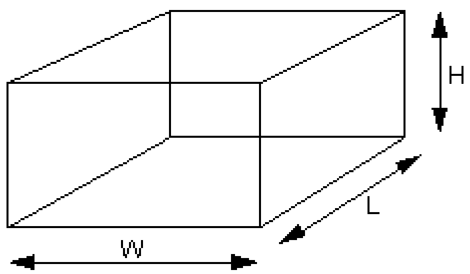
Room Modes

Your basic rectangular room is going to encourage certain frequencies with wavelengths that are equal to the dimensions of the room. While we can take care of perversions such as flutter echo or standing waves with some carefully placed absorptive or diffusive structures, the underlying room shape may still encourage some coloration of the reverberation. This is what's going on:



When a steady tone occurs in the room, the waves will be reflected off the floor and ceiling and arrive back at the source. If the round trip takes exactly one period of the tone, the reflected wave will add to the strength of the new wave, and the amplitude of the tone will be increased. We call this "modal enhancement" and the frequencies at which this occurs are called the modal frequencies or the room modes.

Axial Modes

We can calculate the frequency for this effect when the sound is reflected from the floor to an 8 foot ceiling by using the formula:

$F = s/W$

Where F = frequency, W = wavelength, and s = the speed of sound.

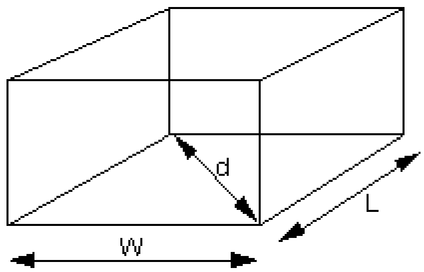
The wavelength is 2H or 16 ft. (Remember, it's a round trip.)

The speed of sound is 1130 ft/second, so the enhanced frequency is 70hz. This is also going to happen at the harmonics of 70hz, 140, 210 and so forth.

The same thing will happen for the length and width of the room. These three simplest paths are called the axial modes.

Tangential Modes

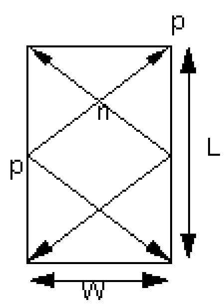
There are other modes, supported by other dimensions of the room. For instance, a mode can get going along the diagonal:



$$d = \sqrt{L^2 + W^2}$$

The wavelength can be figured from the length and width by the Pythagorean theorem. There are three diagonals, each supporting its own frequency and set of harmonics.

There are more tangential modes, such as this one, seen from above:



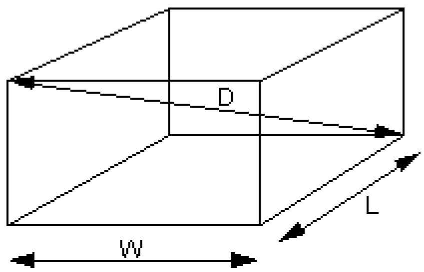
$$pp = \sqrt{\left(\frac{L}{2}\right)^2 + W^2}$$

In this mode, you have two paths that support some standing wave action. At the intersection n both waves come together. They will be exactly in phase, and the experience would be like a standing wave from p to p. The distance pp is calculated from the root of the squares of the width and half the length.

Likewise, there are tangential modes involving one third the length, one half the width, and combinations of the above.

Oblique Modes

The principal oblique mode runs along the grand diagonals from opposite corners such as left top front to right bottom rear.



$$D = \sqrt{L^2 + W^2 + H^2}$$

The diagonal is calculated from Pythagoras as before, but it's three dimensional now. There are more complex oblique modes I won't try to illustrate.

The Grand Formula

For a first approximation, you can get some idea of how a room will behave by calculating the frequencies of the principal modes described. However a complete description can be developed with a computer spreadsheet. To do that, we bring all of the formulas together into one:

$$f = \left(\frac{c}{2}\right)\sqrt{\left(\frac{p}{L}\right)^2 + \left(\frac{q}{W}\right)^2 + \left(\frac{r}{H}\right)^2}$$

We then enter Width, Length, and height of the room, and the speed of sound for c, and solve with values of p, q, and r of

p	q	r
1	0	0
0	1	0
0	0	1
1	1	0
1	0	1
0	1	1
1	1	1
2	0	0

2	1	0

and so on until we have as many values as we have room for, usually for all combinations up to 4,4,4. After we have the frequencies, we sort them and look for clusters of modes and empty regions where there are no modes. Here's an example for a room in my house:

L				15.08	Axial	1
W				9.8	tan	2
H				8.33	ob	3
Mode	P	Q	R	FREQ	TYPE	
1	1	0	0	37.5	1	
2	0	1	0	57.7	1	
3	0	0	1	67.8	1	
4	1	1	0	68.8	2	
5	2	0	0	74.9	1	
6	1	0	1	77.5	2	
7	0	1	1	89.0	2	
8	2	1	0	94.5	2	
9	1	1	1	96.6	3	
10	2	0	1	101.1	2	
11	3	0	0	112.4	1	
12	0	2	0	115.3	1	
13	2	1	1	116.4	3	
14	1	2	0	121.2	2	
15	3	1	0	126.3	2	
16	3	0	1	131.3	2	
17	0	2	1	133.8	2	
18	0	0	2	135.7	1	
19	2	2	0	137.5	2	
20	1	2	1	138.9	3	
21	3	1	1	143.4	3	
22	0	1	2	147.4	2	

23	4	0	0	149.91
24	1	1	2	152.13
25	2	2	1	153.33
26	2	0	2	155.02

From 90hz up, this room is relatively smooth, but there's a hole in the support between 77 and 89 hz with a cluster just under 70. The absorption already in the room is not very effective below 100 hz, so the lack of modal support down there is somewhat compensated. But those 68hz notes really boom out, so I'm going to have to find something absorptive at that frequency.

Since the two modes involved are the 0,0,1 (vertical) and 1,1,0 (tangential parallel to the floor) I can see that both ceiling and corners need treatment. Ceiling treatment will also reduce the 77 hz bump if I take it to the corners.

Mode calculations are most useful when you are building of course- you run the numbers on a blueprint and move walls if potential trouble appears. In an existing room, the chart helps you decide where to put absorptive materials- if you know a problem is on a tangential mode, you can put stuff in the corners, or if the vertical axial mode is the culprit, you can get thicker carpet.

Source: http://www.co-bw.com/Audio_Modes.htm