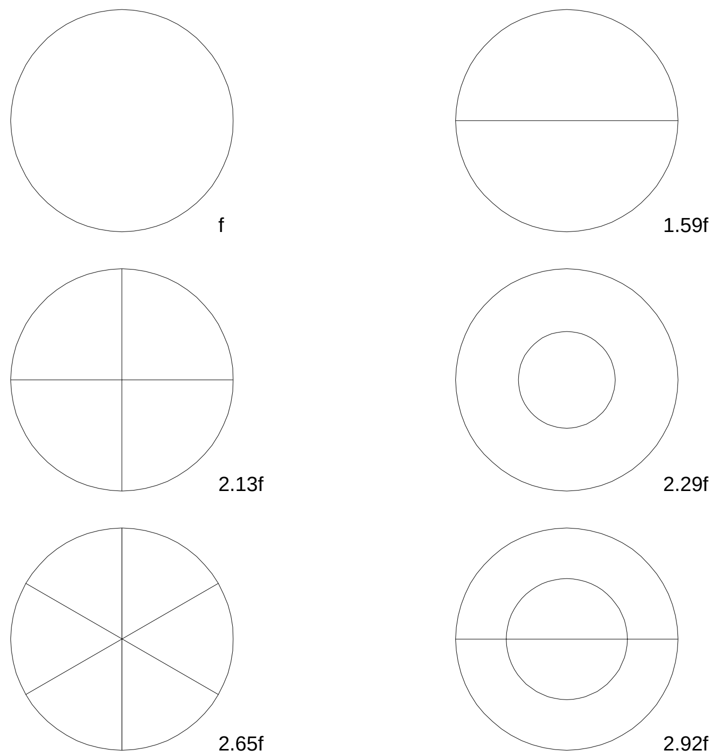
Physics of Music
Physics 341
Assignment 2

1) Figure 1 shows the nodes of the first 6 distinct modes of a drum head with their frequencies compared to that of the lowest mode. (The modes are numbered according to frequency, from the lowest frequency to the highest) Where would you lightly rest your finger(s) to damp out the second mode but not the third . Where to damp out the second and first but not the fourth.



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The lines in the figures are the nodes of the various modes of the drum head. To not damp out a mode by placing your finger lightly, you must place it on a node of that mode. To damp out a mode, you need to put your finger at a place which is NOT a node. The first mode has nodes only at the edge where the drum is attached to its frame. Thus placing your finger anywhere (but on the edges) will damp out that mode.

To damp out the second, you must place your finger not along a diagonal of the drum head. (In the question, the only node is the horizontal diagonal. In actual fact, there are other modes, equivalent to this second mode, which have nodes along any diagonal, but for the purpose of this question, we only concern ourselves with the horizontal diagonal.) The fourth mode has a circular node. Thus to damp out the second but not the fourth, you need to have your finger on that circle but not the diagonal (again, in actuality since the diagonal could be anywhere through the center, one would need to use two fingers, both on the circle. There is no second mode with nodes along two diagonals, so the two fingers on the circle would damp out the second mode (as long as they were not diagonally opposite each other) but not the fourth.)

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2) A uniform pipe is open at both ends. Where would you drill a small hole to damp out the first mode, but not the second. (For a small hole, the difference in pressure in the pipe vs outside forces air through the small hole with a lot of friction.)

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If this small hole is not to affect the second mode, it must be placed at a point where that second mode has a node in the pressure, but the first mode does not. At a hole the pressure in the tube would force air in and out of the hole, with the friction with the edges of the hole damping the motion. The second mode has a node in the center of the pipe, while the first one does not, so that small hole should be placed in the middle of the pipe.

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Where would you insert a piece of gauze into the pipe to damp out the second but not the third mode? (How would the guaze work in damping?)

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In this case the gauze would affect air which moves past the guaze– ie if the velocity of the air at that point were such that the air would have to move back and forth past the gauze the air would rub against the gauze and loose energy doing so. . Thus in order to damp out the second mode but not the third, the second mode have to have non-zero velocity at the gauze , while the velocity of the third mode has a node in the velocity there. The second has modes at the 1/4 and 3/4 points along the pipe while the third has nodes at the 1/6, 1/2 and 5/6 points. Thus to damp out the second but not the third, any of the points 1/6. 1/2 or 5/6 along the length would do, since at all of these points the second mode does not have nodes. However, at the 1/2 point the second mode's velocity is at a maximum which means that this would be the most effective place to place the gauze.

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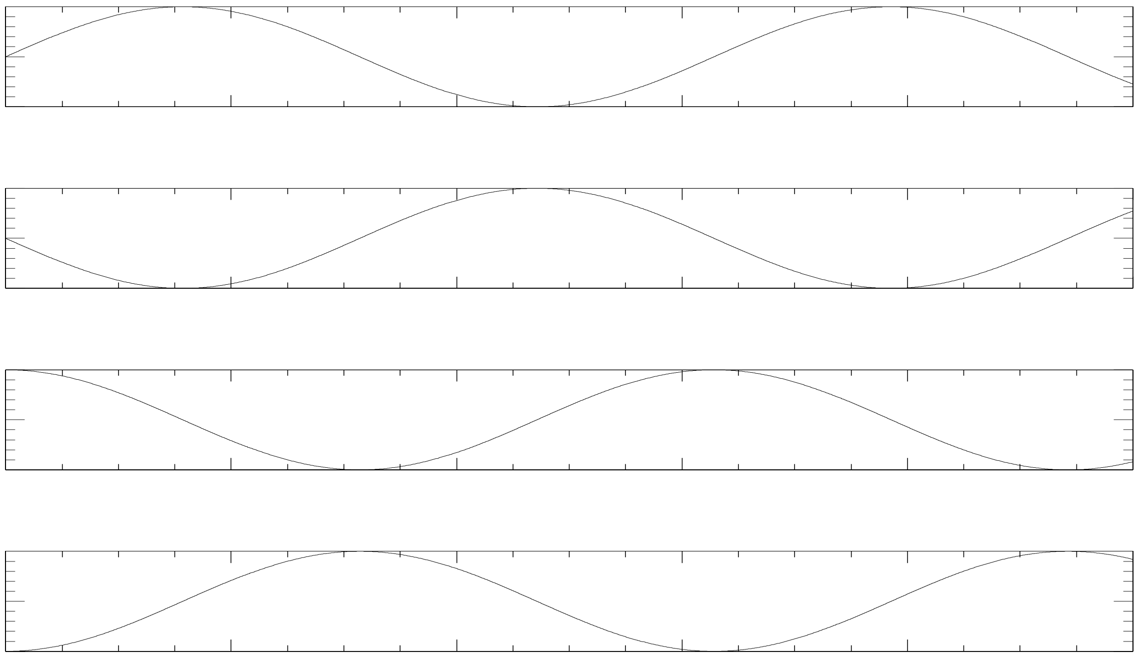
3) In the following set of four graphs, what is the phase shift of each of the graphs 2, 3, and 4 with respect to the graph 1? (Numbering starts from the top graph down)



The phase shift is by what fraction of a cycle (multiplied by 360 degrees) one wave is shifted with respect tot he other. If the shift is toward the future, (one wave "starts" after the other– ie has its maximum for example to the future– the shift is usually called positive.)

Thus wave 2 is half a cycle, or 180 degrees– whtehr to the future or to the past is of course ambiguous. So it could be +180 or -180. The third is 1/4 or 90 and starts earlier– ie it is -90 degrees of +270 degrees. The last one is 90 degrees into the future so is +90 (or it could also be called -270 degrees)

4) The statement has been made (in many undergraduate physics text books) that the Tacoma Narrows bridge fell in 1940 due to resonance. The bridge, built just south of Seattle in the late '30s fell in a wind storm (40 mph winds), and its amplitude of vibration was over 100 times its amplitude in lower winds (the bridge deck tilted back and forth by over 40 degrees from the horizontal). See the web film at http://www.civeng.carleton.ca/Exhibits/Tacoma_Narrows/ Do you find this explanation convincing? Why (or why not)? (Hints: What would the Q of the bridge have to be got it to have such a large response? What would the frequency of pushing of the wind on the bridge have to be in order that the brige oscillated with such a large amplitude?)

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The explanation of the collapse of the Tacoma Narrows bridge as due to resonance is one of the prime examples of a false physics explanation. Unfortunately this explanation was standard in most physics text books and is still often taught to students both in physics and engineering. (I have had to talk to my collegues here about it.) This bridge which collapsed in the fall of 1939 a few months after it opened, shook itself to pieces one morning when the wind increased to about 40 mph. For this to have been a resonance, and since there was a huge response of the bridge, that bridge must have had a very high Q, for the bridge to begun to vibrate so wildly (the amplitude of oscillation– about a 45 degree twisting from side to side) was many hundreds of times larger than normal. Thus the Q would have had to be in the hundreds (since the excess amplitude is proportional to the Q). But this also means that the external oscillating pushing on the bridge must have been tuned exactly to the frequency of the bridge to better than one part in hundreds, since a resonance only responds a lot if the tuning of the external force is very close to the resonant frequency – the higher the Q the closer it has to be.

Since the external force in this case was the wind, the wind would have had to have an oscillating part (eg gusts) which oscillated at exactly the same frequency as the bridge did, to better than one part in hundreds. No wind ever behaves that way. No gusts occur with such regularity. No wind ever maintains its speed to better than one part in hundreds. This explanation is silly, despite the fact that many physics text books say this is the explanation. (A better explanation is that the bridge behaves like a clarinet, which also has the feature that a steady blowing by the player causes a huge vibration– we will be looking at why later in the course).

There is a paper by D Green and myself which analyses the Tacoma Narrows bridge. www.arxive.org/abs/physics/0408101

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During the oscillation phase before the breakup, where are the nodes of oscillation?

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The nodes are places where the bridge is not moving (or is moving much less than at other places). Looking at the film from the side, the center of length of the bridge does not mode, while on either side it tilts back and forth a lot. So there is one node which crosses the bridge at the center of the length of the bridge. Similarly looking at the bridge along its length, the center of the bridge is not moving. We can see that looking at the man walking along the bridge along the centerline. (The reporter who escaped the car tried to go along the sidewalk and could not stand up. He finally crawled all the way to the end of the bridge on his hands and knees while the bridge bucked under him).

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5) A small lump of tape is placed on a guitar string exactly at a point 1/2 of the length from the end of the string. What effect would this have on the frequencies of the various modes of the string? (Consider the lowest 4 modes).

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The piece of tape has mass, but does not alter the stiffness of the string (tape is very pliable). Since it is the moving mass which alters the frequency of the string, if that tape is not moving, it does not affect the frequency.

The modes of the string which have a node is located at a distance of 1/4 from the end is the 2nd (and the 4th, 6th, 8th,...) Thus these modes will be unaffected. The mass does not move for these modes and thus the tape does not contribute to the moving mass. For any of the other modes (1,3,5,...), this point of the string moves. The tape thus increases the moving mass of those modes, lowering their frequencies. The tape does nothing to the tension in the string and thus does not change the stiffness. For the odd mode, this point is an antinode (maximum motin) so the tape will have a large effect for all the odd modes.