Calculating Enclosure Volume

Accurate enclosure volume calculations are essential for proper subwoofer system design. This tutorial will explain the steps used to calculate the internal volume of a speaker enclosure. Methods of determining an existing enclosure's volume will be discussed as well as methods used to design a box to a given target volume. These steps are applicable for all enclosure types.

The volume equation

To calculate volume, we need to accurately determine three dimensions. The term "cubic" simply means "three dimensional" and is used to express volume in conjunction with well-known linear measures. To illustrate this, we will use simple flat sided cube shapes (like dice). Let's look at a common six-sided die as shown below.

The height, width and depth of this die are all 1 inch. In order to determine the volume of the die we must multiply these three dimensions together.

1" X 1" X 1" = 1 cubic inch

This is often abbreviated as "cu. in." or inch³". Now, let's look at a larger object. In this case, the object is made up of 27 dies, each with a volume of 1 cu. in. Intuitively, we realize that the volume of this object should be 27 cubic inches. Let's check the math...

3" X 3" X 3" = 27 cubic inches

It is surprising how many people will look at this object and mistakenly conclude that it measures 3 cu. in. Doing the math clearly shows otherwise.

Since most enclosure volumes are given in cubic feet, but we calculate their dimensions in inches, we need to know how many cubic inches are in a cubic foot. The picture below shows one cubic foot. By multiplying the height, width and depth together we can find the number of cubic inches in one cubic foot.

12" X 12" X 12" = 1728 cubic inches. There are 1,728 cubic inches in a cubic foot
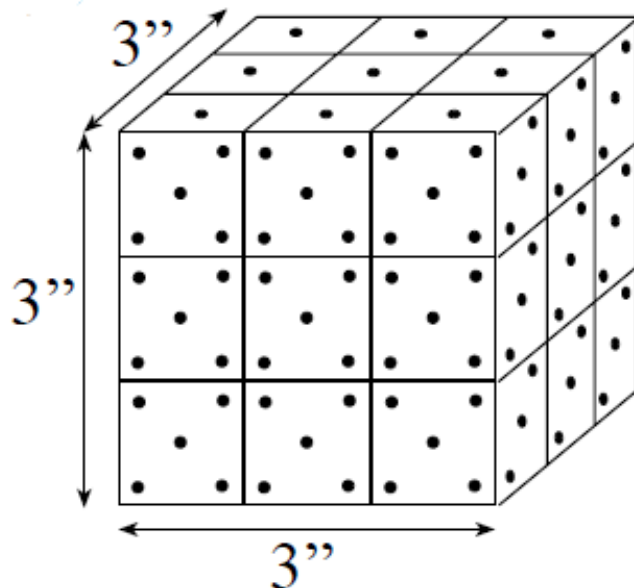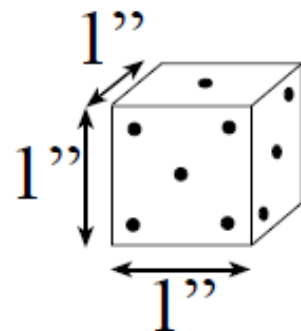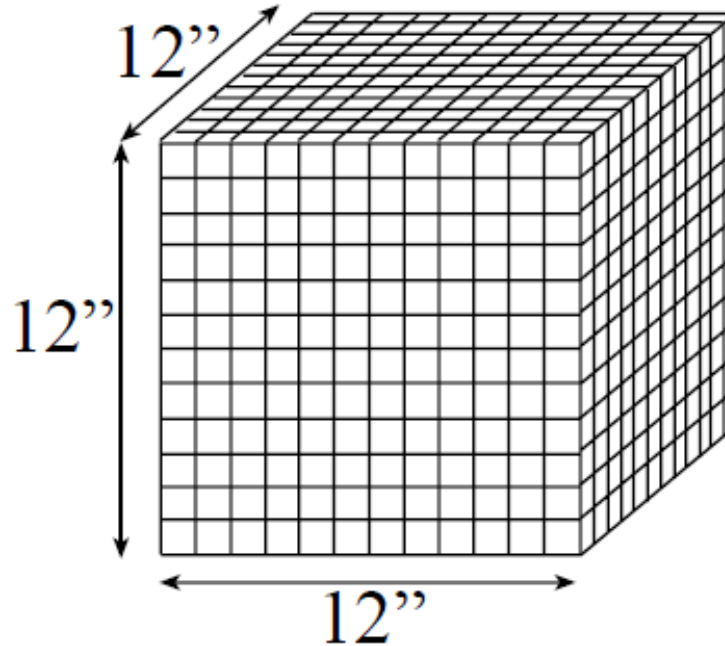
When we multiply three dimensions measured in inches together, the answer is in cubic inches. We also know there are 1,728 cubic inches in one cubic foot. If a volume is known in cubic inches, it can be divided by 1,728 to find the volume in cubic feet. The volume equation, shown here, is used to calculate volume in cubic feet when height, width and depth are measured in inches.

Volume (Cu. Ft.) = Height (in.) X Width (in.) X Depth (in.) / 1728

Calculating Internal Enclosure Volume

To find the internal volume of an enclosure, internal dimensions must be used. Internal dimensions can be found by subtracting the thickness of wall and dividers from an external dimension.

Figure A shows a partially assembled enclosure with an external width of 36"

The thickness of each end panel is 0.75". The internal width can now be found by subtracting the thickness of both end panels from the outside width of the enclosure.
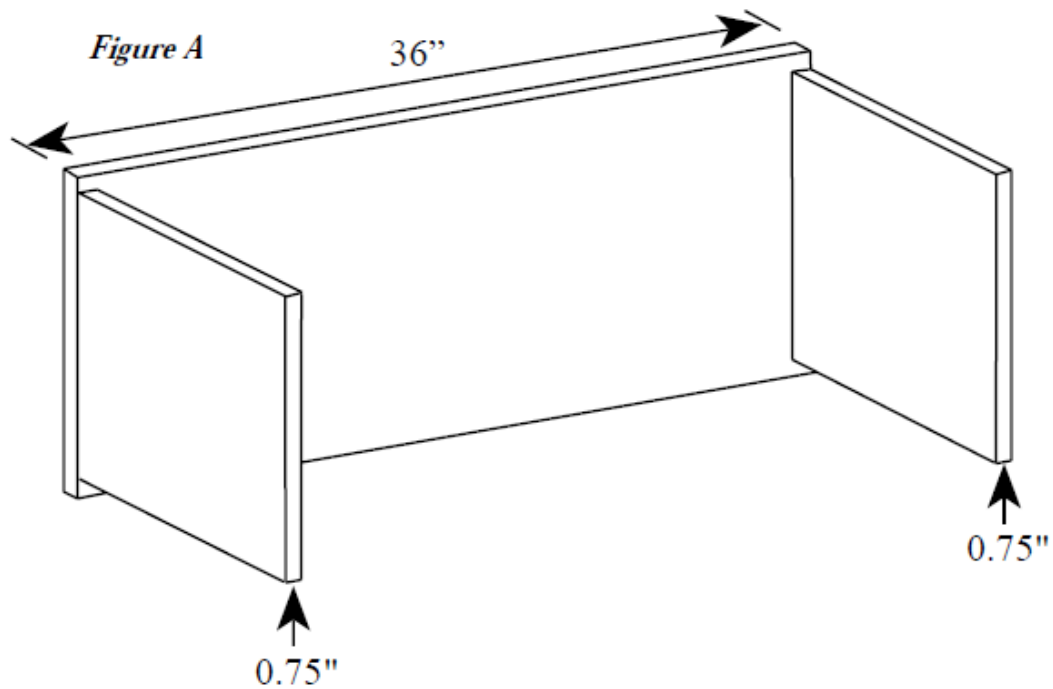
Figure A

Outside Width – End Panel Thickness – End Panel Thickness = Internal Width

36" – 0.75" – 0.75" = 34.5" Internal Width

Figure B shows the external dimensions of the finished enclosure.

Figure B
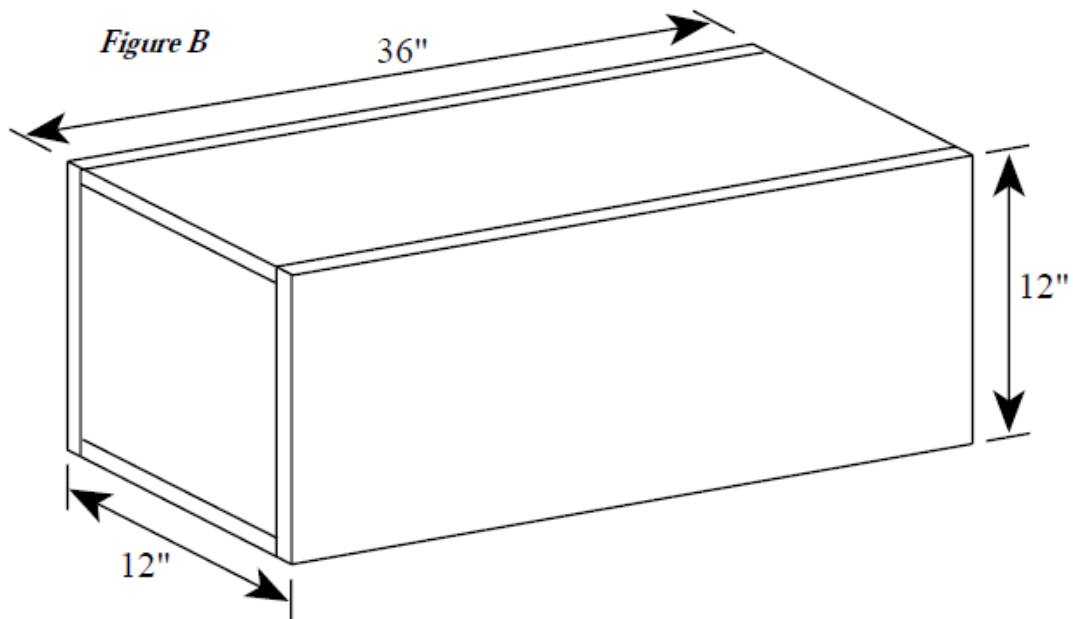
The internal height and internal depth can also be found by subtracting the thickness of walls from the external dimensions. This enclosure is built with 0.75 inch thick material all around.

36" – 0.75" – 0.75" = 34.5" Internal Width
12" – 0.75" – 0.75" = 10.5" Internal Height
12" – 0.75" – 0.75" = 10.5" Internal Height

Now we can calculate the internal volume of the enclosure in Figure B by using the volume equation.

Volume = (10.5" X 34.5" X 10.5") / 1728

Simplify,

Volume = 3803.625 / 1728

Simplify again,

**Volume = 2.2012 Cubic Feet Gross (can be rounded to 2.20 cu. ft.)**

The gross internal volume of this enclosure is 2.20 cubic feet.

Gross volume refers to the total internal volume of the enclosure before the displacement of speakers, ports and other internal structures is taken into account.

Calculating Internal Volume For enclosures With Dividers

The partially assembled enclosure shown in Figure C has the same outside dimensions as the enclosure in Figure B but also has a central divider panel.
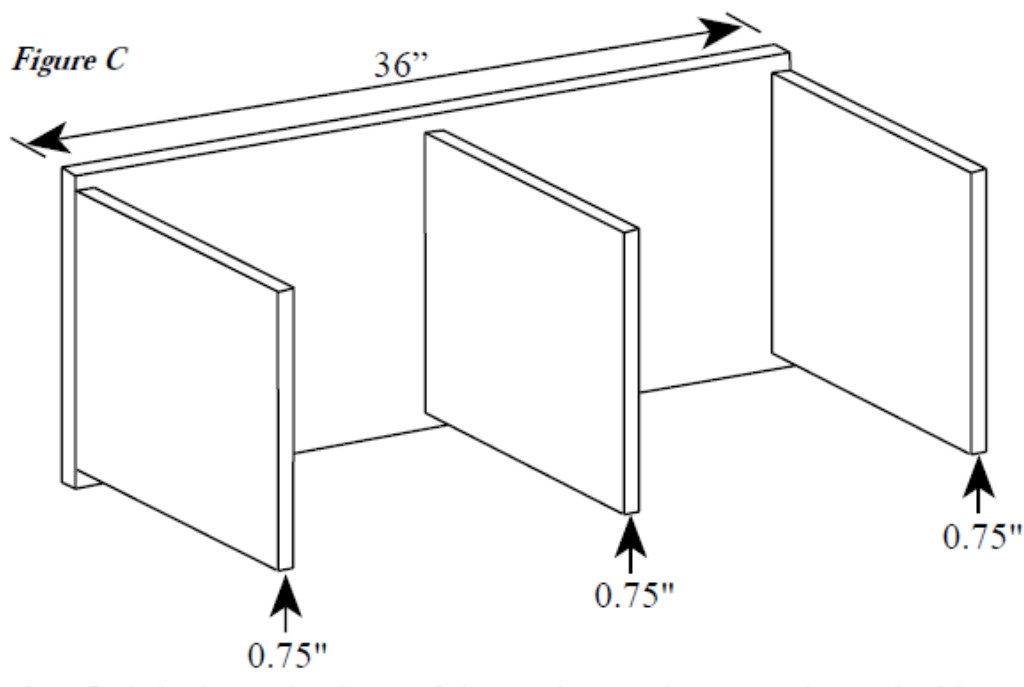
The steps used to find the internal volume of the previous enclosure can be used with one addition; the thickness of the divider must also be subtracted from the external width.

36" – 0.75" - 0.75" – 0.75" = 33.75" Internal Width

We also need to find the internal height and internal depth.

12" – 0.75" – 0.75" = 10.5" Internal Height
12" – 0.75" – 0.75" = 10.5" Internal Depth

Now calculate the gross internal volume of the enclosure in Figure C by using the volume equation.

Volume = (10.5" X 33.75" X 10.5") / 1728

Simplify,

Volume = 3720.94 / 1728

Simplify again,

**Volume = 2.1533 Cubic Feet Gross (can be rounded to 2.15 cu. ft.)**

To determine the volume of each chamber, simply divide the gross volume by the number of chambers.

2.15 / 2 = 1.08 cu. ft. Gross Volume per chamber

Calculating Internal Volume For Wedge-Shaped Enclosures

The enclosure shown in Figure D features and angled surface which results in two different depth measurements, one at the top of the enclosure and one at the bottom. To correctly calculate volume, we simply need to find the average depth of the enclosure by averaging the upper and lower depth measurements.
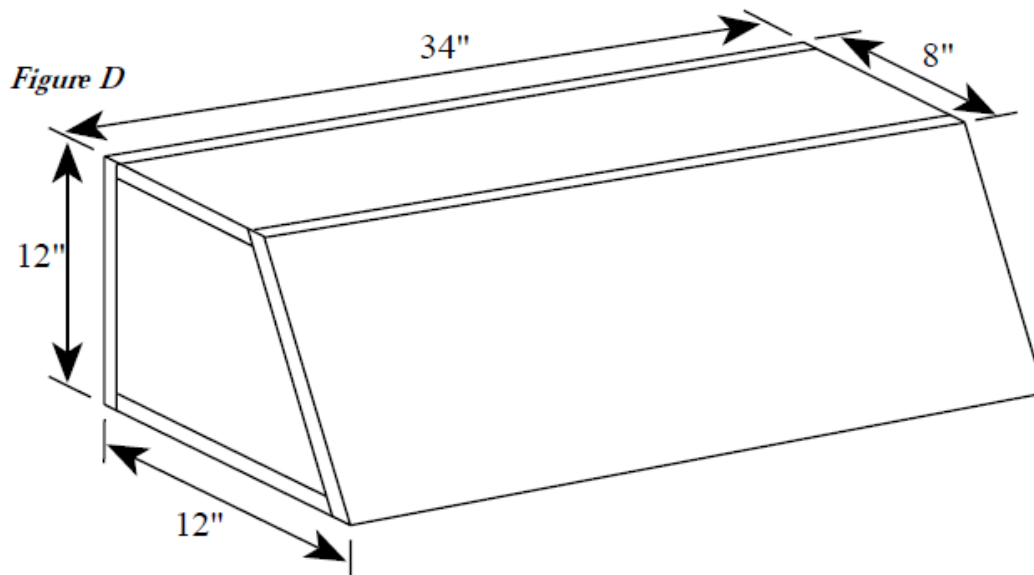
To find the average outside depth, add the "top outside depth" and the "bottom outside depth" and divide the answer, or sum, by two (2).

(8" + 12") / 2 = 10" Average Outside Depth

Next, subtract the front and back panel thickness from this number to arrive at the Average Internal Depth;

10" – 0.75" – 0.75" = 8.5" = Average Internal Depth

We also need to find the internal width and internal height.

34" – 0.75" – 0.75" = 32.5" Internal Width
12' – 0.75" – 0.75" = 10.5" Internal Height

Now calculate the internal volume of the enclosure in Figure D by using the volume equation.

Volume = (10.5" X 32.5" X 8.5") / 1728

Simplify,

Volume = 2900.625 / 1728

Simplify again,

Volume = 1.6786 Cubic Feet Gross Volume (can be rounded to 1.68 cu. ft.)

Calculating Internal Volume For Complex-Shaped Enclosures

The enclosure shown in Figure E features a complex shape which must be broken down into simpler shapes to calculate its volume. In this example, we will separate the enclosure into front and rear sections, calculate the volume of each section and then add the two to arrive at a final gross internal volume.
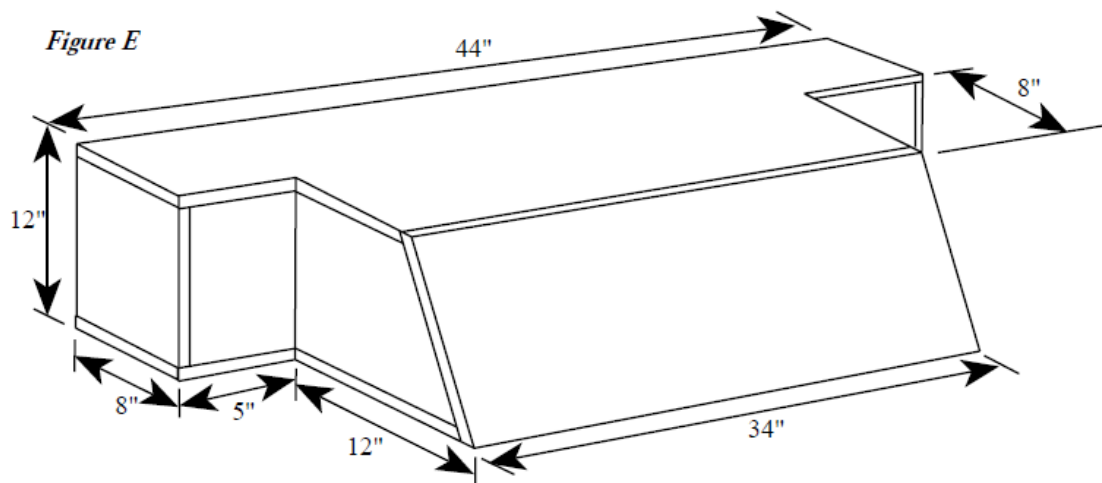
Figure E

In Figure F below, we can see this enclosure split into two sections, labeled A and B. We will determine the volume of each section independently. In this example, all walls are 0.75 inch thick.
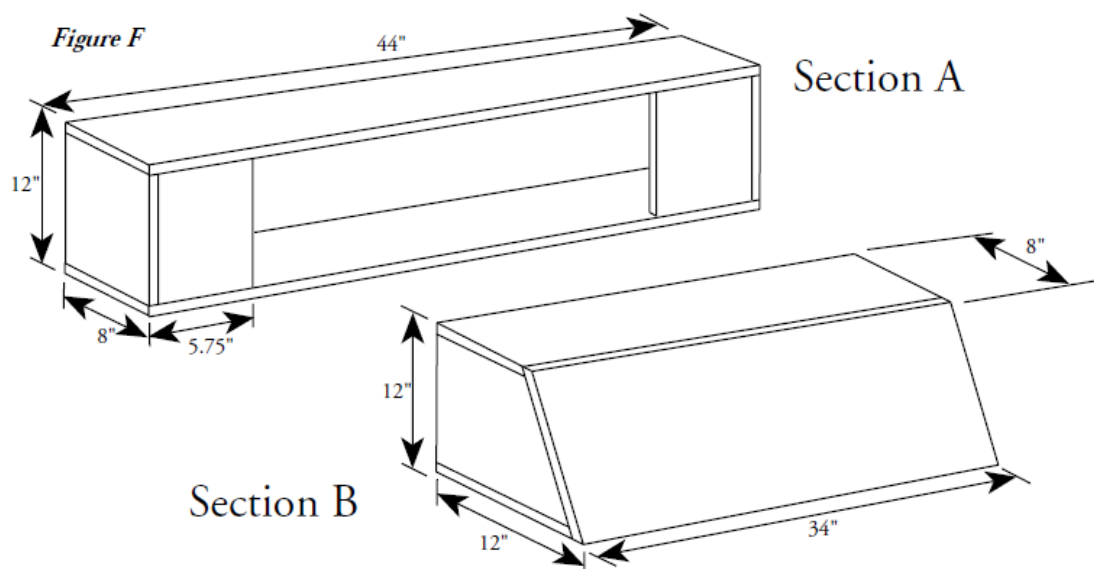

Figure F
Section A
Section B

Figure G shows section A is a simple enclosure with right angle walls. The only added complexity is the calculation of the two short panels on the front plane (labeled Panel 1 and Panel 2). In order to account for these, we will first calculate the box volume as if these panels weren't there, then we will calculate the two panels' displacement and subtract them from the volume figure.

Figure G
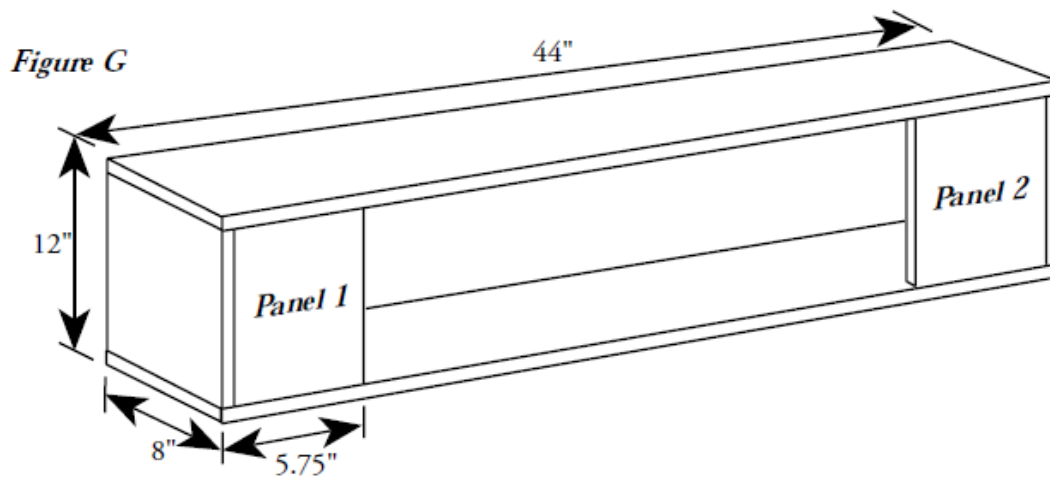
First we will calculate the volume, ignoring the two small panels. To do this, we use the volume formula covered earlier in this tutorial, remembering to use internal dimensions.

Volume (cu.ft.) = Height (in.) X Width (in.) X Width (in.) X Depth (in.) / 1728
Volume (cu.ft.) = (10.5 X 42.5 X 7.25) / 1728

Note that for the depth measurement, we subtract only one wall thickness, since there is only one wall (ignoring the small panels).

Volume (cu.ft.) = 3235.31 / 1728
Volume (cu.ft.) = 1.87

Now, we calculate the displacement of the two small panel, using the volume formula;

Volume (cu.ft.) = (10.5 X 5 X 0.75) / 1728
**Volume (cu.ft.) = 393.75 / 1728**
Volume (cu.ft.) = 0.023 per panel

0.023 X 2 panels = 0.046 (round off to 0.05)

Now, subtract the panel displacement from the calculated volume of this section of the enclosure:

1.87 – 0.05 = 1.82 cu.ft Gross Internal Volume

Next, we will calculate the gross internal volume of the front of the enclosure (Section B) shown below in Figure H. This section has and angled front panel, so we need to average the top and bottom depth dimensions. Also keep in mind that there is no back panel, so we only need to subtract one panel thickness from the depth measurement.

Figure H
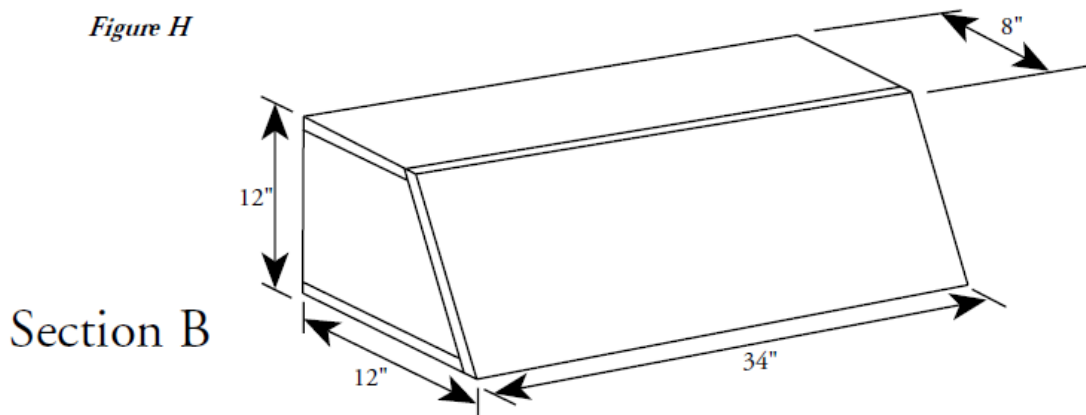
Section B

First, we'll determine the average internal depth of this section:

Top Depth: 8 – 0.075" = 7.25" (only one panel thickness subtracted, there is no back panel)
Bottom Depth: 12" – 0.075" = 11.25" (only one panel thickness subtracted, there is no back panel)
Average Internal Depth: (7.25" + 11.25") / 2 = 9.25"

Now we can combine this average internal depth with the height and width measurements in the standard volume formula:

(10.5" X 32.5" X 9.25") / 1728
3156.56 cu.in. / 1728 = 1.83 cu.ft. Gross Internal Volume

The final step is simple. Add the gross internal volumes of Section A and B to arrive at a total gross internal volume for the complex enclosure:

1.82 cu.ft + 1.83 cu.ft. = 3.65 cu.ft. Total Gross Internal Volume

Calculating Displacement

In the previous sections we have covered how to calculate the gross internal volume of various enclosures. Now we will focus on arriving at net volume (which is the number that really matters). The term "displacement" refers to the fact that any object that occupies space inside the enclosure will take up volume. Because this volume can no longer be considered "air space", it should be subtracted from the gross internal volume to arrive at an accurate net volume figure.
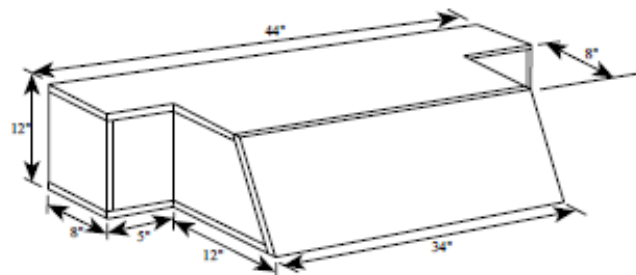
All of the JL Audio recommendations for enclosure size are given as net internal volumes. If you are designing and enclosure based on these figures, you will need to take the displacement of speakers, ports, dividers, braces and any other object that occupies space into account by adding their combined displacements to the net volume figure. This will give you an accurate gross volume target for your enclosure.

Finding a JL Audio speaker's displacement

For JL Audio driver displacement information, go to www.jlaudio.com and click on the *Specifications* tab under each subwoofer and then click the *Physical Specifications* tab. Driver displacement is given in cubic feet and liters.
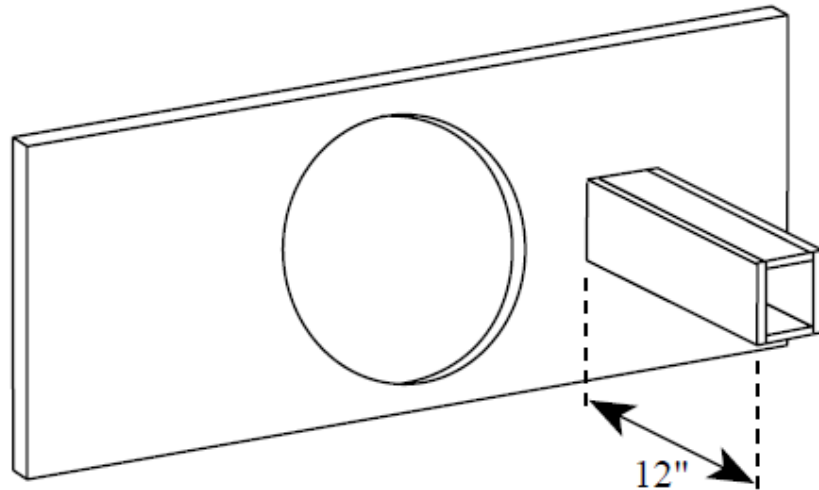
Calculating port displacement

We will look at two different types of ports and how to calculate their displacements. The first type of port is the round port. Round ports can be made from any rigid, cylindrical, hollow object such as PVC pipe. When calculating a round port's displacement, it is necessary to know the port's external diameter and the distance, or length, that the port extends into the enclosure's internal space.
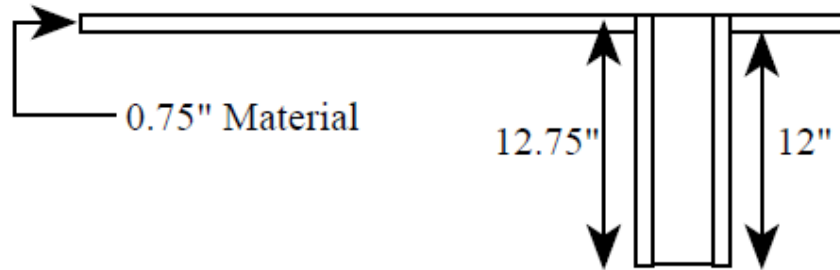
The port shown in Figures I and J extends into the enclosure only 12", even though its total length is 12.75"
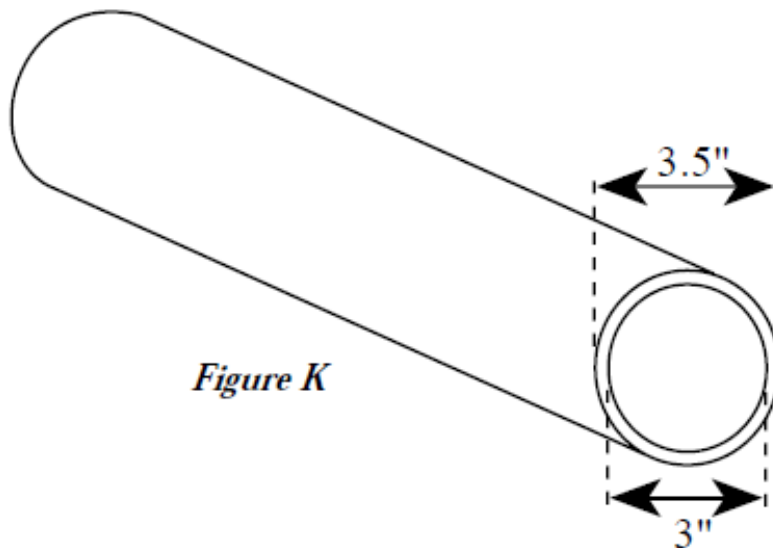
Figure L

Figure M

0.75" Material

12.75"   12"

Note: It is important to understand that the air inside the port is considered part of the port, not part of the enclosure volume. For the purpose of displacement calculations, the port will be considered a solid object, not a hollow one.

Figure K shows that the internal diameter of the port is 3" while the external diameter is 3.5". The external diameter will be used when calculating displacement because the entire port, both the port material and the air inside the port, are occupying enclosure volume.

3.5"

Figure K

3"

To calculate the volume of the port, first we must calculate the area of its circular cross-section. To do this we will use the famous πr^2(Pi X Radius Squared) formula.

Radius is one-half of the diameter as shown in the following equation.

r= 0.5 X d

Plug in the known value of the external diameter (d).

r= 0.5 X 3.5"

Solve for the radius (r).

r= 1.75"

Pi (π) is a constant value of 3.14 (two decimal places is enough for our purposes)
Now that the necessary dimensions are known we can place them into the formula to find the external cross-sectional area of our port tube:

3.14 X 1.75² = External Cross-Sectional Area

Simplify,

3.14 X 3.0625 = 9.61625 square inches External Cross-Sectional Area

To determine the displaced volume of the port, we simply multiply the cross-sectional area by the internal length of the port (which we have already determined as 12" in this example.)

Displaced Volume = 9.61625 X 12 = 115.395 cu.in.

Now, we can convert the volume in cubic inches to cubic feet by dividing by 1,728:

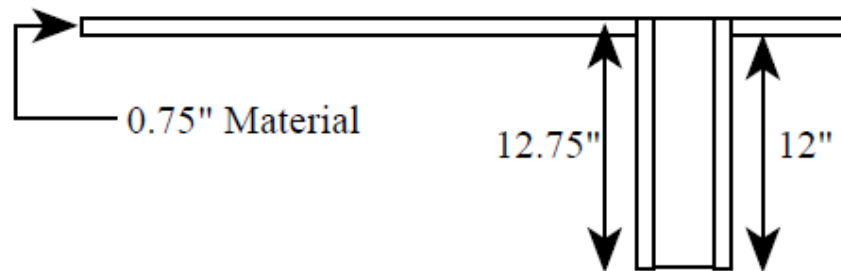**115.395 / 1728 = 0.0668 cu. ft. (can be rounded to 0.07 cu.ft.)**

This gives us our internal port displacement in cubic feet.

Now let's look at a "slot port." Slot ports are typically made from wood and have a square or rectangular opening.The port shown in Figures L and M extends into the enclosure only 12", even though its total length is 12.75"

Figure L

Figure M

0.75" Material

12.75"   12"
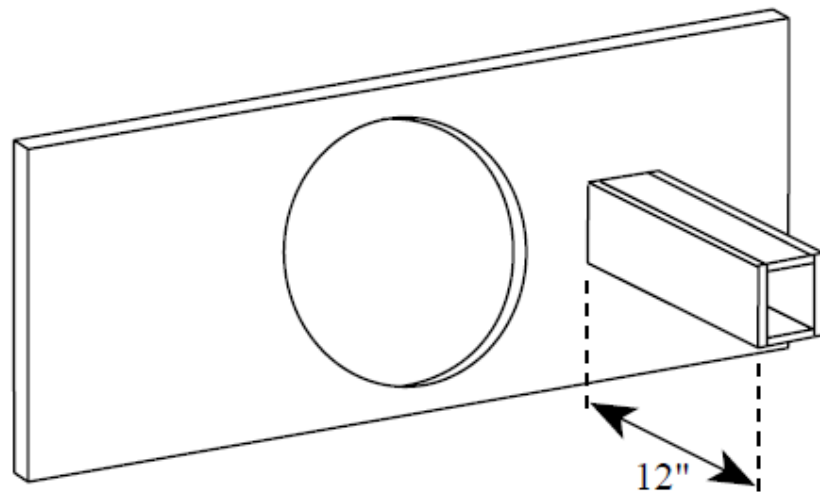
Remember, just like the round port, only use the length that extends into the enclosure when calculating the port's displacement. Figure N shows the internal and external dimensions of the port. The external dimensions will be used when calculating displacement.

Calculating the displacement of a slot port is very similar to calculating enclosure volume. The difference is we are not only concerned with the internal volume of the port, but the total volume of the port, (including its walls) that is inside the enclosure.

4.5"

4.5"   3"

3"

Figure N
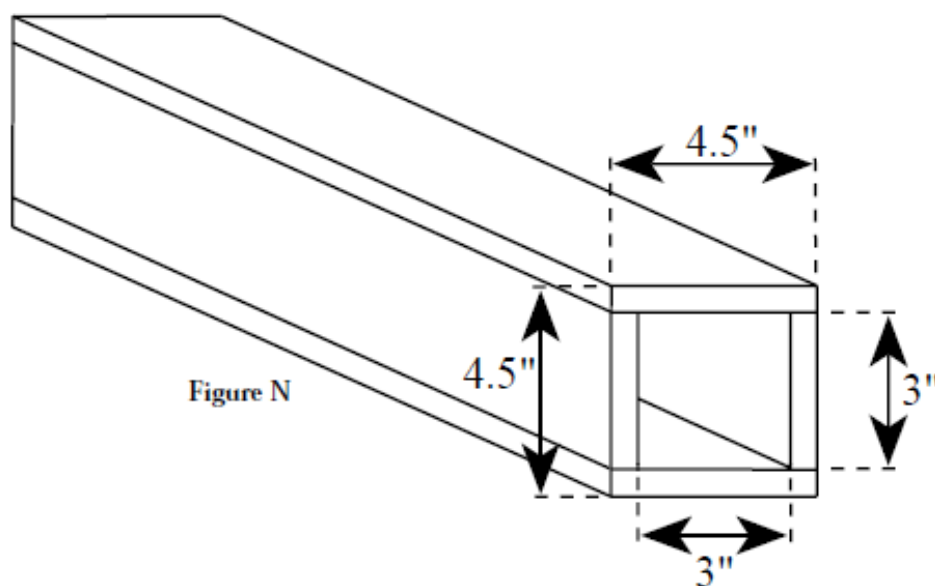
Width = 4.5" Height = 4.5" Depth = 12"

By plugging these dimensions into the standard volume equation we can find the internal displacement of the port in cubic feet.

(4.5" X 4.5" X 12") / 1728 = 0.1406 Cubic Feet (can be rounded to .14 cu.ft.)

**Calculating Enclosure Dimensions From A Known Target Net Volume**

The first step in constructing an enclosure is determining a desired net internal volume. For this example, we'll assume that the enclosure will be sealed and that the desired net volume is 1.00 cubic feet. The displacement of the subwoofer is 0.06 cubic feet. If we add these numbers together we arrive at the total gross internal volume we need for this enclosure.

1.00 + 0.06 = 1.06 cubic Feet

If we were building a ported box, we would also want to add the port displacement to the figure above.

The second step is to find two of the three enclosure dimensions. In most situations, the car's dimensions will dictate two of the three enclosure dimensions. For example, if you want the enclosure to fit within the width of the rear wheel wells, that determines one dimension. If the height is fixed by the rear-deck height of the car, that fixes the second dimension. For our example, we have a fixed height and width as shown in Figure O. Now, we need to calculate the remaining dimension, depth, in order to achieve the target box volume.

The internal width and internal height can be found by subtracting the material thickness (0.75 inch in this example) from our established height and width limits. Remember to subtract material thickness twice for each dimension.

Figure O
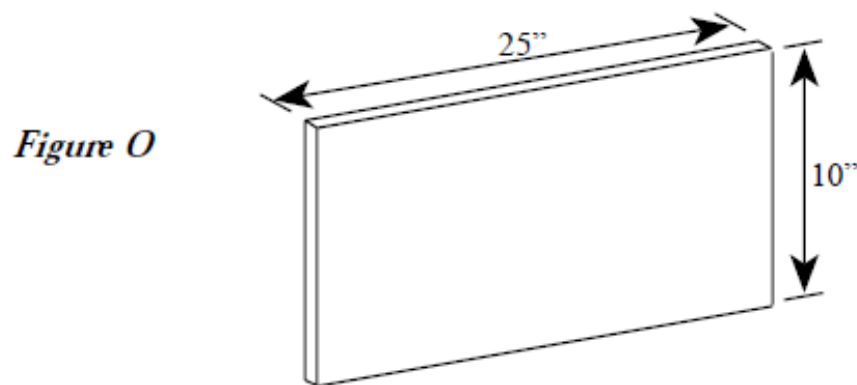
25" – 0.75" – 0.75" = 23.5" Internal Width
10" – 0.75" – 0.75" = 8.5" Internal Height

The next step is to find the number of cubic inches in 1.06 cubic feet, the desired volume of the enclosure. This is done by multiplying 1.06 by 1,728 (the number of cubic inches in a cubic foot).

1.06 X 1728 = 1831.68 Cubic Inches (round off to 1832)

This shows that the enclosure should contain 1832 cubic inches internally. This number can now be divided by one of the two known internal dimensions. Then, that answer should be divided by the other known internal dimension. The answer will be the third internal dimension of the enclosure, in this case, the internal depth.

(1832 / 23.5") / 8.5" = 9.171" Internal Depth

(This can be rounded to the nearest 1/8 inch: 9.125, which is 9 1/8")
The outside depth can be found by adding the thickness of the walls to the internal depth.

9.125" + 0.75" + 0.75" = 10.625" External Depth

Measuring volume in enclosures with irregular walls

Nowadays, many installers are taking advantage of fiberglass and other molding methods to produce enclosures that are form-fitted to a vehicle's contours. Because these enclosures usually have irregular shaped walls, there is no simple measurement method to calculate their volume. The only practical method for finding the internal volume of such an enclosure is commonly referred to as a water test. The volume of the enclosure is determined by pouring known volumes of water into it until the enclosure is full.

A simple method is to use a 1 or 2 liter soft drink bottle and count the number of bottles of water needed to fill the enclosure. For Example: If the enclosure is full after thirty 2 liter bottles of water are poured into it, the enclosure has an internal volume of 60 liters. To convert liters to cubic feet, simply plug the numbers into the following formula:

Volume (liters) / 28.32 = Volume (cubic feet)

60 / 28.32 = 2.12 Cubic Feet

Keep in mind that the enclosure must be entirely built from waterproof materials and must be watertight to conduct a water volume measurement. If the enclosure has wood panels or is not watertight, substitute a finely granulated substance like sand. It is vital that the selected substance is not compressible and has particles small enough to flow freely through the enclosure. Do not use wood shavings, packing peanuts, etc. when conducting this test.

By following all of the methods listed above, you should be able to quickly determine the internal volume of a an enclosure. Proper airspace is vital for proper playback and mechanical reliability of the speaker.