Appendix B
How to Use the Companion Software

The companion software to this book, Telescope Design Tools or TDT4WIN, is intended to allow you to perform all of the mechanical analyses shown in the book without resort to longhand paper and calculator work. Think of it as a mechanical design tool intended to help you optimize the performance vs. weight of your telescope. It is divided into three main sections that reflect the three main parts of a design: tube oriented tools, mount oriented tools and a materials calculator. To use it, you need to know (or have good guesses about) the same things you'd need to design a telescope with pencil and paper. Most of these are obtained with tape measure or by weighing.

TDT4WIN is an analysis program, not a synthesis program; that means that you can't enter a wish list of parameters and have it design a mount for you. You can analyze a telescope and its mount in a lot of detail with it and determine which parts are acceptable, which are not strong enough and which are stronger than they need to be.

TDT4WIN can be run from under the File Manager inside Microsoft Windows® version 3.1 or 3.11. It can be run from Microsoft Windows95®, Windows98® and XP®. It has been tested on all of these operating systems.

Installing TDT4WIN

TDT4WIN can be placed in any convenient subdirectory on a hard drive, or run from a floppy disk. There is no formal "installation" and no need for an "Un-install": nothing is written to the Windows Registry. The directory in which you store TDT4WIN must contain a file that the program needs in order to run. This is called TDT.ini, and it contains configuration information. The default file that comes with the program contains one line:

```
US
```

which denotes US units (note the capitalization). The program will respond to two words in this file; "US" and "metric". This tells the program what the default units are, and changes several displays you'll interact with.

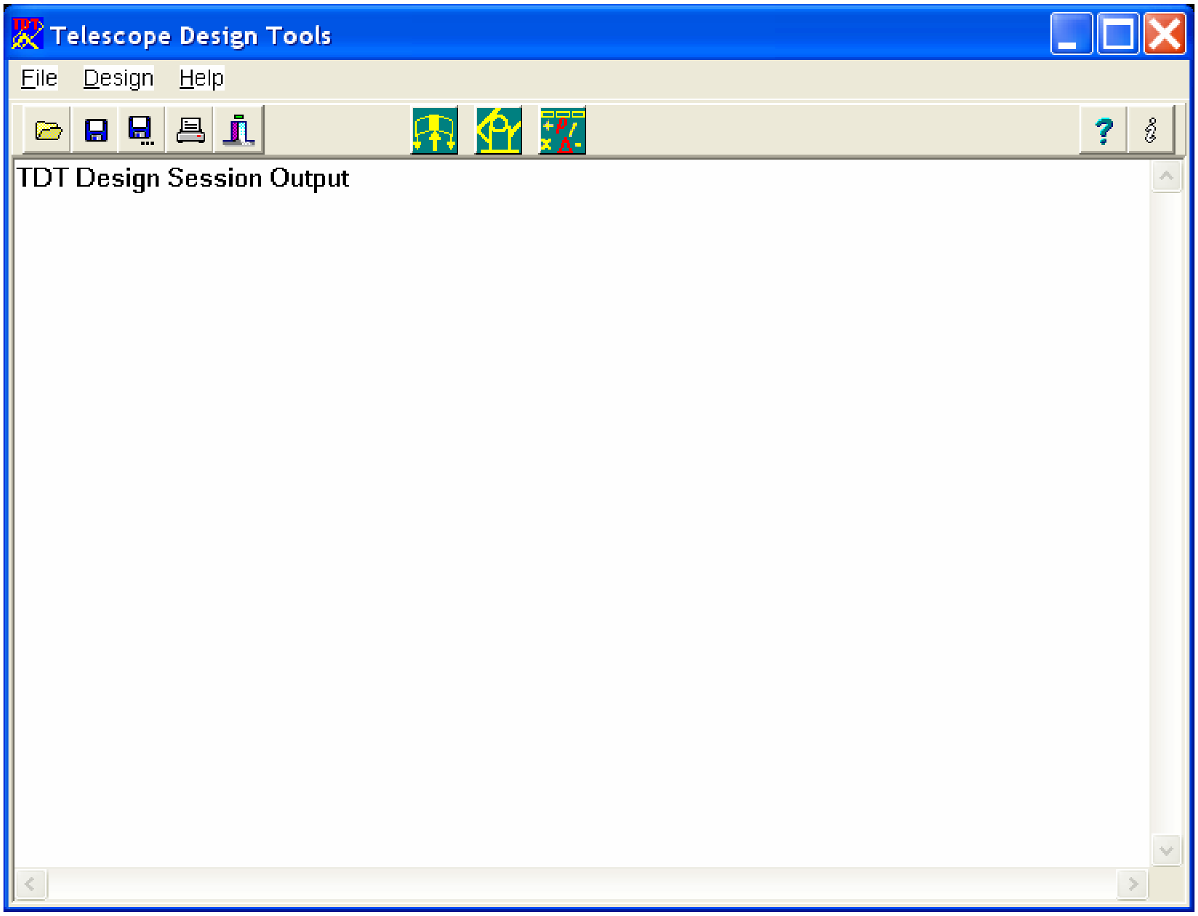
In the event you accidentally loose it, the configuration file can be created or updated using any pure-ASCII editor, such as the Windows Notepad. Note that word processors will add extra characters to the file, unless they can be set for ASCII output. Once TDT4WIN.exe and TDT.ini are in the directory, typing TDT4WIN at the command prompt will start the program.

If the TDT.INI file is not present, the program will run anyway. The default value of US units will be invoked. You will be informed that the file is missing every time you start the program.

Once you have copied the program and the .ini file into the desired directory, you can create a shortcut for it on the desktop, or simply click on its name in Windows Explorer. See your Windows documentation for details if you're unclear how to do this. After all this, you may double-click on the icon for Telescope Design to start the program.

When you start the program, you are at a window with various options available to you. As in all standard Windows programs, type the <F1> key for help. There is an extensive online help system in TDT4Win, including some common values you might need for materials properties. The rest of this appendix is to help you understand what information the program is looking for.

Getting Started



TDT Design Session Output

Figure 1 - Home Screen of TDT4Win

All of the buttons on the row at the top of the main form have "float over" help. If you put the mouse cursor over them and just let it sit a few seconds, a small pop-up window appears telling you what the button does. The three buttons offset toward the center are the three main options in TDT: from left to right these are Tube Oriented Tools, Mount Oriented Tools and the Materials Calculator.

All of the analysis routines write their output to this screen. Once you're done with a design session, you can choose "File-Print" and any Windows printer will print the entire screen buffer. You can have many screens of data in this printout. In fact, your entire design session, from the time you started the program, will be printed out, unless you deliberately delete information from the screen.

This form is also a scratch pad available to you. You can write notes to yourself by simply typing in the form as you would any Windows text editor. You can copy, cut and paste from this form like any other Windows text editor. If you cut text out of the form, it will no longer print (it isn't there anymore, is it?).

Each form that you open will either give you a few choices, with a group of Radio Buttons to click to choose your option. Just like a car radio, if you click one button, you can't click any other. You then choose "Okay" to proceed, or click "Cancel" if you change your mind. All forms that do design calculations have boxes for you to enter numbers. These will accept any form of number, including decimals, and "calculator-style" scientific notation, for example, 1e6 for 1000000.

As with all Windows programs, if you see a letter underlined, as for example, on a "Calculate" button, simply hit the <ALT> key and the underlined letter to activate the button.

Tube Oriented Tools

This is one of three top-level choices for things to do in TDT4Win. It opens a sub-menu that allows you to choose one of the following:

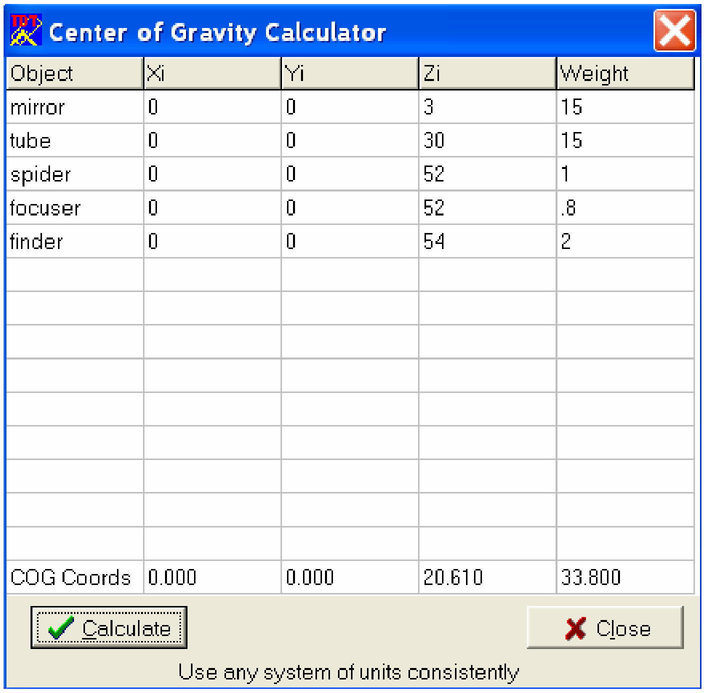
Center of Gravity Spreadsheet
Tube Sag Calculator
Sag in a Simple Truss
Moment of Inertia Calculator

Center of Gravity Calculator

The Center of Gravity Calculator uses the method shown in chapter two for finding the balance point (Center of Gravity or CG) of an assembly by considering it as a collection of homogeneous slices. The module uses a spreadsheet data entry method. The left column, called “Object”, allows you to keep track of the names of the items you enter into the assembly for convenience. In the following three columns, you enter the x, y, and z coordinates of the center of gravity for that part. In the right most column you enter the part's weight.

Much of the time, you will only be concerned about where along the length of a tube the balance point is; in these cases, you should use only one of the three columns. Choose any one column and stick with it. The number that you enter here is the distance from some reference, usually the bottom of the tube, to the center of gravity of the slice. You can track the location of the CG away from the centerline of the tube by entering all three dimensions. This will be handy for equatorials.

The spreadsheet has 14 usable lines. <Tab> moves the active block right and then onto the next row. Alternatively, you may use the arrow keys or the mouse. You edit an entry as you would in any other program; start typing numbers and use the backspace key if you make a mistake. If you start to type in a cell that already has a value, the old value is highlighted in a contrasting color, then cleared and replaced when you type.



Object	Xi	Yi	Zi	Weight
mirror	0	0	3	15
tube	0	0	30	15
spider	0	0	52	1
focuser	0	0	52	.8
finder	0	0	54	2
COG Coords	0.000	0.000	20.610	33.800

Use any system of units consistently

Figure 2 - The Center of Gravity Calculator

Hitting enter has no effect. Use the "Calculate" button to recalculate. If you want to change something, just edit the square you want to change by moving the cursor there with the arrow keys or mouse, and changing the data. If you enter something incorrect, like an extra letter, or hit an extra key while typing in a number, the system's error sound will be used, and the cell changed to "xxxxx". Simply go back to that cell and enter the right number.

It's harder to explain than do. For example, your mirror weighs 12 pounds and its CG is 3" up the tube. You would enter “Mirror” in the left column, use the arrow keys to move to the right to the column you want to use (I use the “z” column because it is closest to the weight column), enter 3 for the distance up the tube, then use the arrow keys to move to the weight column and enter 12. You can also use the left arrow key to wrap around from “Mirror” to the weight column (which is another reason I use the z column). In fact, you don't even need to enter “Mirror”; the calculation doesn't care what you call it, or use the name in any way. It's there for your convenience in keeping track of the things you have entered.

When you hit calculate, the results appear in the last line of the form. They also appear in the main edit menu so that you can print out the results. The results don’t have “pretty” formatting in this window, but the information is there. Here is an example:

```
Telescope Design Tools CG Finder
Item @ X    Y    Z    Wt
mirror  0  0  2  15
spider  0  0  54  1.5
focuser  0  0  54  0.8
tube  0  0  30  15
finder 0  0  58  2
For the Entered Weights and positions, the CG is located at:
CG x = 0.000 in.
CG y = 0.000 in.
CG z = 21.000 in.
Total weight = 34.300 lb.
```

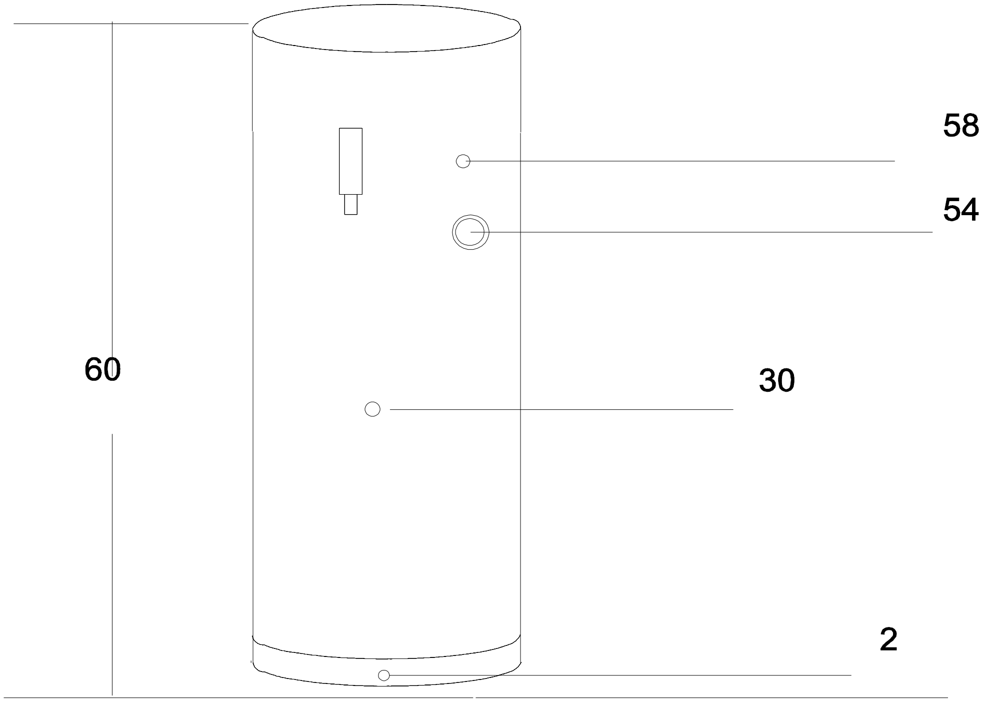


Figure 3 - An example of finding the COG

Figure 3 shows an example of measuring the height of the components as they would be entered for this module. For more discussion of this, see chapter two.

Why are the Blocks so Small?

The result blocks in this spreadsheet are a default five places long. Why? Precision and accuracy. What do these words mean?

Precision and accuracy have pretty similar meanings in everyday conversation, but quite different meanings in science and engineering. The precision of a value is the number of digits in the value that you know. Accuracy is how closely the number you've measured or calculated matches reality. For example, you may say that your tube is 120 1/8 inch long. Is it really 120.125 and not 120.124? It's awfully hard to measure to .001 accuracy over 120 inches. It's hard to measure to .01 accuracy over that length with regular methods. That's five places of precision. I could say the tube is 120.125 inches long and it's really 119.8". I have 6 digits of precision, but, in terms of accuracy, I'm off by almost 3/8 inch. Lots of precision but not much accuracy! For small things, you could possibly have gotten the measurement to .001 accuracy; for larger things, you may get only one or two decimal places.

The program will display answers to three places. This is, therefore, three decimal places of precision. Whether or not that is accurate depends on how accurate your inputs were.

Using the Tube Balancer to Change the Balance Point

One of the more interesting uses for the tube balancer is to find what is required to move the balance point to a desired location. For example, you have entered all of the information on your telescope and find the balance point to be 20 inches up the tube. Unfortunately, you want the balance point to be at the 10 inch point for your mount design.

To re-balance the tube in your shop, you'd add weights to the bottom (really, below the original bottom) of the tube. You do the same thing mathematically in TDT4WIN; enter the values for the weights added and the position of their CG's (centers) with respect to the bottom of the tube, using negative distances for weights placed below the original bottom. The program will calculate the new balance point. You can then move this new balance point by trial and error, adding more weight (or moving the weight farther back), or removing weight (or moving it forward) if you moved the balance point too far back.

Looked at another way, say you have the weights of all the components of the telescope and you want to determine how light the tube must be to put the CG where you'd like it. Simply enter everything you've got and then play with the weight of the tube until the CG of the result moves where you want it. If you need a very light tube, you may know how to do this with fiberglass and foam. If you need a tube with negative weight, well, that either tells you your goals are unrealistic or that you need to put weights below the bottom of the tube.

Moment of Inertia

This routine calculates the Area Moment of Inertia (I) for a variety of common geometric shapes. These include a circular or square solid tube (i.e., not truss), a rectangular beam, a triangle, an elliptical tube, and tapered beam. The value you obtain is used in determining sag and vibration in later modules. If you try to calculate sag in a tube without having a value defined for this, the program will call up this module. All other routines that need a value for this will ask you whether you want to enter a value or if you want to calculate it. If you choose to calculate it (you probably will), it will call this module.

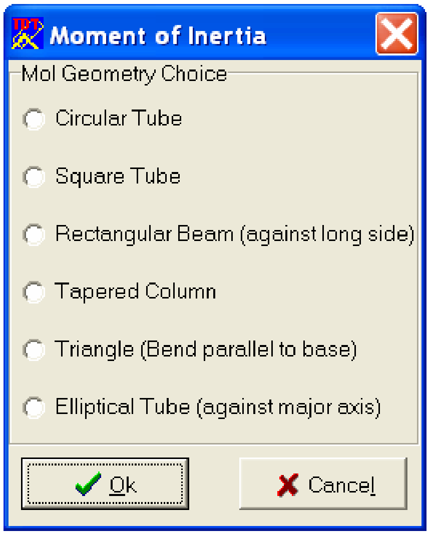


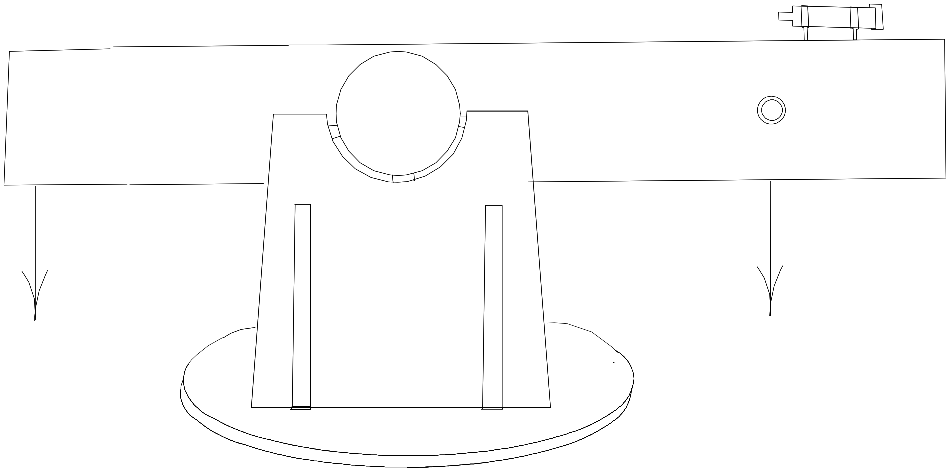
Figure 4 - Moment of Inertia Choices

The neutral axis (the axis about which the bending occurs) is through the center of the round and square tubes. In the rectangular beam, triangular beam, tapered column and elliptical tube it is through the center of the long dimension. The rectangular beam, triangular beam and elliptical tube may be recalculated for bending about the short side by entering the values “backwards”; when it asks for the longer dimension (e.g., the major axis in an ellipse), enter the smaller one.

Calculation routines that need a moment of inertia value will take the value from the last time you calculated it with this form. Alternatively, they will have a button to call this form back again and allow you to set a new value for the MOI.

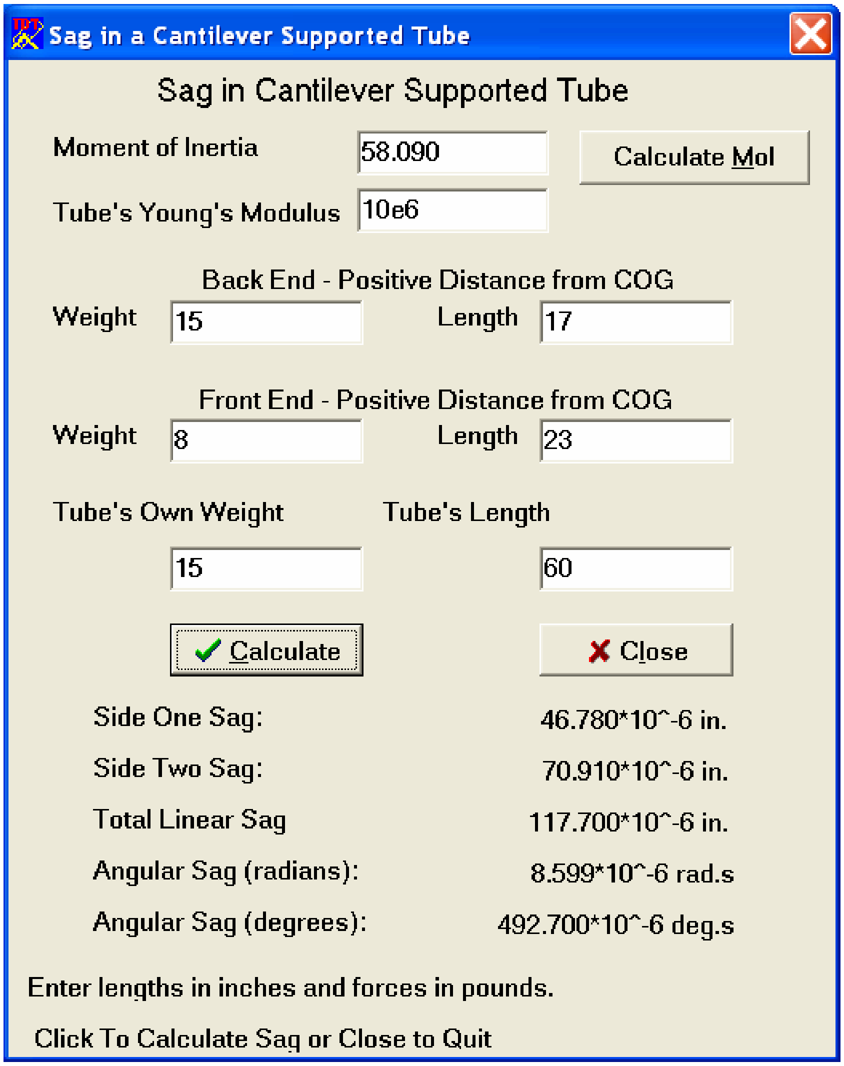
Sag in a Tube

This routine calculates the sag in a tube supported by a cantilever clamped around it at the balance point. The program calculates the sag in both ends of the tube, and adds it to the sag caused by the tube's own weight. It then adds them and shows the results in terms of length units and angular measure (both radian and degrees). The output display includes the units. The addition is valid if the sag is small (a small angle approximation). It doesn't matter how much one end sags if the reflection misses the intended mirror.



The sag is calculated with the full amount of the weight you input applied as a pure bending force, which is the same as having the tube horizontal as seen in figure 2. The program asks you for weight and length for side one and side two; this is just a method for identifying them. I usually call the mirror end (on the left in the figure) side one and the focuser/finder end side two, but that's just habit. The idea is that the clamp divides the tube into two sides, each one loaded by different parts, and you enter them as separate sides.

The form shown in Figure 5 is a sample calculation for a 12” OD aluminum tube, with an inner diameter of 11.825 (.0625 walls). The rear end supports a 15 pound load 17 inches behind the COG and 8 pounds 23 inches in from of it. The tube itself is 60 inches long and weighs 15 pounds.



Sag in Cantilever Supported Tube

Moment of Inertia: 58.090

Tube's Young's Modulus: 10e6

Back End - Positive Distance from COG

Weight: 15 Length: 17

Front End - Positive Distance from COG

Weight: 8 Length: 23

Tube's Own Weight: 15 Tube's Length: 60

Side One Sag: 46.780*10^-6 in.

Side Two Sag: 70.910*10^-6 in.

Total Linear Sag 117.700*10^-6 in.

Angular Sag (radians): 8.599*10^-6 rad.s

Angular Sag (degrees): 492.700*10^-6 deg.s

Enter lengths in inches and forces in pounds.

Click To Calculate Sag or Close to Quit

Figure 5 - Sample Tube Sag Calculation

How much sag is acceptable? That is really an optical question, because the effect of sag is to de-collimate your system. A ray tracing program will tell you this number which varies with the type of optical system, and its characteristics. The programs sold with “Telescope Optics” (Rutten and Van Venrooij) by Willmann-Bell will perform this analysis. In general, the faster the optical system, the less sag is allowed.

In addition, systems with magnifying secondaries, i.e., SCT's, Maksutovs, etc., need to be stiffer than designs with non-magnifying secondaries, such as Newtonians. They are shorter tubes, though, and that makes the stiffness possible.

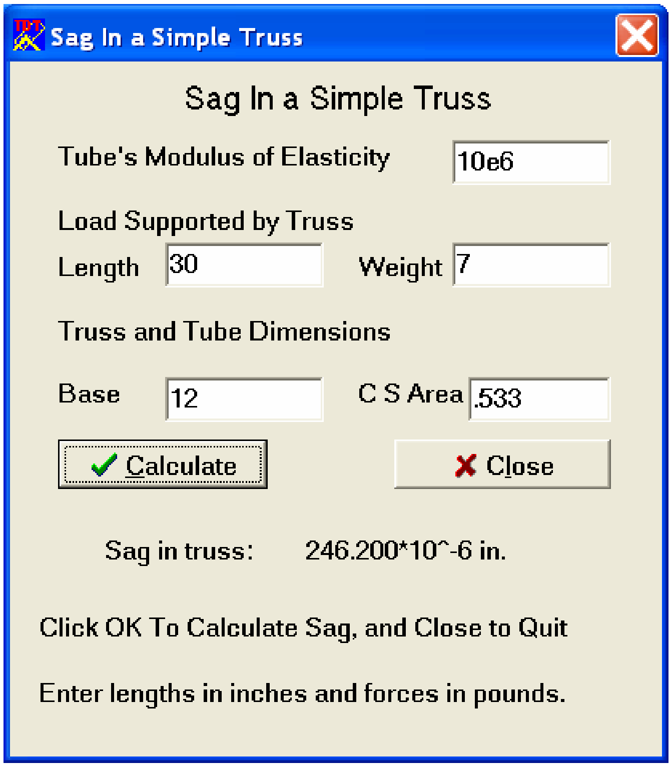
Sag in a Simple Truss

This section is similar to the Sag in a solid tube, but the tube is a simple truss, and the calculation asks for some different data. There are entry fields for the Young's modulus of the truss tubes, the weight of the "eyepiece end" of the telescope, the length of the truss, the cross-sectional area of the tubes (not the diameter or moment of inertia) and the base length of the truss triangles.

The weight you enter is one half of the weight supported, because this method analyzes only one side of the telescope. The other half of the truss supports the other half of the weight. The length will be from the center of the elevation bearing to the CG of the load.

This section uses the method shown at the end of chapter three on tubes. A truss tube can't be handled with the same techniques as a conventional tube. This method uses an approximation to the finite element method that assumes two vertical triangles on the sides of a square box that carry all of the load, and two horizontal triangles on the top and bottom of the square box that contribute almost no strength.

The CSA, or cross sectional area, of the tubing can be obtained from simple calculation, or a table of tubing sizes. *Hint*: There is no "CSA" screen in TDT4Win, but here's a way to calculate CSA in TDT4Win. Go back to the main form and choose the Materials Calculator. For a round tube (the most common truss member) choose "circular tube", and enter 1 for both the length and density! The answer units will be in the weight units you're using (pounds or Newtons), but the numerical value will be the cross sectional area in whatever length units you've used for the data. If you want to use a round rod (like a wooden dowel), just enter zero (0) for the inner diameter. Want to use a square piece of wood? Use the "square tube" settings - everything else is handled the same as for a circular tube.



Sag In a Simple Truss

Sag In a Simple Truss

Tube's Modulus of Elasticity: 10e6

Load Supported by Truss

Length: 30
Weight: 7

Truss and Tube Dimensions

Base: 12
C S Area: .533

Sag in truss: 246.200*10^-6 in.

Click OK To Calculate Sag, and Close to Quit

Enter lengths in inches and forces in pounds.

Figure 6 - Sample Sag in a Simple Truss Calculation

The Mount Oriented Tools

This is one of three top-level choices for things to do in TDT4Win. It opens a sub-menu that allows you to choose one of the following:

Vibration Resonance Calculator
Mount Deformation Calculator
Friction Pad Size Calculator
Bearing Slip Calculation

Vibration Resonance Calculator

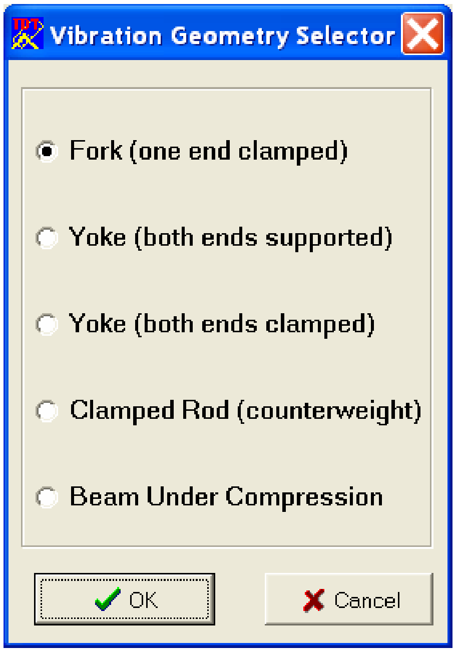
This module will calculate the resonant frequency of various configurations of beams, where “beam” is used to refer to the structural part of any mount, or even a telescope tube. Vibration prediction is a troublesome area and is a complex subject. Nevertheless, these numbers are useful in that they represent numbers that the mount will approach if it is well made.

The resonant frequency is one at which the mount will show some vibrations, no matter how much energy is put into moving it. If you bang it, it will quickly settle down to this frequency; likewise, wind energy can turn into vibration at this frequency. We are not concerned with how big the vibration is because we assume that at some magnification, your telescope will show any vibration. Damping, the measure of how quickly vibration settles out, is not included here. This is very difficult to predict without a lot of detailed information on not only the material used, but also its processing. It is good design practice to use materials in your mount and bearings that help damp out vibration.

These frequencies are not the only ones the mount will display, but can still be very important. If the mount itself displays a high resonant frequency, the mount and telescope may still vibrate due to looseness in the bearings, or components of the optical tube assembly itself.

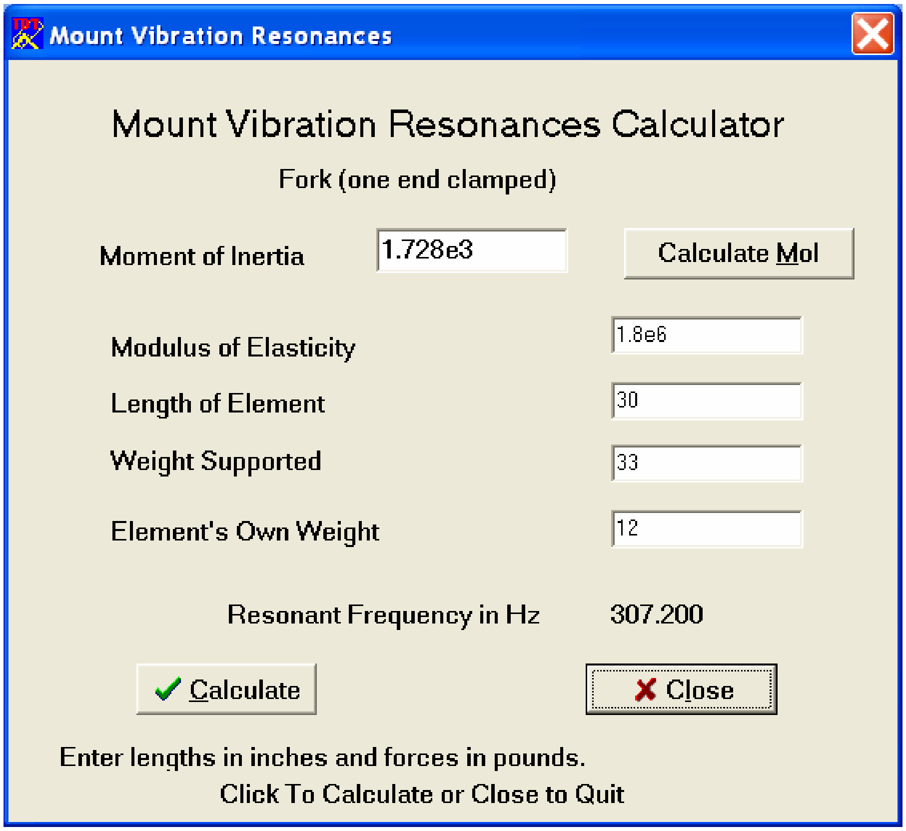
The types of structures that can be analyzed are mount parts such as forks, yokes (supported and clamped), and clamped rods, such as you'll have for the counterweight shaft of a German or Cross Axis design. A telescope may be modeled as a rod clamped in the middle, and the resonant frequency determined for each end.

While the majority of modules are used for determining the frequency for parts of an equatorial mount, they don't figure the effects of the latitude angle. This gives an even worse case result.



● Fork (one end clamped)
○ Yoke (both ends supported)
○ Yoke (both ends clamped)
○ Clamped Rod (counterweight)
○ Beam Under Compression

Figure 7 - Geometry options for resonant frequency calculation.



Mount Vibration Resonances Calculator

Fork (one end clamped)

Moment of Inertia 1.728e3

Modulus of Elasticity 1.8e6

Length of Element 30

Weight Supported 33

Element's Own Weight 12

Resonant Frequency in Hz 307.200

Enter lengths in inches and forces in pounds.

Click To Calculate or Close to Quit

Figure 8 - Sample Screen showing resonant frequency for a large fork arm.

Mount Deformations (Sag)

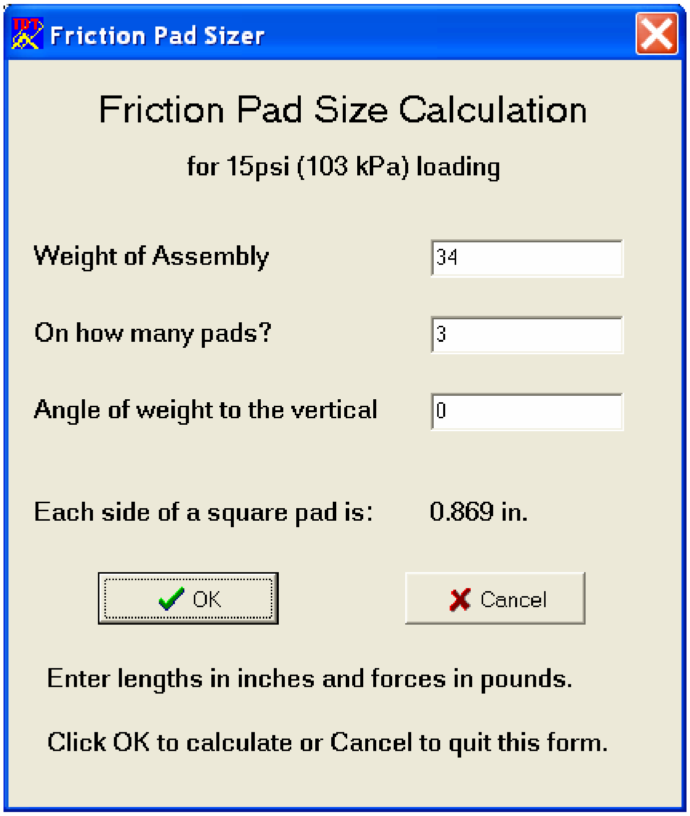
The pieces of a mount can be analyzed to determine the amount that they will deform under load. There are three geometries that may be chosen; an end loaded, cantilevered beam, a center-loaded cantilevered beam, and a center-loaded, simply supported beam. (An end loaded simply-supported beam will flip over!) The module opens by asking you to choose the geometry to analyze. It will then display the geometry chosen while you enter the data.

Although I use the term center loaded here, the load from the telescope can be anywhere along the beam in those two cases. The program will ask for the distance to the closest and farthest bearing, and include the offset in its analysis. Putting the load in the center is not required.

A particular mount may have more than one of these geometries in it, so you may have to go into this module more than once. For example, in a Cross axis mount, you may want to look at the deformation of the axis and the counterweight support. The first is center-loaded, cantilevered, while the second is end-loaded cantilevered. Since these are generally going to be different parts, the value of I you are using is not saved.

Friction Pad Size

This module calculates the size of a friction pad to maintain the recommended optimum 15 psi loading of Formica on Teflon. It will also solve this in SI units, where the number is 103 kPa. Because of this, this module will be used most often in Dobsonian design. You are asked the weight being supported, the number of pads and the angle between the center of the pad and the vertical. For pads under pure compression, as in the azimuth bearing of a Dobsonian, this number is zero. For the elevation (altitude) bearings, this is the angle from the vertical, typically 30 to 45 degrees. Enter this angle in degrees. It will give the size of the pad in inches or meters per side, assuming it to be a square. This module will save its results to the data file.



Friction Pad Size Calculation

for 15psi (103 kPa) loading

Weight of Assembly: 34

On how many pads?: 3

Angle of weight to the vertical: 0

Each side of a square pad is: 0.869 in.

Enter lengths in inches and forces in pounds.

Click OK to calculate or Cancel to quit this form.

Figure 9 - Sample friction pad size calculation for the base of a Dobsonian.

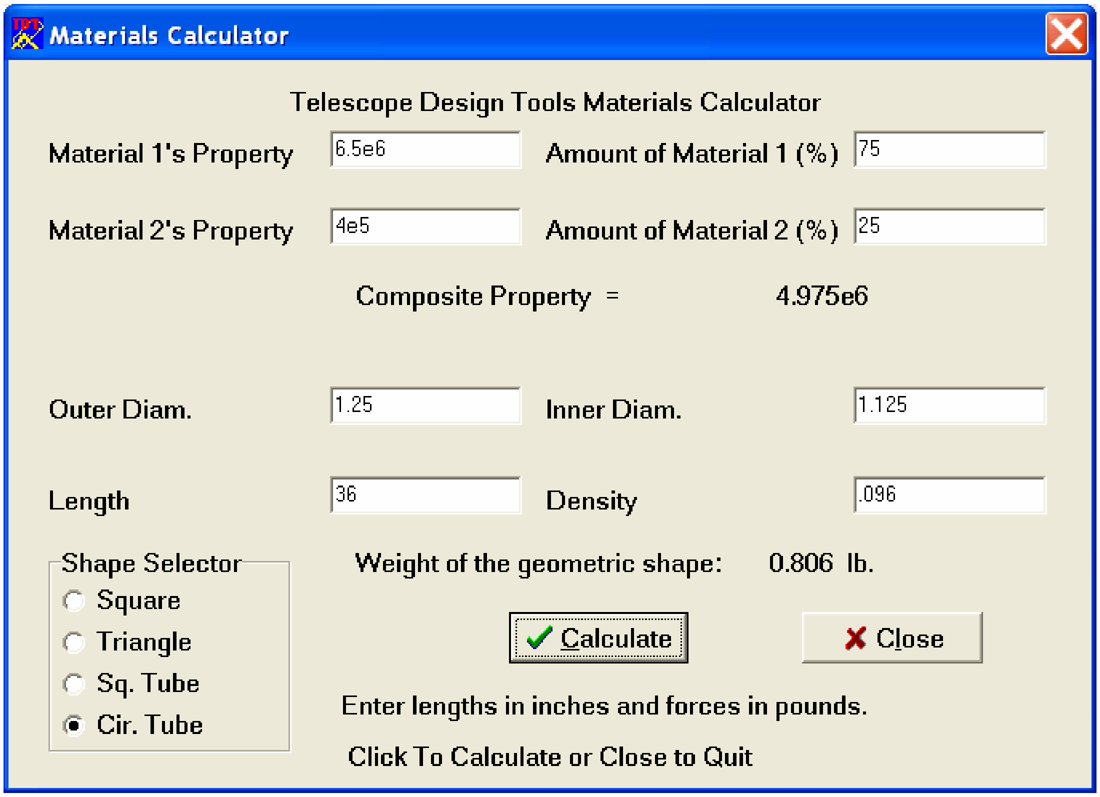
Bearing Slip Force

Another module useful for Dobsonian design, this calculates the force that will be held by friction without slipping. Once the bearings have been chosen, it is worthwhile to determine how much additional force needs to be applied to the end of the tube to cause it to slip. This will tell you the amount of force required to move the telescope while observing an object. It will also tell you, for instance, whether or not the mount will support a large eyepiece, camera, or other instrument out at the eyepiece.

You are asked for the coefficient of friction, the diameter of bearing and the distance from the center of the bearing to the load. Distance to the eyepiece is commonly used. The angle between the vertical and the center of the pads is required for the elevation bearings, which is the most frequently needed calculation. Enter this angle in degrees. The help screen for this module includes a table of commonly needed coefficients of friction. This module will save its results to the data file.

Materials Calculator

The third main choice in the program, the Materials Calculator will perform hand calculator tasks for you. Specifically, it will calculate a rule-of-mixtures solution for density and the strength modulus of composites, and it will compute the weight of a geometric shape based on the dimensions and density that you provide.



Materials Calculator

Telescope Design Tools Materials Calculator

Material 1's Property: 6.5e6
Amount of Material 1 (%): 75
Material 2's Property: 4e5
Amount of Material 2 (%): 25
Composite Property = 4.975e6

Outer Diam.: 1.25
Inner Diam.: 1.125
Length: 36
Density: .096

Shape Selector
○ Square
○ Triangle
○ Sq. Tube
● Cir. Tube

Weight of the geometric shape: 0.806 lb.

Enter lengths in inches and forces in pounds.

Click To Calculate or Close to Quit

Figure 10 - Two sample calculations in the Materials Calculator

In Figure 10 we calculate the elastic modulus of a mixture of 75% Kevlar and 25% epoxy along the top of the form, and the weight of a 36 inch long tube that is 1 ¼ OD with a 1/16 thick wall.

Enter the property and the volume fraction (percentage) where asked. Enter this as a whole number percentage. This input doesn't have to add up to 100%. Although this example is in the context of volume properties, it will work for the area rule of mixtures.

The remainder of the screen is used to compute the weight of a part based on its volume and density. Two lines are used for each type of shape. Due to the nature of the calculations, the proper lines must be used for each shape and no others.

You will notice that this form changes its appearance depending on how it's being used. The labels for the dimension boxes change depending on which button you push in the shape selector in the bottom left. To calculate the weight of a solid bar, enter 0 for the inner dimension. As mentioned above, to calculate the cross sectional area for a tube, enter the dimensions and then “1” and “1” for the second line. The result will still be in pounds but have the numerical value of the CSA.

Units

The equations in the vibration module are unit dependent. In the others, you only need to stay in the same system for any given calculation.

The US option for units uses length in inches and weight in pounds. Since the pound is the real unit of force, enter weights in pounds. The vibration equations require mass, and the true unit of mass in the English system is the slug. Hardly anyone ever uses this, however, using a unit called the pound-mass instead. The conversion for mass to weight is that one pound equals a mass of one slug times an acceleration of 32.12 feet per second per second (ft/sec^2). Since the other dimensions we enter are in inches, we need to convert to inches/sec^2 by using a factor of 385.4. This is built into the vibration equations, so you can just use the module without thinking of this. Remember to watch your units, though; mixing a value for Young's modulus in PSI and lengths in feet will give wrong answers, as will mixing density in pounds per cubic foot and lengths in inches.

The metric option uses the length in meters and weight in Newtons. The Newton (N) is the true metric (SI) unit for force, but, again, conventional use is to refer to mass and weight interchangeably. This is the sort of thing that gives science teachers gray hair. For use in TDT4WIN, use length in meters, and Newtons for force (like weight). Enter the masses in kg in the vibration module. To convert mass to weight, multiply the mass in kilograms (kg) by 9.80 m/sec^2. The unit for Young's modulus is the Pascal (Newtons per square meter). Engineering materials frequently have values of E in GigaPascals, where one giga- anything is equal to 10^9, or one billion of them.

Consistency with units is vitally important and since the program can't tell if you're using mixed units, it is your responsibility to be consistent in your entries. Mixing units, such as an SI value for Young's modulus, but weight and lengths in the US system will give you a nonsense answer.

Designing With TDT4WIN -- Tubes

The OTA is the part of the telescope that has the biggest impact on the system's performance. An OTA should be strong enough to support its required loads without excess deformation. If you are using a tube made from a material for which strength information is available, you only have to design the method of attaching the tube to the mount (usually some sort of clamp box or rings) and decide how much load the tube will support. The sag routine under the Tube Oriented Tools menu will answer any questions about sag.

The distances to the load that are called for should be the distance that is unsupported; from the end of the clamp to the load. The mounting box, of course, does not add to tube deformation because it is centered at the CG. It does add to the weight that the mount sees.

Before you can figure sag, you need to know the CG of the tube because this is where you locate the clamp. The Tube Balancer module will find the CG of any collection of parts you give it. You need to know the weight of the tube before you use this module, and this can be determined by weighing it, or estimated by using the Materials Calculator.

If you are experimenting with a composite material, you can compute its strength properties and density with the Materials Calculator module. This module can then be used to estimate the weight of the composite tube using the density you just calculated.

Mounts

Mounts can be thought of as complex assemblies made from some number of subassemblies, and can be analyzed in a lot of detail. Take for example, the English Yoke mount. Figure 11 shows this mount as it was seen in chapter nine where we analyzed the vibration in the long arms of the yoke. This is the most important place to look, because the longer something is, the lower the resonant frequency can be. But we can go into more detail if we break the mount apart and analyze different pieces of it.

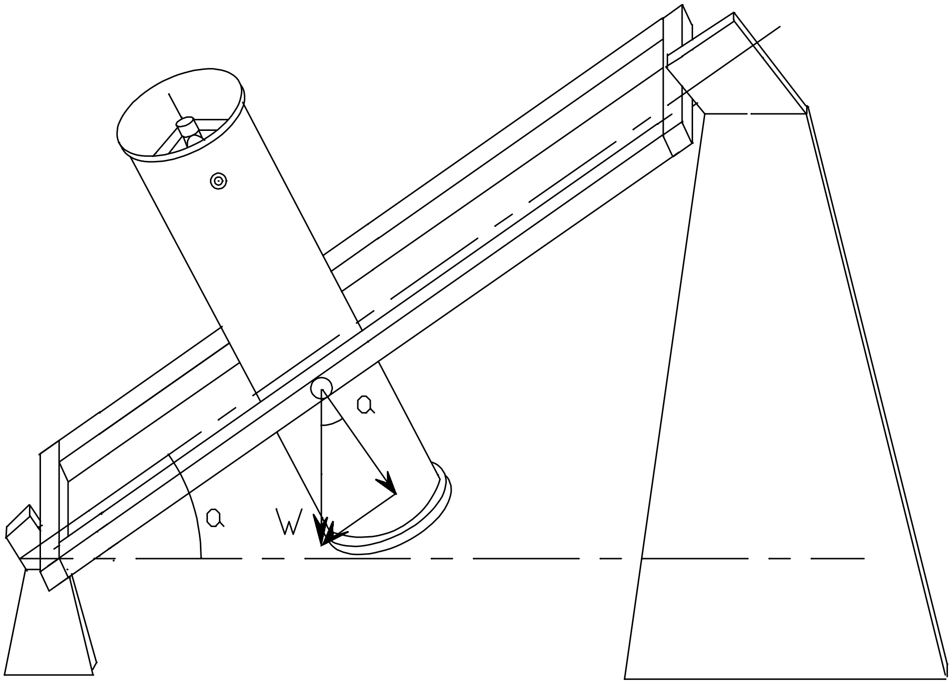


Figure 11 - An English Yoke mount

Beginning our analysis, the cross pieces of the yoke can be thought of as a pair of end-loaded beams, each held in a cantilever support. Each half of the yoke can hold from half to all of the weight of the telescope, depending on how the bearings are implemented, and we can analyze their vibration under those loads with TDT4WIN's Mount Resonance calculations.

Finally, the OTA itself can be analyzed for its vibration contributions. The tube itself, loaded at the ends and held by the clamp at the balance point, is analyzed the same way we analyzed the sag; as an end-loaded, cantilevered beam. Its contribution is typically negligible, but we can extend this analysis to things like the vibration in the spider vanes which are also cantilevered, end-loaded beams.

The pillars holding up the ends can be analyzed in a similar way. If they are part of a structure that extends below ground level, they are cantilevered; otherwise, they are simply supported. We can calculate their resonant frequency using the tapered beam moment of inertia model in the software. These frequencies should be too high to be a concern, but we might want to analyze them to make sure.

A Sample Design Session

Here is an example of using TDT4WIN to design a fiberglass tube and Dobsonian mount. The first thing we do is use the materials calculator to determine the properties of the fiberglass and the weight of the tube. The tube will be 12 inch inside diameter for a 10 inch f6 mirror, and I'll make it solid fiberglass, 1/8 inch thick.

```
   Materials Calculator
Combining 50.000% of 1.2E7 and 50.000% of 4E5 yields a mixture with property of 6.200e6
```

We see the results of the calculations show a Young's modulus of 6.2 x 10^6 PSI, and a density of .0665 PCI. Using this density we find a weight of 9.374 pounds for the circular tube.

```
A Cylindrical Tube with Outer Diameter  12.130 in. , Inner Diameter 12.000 in. , length of 60.000 in.
 and density of 0.067 weighs 9.450 lb.
```

Next, we'll find the balance point of the tube using components available for the design. The primary cell, finder and other components are weighed and a preliminary parts layout drawn up.

```
Telescope Design Tools CG Finder
Item @ X    Y    Z    Wt
tube  0  0  30  9.37
mirror  0  0  3  12
cell  0  0  1.5  2
finder  0  0  50  5
spider/focus  0  0  50  1.5
For the Entered Weights and positions, the CG is located at:
CG x = 0.000 in.
CG y = 0.000 in.
CG z = 21.600 in.
Total weight = 29.870 lb.
```

We find the CG at 21.6 inches from the bottom of the tube. How much sag will our tube give?

```
Sag In a Cantilever Supported Tube

Young's Modulus = 6.200*10^6
 Circular Tube
Moment of Inertia = 43.080 in. ^4
Length on left side = 20.000 in.
Weight on Left side = 15.000 lb.
Length on Right side = 28.000 in.
Weight on Right side = 7.000 lb.
Tube Weight = 9.370 lb.
Tube Length = 60.000 lb.

Left Side Sag = 161.500*10^-6 in.
Right Side Sag = 236.700*10^-6 in.
Total Sag = 398.100*10^-6 in.
Total Angular Sag = 24.420*10^-6 rad.s
Total Angular Sag = 1.399*10^-3 deg.s
```

This sag compares very favorably with the 2 degrees that raytracing says is acceptable for this optical system.

The next thing I'll do is determine how much force is required to make the elevation bearings slip. I'll add a 6 pound clamp assembly to the tube and call the resultant 35 pounds.

```
Friction Bearing Slip Calculator

Force to overcome bearing friction = 0.866 lb.
```

This is in pounds, or 13.9 ounces. I will decide to accept this for now and continue looking at mount parts. First, I'll see what size the elevation bearing's Teflon pads need to be. There’s 35 pounds on 4 pads, so

```
Pad Size = 0.642 in.
```

Now I'll look at the azimuth bearing. Here I need to assume a weight for the tube, clamp box, and rocker box. I think I can build that from 3/4 inch plywood and keep it under 25 pounds, so I'll call the total 60 (35 from the tube and clamp box plus 25 from the rocker box).

```
Pad Size = 1.155 in.
```

Finally, I'll figure out the resonant frequency of the rocker box. There are two boards, 3/4 inch thick by 16 wide loaded by one half of the weight of the tube and the clamp box. They are 15 inches tall and weigh roughly 4 pounds. I enter

```
Modulus of Elasticity = 1.400 * 10^6
Cross sectional area = 12.000
Weight supported 18.000
Member weight = 4.000
Member length = 15.000
```

```
Vibration Calculator

  Vibration Resonant Frequency
In a Solid Beam Under Compression
Resonant Frequency = 752.100 Hz
```

With a frequency of 752 Hz, I decide that vibration from the mount itself is not a concern.

A day or two after doing this, I decide that the CG is too high on the tube, and I'd like to look at a lighter tube. I then go back to the program to figure out what to do. First, I go back to the material calculator. The density of the fiberglass was found before to be .0665 pounds/cu in. Can I reduce this with a foam core?

```
 Combining 16.000% of 0.067 and 3.400% of 0.029 yields a mixture with
property of 11.630e-3

 A Cylindrical Tube with Outer Diameter  12.250 in. , Inner Diameter 12.000
in. , length of 60.000 in.
 and density of 0.012 weighs 3.323 lb.
```

I'll bet the percentages look odd. This tube is 16% fiberglass and 3.4% PVC. That only adds up to 19.4 %; where's the rest? Air in the foam. Where did the 16% come from? I calculated (outside of the program, with a hand calculator) the area of rings of fiberglass from 12.000 to 12.010 and 12.220 to 12.250. These are .188 and .577 square inch, respectively. Then I calculated the area of a the whole tube, from 12.00 to 12.25. This is 4.76 sq.in. The sum of .188 and .577 (.765) is 16% of 4.76. That means the remaining 84% of the area is foam, and only 3 or 4% of the foam is plastic; I used 4% as an estimate. I then used this new density in the bottom of the Materials Calculator to calculate the weight of the tube made of this composite. It weighs 3.32 pounds versus the 9.37 pounds the solid fiberglass tube weighs.

It’s even less obvious that the inner layer of the tube is a .010 inch (10 mil) layer of fiberglass. The foam core is 0.210 inch thick and the outer shell is two layers of the 10 mil fiberglass. These are approximate numbers.

Taking this new tube weight, I recalculated the CG of the tube:

```
Telescope Design Tools CG Finder
Item @ X   Y   Z   Wt
tube  0  0  30  3.32
mirror  0  0  3  12
cell  0  0  1.5  2
finder  0  0  50  5
spider/focus  0  0  50  1.5
For the Entered Weights and positions, the CG is located at:
CG x = 0.000 in.
CG y = 0.000 in.
CG z = 19.460 in.
Total weight = 23.820 lb.
```

The new balance point is only about two inches farther down the tube than before. Clearly, going to the composite has not helped that much (although the lower total weight is nice). Let's try moving the finder onto the clamp box. This removes it from the CG calculation, because we put the tube clamping box at the CG.

```
Telescope Design Tools CG Finder
Item @ X   Y   Z   Wt
tube  0  0  30  3.32
mirror  0  0  3  12
```

```
cell  0  0  1.5  2
moved  0  0  0  0
spider/focus  0  0  50  1.5
For the Entered Weights and positions, the CG is located at:
CG x = 0.000 in.
CG y = 0.000 in.
CG z = 11.350 in.
Total weight = 18.820 lb.
```

The finder still is on the tube cradle, so the mount still has to support it, but moving it there moves the balance point back to 11.35 inches (from the bottom, as always). This will allow me to make the rocker box almost a full foot shorter, although the total weight it supports will be the same since the finder is on the tube box. I might look into a lighter finder (the 5 pound finder is pretty heavy) if I really want it near the top of the tube, a much more convenient place for it to be.

Metric System Use

The first step in using TDT4WIN in the metric system (SI) is the same as using it in the English (US) system: make sure you have all the entries in the right units. Lengths are measured in meters and weights in Newtons. If your vendor supplies the weights in kg (as they do in the US), you need to multiply them by 9.80 to convert kg into Newtons. For example, the mirror vendor I use says his 250 mm mirror weighs 5.44 kg. Then:

05.44 kg ~times ~9.80 {m over sec^2}`=`53.3`N

This is a necessary, though inconvenient, part of preparing to do engineering analysis when companies insist on providing mass and not weight. After a semester or two of college physics, it becomes a deeply ingrained habit to just multiply them without thinking about it. It is very easy to multiply the mass by 10, and you are only off by two percent if you do so.

The following English to SI conversions may help those using SI if they have data in the English system.

1 lb = 4.445 N
1 lb/in^2 = 6891 Pa (N/m^2)

1 lb/in^3 = 271.3 N/m^3