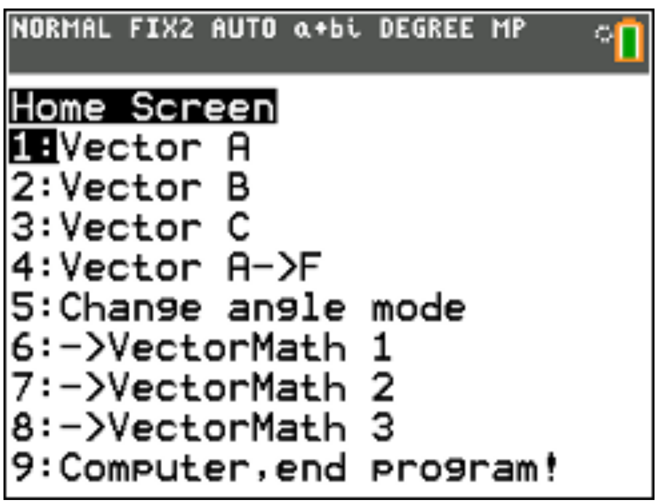
Vector Math

Undated June 27, 2019

The VECTORS program can use either 2- or 3-dimentional vectors. Since all vector calculations are done with rectangular coordinates, when entering a vector you will be prompted to indicate the type of vector entered: rectangular, polar (2D), cylindrical (3D), or spherical (3D). If the vector is not rectangular, it will be converted to rectangular coordinates.

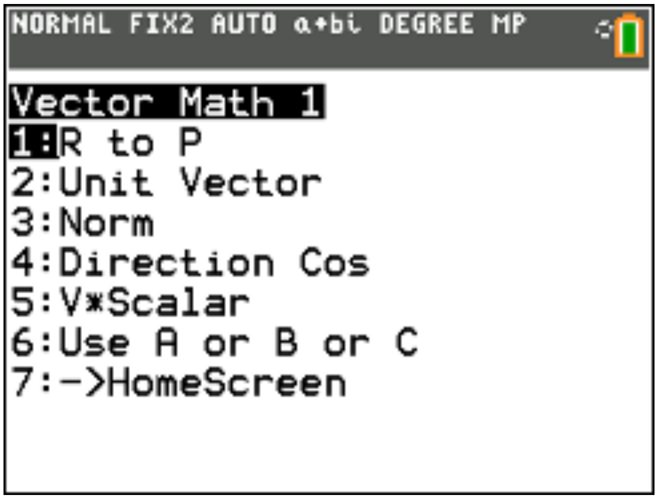
This new version VECTORS has been completely rewritten. The menus are more user friendly and it is easier to get around in the program. There are 4 menu screens. The Home Screen, Vector Math 1, Vector Math 2, and Vector Math 3.

The update allows you to work with 3 vectors in three dimensions to compute the triple scalar product, triple vector product, and 3 reaction forces to balance a 3D force vector.

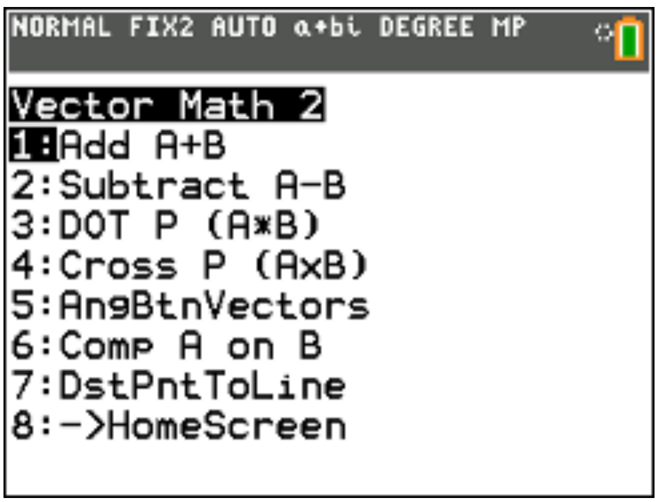



The Home Screen is for entering the three vectors, saving vector A as the force vector, changing the angle mode, and assessing the Vector Math 1, 2, and 3 menus.

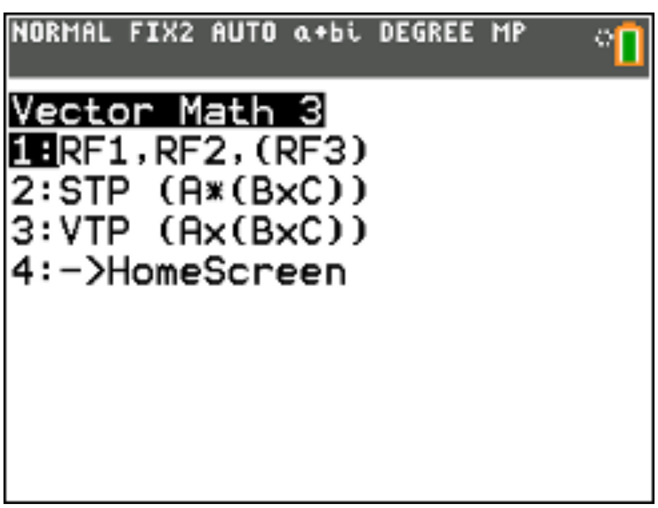
Vectors can be entered as 2 or 3 dimensional vectors; however, if you are working on 2 or 3 vectors at a time, they better be the same dimension.




Vector Math 1 allows you to work with one vector. You can change a rectangular vector to a polar vector (2D), cylindrical vector (3D), or spherical vector (3D). You can also compute the unit vector, norm, direction cosines and angles, and multiply a vector by a scalar. Normally, the last vector you entered will be the one you will work on. However, you also have the ability to choose the vector you want to work with.




Vector Math 2 lets you work with 2 vectors at a time. You can add or subtract them, compute the dot product, cross product, angle between the vectors, the component of vector A on Vector B, and the distance of a point to a line. If the result of an operation is another vector, it will replace vector A.




Vector Math 3 lets you compute the reaction forces RF1, RF2, (RF3), the scalar triple product, and the vector triple product.

Finally, for a vector P in three dimensions, cylindrical coordinates are entered as { r, θ, z } and spherical vectors as { ρ, θ, ϕ }. (In some math books, the angles of spherical coordinates are switched. So be sure to enter them in the appropriate order.) In cylindrical coordinates, r and θ are the polar coordinates for the projection P' of P onto the xy-plane and z is the third rectangular coordinate of P. For spherical coordinates, ρ is the length of OP, θ is the polar angle associated with the projection P' of P onto the xy-plane and ϕ is the angle from the z-axis to P.

Now, let's get down to business!

When you open the program, you will be asked to choose between degrees or radians as your angle mode. Once chosen, you will be presented with the Home Screen for entering vectors.

After any calculation in Vector Math 1, 2, or 3, you will be taken back to the Home Screen.

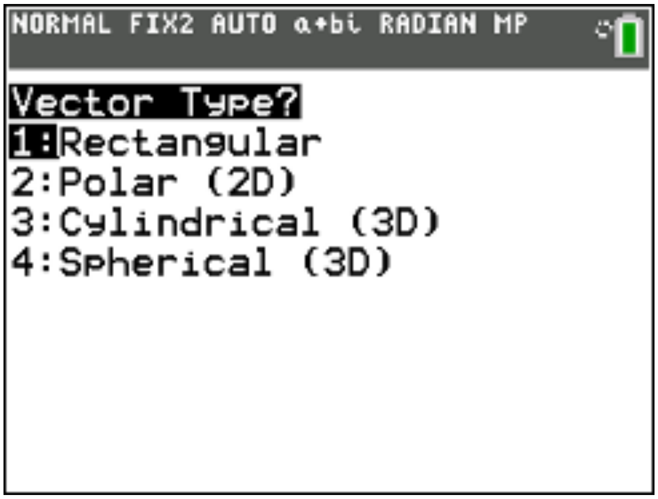
In the examples that follow I will simply tell you what keys to press. You can follow along use the screen shots above.

Example 1: If a point P has spherical coordinates {4, $\pi/3$, $\pi/6$}, find rectangular and cylindrical coordinates for P.

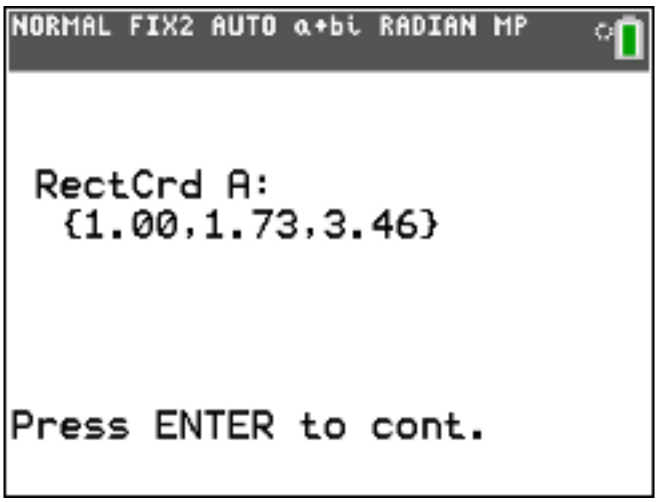
First, open the VECTORS program and choose radians as the angle mode.

From the Home Screen, press 1 to enter Vector A. (ALL VECTORS MUST BE ENTERED IN A LIST OF DIMENTION 2 OR 3.)

Enter the vector, {4, π/3, π/6}, and press ENTER.



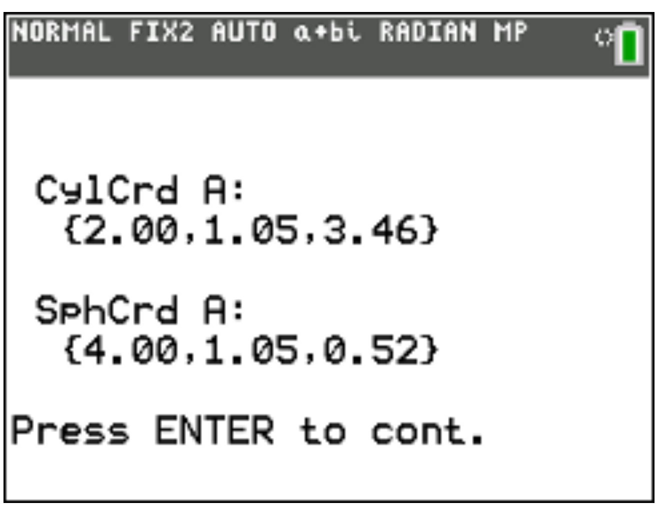

You will now be asked the type of vector you entered. Since it was spherical, press 4. (All vectors that are not rectangular will be converted to rectangular form as all calculations are done with rectangular vectors.)




The spherical coordinates have been converted to rectangular form and stored as vector A.

Press ENTER to go to the Home Screen.

Then press 6 to go to Vector Math 1. Now press 1 (R to P) to find the cylindrical coordinates.




The cylindrical coordinates are {2, 1.05, 3.46}.

Press ENTER to go to the Home Screen.

Then Press 5 to change from radians to degrees for the rest of the examples.

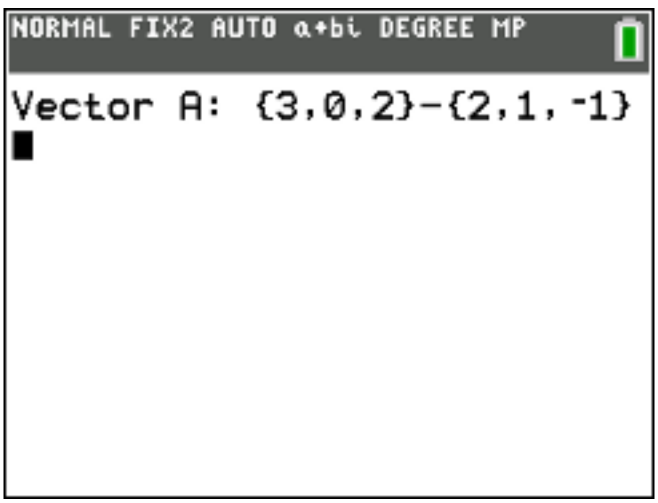
Example 2: Find the volume of a box having adjacent sides ab, ac, and ad

Let point a be {2, 1, -1}, point b be {3, 0, 2}, point c be {4, -2, 1}, and point d be {5, -3, 0}.

The volume of a box is V = |(a * (b x c)|, which is the triple scalar product.

So, let vector A = b - a, vector B = c - a, and vector C = d - a.

Start by entering vector AB.




Notice that I entered point b – point a for the side ab.

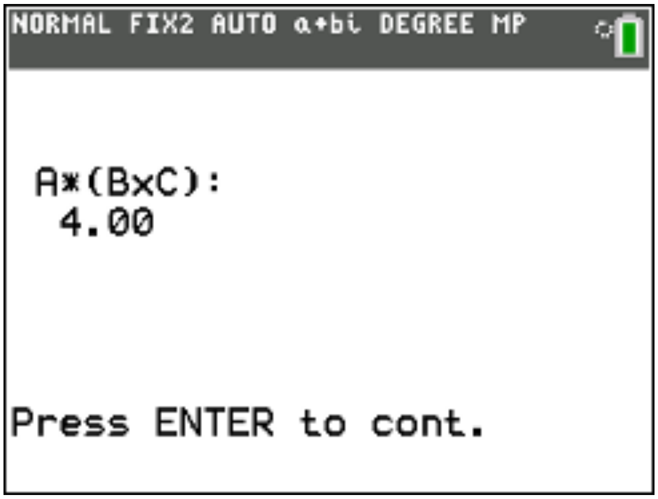
Press ENTER, and then ENTER again since you are entering a rectangular vector. You will be shown the vector entered: {1, -1, 3}. (The math was done for you!)

Press ENTER to continue. Now press 2 to enter line ac in Vector B.

Press ENTER, and then ENTER again since this is a rectangular vector. The vector shown is {2, -3, 2}.

Press ENTER to go to the Home Screen and press 3 to enter line ad in Vector C. Press ENTER, and then ENTER again since this is a rectangular vector. The vector shown is {3, -4, 1}. Press ENTER to go to the Home Screen.

Now, press 8 to go to Vector Math 3.  Press 2 to compute the TSP.



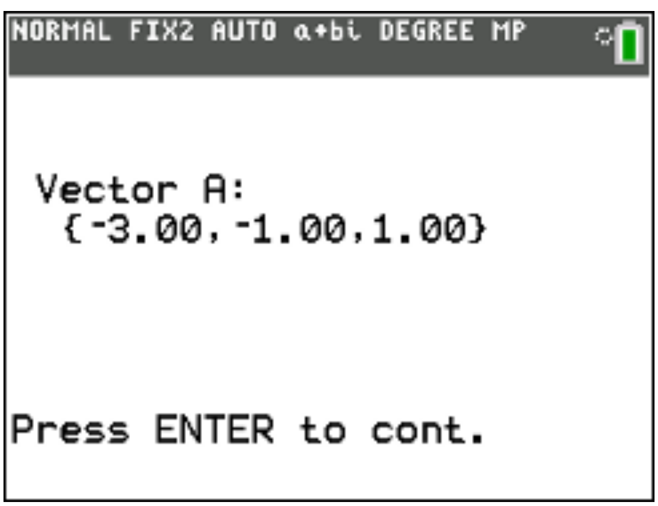

The volume of the box is 4 cubic units.  (If the computation came out negative, ignore the minus sign as volume cannot be negative.)

Press ENTER to go to the Home Screen.

Example 3:  Find the distance from a point P to the line Q and R. The point P must be anchored to the beginning of the line QR.
Let P = {3,1, -2}, Q =  {2, 5, 1}, and R = {-1, 4, 2}.

The line QR must be entered in Vector A and the point P, on line QP, is entered in Vector B.

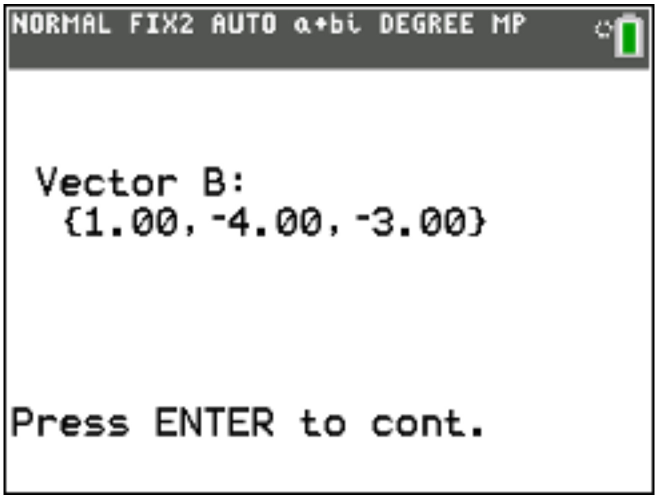
In the Home Screen, press 1 and enter Vector A, in this case, the line QR:  {-1, 4, 2} – {2,5,1}.  Press ENTER, ENTER.




The simplified vector is {-3, -1, 1}.

Press ENTER to go to the Home Screen.

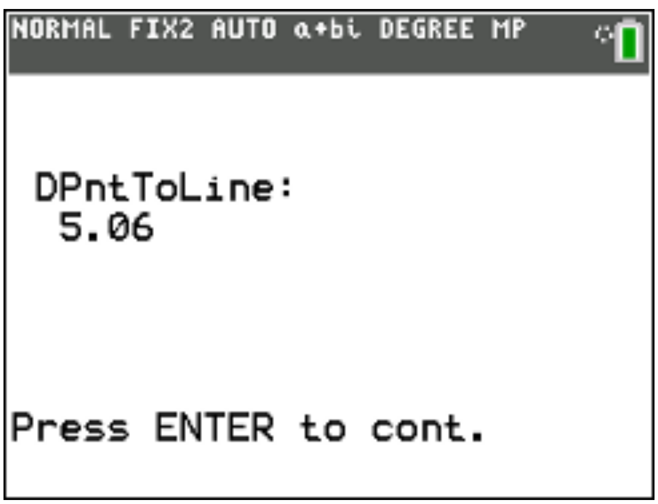
Now enter line QP as Vector B:  {3,1, -2} - {2, 5, 1}.




Press ENTER and ENTER again.  Vector B is shown as {1, -4, -3}.

Press ENTER to go to the Home Screen.  Then press 7 to go to Vector Math 2.

Press 7, DstPntToLine.




The distance of the point P from line QR is 5.06.

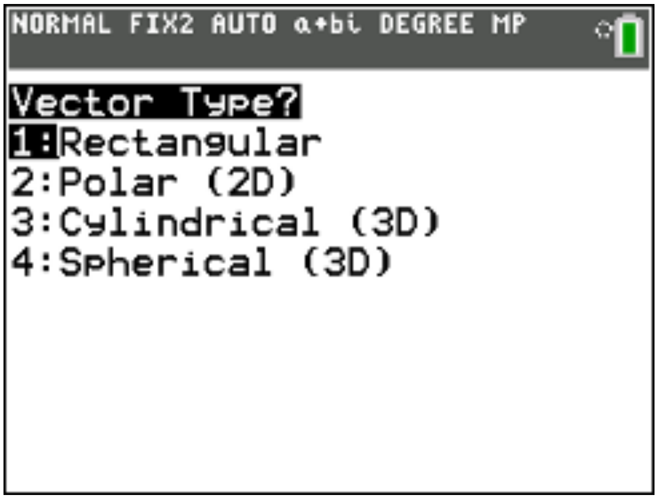
Press ENTER to go to the Home Screen.

Example 4:  Two forces P and Q are applied to an aircraft connection.  The forces are: P{500 lb., -90°} and Q{650 lb., -50°}. Two reaction forces, one at 0° and the other at 130° balance the forces of P and Q.  Find the magnitudes of the reaction forces.

You need to add P and Q together to get the resultant force that is needed to find the two reaction forces.

At the home screen, enter the forces P and Q into vectors A and B.

Enter P{500,-90} in Vector A and press enter.

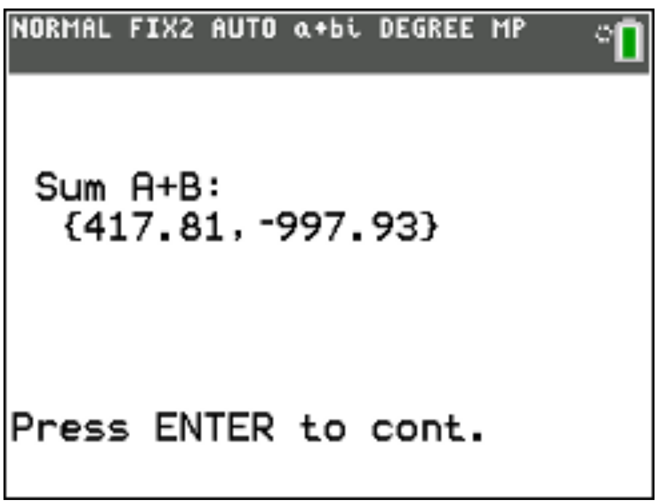



Vector A is in Polar form, so press 2 (2D).

It will be converted to rectangular form: {0, -500}.

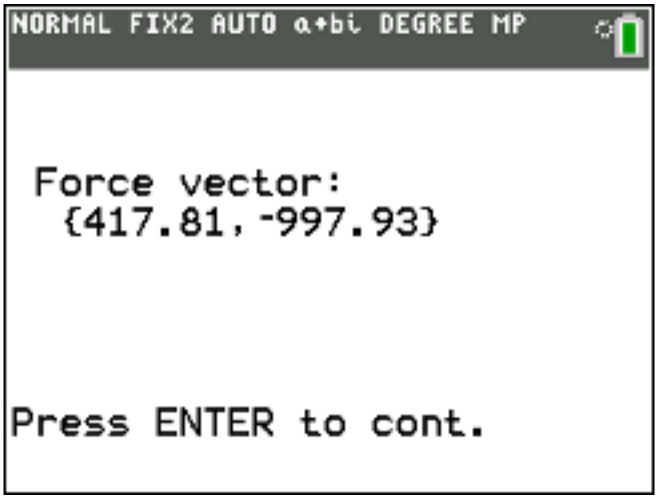
Press ENTER to go to the Home Screen.

Press 2 to enter Vector B: {650,-50}.  Now press ENTER and then 2 for Polar (2D).  Then press ENTER to get back to the Home Screen.




Press 7 to go to the Vector Math 2 screen and then 1 to add the two vectors.

The sum of A + B is: {417.81, -997.93}.  This vector is stored in Vector A. Press ENTER to continue to go to the Home Screen.




Pres 4: Vector A ->F to store vector A as the Force Vector.

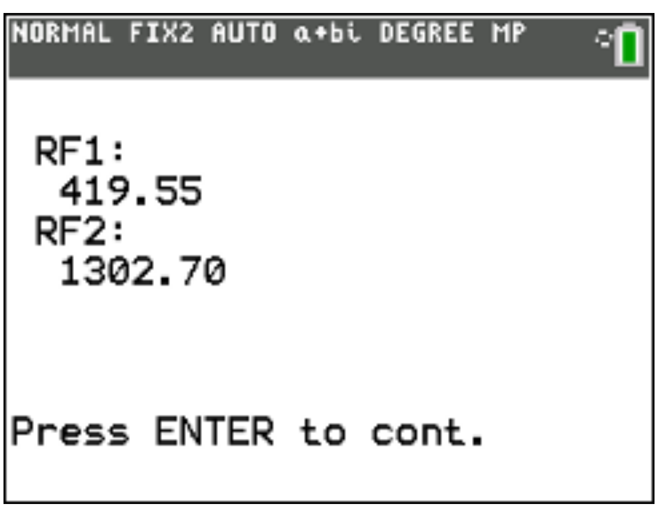
Press ENTER to continue. You can now input the 2 reaction vectors that balance the force vector.

Since the reaction vectors can be of arbitrary length, I choose a length of 1.

Press 1 to enter Vector A: {1, 0}. This is a polar vector since 0 is an angle. Enter the vector and then press 2: Polar (2D).

Press ENTER to continue and press 2 for Vector B: {1,130}. Enter it and then press 2:Polar (2D). Press ENTER to continue.

At the Home Screen, press 8, Vector Math 3. Then press 1, RF1, RF2, (RF3) to compute the 2 reaction forces.




The 2 reaction forces are 419.55 at 0 degrees and 1302.70 at 130 degrees.

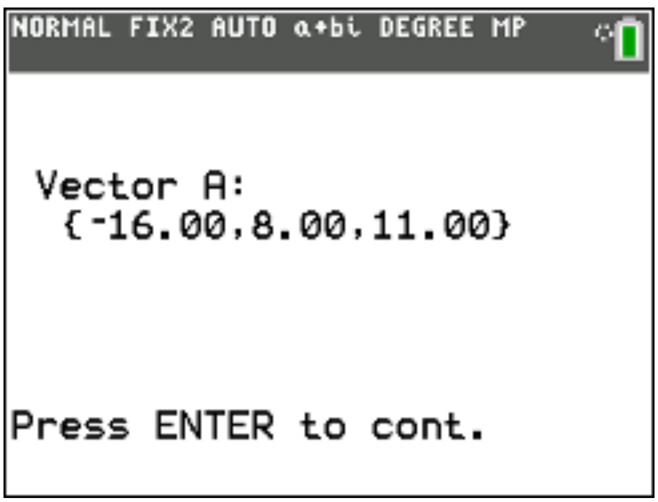
With 3-dimentional vectors you can compute 3 reaction forces, which makes sense as it takes 3 reaction forces to balance a force vector in 3D-space.

Example 5: A wall section of precast concrete is temporarily held by 2 cables, AB and AC. The tension in cable AB is 840 lb and in cable AC it is 1200 lb. Determine the magnitude and direction of the forces exerted by cables AB and AC on stake A.

The tension in AB is directed along the vector {-16, 8, 11} and the tension in AC is directed along the vector {-16, 8, -16}.

You need to find the {x, y, z} components of the tensions along the two vectors. To do this, compute the unit vectos of each vector and multiply it by the tension in the cable.

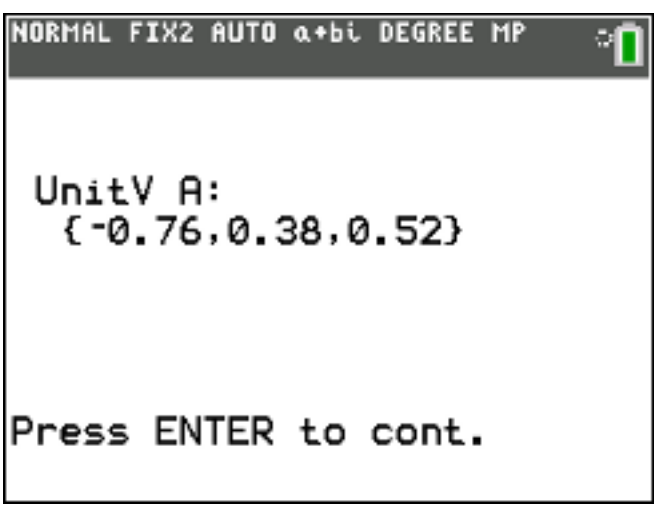
Enter the vector for AB: {-16, 8, 11} and press ENTER, ENTER.




Now compute the unit vector of A.

Press ENTER, then press 6 for Vector Math 1.

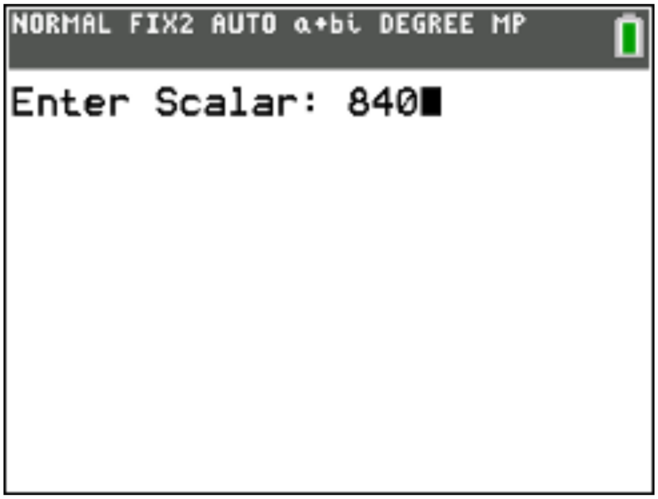
Press 2: Unit Vector.



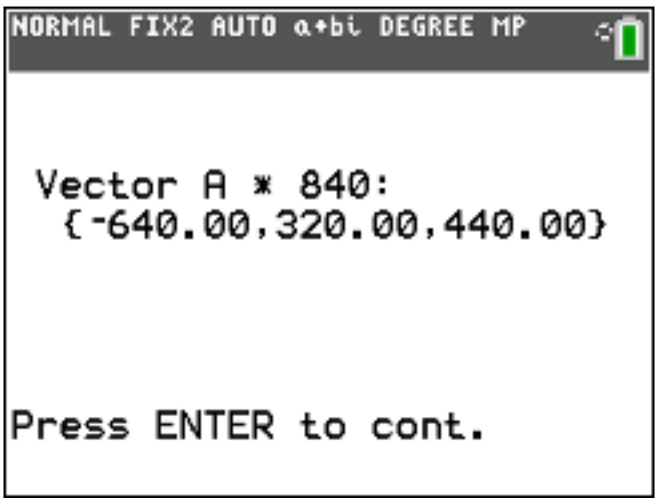

This is the unit vector of A. Now multiply the unit vector by the scalar tension of 840.

Press ENTER and then press 6.

Then press 5: V*Scalar and enter 840.

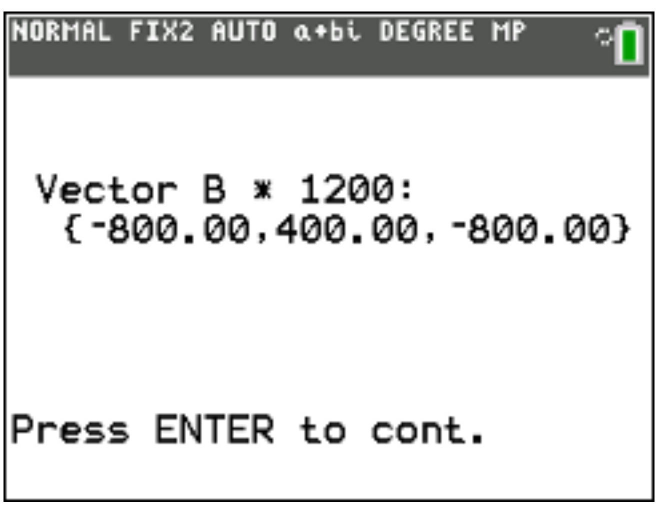



Press Enter.




This is the x, y, z components of the 840 lb tension.

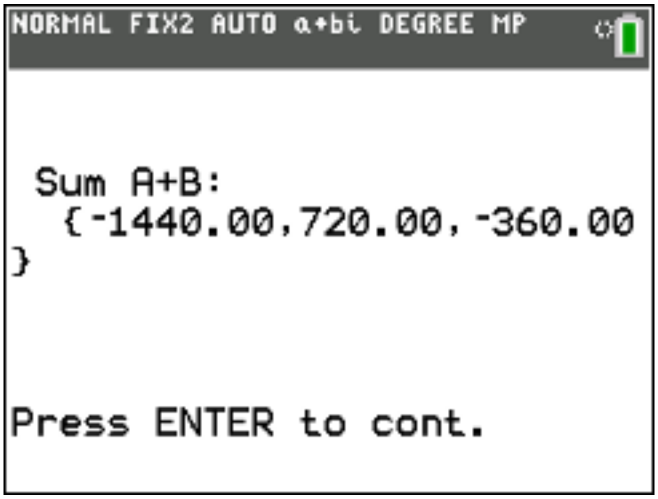
Now do the same for the second cable as Vector B.




This is the result you should have.

Press ENTER to go to the Home Screen.

Now you can add the two forces.  Press 7 and add the two vectors.

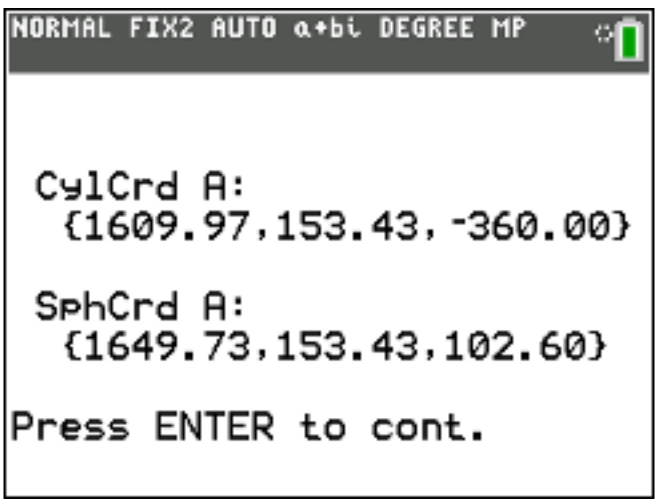



This is the result you should have.

Now you can compute the magnitude and direction of the resultant force.

Press ENTER to go to the Home Screen.

To find the magnitude press 6, Vector Math 1, and then press 1, R to P.

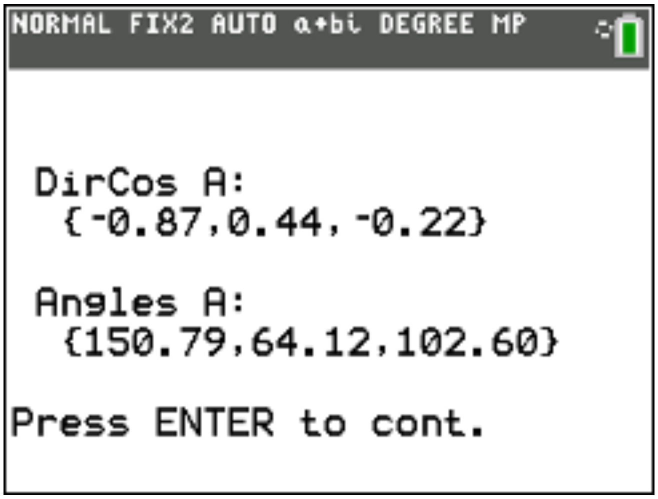



The first element of the spherical coordinate is the magnitude of the resultant force: rounded it is 1650 lb.

Press ENTER to go to the main screen.

Now you can compute the directions of the x, y, z forces.  Press 6 for Vector Math 1.

Now press 4: Direction Cos to compute the direction cosines and angles.




The direction about the x-axis is 150.8 deg, about the y-axis it is 64.1 deg, and about the z-axis it is 102.6 deg.

Example 6: Three cables, (AB, AC, and AD), are used to tether a hot-air balloon. Knowing that the balloon exerts an 800 N vertical force at A, determine the tension in each cable.

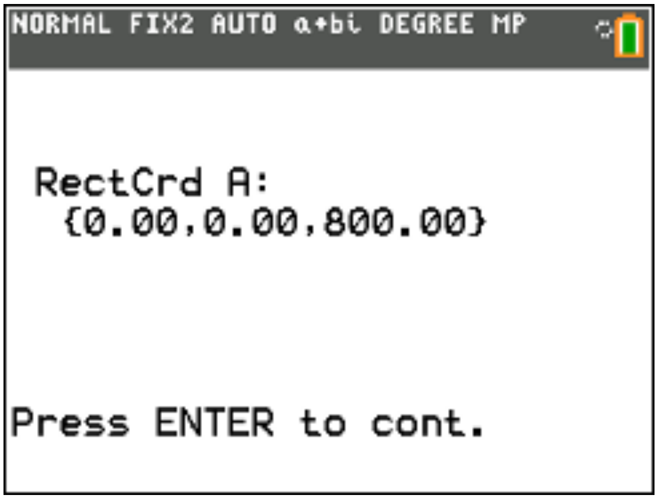
The x,y,z coordinates, in meters, of the cables from A, to the ground are:

AB: {0, -4.2, 5.6}
AC: {4.2, 2.4, 5.6}
AD: {-3.3, 0, 5.6}

The spherical coordintates of the 800 N force are {800,0°, 0°}. (The coordinates of point A are {0, 0, 5.6}. You could find the unit vector of A, multply it by 800 to get the retangular vector {0, 0, 800}. Or you could just enter the spherical coordinates in the first place and it will be converted to redctangular coordinates.)

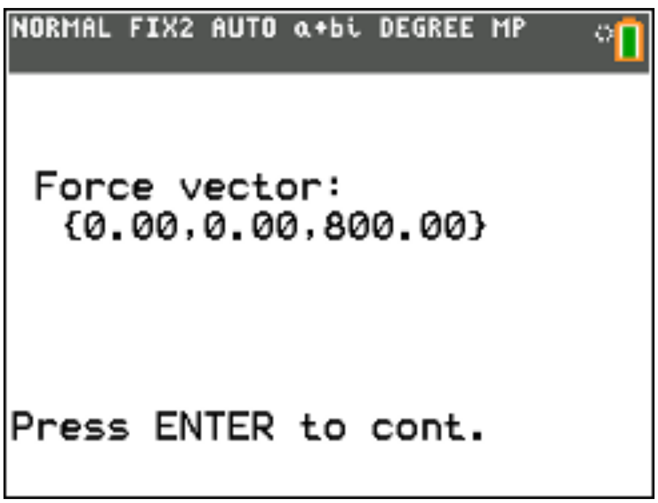
The three cables balance the 800 N vertical force so they are reaction forces. They can be solved like Example 4.

From the Home Screen enter the force vector, {800, 0 0}, as Vector A, then press 4 for Spherical (3D).

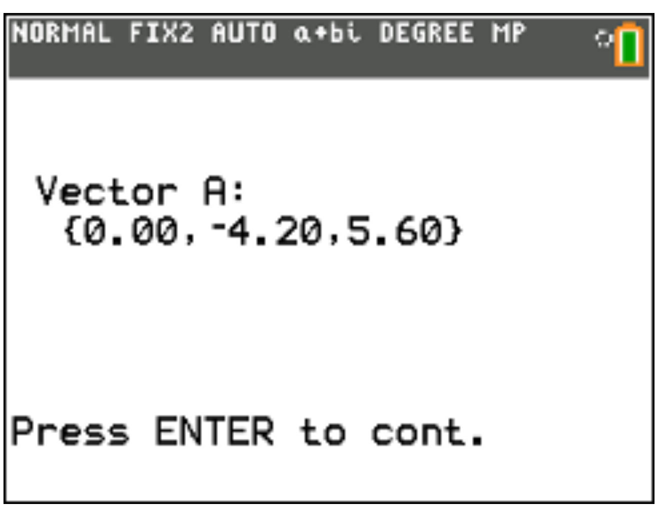



It is changed to rectangular form.

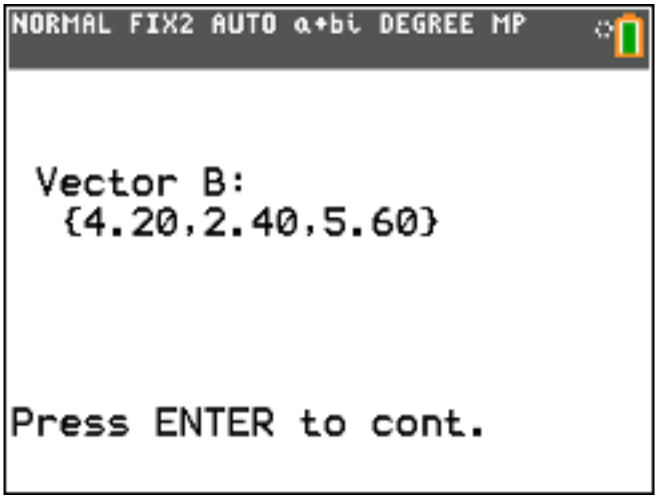
Press ENTER to go the Home Screen and then press 4: Vector A ->F.



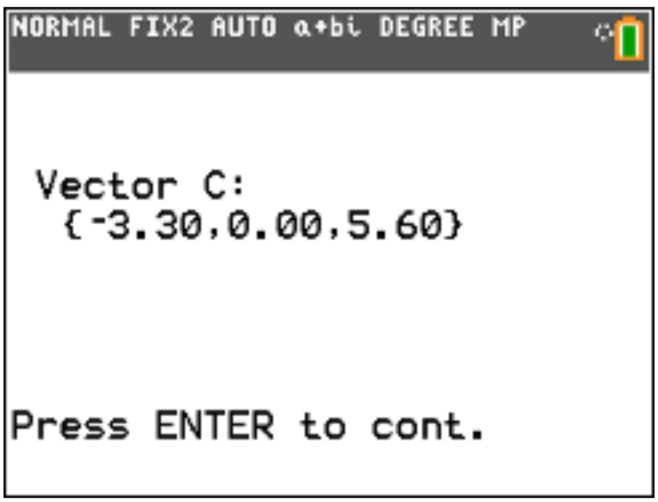

Now you can enter the coordinates of the 3 cables.




Cable AB

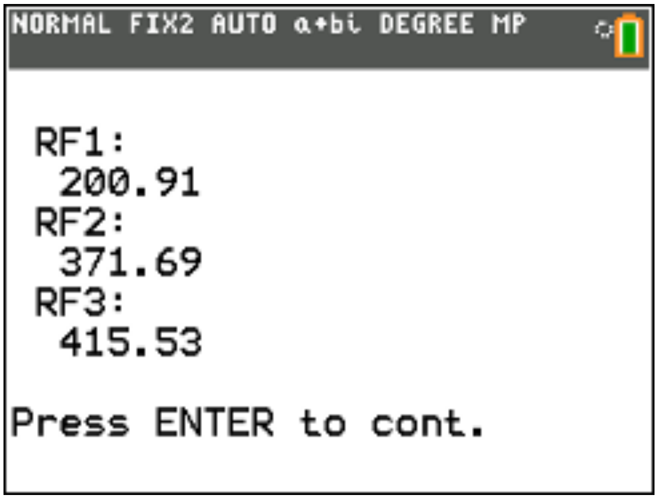



Cable AC




Cable AD

You can now compute the tension in each cable. Reture to the Home Screen and press 8: Vector Math 3. Now press 1 to compute.




The tension in cable AB is 200.9 N, in cable AC 371.7 N, and in cable AD 415.5 N.

I was able to enter and use the cable coordinates because the vectors are converted to unit vectors before computing the reaction forces.

I hope you have enjoyed this introduction my vector math program. If you have any questions of suggestions, please send an email to me at don.phillips@gmail.com.