

Section: Monday / Tuesday
(circle one)

Name: _____
Partners: _____

/29 pts

PHYSICS 107 LAB #6: SINGING IN THE SHOWER, SINGING IN THE CHAPEL: ROOM ACOUSTICS

Equipment: computer, headphones, audio splitters, Odeon Program, LoggerPro software, LabPros **with batteries** (take out over night), SIL Meter. Computer logged in as administrator / physics (Odeon doesn't work well in other account on XP machines)

OBJECTIVES

- Understand reverberant sound and reverberation time.
- Understand how the size, geometry and materials in a space affect the behavior of sound

INTRODUCTION

Have you ever wondered what makes the church choir sound so powerful in the chapel? Or what exactly makes your shower so great for singing? In this lab you'll explore the various aspects of room acoustics, determining how the geometry and the materials of a given room affect sounds as they propagate through it. You'll listen to audio simulations of sounds in different spaces and *hear* the differences for yourself; you'll run a visual/computational simulation to *see* how sound interacts with the different spaces; you'll go out and *measure* the acoustics of different spaces on campus.

Physically, room acoustics depends on the size of a space, which determines how far sound travels between reflection, and on the materials of the space, which determines how severely different frequencies of the sound are adsorbed upon reflection. As simple as those ingredients are, combined differently, they can give different spaces very distinct audio qualities, effecting a sounds clarity (are sounds distinct or muddled), envelopment (does the sound all seem to come from the source, or does it come from all around), smoothness (do you hear discrete echoes or just single extended sounds), reverberation (does the sound get reinforced and extended or is it dead like you're listening outside.) While it's hard to get too quantitative about any of these, one quality that's easily measured is a sound's duration. This is quantified in its *reverberation time* – the time required for the sound to drop 60dB below its original intensity level.

Visual and Audio Simulation

You will use a computer to model spaces that are similar to those in the previous activity. You'll be able to see how sound moves through the spaces and reverberation times will be calculated. In this activity, you'll use a computer to model different spaces and both visualize how sound propagates through them and listen to sounds that have been processed as if heard in these spaces.

Could add in a simple "Articulation test" (p. 186 of "The Taylor Manual" of experiments or at <http://arch373.wikispaces.com/Sound+Off>) for each space chosen and a

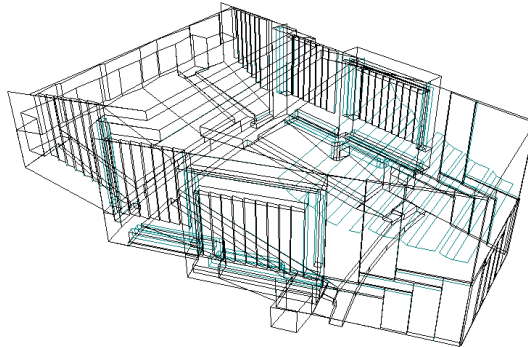
Simulation Background.


In Odeon, a sharp sound, like that of a single clap, is represented as a shell of balls flying out from the sound source. When they strike surfaces (floors, walls, ceilings, etc.) the ‘sound balls’ reflect in the appropriate directions and weaken (represented by a change in color.) In a well designed listening environment, sound uniformly fills the space – there are no locations that the sound misses or focuses into. Conversely, domes are famous for focusing sounds from specific source locations into specific listening locations (with intriguing consequences when their parts of governmental buildings.) In addition to providing a visualization of sound in a given space, Odeon can calculate the sound’s reverberation time. How severely a sound is weakened by reflection from a surface depends both on the sound’s frequency and the material of the surface. So, for a given space, Odeon calculates reverberation times for ranges of frequencies, and by changing the simulation’s building materials you can change those reverberation times.

Open the program Odeon


Concert Hall. This space is specially designed to give uniform sound coverage and a reverberation time appropriate for music. Let’s see how it does.

1. Visualize sound. (this is more of a qualitative exploration, so just have fun)
 - a. Open the virtual Concert Hall within it by selecting “Open Room” from the “File” menu, and then selecting “Elmia RoundRobin2 detailed.Par” (let your instructor know if you can’t find it.)




- b. Notice the reflector panels in the room’s ceiling. To see their effect,  click on the “3D Reflector Coverage” button on the top toolbar (6th from the right) or hit Shft+Ctrl+C. The panel segments and the surfaces to which they reflect sound are color coordinated.

Note: The line-drawing of the room can be rotated by clicking and dragging with the mouse, moved by right-clicking and dragging, and zoomed in and out with Ctrl+U and Ctrl+I, respectively.

- c. To run the simulation, click on the “3D-Billiard” button on the top  toolbar (fourth from the right) or hit Shift+Ctrl+B. Observe how the sound fills the space.

Note: you can choose to view different slices of the source sound (x-y, y-z, x-z, or 3D Random) at the right of the visualization window. Try some of them.

2. Determine Reverberation.

- a. Click the “Global Estimator” button at the top of the screen (11th from the right) or hit Sft+Ctrl+E.
 **Note:** you’ll need to close the “3D-Billiard” window for the Global Estimator window to come up.
- b. To set it running, you may need to hit the “recalculate” button at the bottom of the screen.
- c. After about half a minute, the calculations should converge (the plot getting drawn should stop squiggling). Then hit the “Derive Results” button at the bottom, and then the “Yes” button in the pop-up.
- d. You’ll see a plot of how different frequency sounds weaken with time. In the box to the right will be a list of reverberation times for the different frequencies. Alternatively, you can see the Reverberation Times plotted if you select the “Estimated Reverberation Times” tab. (T20 and T30 denote slightly different ways of calculating the times – if their values differ significantly, the simulation needs to be run longer.)

Question: Which frequency dies off fastest? What’s its reverberation Time?

1 pt

Question: Which frequency lasts longest? What’s its reverberation Time?



1 pt

Question: There’s a range of reverberation times for the different frequencies, but think about what’s a representative / average time, then looking at your book’s Figure 15.10, what kind of performances would this space be good for? Note: the room’s volume is estimated on the “Energy Curves” page in Odeon.

1 pt

Keeping the program open, close all windows within it except the simple 3D View.

3. Hear Sound.

- a. Auralization Setup – hit Shift+Cntrl+A to open the Auralization Setup window; make sure that the “create binaural impulse response file” box (second from top on left) is checked and then close the window.

- b. Job List – hit Shift+Cntrl+J to open the Job List window. Job 1 should already be highlighted in the list; click on *Job 3* instead. You’ll see that the sound source location is represented in with a red dot in the


picture of the room and the microphone's location is represented with a teal dot.

- c. Run Job – hit Alt+R; if it has already been run, then a pop-up box will tell you so, and you can dismiss it.
- d. Play Sound – hit Alt+C; in the window that opens, you can use the “signal file” menu to choose what sound to hear. Listen to the four different sound sources in this space: clap, the quickly played piano, the slowly played viola, and the spoken word (you can check and uncheck the “listen to input signal” box for comparison.)




Question: Describe how the space affects the sound; consider the clarity, envelopment, smoothness, reverberation,...

1 pt

Question: What kind(s) of sound (speech, chamber music, orchestral music...) might this space be good or bad for?

1 pt

Chapel. This space was designed before room acoustics became a real science, so it's beautiful, but there's no guarantee about uniform coverage or that the reverberation time will be suitable for a wide range of sounds. Let's see how it fairs.

1. Visualize Sound. (this is more of a qualitative exploration, so just have fun)
 - a. Open the virtual Chapel within it by selecting “Open Room” from the “File” menu, and then selecting “Hagia Irene.Par”; a pop-up window will ask you to verify that you're done working with the concert hall.
 - b. This time, run the ray-trace simulation (5th button from the right or  Sft+Ctrl+I), this allows you to follow the path of individual ‘sound balls.’
 - i. Check the OK box at the bottom, then hit the “Single Ray”  button a few times. Notice how some of the sound rays get ‘trapped’ in different spaces.
 - c. Now to see the focusing effect of the dome, run the 3D-Billiard simulation (fourth from the right or hit Shift+Ctrl+B) and select from the “source” menu at the right source 4 (in the dome). It's particularly striking if you select “none” in the Diffusion box at the right.
2. Determine Reverberation.
 - a. Click the “Global Estimator” button at the top of the screen (11th from the right) or hit Sft+Ctrl+E. Note: it will probably freeze before 

completing the calculation – *don't hit "ok" in the pop-up box*. The reverberation time is how long it takes for the SIL to drop by 60dB, you should be able to get a ballpark value from what's already been plotted.

Question: What's the typical reverberation time in this space?

1 pt

Question: Looking at your book's Figure 15.10, what kinds of sound would this space be suited for (if any)?

1 pt

Keeping the program open, close all windows associated with the chapel.

3. Unfortunately, the chapel model is 'leaky', and you can't listen to the sound in this space.

Bathroom

1. Visualize Sound.

- a. First select "Open Room" from the "File" menu, and open "Transmission Rooms.Par" (as a bonus, you also get to see how sound transmits through walls between adjoining rooms.) All the surfaces are set to 'glazed tile' – not much different from a bathroom.
- b. We'll be focusing on the back left space; first, we'll want to adjust the surface materials to be appropriate for a bathroom – tile, glass, and plasterboard.



- i. Click on the "Material List" button on the top toolbar or hit Shift+Ctrl+M, and within the pop-up window.

- ii. In the table on the left (listing all the surfaces), the far left column gives the "Surface" number, and the next column gives the "Material" number; make surfaces 22 and 26 be material # 2001 (marble or glazed tile); make surfaces 23 and 25 be material #4046 (plasterboard); surface 27 material number #4038 (Acoustic Plaster); and surface 28 be material #10005 (glass).



- c. Use the 3-D Billiard or Investigate Rays (or both) to see how sound bounces in this space.

2. Determine Reverberation time.

- a. Use the Global Estimator to calculate reverberation times.



Question: Which frequency dies off fastest? What's its reverberation Time?

1 pt

Question: Which frequency lasts longest? What's its reverberation Time?

1 pt

4. Hear Sound.
 - a. Auralization Setup – hit Shift+Cntrl+A to open the Auralization Setup window; make sure that the “create binaural impulse response file” box (second from top on left) is checked and then close the window.
 - b. Job List – hit Shift+Cntrl+J to open the Job List window. Job 1 should already be highlighted in the list; if not, select it so it becomes highlighted. You'll see that the sound source location is represented in with a red dot in the picture of the room and the microphone's location is represented with a teal dot.
 - c. Run Job – hit Alt+R; if it has already been run, then a pop-up box will tell you so, and you can dismiss it.
 - d. Play Sound – hit Alt+C; in the window that opens, you can use the “signal file” menu to choose what sound to hear. Listen to the four different sound sources in this space: clap, the quickly played piano, the slowly played viola, and the spoken word (you can check and uncheck the “listen to input signal” box for comparison.)


Question: Describe how the space affects the sound; consider the clarity, envelopment, smoothness, reverberation,...

1 pt

Question: What kind(s) of sound (speech, chamber music, orchestral music...) might this space be good or bad for?



1 pt

(empty) Dorm Room

1. Modify the Room
 - b. You'll probably need to close all of the windows except the simple 3D view. Now modify one of the rooms to be a typical dorm by changing the surface materials as follows.
 - i. Click on the “Material List” button on the top toolbar or hit  Shift+Ctrl+M, and within the pop-up window.

- ii. In the table on the left (listing all the surfaces), the far left column gives the “Surface” number, and the next column gives the “Material” number; make surfaces 23,25, and 28 material #4049 “Plasterboard (with mineral wool)”, surface 26 material #8011 “Curtains”, surface 22 material #7001 “6mm pile carpet”, and surface 27 material number #4038 “Acoustic Plaster.”

2. Visualize Sound.

- c. Use the 3-D Billiard or Investigate Rays (or both) to see how sound   bounces in this space. Note: a pop-up box will ask you to confirm that you want to calculate new data using your new surfaces – click “yes.”

3. Determine Reverberation time.

- a. Use the Global Estimator to calculate reverberation times.







Question: Which frequency dies off fastest? What’s its reverberation Time?

1 pt

Question: Which frequency lasts longest? What’s its reverberation Time?

1 pt

4. Hear Sound.

- e. Auralization Setup – hit Shift+Cntrl+A to open the Auralization Setup  window; make sure that the “create binaural impulse response file” box (second from top on left) is checked and then close the window.
- f. Job List – hit Shift+Cntrl+J to open the Job List window. Job 1 should already be highlighted in the list; if not, select it so it becomes  highlighted. You’ll see that the sound source location is represented in with a red dot in the picture of the room and the microphone’s location is represented with a teal dot.
- g. Run Job – hit Alt+R; if it has already been run, then a pop-up box will  tell you so, and you can dismiss it.
- h. Play Sound – hit Alt+C; in the window that opens, you can use the  “signal file” menu to choose what sound to hear. Listen to the four different sound sources in this space: clap, the quickly played piano, the slowly played viola, and the spoken word (you can check and uncheck the “listen to input signal” box for comparison.)

Question: Describe how the space affects the sound; consider the clarity, envelopment, smoothness, reverberation,...

1 pt

Question: What kind(s) of sound (speech, chamber music, orchestral music...) might this space be good or bad for?

1 pt

Question: There's a range of reverberation times for the different frequencies, but think about what's a representative / average time, then looking at your book's Figure 15.10, what kind of performances would this space be good for? Note: the room's volume is estimated on the "Energy Curves" page in Odeon.

1 pt

For easy comparison, copy the reverberation time values to the table below.

Reverberation Time Summary			
Concert Hall	Chapel	Bathroom	Dorm Room
Max:	Typical:	Min:	Min:
Min:		Max:	Max:



1 pt

EXPERIMENT

Now you will be able to use a LabPro to go around campus and measure the reverberation times in several different locations. You will then report back to the classroom to construct somewhat of an "Acoustical Map" of the campus using all of the class data.

1. First, to get practice we'll measure the reverberation time of the lab room.
 - a. With the Sound Intensity Level Meter (SLM) plugged into the LabPro, open "Room Acoustics" from the "Physics Experiments" folder on the computer's desktop.
 - b. Turn on the SLM in the Lo setting (35-90dB), and set for fast response (the F/S switch set to F).
 - c. Now, when you're ready, hit the green "collect" button in the LoggerPro program – it won't start collecting data until you clap. So clap four or five times at least a meter from the detector (so the direct sound isn't too loud for it.) Each clap should be registered as a sharp spike with a gradual decay.



- d. When LoggerPro is done collecting data (it runs for only about 10 seconds), you'll want to determine the initial slope of the decay curve for each clap. To analyze the data do the following for each peak:
- i. First zoom in on the peak and the tail that trails behind it, to do this  highlight the area you wish to zoom in on and then push the button that looks like a magnifying glass with a "+" in it.
 - ii. Then determine the initial slope of peak's decay – so from the peak to about half-way down. To do this, highlight the desired region  and then click the Linear Fit button (Looks like "R=") on the top toolbar. Note: two square brackets, [and], will mark the region of data being fit – you can click on and drag the brackets to change the region.
 - iii. The pop-up box will give the fitting line's slope; copy that into the data table below.
 - iv. Then perform the following calculation:

$$-60 \div \text{slope} = \text{reverberation time}$$
and enter your answer into the data table on the next page.
- e. Since you clapped a few times, there are a few peaks; for three more measure their slopes and determine the corresponding reverberation times (they should all be about the same as each other.)

Location: Lab Room	Slope (dB/s)	Reverberation Time (s)	Average Reverberation Time: (s)
Clap1			
Clap 2			
Clap 3			
Clap 4			

5 pts

2. You're going to go measure the reverberation time of some other room of your choice; but first, you'll practice using the LabPro "remotely" here in the class room.
- a. Very first thing, you'll want to clear the old data (LoggerPro tends to error when importing remotely collected data into a file that already has data).
 - i. Under the Data menu, select Clear Data.
 - b. Now you will need to set up the LabPro so that it can be used in its remote setting.
 - i. Select "Remote" from the "Experiment" menu, then "LabPro: 1" under "Set Up."
 - ii. Click "Ok" in the two pop-up boxes that appear.
 - iii. When instructed to do so, unplug the LabPro from the computer and from its power cable. You are now ready to "remotely" collect your data.
 - c. When you are ready, push the "Start/Stop" button on the LabPro and the central light should blink orange. Clap 4 - 5 times some distance from the

SLM. *Do not press "Start/Stop" a second time.* Once your 10 seconds of data collecting are up, the central light will blink orange once more.

- d. Plug the LabPro back into the computer and into its power cord. A pop-up box should ask you if you want to import your data - "yes."
 - e. If LoggerPro plots your remote data, you did everything right, and you're ready to do it for real!
3. Now you're ready to get remote data from another room, say, the bathroom, Hedco's entry, the chapel (if no one's using it), your dorm,... wherever you like.
 - a. Again, set up LabPro for remote collection, as in part 2 above, then go to your chosen space and collect data.
 4. Return to the lab and attach the LabPro back into the computer using a USB cord. Once connected, open LoggerPro and a box should appear and be sure to import the data.
 5. Now you'll analyze the data as you did before (1.d on the previous page) and fill in the table on the next page.

5 pts

Location:	Slope (dB/s)	Reverberation Time (s)	Average Reverberation Time: (s)
Clap 1			
Clap 2			
Clap 3			
Clap 4			

6. Once you have finished your data, enter in your average reverberation time into the class data table on the board and be sure to also copy down everyone else's data as well.

1 pt

Location	Average Reverberation Time (s)

Question: How does the class data compare to what you'd expect for the variety of rooms; are the ones with longest or shortest reverberation times the ones you'd expect based on the simulations you did earlier in the lab?

1 pt