ROOM ACOUSTIC COMPUTER MODELLING
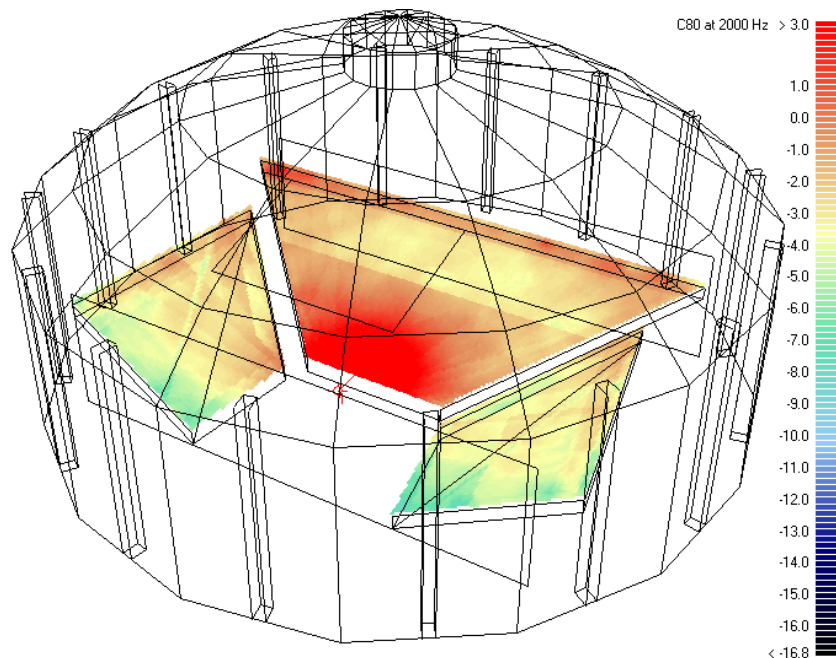
Guide to lab-exercise

Can be used with the Odeon Free Trial – from www.Odeon.dk

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This exercise may be performed in about four hours. The purpose of the exercise is to make you acquainted with a room acoustic modelling program and to demonstrate its use as a room acoustic diagnostics and design tool. The program called "Odeon" is being developed at Odeon A/S and it is fast enough for several examples to be investigated within a few hours.

In evaluation of the results, you may focus your attention on RT, SPL at 1000 Hz and STI.

1. Guided tour

The first part of this exercise is a guided tour to Odeon. The tour will make you acquainted with the most common features in the program. Spend around one hour on the tour then move on to the next part.

Run the Odeon application
Normally you will find the Odeon program at the Windows Menu Start|Programs|Odeon (#) Combined (Demo)|Odw. Execute the program and begin the tour.

Open a room model to work on
Click the Open a room model button to select a room. For this guided tour select the room model named Example.par.

3D View
Have a look at the room. Whenever Odeon loads a room, it is displayed in a 3DView. This allows you to investigate the geometry and check it for errors, etc. Several facilities are available in the 3DView, e.g. rotation, zooming, highlighting of selected surfaces and corner numbers etc. Hit the F1 shortcut to get an overview of the facilities and their use.

Having assigned a room, this is a good time to get familiar with the MDI concept (Multiple Document Interface). At this point the title bar of the 3DView will be blue (or some other colour) indicating this is the active window. Being the active window, the 3Dview dropdown menu is added to the menu bar next to the toolbar dropdown menu. You can operate the functions of the active window using the corresponding menu or the shortcut keys displayed in the menu.

Define sources and receivers
Before any calculation can be carried out by Odeon, at least one source will have to be defined. Also a receiver will have to be defined in order to calculate a point response.

In this guided tour we shall define point, line and surface sources although only the point source is relevant to this auditorium type of room. Finally we define a receiver.

Click the Source-receiver list button at the toolbar to open the Source-receiver list from which sources and discrete receivers are defined. If the Source-receiver list is already open, but hidden behind other windows etc., clicking this button will rearrange the windows as needed.

⊚ Define a point source

Click the New point source button in the local toolbar at the right side to open the Point source editor. Enter the values x = 3 (metres), y = 2 (metres) and z = 1.2 (metres)[1][2]. If you are not sure of the position of the source, you can select the 3D Edit source display. If you do so, you should notice how the menu item 3D Edit Source appears on the dropdown menu, when this window becomes active. The 3D Edit Source-Receiver menu will allow you to operate the 3D display, e.g. use the SPACE key to switch between different predefined views.

Finally set the overall gain to 65 dB. To save the new source just close the Point source Editor and confirm.

≡ Define a line source

Click the New line source button to open the line source editor. Enter the values x = 4 (metres), y = 2 (metres), z = 2 (metres), Length = 2 (metres) and Azimuth = 135°.
Finally set the Overall Gain to 65 dB. To save the new source just close the Line source Editor and confirm.

▦ Define a surface source

Click the New surface source button to open the Surface source editor. Select surface 2001 End wall behind podium for this source and click the Invert normal checkbox to make the source radiate into the room.
Finally set the Overall gain to 65 dB. To save the new source just close the Surface source Editor and confirm.

▨ Define a receiver

Click the New receiver button to open the Receiver editor. Enter the values x = 18 (metres), y = -5 (metres) and z = 3 (metres). To save the new source just close the Receiver Editor and confirm.

Define other receivers at:

        (x, y, z) = (12; 3; 2,2)
        (x, y, z) = (8; 7; 1,5)
        (x, y, z) = (21; 1; 3,6)

We will get back to the receiver and the activated sources under the point: Calculating Point Responses.

▦ Assign material properties

Open the Materials List and see how to operate it in the Materials menu.

Assign the following material data to the surfaces in the model:

Surface number	1001	1002	2001	-2002 2002	-2003 2003	2004	3001	3002
Material	Audience, choir or orchestra	Empty chairs	Plaster-board	Plaster-board	Plaster-board	Plaster-board	Plaster-board	Plaster-board
Scatter	*0.7*	*0.7*	0.1	0.1	0.1	*0.3*	0.1	0.1
Transparency	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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1 Hint; Use the Tab or Shift+Tab keys to move between fields.
2 Depending on the language selected on your computer '.' or ',' is used as decimal point.

Hit the F1 shortcut to learn more about scattering and transparency coefficients. The transparency coefficient allows you to easily model a reflecting panel build from many small surfaces, simply by modelling one surface and applying an appropriate transparency coefficient.

Quick Estimate, fast estimation of Reverberation Time

From within the Materials List run the Quick Estimate to get an idea of the size of the reverberation time and the distribution over frequencies. Note the longest reverberation time. This calculation is very useful while assigning materials for the evaluation of different materials and their impact on the overall reverberation time. Before leaving Quick Estimate you may want to try this out by selecting different materials. It is also possible to select among the defined sources. However in the Quick Estimate calculation, the source position will only have minimal effect on the estimated reverberation time, unless strong decoupling effects are present in the room.

3D open GL

Look at the room in 3D open GL to see how the surface colours corresponds to the acoustic absorption you have added. You can move around in 3D open GL using the mouse or with the shortcuts shown in the 3D open GL dropdown menu.

Room setup, calculation parameters

At this point you should have an idea of the size of the reverberation time and the distribution over frequencies. To continue the series of calculations you should enter the Room setup and specify the Impulse response length. The Impulse response length should cover at least 2/3 of the reverberation curve; in this case 1500 ms should be sufficient. To learn more about the other parameters available from this page, please press F1.

Global Estimate, a reliable method for estimation of reverberation time

Run Global Estimate and let it run until you are satisfied that the decay curve has become stable, then press the Derive results button. Note the longest reverberation time. The reverberation time differs from the values calculated by Quick Estimate, because the room shape and the position of absorbing material are taken into account in this calculation. It is important that the Impulse response length in the Room Setup is at least 2/3 of the longest reverberation time.

Calculating point responses

At this point we are ready to calculate point responses. Three different point response calculations are available:

- Single Point response offering detailed calculation results and auralisation options for a selected receiver.
- Multi Point response offering room acoustical parameters for all the receivers defined in the Receiver list at the Source-receiver list.
- Grid response offering a calculated map of room acoustical parameters, if a grid has been specified from the Define grid menu.

Setup a single point response and run it:

- Select source number 1 as the Receiver towards source for each of the jobs 1 – 4. Notice how the blue cross changes into red in the Source Receiver view, indicating that it has been selected for the selected job.
- Select receiver number 1 as the Single Point receiver for job 1, 2, 3 and 4.

- Activate source 1 in job one, source 2 in job two, source 3 in job three and all three sources in job four.
- Click the Run all button in the local toolbar at the right side to run the jobs and the four Single Point response responses will be calculated.

⬤ View Single point response

Select job number 1 in the Job List and click the View Single Point response button when the calculations have ended to see the results. You will find six pages available in the Single Point Response window displaying room acoustical parameters, energy curves, reflectograms, 3D reflection paths and Binaural Room Impulse Response filters (BRIR). You can view results for each of the four jobs by first selecting the job in the Job List, then clicking the View Single Point response button. To learn more about the results and options available from the Single Point response window please press F1 to consult the online help. You may also select the page of interest and investigate the menu, which then appears at the top menu bar. As a last option you may want to play the Binaural Room Impulse Response through headphones using the ALT+I keystroke.

Re Streaming auralisation

It is possible to listen to sound filtered through the BRIR, which has just calculated as part of the Single point response. Select the relevant job in the JobList, then open the Streaming convolution dialog. This dialog will provide real-time convolution (with a delay) of the BRIR with a signal of you choice. Select a signal file in the Signal source dropdown box and listen to the result using headphones.

⠿ Calculate Multi point

Activate the Multi option from the Job list, by checking the Multi option for job 4; then click the Run all or Run Selected Job button.

When the calculation has finished, select job number 4 in the Job list and click the View Multi button to view the Multi point response results. To learn more about the results and options available from this display; press F1. You may also select the page of interest and investigate the menu, which then appears at the top menu bar.

▨ Define a receiver grid and calculate grid response

Enter the Define Grid menu and select the two floor surfaces (surface 1001 and surface 1002). Specify the Distance between receivers to 2 (metres) then click the Show grid button.

Note! If the Define Grid button is disabled this is because some process is open, which requires data to be saved. In this case, it is probably the Estimate Reverberation display that needs to be closed. To find this open window, use the Windows menu item on the menu bar. Other displays containing calculation processes may cause the same kind of disabling of miscellaneous options.

Hint! The grid may also be used for easy location of point sources and discrete receivers, which are usually defined in the Source-receiver list. To learn how to operate the 3DGrid display, select the display - then select the 3DGrid Parameters dropdown menu.

Calculate grids

Click the Job list button again. Activate the Grid option from the Job list, by checking the Grid option for job 1; then click the Run all or Run Selected Job button. Odeon will now start calculating the Grid response for this job; this may take a while.

When the calculation is finished, select job number 1 in the Job list and click the View grid button to view the grid results. To learn more about the results and options available from this display; press F1.

Calculate Reflector Coverage

Enter the Define reflector surfaces menu and select the podium-ceiling surface (surface 3001). Then click the Calculate reflector coverage button on the main toolbar to calculate the reflector coverage for the selected surface(s).

Reflector coverage calculates the coverage provided by chosen reflecting surfaces, at the first reflection order only. This is an efficient tool for investigating whether the receiver area is covered by the reflectors or not and if the reflectors are positioned correctly.

Investigate Ray Tracing and 3DBillard

The Investigate ray tracing display visualises the ray tracing as it is carried out during any point response calculation. 3DBillard shows how sound propagate and scatter as billiard balls.

By default its calculation parameters are also set up as the parameters used for the point response calculations (Single Point, Multi and Grid). These two displays are valuable tools for testing new room models, e.g. to detect missing or misplaced surfaces. They may also give an impression of what is happening in the calculations, e.g. the effect of the scattering assigned to the surfaces. In the Investigate Ray Tracing display Click the Ok button, then click the Single forward button a few times and note the behaviour of the ray tracing. In the 3Dbillard display, try some of the different options E.g. switching between 3D propagation and propagation in different planes.

Mechanisms of diffusion

Before leaving the SymmetricExample -room we may use it to illustrate the effects of diffusion; on the ray flights and on the estimated T_{30} values. These effects are particularly noticeable in rectangular rooms with uneven distribution of highly absorbing surfaces. Enter the material list and fill the room with audience by changing the material for the audience floor (1002).

Run Investigate Ray Tracing with the present setting of diffusion (as listed in the Assigning materials table above) and observe the ray paths. Open Global Estimate and derive results when the curve has become stable.

Enter Room Setup and change Scattering Method from Lambert to None. Then try Investigate Ray Tracing, 3DBillard and Global Estimate again and observe the changes. *Note: This setting should never be used for serious acoustic simulations!*

As above, but change back to Lambert scattering in the Room Setup. Enter Material List and make all surfaces highly diffusing by setting all scattering coefficients to 1.00 (Enter 1 in the field Scatter at one of the surfaces and then press A). Press F1 and read about scattering coefficients and their use. Then look at Investigate Ray Tracing and try Global Estimate once more and observe the changes compared to the two previous situations with moderate diffusion and no diffusion respectively.

2. Investigations of a theatre before acoustic treatment (Room version 1).
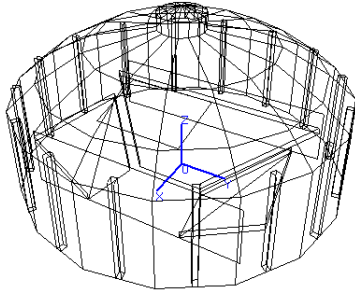
For this part of exercise a room has been prepared for you. It is actually a model of an old gas container, which has been transferred into a theatre. The geometry has been defined, materials have been selected and a point source has been defined. The source has been assigned the Omni directivity pattern and the sound power of the source to 31 dB. This means that the source is calibrated to give 0 dB SPL (sound pressure level) at a distance of 10 m in a free field

2.1 Load the room "EasterGasWorks1" into Odeon and take a look at it from different angles.

2.2 Open the Material List *(Short key:* Ctrl-M*)* and look at the materials applied in the model. The ceiling is plasterboard and all walls are brickwork. Make sure the proscenium wall and the reflector over the stage are transparent *(*material no 0*)* in this phase. You may open Investigate Ray Tracing and start single ray or Free Run to make sure that this is the case. (Instead of starting with ray no 1 it is recommended to start with a ray number, which is approximately half the total number of rays specified. The first rays are usually not so interesting, because they are emitted down towards the floor).

2.3 Open Global Estimate and derive results when the curve has become stable. Notice the estimated volume and the estimated T_{30} values. Press F1 and read about the calculation method.

2.4 Define a receiver R1 with coordinates (8; 12; 3,7) and create a new job with point response calculation in this point. Make the calculation, evaluate the values of the energy parameters and look at the reflectogram. Zoom in on the reflections around 70 ms and around 230 ms. You can find out about which surfaces are responsible for the different reflections in 3D reflection paths/active sources.

2.5 In this version of the room, the time-consuming grid response calculations have been pre-calculated as job No. 20. Open the job list and look at the results of the grid response calculations. Check the distribution of values across the audience seating areas. Click on the 3D Grid and move through some of the receiver points (use the 1 and 4 keys). From the grid choose another receiver point with properties different from R1 and Press (shift R) to save this point as a new receiver R2.

The theatre is supposed to be used primarily for musicals. In view of this, point out the acoustical problems and think about possible treatments of relevant surfaces in order to improve the situation. (A suitable target value for the reverberation time is about 1,4 sec.)

2.6 Define a new job with point response calculation in R1 and start it. (Remember to check that the source is turned on for this job.) The point response results will be used for auralisation later.

3. Acoustic treatment of the theatre (Room Version 2).

3.1. You should now test your ideas about how to improve the acoustics of the theatre based on your analyses in section 2. Start a new Odeon session and open EasterGasWorks 2.

To begin with we want to have room settings of EasterGasWorks2 Identical to the settings you have made in EasterGasWorks1. Therefore import the settings into EasterGasWorks2: - go to File / import settings from another Room choose EasterGasWorks1 make sure the box sources/receivers (source receiver list) and job list is checked.

a)   Enter Materials List and change the absorption properties on relevant surfaces until you obtain a suitable reverberation time (approximately 1.4 sec.) This you judge from Quick Estimate during the process of choosing new materials.

b)   You may also wish to make use of the proscenium wall and the reflector over the stage by these surfaces having "real" materials assigned to them in stead of being transparent (i.e. non existing).

c)   Finally you may find it relevant to apply diffusing treatment to certain surfaces, preferably surfaces that can be seen from the source. Such surfaces should have a moderate absorption coefficient but first of all a high scatter coefficient between 0.5 and 1.0 in order to simulate a highly diffusing surface.

3.2. In the importing process, also the calculation parameters as well as the source /receiver and grid parameters are copied. Open Define Grid and check that the audience areas relevant for receiver positions are still the ones chosen. The height above the floor should be 1.2 m and the grid size should be 3 m. (The total number of receivers in the grid should not exceed approximately 50 in order to avoid too long calculation times.) Check in Room Setup that Impulse Response Length has a reasonable value, i.e. approximately the same size as the maximum expected reverberation time. Use Global Estimate to get a better estimate of reverberation time (T_{30}) as a function of frequency.

3.3. Open the Job List and define two jobs, one for each of the point responses with receivers R1 and R2. Remember to make a short description to identify each job. Then start these jobs, wait for and check the results. If you are reasonably satisfied, proceed to section 2.4. The R1 and R2 point responses will be used for auralisation in a moment. If the results are very unsatisfactory - and if time is available - you may reconsider some of your choices in section 2.1.

3.4. Open the Job List, define a grid response job and start it. While the grid response job is running you can proceed with the auralisation.

4.   Auralisation of room versions 1 and 2.

4.1. Listen to speech in receiver position R1 and R2 in both Odeon-sessions (EasterGasWorks1 and EasterGasWorks2). Listen to the responses, try to describe what you hear and compare your listening impressions with the calculated parameter results.

5. Comparison of Grid Response results from room versions 1 and 2.

5.1. Go back to the JobList in order to see if the Grid response calculation has finished. Recall also the Grid response results from the first Odeon session with room version 1. Compare the two versions with respect to the 1 kHz octave band values to EDT and the SPL (Sound Pressure Level relative to free field at 10 m) - and STI. If the scaling is not satisfactory, you may change the scaling in Define Grid, but the same scaling should be used for both room versions. How did your modifications change the acoustics?

6. Clean up the models for the next user

Prepare the rooms EasterGasWorks1 *and* EasterGasWorks2 *for other students by opening the room* EasterGasWorks_Original *choose* copy files *– in the* file *menu and copy room and result files and replace into both* EasterGasWorks1 *and* EasterGasWorks2. *Open the job list and make sure Job number 20 is pre-calculated.*

Prepare the room Example.par *for other students by deleting sources and receivers and adding material number 0 to all surfaces.*