P  NEXT K  R"
232 AVIEW
233 RTN
234♦LBL H
235 CLD
236 XEQ 02
237 FC? 01
238 GTO 00
239 FC?C 25
240 GTO 23
241♦LBL 00
242 FS? 01
243 GTO 00
244 FC?C 25
245 GTO 17
246♦LBL 00
247 INT
248 MRIJA
249 1 E3
250 /
251 +
252 R<>R
253 DIM?
254 1
255 -
256 MATDIM
257 "ZAPPED"
258 AVIEW
259 INT
260 MSIJ
261 X≠0?
262 GTO 21
263 "P"
264 FC? 01
265 PURFL
266 GTO 17
267♦LBL 16
268 "K"
269 SF 25
270 PURFL
```

```
271 CF 25
272 ASTO 00
273♦LBL 23
274 XEQ 08
275 CF 01
276 " K U 0 ΣK 3U"
277 PROMPT
278 GTO 23
279♦LBL F
280 X<>Y
281♦LBL b
282♦LBL c
283♦LBL d
284♦LBL e
285♦LBL J
286 GTO 23
287♦LBL 03
288♦LBL C
289 GTO 17
290♦LBL E
291 GTO 06
292♦LBL D
293 GTO 07
294♦LBL a
295 "K"
296 SF 25
297 PURFL
298 CF 25
299♦LBL A
300 SF 01
301 GTO 22
302♦LBL B
303 "U"
304 0
305 MSIJA
306 MR
307 "∡ UNKNWN Y↑X"
308 AVIEW
309♦LBL 24
310 FIX 4
311 STOP
312♦LBL J
313 GTO 23
314♦LBL F
315♦LBL G
316♦LBL H
317♦LBL a
318♦LBL b
319♦LBL c
320♦LBL d
321♦LBL e
322 GTO 23
323♦LBL E
324 R-P
325 X<>Y
326♦LBL A
327 MSR+
328 CF 27
329 "AT POINT?"
330 PROMPT
331 XEQ 10
332 SF 27
333 MSR+
334 RDN
335 FC? 10
336 GTO 24
337 GTO 23
338♦LBL D
339 I+
340 FC? 09
341 GTO 00
342 0
343 MSIJ
344 GTO 00
345♦LBL B
346 I-
347 FC? 09
348 GTO 00
349 3
350 MSIJ
351♦LBL 00
352 MR
353 GTO 24
354♦LBL C
355 "AT POINT: "
356 J+
357 MR
358 J-
359 AIP
360 AVIEW
361 GTO 24
362♦LBL 07
363 SF 01
364♦LBL 06
365 XEQ 02
366 FC?C 25
367 GTO 23
368 0
369 MSIJA
370♦LBL 05
371 MRR+
372 MRR+
373 MRR+
374 FS? 10
375 SF 00
376 "P"
377 MSIJA
378 RDN
379 MRR+
380 *
381 X<>Y
382 MR
383 *
384 -
385 +
386 "K"
387 MRIJA
388 X<>Y
389 FC? 00
390 GTO 05
391 "V"
392 .003
393 XEQ 12
394 FC?C 25
395 GTO 23
396 "K,V"
397 CSUM
398 -1
399 "X,V,V"
400 MAT*
401 "V"
402 CLX
403 .003
404 MSIJA
405 R↑
```

```
406 R↑
407 MS
408 FC?C 01
409 GTO 00
410 MRR-
411 CHS
412 "ΣM="
413 FIX 4
414 ARCL X
415 CF 27
416 PROMPT
417 "ΣFY="
418 MRR-
419 CHS
420 ARCL X
421 PROMPT
422 "ΣFX="
423 MRR-
424 CHS
425 ARCL X
426 PROMPT
427 "V"
428 PURFL
429 SF 27
430 GTO 23
431♦LBL 00
432 "A"
433 3.003
434 XEQ 12
435 FC?C 25
436 GTO 23
437 "U"
438 0
439 MSIJA
440♦LBL 04
441 MRR+
442 1
443 P-R
444 "A"
445 MRIJA
446 RDN
447 MSC+
448 X<>Y
449 MSC+
450 "U"
451 MRIJA
452 RDN
453 MRR+
454 "P"
455 MSIJA
456 RDN
457 MRR+
458 *
459 CHS
460 X<>Y
461 MR
462 *
463 +
464 "A"
465 MRIJA
466 X<>Y
467 MSC+
468 "U"
469 MRIJA
470 FC? 10
471 GTO 04
472 SF 00
473 "V"
474 TRNPS
475 "A,V"
476 MSYS
477 "A"
478 PURFL
479 "K"
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481 3
482 X<>Y
483 +
484 MATDIM
485 1
486 ST+ L
487 "V"
488 0
489 MSIJA
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491 MRC+
492 MR
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496 "K"
497 INT
498 MSIJA
499 R↑
500 MSC+
501 R↑
502 MSC+
503 R↑
504 MS
505 R↑
506 MSIJ
507 "U"
508 .002
509 MSIJA
510♦LBL 09
511 MRR-
512 MR
513 I+
514 J+
515 "K"
516 MRIJA
517 RDN
518 MR
519 P-R
520 MSR+
521 RDN
522 MSR+
523 RDN
524 MSR+
525 RDN
526 "U"
527 MRIJA
528 FC? 10
529 GTO 09
530 CLA
531 SF 01
532 ARCL 00
533 DIM?
534 3
535 -
536 INT
537 MSIJA
538 GTO 22
539 END
```

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ROW 2: LINES 5-11

ROW 3: LINES 11-14

ROW 4: LINES 14-19

ROW 5: LINES 19-25

ROW 6: LINES 25-27

ROW 7: LINES 27-29

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ROW 9: LINES 35-40

ROW 10: LINES 41-46

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ROW 12: LINES 53-58

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ROW 25: LINES 140-146

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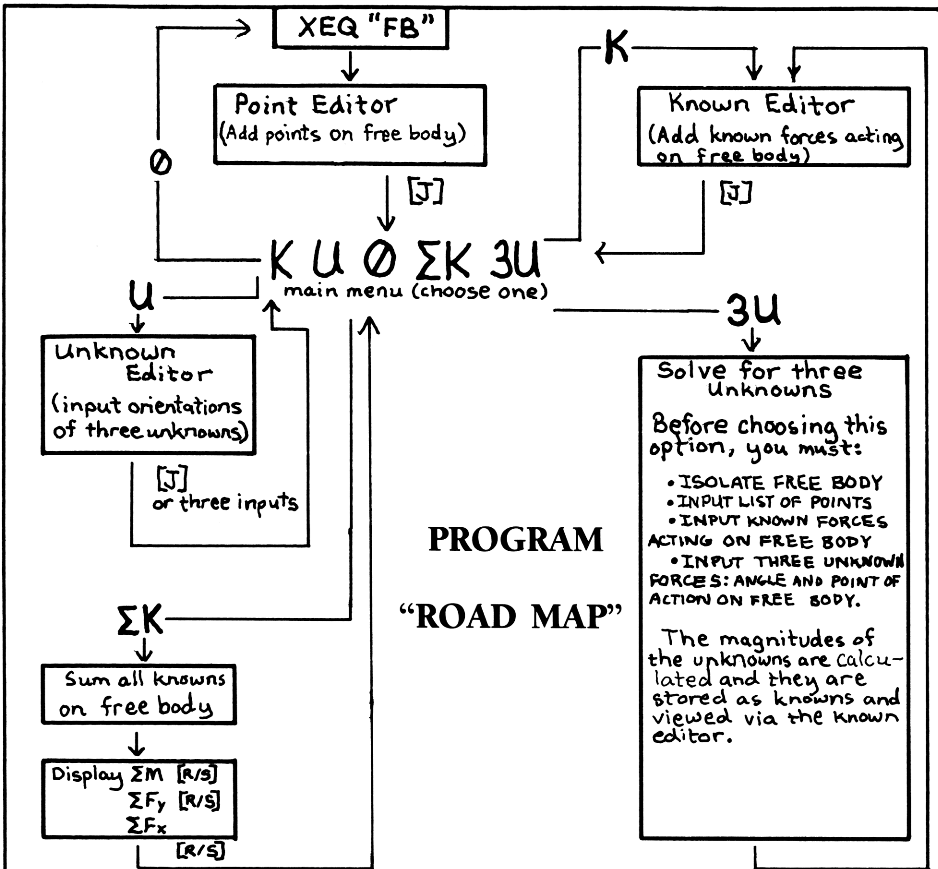


## Point / Known Editor: top rows of keys

| Change Value polar coordinates | Backspace: view in polar coordinates | Total ? | Forward space: view in polar coordinates | Change value polar coordinates |
|---|---|---|---|---|
| **A** Add a value polar coordinates | **B** Backspace: view in rectangular coordinates | **C** which point is this? or at which point does this known act? | **D** Forward space: view in rectangular coordinates | **E** Add a value rectangular coordinates |
| **F** X<>Y view other coordinate | **G** Point on negative Y-axis or Downward load | **H** Delete current value (press [C] to locate current value) | **I** COS (as usual) | **J** Exit (to main menu) |

## Unknown Editor: top row

| A | B | C | D | E |
|---|---|---|---|---|
| Input angle of orientation of unknown load | Back space | At which point does this unknown act? | Forward space. | Input slope of unknown Y [ENTER] X rise=Y run=X |

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